Partition of Amino Acids Requirement for Maintenance and Growth of Broiler III. Tryptophan

J. H. Kim, W. T. Cho, I. S. Shin[1], C. J. Yang and In K. Han[2]
Department of Animal Science and Technology, College of Agriculture and Life Sciences, Seoul National University, Suweon 441-744, Korea

ABSTRACT : Purified diets containing five graded levels of tryptophan were fed to growing chicks to evaluate tryptophan requirements for growth and maintenance. A model was developed to separate tryptophan requirement for maintenance from requirement for growth. From this model, the daily tryptophan requirement for growth was 2.16 mg/g gain, and the daily requirement for maintenance 0.029 times metabolic body size ($Wg^{0.75}$). Based on nitrogen gain response, the tryptophan requirement for growth was 0.078 mg/mg N gain, and the daily maintenance requirement was 0.029 times metabolic body size. The total tryptophan requirements were 71.56 mg/day or 0.173% of the diet, 69.48 mg/day or 0.168% of the diet based on the weight gain response and nitrogen gain response, respectively. Previous tryptophan requirements for growing chicks aging 1-28 days are in close agreement with these estimates. Based on the relationship of weight gain and N gain, about 1.25% of the retained CP was consisted of tryptophan; the previously reported value of tryptophan content of chick muscle CP was 1.03%.

(**Kew Words**: Tryptophan, Requirement, Growth, Maintenance, Broiler Chicks)

INTRODUCTION

NRC (1994) recommended 0.20% tryptophan of the diet as a requirement of growing chicks and the estimated requirements for tryptophan by ARC (1975) and SCA (1987) were 0.21% of the diet. Based on the work done by Boomgaardt and Baker (1971), the tryptophan requirements appears to be in the range of 0.78-1.0% of the crude protein. Previous studies indicated that the tryptophan requirement is in the range of 0.14-0.25% of the diet (Almquist, 1947; Wilkening, 1947; Griminger et al., 1956; Dean and Scott, 1965; Hewitt and Lewis, 1971; Hurwitz et al., 1978).

The tryptophan requirement for maintenance has not been intensively studied. Owens et al. (1985) reported that the tryptophan requirement for maintenance was 62 mg/kg body weight/day for broiler chicks using zero response as a criteria. For a adult rooster, Leveille et al. (1960) indicated that the maintenance requirement for tryptophan was 19 mg/kg body weight/day.

The growth and maintenance requirements for tryptophan would be expected to vary with concentration of the dietary nutrient, response criteria, environmental conditions, or physiological potentials. Therefore, it would seem to be desirable to express amino acid requirements as functions of growth rate and maintenance needs.

The objective of this study was to divide the tryptophan requirement into two portions: one portion for maintenance and the other portion for growth. Estimated requirements for growth and maintenance were compared with previous data.

MATERIALS AND METHODS

Male Arbor Acres chicks of a broiler strain were used as experimental subjects. Five groups of 5 chicks each housed in battery cages made of wire in a room with constant light and air ventilation, were fed each of five test diets. These diets contained either 25, 50, 75, 100, 125% of NRC (1994) estimated tryptophan requirement for growing chicks with 100% of NRC requirement for all other amino acids. The composition of a basal diet is presented in table 1.

L-tryptophan was substituted for L-glutamic acid on an equal weight basis so that all diets had the same amounts of amino acid mixture. Based on the values given by NRC (1994), the basal diet was calculated to provide 17.4% crude protein and approximately 3,578

[1] Present address: American Soybean Association, Seoul, Korea.
[2] Address reprint requests to In K. Han.
Received October 29, 1996; Accepted December 21, 1996

kcal ME/kg.

The chicks were fed a commercial diet (CP: 23%, ME 3,200 kcal/kg) for 1 week before the study started, from the eighth day posthatching the chicks were fed experimental diets for 2 weeks of experimental period. The chicks had *ad libitum* access to fresh water and test diets. Mean initial body weight was 115.4 g. Body weight was measured each week on a replication basis and feed intake was measured each day during the experiment to calculate average daily gain and feed intake. To prevent any deterioration of the experimental feed, the feeds were stored at −4℃ throughout the experimental period and changed daily. On the final day of the experiment, five chicks from each treatment were sacrificed by cervical dislocation and intestinal contents were removed immediately. The carcasses were stored in −20℃ until body composition (total body water and N content) was determined. Carcass sample was freeze-dried (Ilsin Engineering, Korea), ground and analyzed by AOAC (1990) methods.

Table 1. Composition of basal diet for broiler

Ingredient	% of diet	Amino acid mixture[c]	% of diet
Corn starch	to 100	L-Arginine	1.250
A. A. mixture	23.397	L-Histidine · HCl · H_2O	0.473
Mineral mixture[a]	5.250	L-Isoleucine	0.800
Refined soy oil	5.000	L-Leucine	1.200
Cellulose	5.000	L-Lysine · HCl	1.374
$NaHCO_3$	1.500	L-Methionine	0.500
Vitamin mixture[b]	0.500	L-Cystine	0.400
Choline chloride	0.200	L-Phenylalanine	0.720
Tocopheryl acetate	0.002	L-Tyrosine	0.620
BHT	0.003	L-Threonine	0.800
		L-Tryptophan	variable
Total	100.000	L-Valine	0.900
		L-Proline	0.600
		L-Glycine	0.750
		L-Glutamic acid	Variable
		Total	23.397

[a] Mineral mixture (per kilogram of diet): $CaCO_3$, 3 g; $Ca_3(PO_4)_2$, 28 g; KH_2PO_4, 9 g; NaCl, 8.8 g; $MgSO_4 \cdot H_2O$, 2.2 g; $MnSO_4 \cdot H_2O$, 0.65 g; $FeSO_4$, 0.5 g; $ZnSO_4$, 0.15 g; $CuSO_4 \cdot H_2O$, 0.142 g; H_3BO_3, 9 mg; $Na_2MoO_4 \cdot H_2O$, 9 mg; KI, 40.6 mg; $CoSO_4 \cdot H_2O$, 0.6 mg; $Na_2(SeO_3)_2$, 0.215 mg.

[b] Vitamin mixture (per kilogram of diet): thiamin, 20 mg; niacin, 50 mg; riboflavin, 16 mg; Ca-pantothenate, 30 mg; Vit B_{12}, 0.04 mg; pyridoxine, 6 mg; biotin, 0.9 mg; folic acid, 4 mg; inositol, 20 mg; menadione, 2 mg; Vit. C, 50 mg; Vit. A, 5,200 IU; Vit. D, 600 IU.

[c] Patterned after NRC (1994).

The mathematical equation for the model to subdivide the tryptophan requirement into a maintenance fraction based on metabolic body size and to a growth fraction based on weight gain or nitrogen gain was developed as described by Shin et al. (1991).

$$I = 1/a\ (R - bWg^{0.75})$$

where I = amino acid intake,

R = response,

-b/a $W^{0.75}$ = maintenance requirement per metabolic body size

1/a = growth requirement per g gain or mg nitrogen gain.

All parameters were determined at the point at which the residual sum of square was minimized by the Nonlinear Least Squares method (SAS, 1985). The equation covering the plateau portion was not included in the equation estimating the tryptophan requirement because, genetic potential, energy or some nutrients other than amino acids was limiting respose in that region of the response curve (figure 1).

Statistical analysis were conducted using GLM procedure of SAS package (1985), and treatment means were compared using Duncan's multiple range test (Duncan, 1955).

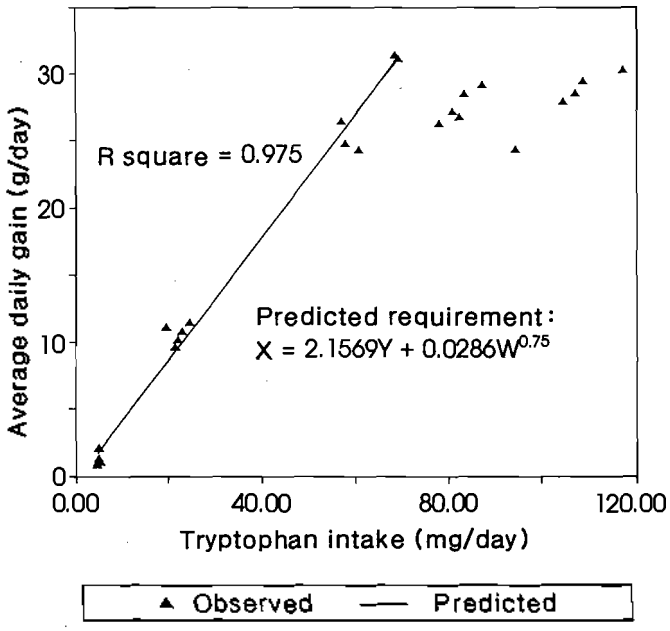

Figure 1. Weight gain responses to daily tryptophan intake.

RESULTS AND DISCUSSION

Responses of chicks fed diets containing five different levels of tryptophan are presented in table 2. Feed intake, weight gain, nitrogen gain, and gain to feed ratio increased rapidly up to 0.15% tryptophan, beyond 0.15% tryptophan the responses were increased slightly or remained relatively constant. Data revealed that less than 0.55% tryptophan was required for maintenance.

Water and protein contents of chicks' carcasses increased in the same manner up to 0.15% tryptophan as is seen in table 3. Only the group of chicks fed 0.05% tryptophan diets had slightly lower protein gain to water gain ratio than any other groups. But it seemed that the body composition of the chicks were not severely affected by the moderate deficiency or excess of a single amino acid.

The data for separating tryptophan requirements into one portion for maintenance and the other portion for growth is shown in figure 1. Based on the weight gain response, the estimated growth requirement was 2.16 mg

Table 2. Responses of broilers fed diets containing five different levels of tryptophan[1,4]

Tryptophan	Mean[2] $Wg^{0.75}$	Average daily feed intake	Average daily gain	Tryptophan intake	Nitrogen[3] retention	Gain / feed
%	g	g/day	g/day	mg/day	%	
0.05	37.20 ± 0.40	9.94 ± 0.22	1.30 ± 0.21	4.97 ± 0.11	1.45 ± 0.26	0.13 ± 0.02
0.10	50.24 ± 0.65	22.11 ± 0.81	10.68 ± 0.33	22.12 ± 0.81	5.64 ± 0.26	0.48 ± 0.02
0.15	70.96 ± 1.81	41.82 ± 1.73	27.64 ± 1.52	62.73 ± 2.59	7.95 ± 0.08	0.66 ± 0.02
0.20	71.12 ± 0.53	41.18 ± 0.77	27.62 ± 0.55	82.36 ± 1.54	7.66 ± 0.12	0.67 ± 0.01
0.25	71.61 ± 1.11	42.56 ± 1.46	28.16 ± 1.02	106.40 ± 3.66	7.70 ± 0.15	0.66 ± 0.01

[1] Average initial weight was 115.4 g.
[2] $Wg^{0.75}$ is $\{(\text{initial weight} + \text{final weight})/2\}^{0.75}$.
[3] Values are means ± S.E. of 5 chicks of each treatment.
[4] Values are means ± S.E. of 25 chicks of each treatment except nitrogen retention.

Table 3. Body composition of broilers fed five graded levels of tryptophan

Tryptophan	Live body weight	Day body weight	Water gain	Protein gain	Protein gain /water gain
%	g	g	g	g	
0.05	16.95 ± 2.77[c]	2.23 ± 1.12[c]	12.01 ± 1.99[c]	2.68 ± 0.48[c]	0.223 ± 0.01[b]
0.10	138.82 ± 4.25[b]	44.87 ± 1.43[b]	94.83 ± 3.77[b]	23.19 ± 0.72[b]	0.245 ± 0.00[ab]
0.15	359.34 ± 19.80[a]	114.05 ± 5.64[a]	246.01 ± 14.82[a]	62.18 ± 2.99[a]	0.254 ± 0.01[a]
0.20	359.03 ± 7.11[a]	112.55 ± 4.35[a]	246.79 ± 6.62[a]	58.93 ± 1.44[a]	0.239 ± 0.01[ab]
0.25	366.08 ± 13.26[a]	115.04 ± 5.97[a]	251.42 ± 10.18[a]	61.24 ± 2.59[a]	0.244 ± 0.01[ab]

[abc] Means with different superscripts in the same column differ significantly ($p < 0.05$).

per g weight gain, while the estimated requirement for maintenance was 0.029 mg/day per unit of metabolic body size. The estimated requirement for growth is in very close agreement with the result (2.0 mg/g gain) obtained by Owens et al. (1985). The sum of these requirements is the total tryptophan requirement. For example, if a growing chick weighing 376 g and gaining at the rate of 32 g weight gain per day is given as suggested by NRC (1994), the growth requirement would be 69.12 mg per day and the maintenance requirement would be 2.44 mg per day. Thus, the total requirement for tryptophan needed by this growing chick would be 71.56 mg per day. This means that about 3.4% of the total requirement would be utilized for maintenance. With 41.43 g per day of feed intake (NRC, 1994), the dietary level of tryptophan calculated to be 0.173% of the diet. This is close to the previous tryptophan requirements expressed as a percentage of the diet (0.18 ± 0.04) as presented in tabel 4.

Table 4. Comparison of tryptophan requirement in growing chicks

References	Age (days)	Response criteria	Breed	Requirement
Almquist, 1947	10-20	Growth	Not specified	0.25
Wilkening et al., 1947	10-24	Growth, feed efficiency	New hampshire × White leghorn	0.18
Griminger et al., 1956	10-20	Growth, feed efficiency	New hampshire × Columbian	0.143
Klain et al. 1960	7-14	Growth, feed efficiency	Not specified	0.17
Dean and Scott, 1965	7-14	Growth, feed efficiency	New hampshire × Columbian	0.225
Boomgaardt and Baker, 1971	8-14	Growth, feed efficiency (adjusted to 23% CP)	New hampshire × Columbian	0.20
Hewitt and Lewis, 1972	7-21	Growth, feed efficiency	Broiler strain	0.17
Hurwitz et al. 1978	7-14	Computer model	Not specified	0.163
Hurwitz et al. 1978	14-21	Computer model	Not specified	0.144

Daily tryptophan intakes are plotted against daily nitrogen gains in figure 2, including the prediction line and equation. The estimated requirement for growth was 0.078 mg per 1 mg nitrogen gain and the estimated requirement for maintenance was 0.029 mg/day per unit of metabolic body size. For instance, a chick weighing 376 g and gaining at the rate of 855 mg nitrogen gain per day would require 67 mg of tryptophan per day for growth. The maintenance requirement for tryptophan would be 2.45 mg per day. Thus, the total daily requirement needed by this growing chick would be 69 mg per day. About 3.5% of the total requirement would be utilized for maintenance. When this total requirement is expressed on daily intake basis, assuming that feed intake is 41.43 g per day, the dietary level of tryptophan would be 0.168% of the diet. The previously reported tryptophan requirements (0.18 ± 0.04) are in close agreement with this estimate.

From the equations of weight gain and nitrogen gain responses, the maintenance needs for tryptophan of a 1,000 g chick would be 5.09 mg/kg body weight/day, 5.12 mg/kg body weight/day, respectively. These estimates are much lower than previously reported values (62 mg/kg body weight/day, 19 mg/kg body weight/day) by Owens et al. (1985), Leveille et al. (1960), respectively.

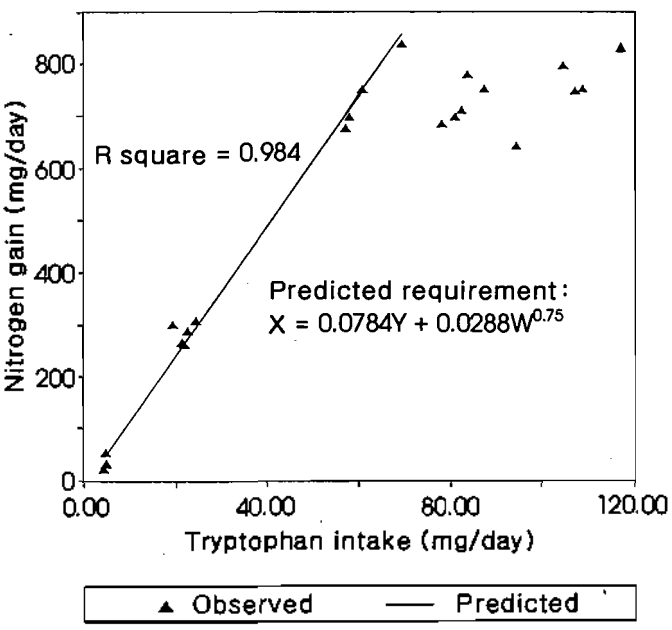

Figure 2. Nitrogen gain responses to daily tryptophan intake.

Based on the relationship of weight gain to nitrogen gain, the N percentage of retained body weight was 2.76%. Multiplied by 6.25, the protein content of weight gain would become 17.25%. Tryptophan as a percentage of retained CP calculated to be 1.25%. Previously reported tryptophan content of chick muscle; 0.77% (Williams et al., 1954), 1.03% (Price et al., 1953), respectively.

In conclusion, based on the comparison between the estimated value in this study and the previous estimated values, the model equation used in this study which was first tested by Shin et al. (1991) with rats, seems to be very useful in estimating a single amino acid requirement for growth and maintenance of growing chicks. However, since the estimates of this study was obtained only with male growing broilers, more study is needed to get the tryptophan requirement for female chicks, because tryptophan requirements can be different between male and female growing broilers (Freeman, 1979).

ACKNOWLEDGEMENTS

The authors are grateful to the Ajinomodo Co. for their donation of the amino acids and to Korea Chimical for their donation of the vitamin and mineral mixture. Without their donation, this research may not be completed.

REFERENCES

Almquist, H. J. 1947. Evaluation of amino acid requirements by observations on the chick. J. Nutr. 34:543-563.

AOAC. 1990. Official method of analysis (15th ed.). Association of official analytical chemists, Washington, D.C.

ARC. 1975. The nutrient requirements of farm livestock. No. 1. Poultry. 2nd ed. Agricultural Research Council (Her Majesty's Stationery : London.)

Boomgaardt, J. and D. H. Baker. 1971. Tryptophan requirement of growing chicks as affected by dietary protein level. J. Anim. Sci. 33:595-599.

Dean, W. F. and H. M. Scott. 1965. The development of an amino acid reference diet for the early growth of chicks. Poult. Sci. 44:803-808.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometrics 11:1-44.

Freeman, C. P. 1977. The tryptophan requirement of broiler chicks. Br. Poult. Sci. 20:27-37.

Griminger, P., H. M. Scott and R. M. Forbes. 1956. The effect of protein level on the tryptophan requirement of the growing chick. J. Nutr. 59:67-76.

Hurwitz, S., D. Sklan and I. Bartov. 1978. New formal approaches to the determination of energy and amino acid requirements of chicks. Poult. Sci. 57:197-205.

Klain, G. J., H. M. Scott and B. C. Johnson. 1960. The amino acid requirement of the growing chick fed a crystalline amino acid diet. Poult. Sci. 39:39-44.

Leveille, G. A., R. Shapiro and H. Fisher. 1960. Amino acid requirements for maintenance in the adult rooster. IV. The requirements for methionine, cystine, phenylalanine, tyrosine and tryptophan; the adequacy of the determined requirements. J. Nutr. 72:8-15.

NRC. 1994. Nutrient requirements of poultry. Ninth revised edition. National Research Council. Washington, D.C.

Owens, F. N., J. E. Pettigrew, S. G. Cornelius and R. L. Moser. 1985. Amino acid requirements for growth and maintenance of rats and chicks. J. Anim. Sci. 61(suppl. 1):312.

Price, W. A. Jr., M. W. Taylor and W. C. Russell. 1953. The retention of essential amino acids by the growing chick. J. Nutr. 51:413-422.

SAS. 1985. User's guide: Statistics. 5th Ed.

SCA. 1987. Feeding standards for australian livestock; Poultry. Standing Committee on Agriculture. Poultry subcommittee.

Shin, I. S., F. N. Owens. J. E. Pettigrew and J. W. Oltjen. 1991. Apportioning histidine requirements for maintenance versus growth. Nutr. Res. 11:1451-1463.

Wilkening, M. C., B. S. Schweigert, P. B. Pearson and R. M. Sherwood. 1947. Studies on the requirement of the chick for tryptophan. J. Nutr. 34:701-713.

Williams, H. H., L. V. Curtin, J. Abraham, J. K. Loosli and L. A. Maynard. 1954. Estimation of growth requirements for amino acids by assay of the carcass. J. Biol. Chem. 208:277-286.