J. Food Sci. Nutr.
Vol. 3, No. 4, p. 368~373 (1998)

Plasma Aminogram and Urinary Excretion of Free Amino Acids in Adult Vegetarians Compared with Age-Matched Omnivores in Korea

Tae-Sun Park[†], Jun-Sung Chang and Mi-Kyung Sung[*]

Dept. of Food and Nutrition, Yonsei University, Seoul 120-749, Korea
[*]Dept. of Food and Nutrition, Sookmyung Women's University, Seoul 140-742, Korea

Abstract

Plasma amino acid concentrations and urinary excretion of free amino acids were measured in healthy female vegetarians (n=20, 19.9±0.43 years old) and age-matched omnivores (n=20, 21.9±0.38 years old) in Korea. Differences in fasting plasma amino acid concentrations and plasma aminogram pattern were not spectacular between the vegetarian and omnivore controls. Compared to the omnivores, vegetarians showed significantly lower plasma levels of methionine, phenylalanine, α-aminobutyrate, citrulline, phosphoserine and taurine, and significantly higher plasma concentrations of arginine, α-aminoadipate, asparagine, aspartate, glutamate and ornithine. Although these differences were statistically significant, they were all within the normal range (21~70% differences) for human adults. Most of the urinary amino acids (nmol/mg creatinine or μmol/24 hr urine) were excreted to significantly lesser degrees in vegetarians than was the case in omnivore controls. For almost every individual free amino acid, plasma concentration did not significantly correlate with urinary excretion level. These results indicate that vegetarians excreted less amino acids in their urine than did omnivores, most probably in an effort to maintain amino acid homeostasis to an altered dietary protein intake level and/or amino acid composition of their diets.

Key words: plasma aminogram, urinary amino acid excretion, vegetarian, amino acid analyzer

INTRODUCTION

Recently, many adults have been turning to vegetarianism to reduce the risk of developing chronic degenerative disease. Also, vegetarian diets are frequently used by young women to lose weight in Western countries (1). Although a strict vegetarian diet may offer several advantages, their nutritional adequacy is still in debate. Studies indicated that vegetarian diets lack micronutrients especially iron, calcium, zinc, folate and vitamin B_{12} (2,3). While an adequate protein intake can be easily attained by most vegetarians, recent studies indicate that the level of total protein intake was significantly lower among vegetarian subjects (4,5). Although much attention has been paid to the quality and quantity of protein intake among vegetarians, few studies have been conducted to examine the changes in plasma amino acid pattern and urinary excretion levels in those subjects.

Concentrations and proportions of each free amino acid in the plasma pool of a subject consuming adequate levels of protein appear to be kept within a narrow range across species (6-8). This relatively stable pattern of plasma amino acid in mammals after fasting for 12~24 hr makes it useful as a reference or baseline in plasma amino acid studies of patients with liver necrosis (9), cancer (10,11), trauma (12), and uremia (13), and also in the evaluation of protein quality of foods. Plasma amino acid concentrations were known to be influenced to a certain extent by dietary factors. Felig et al. (14) and Holt et al. (15) have shown that circulating plasma amino acid levels decline with starvation and poor nutrition, and these changes revert back to normal with provision of adequate protein and calories. Since there is no storage of amino acids, excess intake beyond requirements for protein synthesis will be oxidized. On the other hand, if a diet deficient in essential amino acids is administered for prolonged period, the circulating essential amino acid levels will be reduced, and protein synthesis impaired.

Normal plasma amino acid patterns have been established for the diverse populations in different countries (16, 17). However, many studies have not been conducted for Korean populations since Yoon and Im (18) reported serum free amino acid levels in healthy adults in 1984. The aim of the present paper was to give quantitative data on plasma amino acid levels and urinary amino acid excretion of adult vegetarians, and compare these values to age-matched omnivores in Korea. Lack of a significant correlation between plasma concentration and urinary excretion level was the case for most of the individual amino acids.

MATERIALS AND METHODS

Subjects

Vegetarian subjects(n=20) were recruited from female college students belonging to the religious group (the Seventh Day Advantist) in Seoul. Criteria for admission to the study was

[†]Corresponding author

that the subjects had followed a strict vegetarian diet for at least 5 years. A vegetarian diet was defined as one that include dairy products and eggs, but not fish, meat or meat products. The vegetarian subjects were matched for age with female omnivore controls (n=20) who were recruited from the college student population in the Seoul area. Care was taken to select controls of similar height and body build. Volunteers were excluded if they had a history of major medical problems, routinely used medications, or had received any surgical procedures. Consents for all procedures were obtained from each individual and from the college ethical committee.

Protein intake was measured via 3-day food records, and analyzed by a computer aided nutritional analysis program for professionals(CAN-PRO, APAC Intelligence, Seoul, Korea).

Sample collection

Fasting venous blood samples were collected between 9:00 and 11:00 into collection tubes containing EDTA from indwelling catheters. Plasma was collected after centrifugation at 1500×g for 15 minutes, and immediately frozen for batch analyses.

Twenty-four hour urine specimens were collected in 2L bottles containing toluene, a bactericidal preservative, on the same day blood samples were collected. After the volume had been measured, an aliquot of the urine sample was stored at -20°C until analysis.

Determination of amino acid concentration

Thawed plasma and urine samples were supplemented with the internal standard norleucine, and deproteinized by using 10% sulfosalicylic acid. Individual free amino acids were determined by ion-exchange chromatography (19), using an automatic amino acid analyzer (Biochrom 20, Pharmacia Biotech, Cambridge, England). Plasma and urinary amino acids were eluted from the lithium high performance column by a sequence of lithium citrate buffers of increasing concentration and pH (0.20 M, pH 2.80; 0.30 M, pH 3.00; 0.50 M, pH 3.15; 0.90 M, pH 3.50; and 1.65 M, pH 3.55) in the mobile phases. The column temperature was maintained at 47°C, and the flow rate through the column was 0.45 ml/min. Postcolumn derivatization with ninhydrin was followed by spectrophotometric detection at 440 nm and 570 nm. The coefficient of variation of multiple analyses was within 5%. The internal standard method eliminated the error caused by the loss associated with analytical technique. Concentrations of plasma free amino acids were reported as μmol/L, and those of free urinary amino acids as both nmol/ mg creatinine and μmol/24 hr urine.

Urinary creatinine concentration was measured colorimetrically using a commercial kit (Eiken Chemical Co. Tokyo, Japan) based on the Jaffe reaction (20).

Statistical analysis

Values in the tables and figures were expressed as mean± SEM of twenty subjects in each group. Significance of the differences between means for vegetarians and omnivores were tested by Student's t-test at $p<0.05$, $p<0.01$ or $p<0.001$ for the data exhibited the normal distribution. Wilcoxon's signed rank test was used as a nonparametric method to test the significance of the differences between means when the data did not follow the normal distribution. Correlations between plasma levels and urinary excretion levels of free amino acids were tested by the Pearson's product moment analysis at $p<0.05$, $p<0.01$ or $p<0.001$. All statistical analyses were performed using the Statistical Analysis System (SAS/STAT version 6, SAS Institute Inc. Cary, NC).

RESULTS AND DISCUSSION

Anthropometric status of the subjects

Age and anthropometric information of the subjects are shown in Table 1. The age of vegetarians and omnivore controls were 19.9±0.43 and 21.9±0.38 years, respectively. Percent body fat and body mass index were 20.1±0.58% and 20.3±0.36 in vegetarians, and 20.8±0.81% and 20.0±0.51 in omnivores, respectively. There was no significant differences in age and anthropometric data between the vegetarian and omnivore controls.

Plasma free amino acid concentrations

Free amino acid levels of fasting plasma are listed for the vegetarians and omnivores in Table 2 and Fig. 1. Since concentrations of free amino acids in human plasma are known to fluctuate regularly on a biological time cycle (21), all the blood samples were collected between 9:00 and 11:00 in the present study in order to eliminate diurnal variation. In both groups, glutamine existed in plasma at the highest level, followed by alanine, valine, sarcosine, glycine, lysine and serine. Plasma levels of methionine, phenylalanine, α-aminobutyrate, citrulline, phosphoserine and taurine were significantly lower (21~52% lower depending on the amino acids) in vegetarians compared to the values for omnivores. Concentrations of the following plasma amino acids were significantly higher (18~70% higher) in vegetarians than the values for omnivores: arginine, α-aminoadipate, asparagine, aspartate, glutamate and ornithine. Despite this shift in plasma amino acid pattern, amino acid concentrations of fasting plasma for control volunteers and vegetarians were all within the normal range as reported in the literature (16,18,22). This relative constancy of plasma amino acids within the normal range had also been encountered when urinary excretion of amino acids was increased

Table 1. Anthropometric assessment of the subject

	Omnivores	Vegetarians	Significance
Age (years)	21.9±0.38	19.9±0.43	N.S.[1)]
Height (cm)	161.5±1.2	159.7±1.5	N.S.
Weight (kg)	52.3±1.5	51.7±1.3	N.S.
Body fat (%)	20.8±0.81	20.1±0.58	N.S.
LBM[2)] (kg)	40.3±1.3	40.9±0.85	N.S.
BMI[3)] (kg/m^2)	20.0±0.51	20.3±0.36	N.S.

Values are mean±SEM of 20 subjects.
[1)]Not significant
[2)]Lean body mass
[3)]Body mass index

Table 2. Free amino acid concentrations in the plasma of healthy female omnivores and vegetarians (μmol/L)

Amino Acid	Omnivores	Vegetarians
EAA		
Arginine	46.9 ± 4.4	63.2 ± 5.6*
Histidine	80.1 ± 2.4	72.9 ± 4.4
Isoleucine	46.8 ± 4.1	49.3 ± 2.6
Leucine	92.0 ± 4.5	92.5 ± 4.5
Lysine	136 ± 6.0	130 ± 6.1
Methionine[1)]	40.2 ± 5.2	23.2 ± 1.1**
Phenylalanine	61.1 ± 6.5	48.4 ± 1.9*
Threonine	77.3 ± 4.9	92.8 ± 6.3
Valine	206 ± 18.6	130 ± 8.1
NEAA		
Alanine	288 ± 13.5	289 ± 16.6
α-Aminoadipate	11.1 ± 1.1	19.0 ± 1.9***
α-Aminobutyrate[1)]	26.8 ± 4.8	12.7 ± 1.0***
Asparagine	41.3 ± 2.2	48.9 ± 2.6*
Aspartate	18.2 ± 0.9	21.5 ± 1.3*
Citrulline[1)]	37.1 ± 3.9	27.5 ± 1.5*
Glutamate	72.5 ± 3.2	88.4 ± 3.6**
Glutamine	754 ± 25.6	794 ± 40.6
Glycine	159 ± 5.8	179 ± 8.0
1-Methylhistidine	4.8 ± 0.7	7.0 ± 1.3
3-Methylhistidine	4.8 ± 0.7	6.0 ± 0.9
Ornithine	55.7 ± 3.1	69.4 ± 4.8*
Phosphoethanolamine	11.3 ± 1.7	9.3 ± 1.1
Phosphoserine[1)]	31.8 ± 2.1	19.0 ± 1.1***
Sarcosine	174 ± 16.3	135 ± 20.9
Serine	110 ± 4.3	119 ± 6.3
Taurine[1)]	98.9 ± 4.8	77.4 ± 3.9**
Tyrosine	59.1 ± 3.7	54.0 ± 2.7

Values are mean ± SEM of 20 subjects.
[1)]Wilcoxon's signed rank test was used as a nonparametric method.
Significantly different from the value for omnivores by the Student's t-test at *$p<0.05$, **$p<0.01$ or ***$p<0.001$.

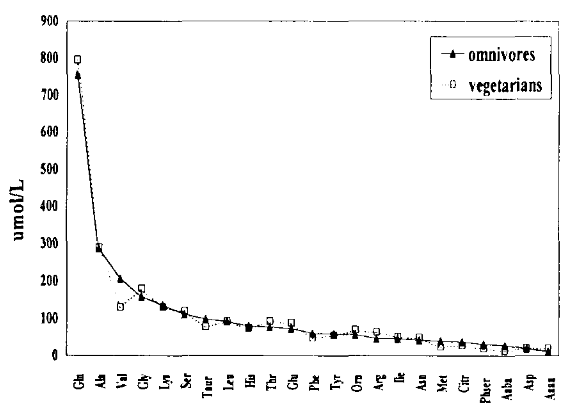

Fig 1. Plasma aminogram of healthy female omnivores and vegetarians.

under the influence of cortisol (23) or pregnancy (24).

Plasma levels of individual amino acid may conceivably be affected by several factors including the ease of assimilation, the need for the amino acid, the ease of degradation of non-utilizable surpluses and the ease of renal excretion. It is not possible at the present time to offer all the explanations for the response of individual amino acid to dietary patterns, although some hypotheses might be suggested. Deviations of plasma amino acid pattern observed in vegetarians compared to age-matched omnivores in this study most probably appear to reflect the differences in their protein intake level as well as the amino acid composition of their diets. Vegetarian subjects in our study were estimated to consume significantly lower amount of total protein (44±2.9 g/day) compared to the value for omnivores (58±4.6 g/day), and only 15% of the total protein consumed daily by the vegetarians was derived from animal sources, while 47% of the total protein intake was from animal sources in the case of omnivore controls (data not shown). An earlier study by Snyderman et al. (25) demonstrated that the plasma aminogram of infants responded promptly to alterations in protein intake. Lower protein intakes were accompanied by a depression of the levels of a number of amino acids including branched chain amino acids, lysine and tyrosine, and an elevation of glycine and serine concentrations. Clinical findings on kwashiorkor (15) clearly indicated that fasting plasma amino acid concentrations may be drastically altered by prolonged ingestion of a protein-deficient diet. Plasma levels of the essential amino acids (especially valine, leucine, threonine, isoleucine, tryptophan and arginine) were significantly decreased, while those of nonessential amino acids such as serine, proline, glycine and histidine were substantially increased in kwashiorkor patients compared to the values for normal subjects. According to the study on rats by Jansen et al. (26), amino acids that increased most often in the serum, with protein quality or quantity improvement, were essential amino acids, with variable or inconsistent changes in the concentrations of nonessential amino acids.

Since dietary taurine is found mostly in foods of animal origin (27), vegetarians consume a limited amount of taurine, and this appears to be reflected by a lower plasma taurine concentration in vegetarians in this study and by others (28). Significantly lower levels of decrease in plasma methionine among vegetarians may be attributed to an enhanced need of this amino acid for conversion to cysteine and taurine, in addition to the lower levels of methionine in plant proteins than in animal proteins. Significantly higher levels of plasma arginine and ornithine observed in vegetarians could possibly be explained by the reduced rates of urea and glucose syntheses in the course of amino acid metabolism among vegetarians compared to those of omnivore controls.

Urinary amino acid excretion

There was no significant difference between healthy female omnivores and vegetarians in 24 hr urine volume and urinary creatinine excretion expressed as both g creatinine/24 hr and mg creatinine/24 hr/kg body weight (Table 3). Creatinine is an endogenous metabolic substance, the excretion of which is relatively constant for a given individual from day to day (29). By expressing the excretion of individual amino acids in terms of ratios to creatinine excretion, it is possible to compare patterns of urinary excretion in each subject independent of the urine volume. Our values of 24 hr urinary creatinine excretion

Table 3. Urinary creatinine excretion in healthy female omnivores and vegetarians

	Omnivores	Vegetarians
24 hr Urine volumn (ml)	982 ± 80	990 ± 69
g Creatinine/24 hr urine	0.95 ± 0.07	0.95 ± 0.06
mg Creatinine/24 hr urine/kg BW	18.1 ± 1.0	18.4 ± 1.1

Values are mean ± SEM of 20 subjects.

which were normalized based on body weight coincide well to the values previously reported for healthy adults (29,30), and therefore the 24 hr urine collection appears to be complete in the present study.

Urinary excretion of free amino acids in vegetarians and omnivore controls were presented as both nmol/mg creatinine and μmol/24 hr urine in Table 4. Values for β-aminoisobutyrate, citrulline, γ-aminobutyrate and phosphoethanolamine were given only in instances in which a distinct peak with the characteristic retention time occurred. Patterns of urinary amino acid excretion did not follow the plasma amino acid composition in general. Taurine and glycine were the most prominent urinary constituents the molar concentrations of which comprise almost 1/3 of the total amino acids excreted in the urine of omnivores. Glycine is an amino acid for which the demands for protein synthesis and nonprotein metabolic pathways are substantial, and endogenous formation of glycine may be ten times the dietary intake (31). Histidine, ethanolamine, alanine and glutamine were relatively abundant (425~685 nmol/mg creatinine) in the urine of omnivores, while isoleucine, arginine and leucine were excreted at the lowest levels (20~52 nmol/mg creatinine) among urinary free amino acids. These results agree with the previous reports on healthy human adults (9,30) showing that histidine, glycine, taurine, glutamine and ethanolamine were the most abundantly excreted amino acids in urine.

All of the urinary amino acids (except glutamine) were excreted to a lesser degree in vegetarians than was the case in

Table 4. Urinary excretion of free amino acids in healthy female omnivores and vegetarians

Amino Acid	(nmol/mg creatinine)		(μmol/24 hr urine)	
	Omnivores	Vegetarians	Omnivores	Vegetarians
EAA				
Arginine	32.6 ± 3.2	18.3 ± 2.3$^{**1)}$	27.4 ± 1.3	25.7 ± 3.8
Histidine	685 ± 74.9	580 ± 52.1	690 ± 70.1	698 ± 65.9
Isoleucine	19.6 ± 1.9	5.2 ± 0.94$^{***1)}$	18.1 ± 2.6	6.0 ± 1.0$^{**1)}$
Leucine	51.6 ± 5.7	23.0 ± 3.3$^{***1)}$	51.6 ± 7.9	28.1 ± 3.8$^{*1)}$
Lysine	222 ± 24.5	135 ± 12.9$^{**1)}$	260 ± 41.8	151 ± 13.3$^{*1)}$
Methionine	122 ± 9.4	46.9 ± 4.5$^{***1)}$	120 ± 16.4	52.4 ± 4.2$^{*1)}$
Phenylalanine	72.2 ± 6.4	44.0 ± 3.9***	80.1 ± 13.0	51.7 ± 5.4
Threonine	112 ± 20.2	85.5 ± 7.8	98.4 ± 14.6	106 ± 12.8
Valine	89.5 ± 9.7	30.3 ± 3.7$^{***1)}$	90.9 ± 13.7	34.0 ± 3.7$^{**1)}$
NEAA				
Alanine	488 ± 38.8	292 ± 31.3***	492 ± 68.0	316 ± 28.1*
α-Aminoadipate	63.4 ± 5.9	44.4 ± 5.2*	59.0 ± 6.5	45.6 ± 4.0
α-Aminobutyrate	58.2 ± 6.6	19.2 ± 2.1$^{***1)}$	67.9 ± 11.1	20.3 ± 1.7$^{***1)}$
Asparagine	126 ± 15.1	100 ± 10.3	108 ± 16.4	121 ± 16.5
Aspartate	151 ± 10.4	121 ± 12.2	149 ± 17.8	134 ± 12.7
β-Alanine	196 ± 17.5	79.6 ± 7.3$^{***1)}$	196 ± 29.0	85.0 ± 6.1$^{***1)}$
β-Aminoisobutyrate	271 ± 69.0	142 ± 23.2	182 ± 37.7	163 ± 29.9
Carnosine	178 ± 17.1	119 ± 11.3$^{**1)}$	188 ± 27.5	144 ± 22.3
Citrulline	81.6 ± 13.5	12.5 ± 1.9$^{***1)}$	62.6 ± 11.3	13.0 ± 1.6$^{***1)}$
Ethanolamine	497 ± 56.4	313 ± 28.3$^{**1)}$	534 ± 72.5	328 ± 32.5*
γ-Aminobutyrate	124 ± 24.4	40.0 ± 3.6	145 ± 22.8	54.2 ± 4.5$^{**1)}$
Glutamate	99.2 ± 10.9	77.8 ± 13.5	95.6 ± 11.4	90.6 ± 12.0
Glutamine	425 ± 42.8	629 ± 38.7**	397 ± 63.4	751 ± 93.5
Glycine	1281 ± 143	1100 ± 120	1192 ± 163	1163 ± 115
Hydroxyproline	88.8 ± 13.6	76.2 ± 7.9	88.0 ± 10.8	94.1 ± 8.4
1-Methylhistidine	175 ± 21.4	73.8 ± 7.8$^{***1)}$	187 ± 36.6	81.8 ± 7.0$^{**1)}$
3-Methylhistidine	197 ± 10.9	108 ± 9.7***	195 ± 19.1	126 ± 12.2*
Ornithine	62.5 ± 3.8	54.7 ± 4.5	64.8 ± 8.9	60.0 ± 4.5
Phosphoethanolamine	61.4 ± 8.8	50.6 ± 6.1	55.2 ± 10.9	52.6 ± 4.9
Phosphoserine	76.9 ± 5.6	44.9 ± 3.2***	86.8 ± 13.4	50.4 ± 4.0$^{*1)}$
Sarcosine	311 ± 38.7	229 ± 30.1	314 ± 55.1	271 ± 34.0
Serine	166 ± 30.6	98.9 ± 22.6	167 ± 33.3	150 ± 32.5
Taurine	1378 ± 152	538 ± 67.4$^{***1)}$	1569 ± 290	589 ± 69.0$^{***1)}$
Tyrosine	95.7 ± 10.2	58.3 ± 5.9$^{**1)}$	88.4 ± 12.4	69.3 ± 7.5

Values are mean ± SEM of 20 subjects.
$^{1)}$Wilcoxon's signed rank test was used as a nonparametric method.
Significantly different from the value for omnivores by the Student's t-test at $^{*}p<0.05$, $^{**}p<0.01$ or $^{***}p<0.001$.

the omnivore controls when expression was based on mg creatinine in urine. Significant reductions in urinary amino acids were found for arginine, isoleucine, leucine, lysine, methionine, phenylalanine and valine among the essential amino acids, and alanine, α-aminoadipate, α-aminobutyrate, β-alanine, carnosine, citrulline, ethanolamine, 1-methylhistidine, 3-methylhistidine, phosphoserine, taurine and tyrosine among the non-essential amino acids. These decreases in urinary amino acid excretion (nmol/mg creatinine) observed in vegetarians were in the range of 30% (α-amino adipate)~85% (citrulline) which are considered to be normal for human adults. Similar results were obtained when urinary amino acid excretions were expressed as μmol/24 hr urine. For amino acids such as isoleucine, leucine, lysine, methionine, valine, alanine, α-aminobutyrate, β-alanine, citrulline, ethanolamine, γ-aminobutyrate, 1-methylhistidine, 3-methylhistidine, phosphoserine and taurine, urinary excretions in 24 hr were significantly lower (35~79% lower) in vegetarians than in omnivore controls (Table 4). These results indicate that the urinary excretion pattern of free amino acids might be a more sensitive indicator in reflecting the changes in dietary pattern and the efficiency of amino acid metabolism, than the plasma level, which is under control of homeostatic regulation. Our results agree with the previous study (32) showing that the amount of free amino acids excreted in urine depends on the dietary level of protein. A significantly higher urinary excretion in infants with higher protein intake was found for amino acids, proline, citrulline, α-aminobutyrate, valine, methionine, leucine, tyrosine, phenylalanine, ornithine, lysine, histidine, and 3-methylhistidine (32).

Correlations between plasma and urinary excretion levels of amino acids

Correlations between 24 hr urinary amino acid excretion, urinary amino acid in terms of creatinine excretion and plasma amino acid level were tested for individual amino acids, and the results are presented in Table 5. For all of the individual amino acids, the 24 hr urinary excretion level was positively correlated to the urinary amino acid excretion value expressed as nmol/mg creatinine. Significant correlations were found in all of the essential amino acids (excluding histidine), and most of the non-essential amino acids with the exception of α-aminoadipate, aspartate, glycine, hydroxyproline, ornithine, phosphoethanolamine and tyrosine. These results indicate that random urine samples could possibly be used as an alternative to the 24 hr urine specimens in evaluating an individual's urinary amino acid excretion.

Most of the individual amino acid did not show a consistent correlation between plasma concentrations and urinary excretion levels. A significant positive correlation was observed for methionine, α-aminobutyrate and phosphoserine ($p<0.001$), while a negative correlation was found for threonine, α-aminoadipate, and sarcosine ($p<0.05$) between the plasma concentrations and urinary excretion levels in terms of ratios to creatinine excretion. On the other hand, citrulline was the only amino acid which exhibited a significant positive correlation ($p<0.01$) between the plasma concentration and the 24 hr urinary excretion value.

Table 5. Correlations between the plasma level and urinary excretion of free amino acids

Amino Acid	UC vs UT	P vs UC	P vs UT
		r[1)]	
EAA			
Arginine	0.4985**	-0.2135	-0.0257
Histidine	0.2918	0.1055	0.1870
Isoleucine	0.4879*	-0.2978	-0.1274
Leucine	0.4530*	0.1194	0.0511
Lysine	0.5022**	0.1191	0.1237
Methionine	0.5626***	0.6494***	0.2723
Phenylalanine	0.4376*	0.2093	0.2271
Threonine	0.4234*	-0.5863*	-0.0795
Valine	0.7115***	0.1340	0.0358
NEAA			
Alanine	0.3872*	-0.1416	-0.0478
α-Aminoadipate	0.2314	-0.9046*	-0.1932
α-Aminobutyrate	0.7762***	0.5653***	-0.3434
Asparagine	0.4253*	-0.1310	-0.3055
Aspartate	0.3014	-0.1516	-0.2179
β-Alanine	0.4629**	0.3535	0.2172
β-Aminoisobutyrate	0.6206***	-	-
Citrulline	0.7739***	0.1203	0.5352**
Ethanolamine	0.4965**	-	-
γ-Aminobutyrate	0.8071***	-	-
Glutamate	0.5336**	-0.2837	-0.0222
Glutamine	0.7312***	0.1044	-0.0912
Glycine	0.1625	-0.1289	-0.1998
Hydroxyproline	0.2660	-	-
1-Methylhistidine	0.6477***	-0.3476	-0.2539
3-Methylhistidine	0.5041**	-0.3233	-0.3725
Ornithine	0.1802	-0.3387	-0.1369
Phosphoethanolamine	0.3695	-0.2092	-0.3218
Phosphoserine	0.3731*	0.5416***	0.2349
Sarcosine	0.5614***	-0.6728*	-0.0029
Serine	0.8423***	-0.1446	-0.3286
Taurine	0.6315***	0.3485	0.0657
Tyrosine	0.3285	0.0390	0.3156

[1)]Pearson's correlation coefficient
Significantly correlated at *$p<0.05$, **$p<0.01$ or ***$p<0.001$.
P: plasma amino acid (μmol/L)
UC: urinary amino acid (nmol)/mg creatinine
UT: urinary amino acid (μmol)/24 hr

ACKNOWLEDGEMENTS

This study was supported by a grant #HMP-97-F-5-0022 of the 1998 Good Health Research and Development Project, Ministry of Health and Welfare, Republic of Korea.

REFERENCES

1. Kalucy, R. S. : The "new" nutrition. *Medical Journal of Australia*, **147**, 529 (1986)
2. Ball, M. : Vegetarian, vegan or meat eater : The pros and cons. *Aust. Family Physician*, **26**, 1269 (1997)
3. Dwyer, J. T. : Vegetarianism for women. In "*Nutrition in women's health*" Krummel, D. A. and Kris-Etherton, P. M. (eds.) Aspen Publisher Inc., Gaithersburg, MA, p. 232 (1996)
4. Janelle, K. C. and Barr, S. I. : Nutrient intakes and eating behavior scores of vegetarian and nonvegetarian women. *J. Am. Diet. Assoc.*,

95, 180 (1995)
5. Nathan, I., Hackett, A. F. and Kirby, S. : The dietary intake of a group of vegetarian children aged 7-11 years compared with age matched omnivores. *Br. J. Nutr.*, **75**, 533 (1996)
6. Potter, E. L., Purser, D. B. and Cline, J. H. : Effect of various energy sources upon plasma free amino acids in sheep. *J. Nutr.*, **95**, 655 (1968)
7. Anderson, H. L. and Linkswiler, H. : Effect of source of dietary nitrogen on plasma concentration and urinary excretion of amino acids of men. *J. Nutr.*, **99**, 91 (1969)
8. Boomgaardt, J. and McDonald, B. E. : Comparison of fasting plasma amino acid patterns in the pig, rat, and chicken. *Can. J. Physiol. Pharmacol.*, **47**, 392 (1969)
9. Zinneman, H. H., Seal, U. S. and Doe, R. P. : Plasma and urinary amino acids in Laennec's cirrhosis. *Am. J. Dig. Dis.*, **14**, 118 (1969)
10. Norton, J. A., Gorschbboth, C. M., Wesley, R. A., Burt, M. E. and Brennan, M. F. : Fasting plasma amino acid levels in cancer patients. *Cancer*, **56**, 1181 (1985)
11. Clarke, E. F., Lewis, A. M. and Waterhouse, C. : Peripheral amino acid levels in patients with cancer. *Cancer*, **42**, 2909 (1978)
12. Jeevanandam, M., Young, D. H., Ramias, L. and Schiller, W. R. : Aminoaciduria of severe trauma. *Am. J. Clin. Nutr.*, **49**, 814 (1989)
13. Delaporte, C. and Broyer, J. G. : Free plasma and muscle amino acids in uremic children. *Am. J. Clin. Nutr.*, **31**, 1647 (1978)
14. Felig, P., Owen, O. E., Wahren, J. and Cahill, G. F. Jr. : Amino acid metabolism during prolonged starvation. *J. Clin. Invest.*, **48**, 584 (1969)
15. Holt, L. E. Jr., Snyderman, S. E., Norton, P. M., Roitman, E. and Finch, J. : The plasma aminogram in kwashiorkor. *Lancet*, **2**, 1343 (1963)
16. Armstrong, M. D. and Stave, U. : A study of plasma amino acid levels. II. Normal values for children and adults. *Metabolism*, **22**, 561 (1973)
17. Fukuda, K. and Usui, T. : Characteristic patterns of free amino acid content in plasma, erythrocytes, lymphocytes, and granulocytes in man. *Hiroshima J. Med. Sci.*, **32**, 163 (1983)
18. Yoon, T. H. and Im, K. J. : Serum free amino acid levels in Korean adult males and females. *J. Kor. Soc. Food Nutr.*, **13**, 421 (1984)
19. Moore, S. and Stein, W. H. : Chromatographic determination of amino acids by the use of automatic recording equipment. In "*Method in enzymology*" Colowick, S. P. and Kaplan, N. O. (eds.) Academic Press, New York, p. 819 (1963)
20. Bonsnes, R. W. and Taussky, H. H. : The colorimetric determination of creatinine by the Jaffe reaction. *J. Biol. Chem.*, **158**, 581 (1945)
21. Wurtman, R. J., Rose, C. M., Chou, C. and Larin, F. L. : Daily rhythms in the concentrations of various amino acids in human plasma. *New. Eng. J. Med.*, **279**, 171 (1968)
22. Tweedle, D. E., Fitzpatrick, G. F. and Brennan, M. F. : Intravenous amino acids as the sole nutritional substrates: Utilization and metabolism in fasting normal human subjects. *Ann. Surg.*, **186**, 60 (1977)
23. Zinneman, H. H., Johnson, J. J. and Seal, U. S. : Effect of short-term therapy with cortisol on the urinary excretion of free amino acids. *J. Clin. Endocr.*, **23**, 996 (1963)
24. Zinneman, H. H., Seal, U. S. and Doe, R. P. : Urinary amino acids in pregnancy, following progesterone and estrogen-progesterone. *J. Clin. Endocr.*, **27**, 397 (1967)
25. Snyderman, S. E., Holt, L. E. Jr., Norton, P. M., Roitman, E. and Phansalkar, S. V. : The plasma aminogram. I. Influence of the level of protein intake and a comparison of whole protein and amino acid diets. *Pediatr. Res.*, **2**, 131 (1968)
26. Jansen, G. R., Binard, R. and Longenecker, J. B. : Protein quality and quantity influence free amino acid levels in the brain and serum of rats during lactation. *J. Nutr.*, **121**, 1187 (1991)
27. Jacobsen, J. G. and Smith, L. H. : Biochemistry and physiology of taurine and taurine derivatives. *Physiol. Res.*, **48**, 424 (1968)
28. Laidlaw, S. A., Shultz, T. D., Cecchino, T. J. and Kopple, J. D. : Plasma and urine taurine levels in vegans. *Am. J. Clin. Nutr.*, **46**, 660 (1988)
29. Folin, O. : Laws governing the chemical composition of urine. *Am. J. Physiol.*, **13**, 66 (1905)
30. Emery, A. E. H. and Burt, D. : Amino acid, creatine and creatinine studies in myotonic dystrophy. *Clin. Chim. Acta*, **39**, 361 (1972)
31. Neuberger, A. : The metabolism of glycine and serine. *Comp. Biochem.*, **19A**, 257 (1981)
32. Przyrembel, H., Leupold, D., Tosberg, P. and Bremer, H. J. : Amino acid excretion of premature infants receiving different amounts of protein. *Clin. Chim. Acta*, **49**, 27 (1973)

(Received November 18, 1998)