Partition of Amino Acids Requirement for Maintenance and Growth of Broilers I. Lysine

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ABSTRACT : Purified diets containing five graded levels of lysine were fed to a total of 125 growing chicks (25 chicks per treatment) to evaluate lysine requirements for growth and maintenance. A model was developed to separate lysine requirement for maintenance from requirement for growth. Based on weight gain response, the daily lysine requirement for growth was 12.06 mg/g gain and the daily lysine requirement for maintenance was 0.332 times metabolic body size ($W^{0.75}$). Similarly, the lysine requirement for growth was 0.457 mg/mg nitrogen gain and the daily lysine requirement for maintenance was 0.344 times metabolic body size. The plateau of plasma lysine concentration was reached at 354.75 mg intake/day. The total lysine requirement was 414.27 mg/day or 1.0% of the diet, 420.11 mg/day or 1.01% of the diet based on weight gain response and N gain response, respectively. Previous lysine requirements for growing chicks of 1-28 days old were in close agreement with these estimates. As a percentage of protein, lysine requirement was calculated to be 7.3% and the reported lysine content of chick muscle crude protein of 7.46% was closely related.
(Key Words: Lysine, Growth, Maintenance, Broiler Chicks)

INTRODUCTION

Several studies have been conducted to estimate lysine requirement for growing chicks. As a result, there is ample information on total requirement of lysine for growing chicks. The lysine requirements estimated by NRC (1984, 1994) are 1.2% and 1.1% of the diet, respectively. However, Han and Baker (1991) reported that lysine requirement for maximal weight gain was 1.01% of the diet regardless of strain. Klain et al. (1960) also indicated that the lysine requirement for the growing chicks was 1.01% of the diet, using a crystalline amino acid diet. Boomgaardt and Baker (1973a) clearly demonstrated that the lysine requirement was 1.05% but affected by protein level. However, these lysine requirements are all expressed as total lysine requirements. There is little information on the lysine requirement for maintenance, especially for the broiler chicks. Other researchers have reported lysine requirement for maintenance is 99 mg per kg weight per day for broilers (Owens et al., 1985), and 29 mg per kg weight per day for adult roosters (Leveille and Fisher, 1959). Amino acids are required for a number of different functions in the body, and the requirements for some of these functions, although physiologically essential, are often ignored. The growth and maintenance requirements for lysine can vary according to the criterion and environmental conditions, nutrient limitations, or genetic potential influencing feed intake. It seems desirable to express amino acid requirements for maintenance, like energy requirements, on metabolic body size because daily nitrogen loss should be a result of surface and intestinal protein losses and like basal metabolic rate should be proportional to body weight (Shin, 1990).

The objective of the present study was to subdivide the lysine requirements into growth and maintenance, and to compare the estimates to previous estimates of total lysine requirements.

MATERIALS AND METHODS

Male Arbor Acres chicks of a broiler strain were used as experimental subjects. 5 groups of 5 chicks each were housed in battery cages made of steel wire in a room with constant light and air ventilation. The chicks, grouped to have uniform mean body weight, were alloted to the respective experimental groups. The experimental diets contained either 25, 50, 75, 100, 125% of NRC (1994)

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estimated lysine requirement for growing chicks with 100% of NRC requirement for all other amino acids. The composition of the basal diet is shown in table 1.

Table 1. Composition of basal diet for broilers

Ingredient	% of diet	Amino acid mixture[c]	% of diet
Corn starch to	100	L-Arginine	1.250
Amino Acids 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	Variable
$NaHCO_3$	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
Butylated hydroxy toluene	0.003	L-Threoine	0.800
		L-Tryptophan	0.200
		L-Valine	0.900
		L-Proline	0.600
		L-Glycine	0.750
		L-Glutamic acid	Variable
Total	100.000	Total	23.397

[a] Mineral mixture provided 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 provided 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).

L-lysine · HCl was substituted for L-glutamic acid on an equal weight basis so that all diets had the same amounts of amino acid mixture. During a 1 week pre-experimental period the chicks were fed a commercial diet. The experiemental diets were fed to the chicks for 2 weeks starting 8 days after hatching. The chicks had ad libitum access to fresh water and test diets. Initial body weight was 116.1 g. Body weights were measured each week to calculate weight gain and feed intake was measured daily on an replication basis during the entire experimental period. The experimental feeds were stored at −4℃ throughout the experimental period and residues were discarded daily to avoid any deterioration. Lysine intake was calculated by multiplying feed intake with dietary lysine concentration. On the final day of the experiment, plasma samples from five chicks selected randomly from each treatment were collected at the cervical arteries after decapitation. Samples were centrifuged (Hanil, Korea) at 3,000 rpm for 20 minutes in the heparinized tube immediately. Blood plasma obtained was deproteinized with sulfosalycilic acid (Terrlink et al., 1994), stored at −4℃ and analyzed for amino acid concentration using an automatic amino acid analyzer (LKB 4150, Pharmacia Instrument Co., England). In addition, five chicks from each treatment were sacrificed by cervical dislocation for carcass analysis including feathers. After removing intestinal contents, carcasses including internal organs and feathers were stored at −20℃ until body composition (total body water and N content) was determined. Carcass samples were freeze dried (Ilsin Engineering, Korea), ground and analyzed by AOAC (1990) methods. At the beginning of the experiment, body composition of 6 chicks (8 days old) was determined for calculation of body nitrogen.

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

I = 1/a (R-bW$^{0.75}$) Also to
where I = amino acid intake, 0.05).
R = response,
-b/a Wg$^{0.75}$= maintenance requirement per metabolic body weight
1/a = growth requirement per g body gain or mg nitrogen gain.

All parameters were determined at the point at which the residual sum of squares was minimized by the Nonlinear Least Squares method (SAS, 1985). The equation covering the plateau portion was not included in the equation estimating lysine requirement because, genetic potential, energy or some nutrients other than amino acids were limiting response in that region of the response curve (figure 1). The relationship between plasma lysine concentration and daily lysine intake was described by a broken-line model and the breakpoint was determined by solving the two equations.

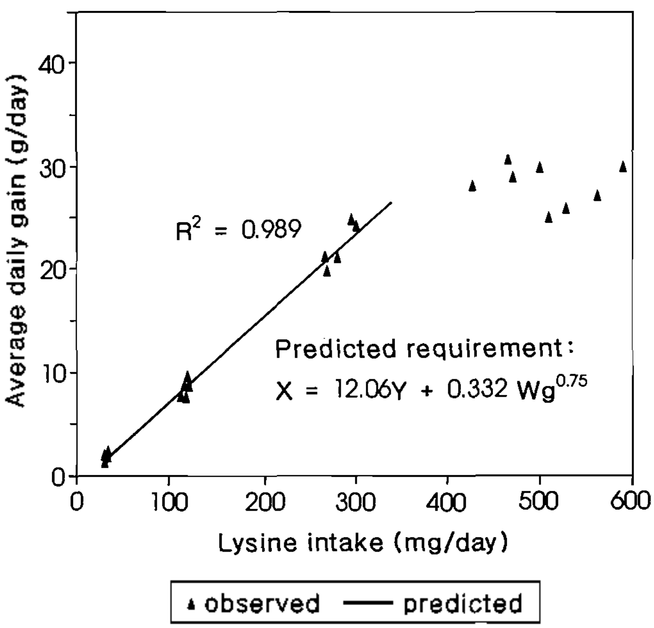

Figure 1. Weight gain responses to daily lysine intake.

RESULTS AND DISCUSSION

Responses of chicks fed diets containing five different levels of lysine are shown in table 2. Feed intake, weight gain, nitrogen gain, and gain to feed ratio increased linealy up to 1.1% lysine, beyond 1.1% lysine the responses were diminished. It was found that less than 0.275% lysine was required for maintenance.

Water content of chick carcasses increased in the same manner as protein content of chick carcasses increased up to 1.1% lysine as indicated in table 3. The dry matter in weight gain decreased consistently as the level of dietary lysine increased up to 1.1%, and the protein concentration in dry matter also increased (from 39 to 51% of dry matter). But the ratio of protein gain to water gain remained relatively constant. The data for separating lysine 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 12.06 mg per g weight gain, while the estimated requirement for maintenance was 0.332 mg/day per unit of metabolic body size. The sum of these requirements is the total lysine requirement. The typical body weight, feed intake, and weight gain of 2 week old broilers suggested by NRC (1994) are 376 g, 41.43 g/d, 32 g/d, respectively. From the equation in figure 1 using the NRC figures, the lysine requirement for growth is 385.92 mg per day, and for maintenance 28.35 mg per day. Thus, the total requirement of lysine is 414.27 mg per day. At this rate of gain, about 6.84% of total lysine requirement would be utilized for maintenance. With 41.43 g of average daily feed intake (ADFI), the dietary level of lysine needed would be 1.0% of the diet.

Table 2. Responses of chicks fed diets containing five different levels of lysine[1]

Lysine	Mean[2] $W^{0.75}$	Average daily feed intake	Average daily gain	Lysine intake	Nitrogen[3] retention	Gain/ feed
%	g	g/day	g/day	mg/day	%	
0.275	37.81 ± 0.22	11.60 ± 0.33	1.68 ± 0.19	31.90 ± 0.90	1.65 ± 0.18	0.14 ± 0.01
0.550	47.66 ± 0.39	21.71 ± 0.22	8.41 ± 0.36	119.41 ± 1.22	4.37 ± 0.23	0.39 ± 0.01
0.825	64.37 ± 0.97	34.51 ± 0.90	21.97 ± 0.94	284.72 ± 7.39	7.29 ± 0.31	0.64 ± 0.01
1.100	71.70 ± 1.67	40.64 ± 2.12	27.84 ± 1.54	447.02 ± 23.35	8.05 ± 0.10	0.68 ± 0.02
1.375	68.93 ± 1.44	38.12 ± 1.97	24.69 ± 2.31	524.21 ± 27.02	7.49 ± 0.31	0.64 ± 0.03

[1] Average initial weight was 116.1 g.
[2] $W^{0.75}$ is {initial weight + final weight)/2}$^{0.75}$.
[3] Values are means ± S.E. of 5 chicks of each treatment.

Table 3. Body composition of chicks fed five graded levels of lysine

Lysine	Live body weight gain	Dry matter in body weight	Water gain	Protein gain	Protein gain/ water gain
%	g	g	g	g	
0.275	21.90 ± 2.42^{d}	9.20 ± 1.12^{c}	14.73 ± 1.64^{a}	3.61 ± 0.46^{d}	0.243 ± 0.01
0.550	109.38 ± 4.67^{c}	41.76 ± 2.37^{b}	71.67 ± 2.81^{c}	17.76 ± 0.99^{c}	0.247 ± 0.01
0.825	285.63 ± 12.17^{b}	94.68 ± 6.83^{a}	192.64 ± 7.45^{b}	47.11 ± 2.76^{b}	0.244 ± 0.01
1.100	361.99 ± 19.98^{a}	107.70 ± 7.54^{a}	253.20 ± 14.36^{a}	61.10 ± 3.21^{a}	0.242 ± 0.01
1.375	320.95 ± 30.04^{ab}	105.65 ± 4.30^{a}	221.01 ± 22.03^{ab}	53.73 ± 4.53^{ab}	0.246 ± 0.01

^{abcd} Means with different superscripts in the same column differ significantly ($p < 0.05$).

Table 4. Blood plasma amino acid concentrations of broilers fed five graded levels of lysine (mg/100 ml)

AA	Dietary lysine (%)					SE[1]
	0.225	0.550	0.875	1.100	1.375	
THR $^{\ell}$	29.206^{a}	24.242^{ab}	21.722^{ab}	21.780^{ab}	11.248^{b}	2.29
VAL	5.432^{c}	6.702^{bc}	7.788^{abc}	8.380^{ab}	9.450^{a}	0.43
MET	2.470	3.568	3.028	3.526	3.202	0.31
ILE	3.064	4.300	4.804	3.258	3.526	0.34
LEU	4.010	5.452	5.316	4.148	4.474	0.33
PHE	4.728	7.770	8.098	7.330	5.014	0.85
HIS^{q}	6.706^{ab}	9.494^{a}	9.700^{a}	6.050^{b}	6.104^{b}	0.52
LYS	4.216^{c}	4.222^{c}	3.436^{c}	12.476^{b}	25.196^{a}	1.85
ARG $^{\ell}$	9.070^{b}	13.908^{ab}	14.128^{ab}	14.364^{ab}	15.350^{a}	0.82
EAA :	68.89	80.74	79.67	79.63	82.50	3.91
ASP $^{\ell}$	3.500^{b}	4.216^{ab}	4.840^{ab}	4.572^{ab}	5.778^{a}	0.25
SER	13.360	12.704	12.926	10.666	11.658	0.56
GLU $^{\ell}$	13.834^{b}	20.330^{ab}	19.978^{ab}	19.186^{ab}	27.060^{a}	1.34
PRO	6.074	7.304	7.134	11.122	8.238	0.75
GLY $^{\ell}$	13.252^{ab}	15.184^{a}	11.670^{b}	10.552^{b}	11.060^{b}	0.56
ALA $^{\ell}$	11.826^{b}	18.128^{ab}	27.102^{a}	22.934^{a}	24.116^{a}	1.60
TYR	7.470	10.540	12.082	9.932	8.114	1.17
NEAA $^{\ell}$:	69.31^{b}	88.21^{ab}	95.72^{a}	88.96^{ab}	96.03^{a}	3.69
Total	138.20	168.95	175.39	168.60	178.52	7.05

[1] Standard error of the mean.

^{abc} Means with different superscripts in the same row differ significantly ($p < 0.05$).

$^{\ell}$ Linear relationship among treatment means ($p < 0.05$).

^{q} Quadratic relationship among treatment means ($p < 0.05$).

This value was compared with previous estimates of lysine requirement for growing chicks presented in table 5. Except for Zimmerman and Scott (1965), estimates were in reasonably close agreement with present estimates. Previously estimated requirement of lysine for growing chicks aging 1-28 days, averaged 1.01 ± 0.14 (N = 12) as indicated in table 5.

Daily lysine intake was plotted against daily nitrogen gains in figure 2, including the prediction equation. The estimated requirement for growth was 0.457 mg/ per mg nitrogen gain and the estimated requirement for maintenance was 0.344 mg/day per unit of metabolic body size.

Table 5. Comparison of lysine requirements in growing chicks

References	Age (days)	Response criteria	Breed	Requirements (%)
Grau et al. 1946	14-28	Growth	Not specified	0.96
Almquist, 1947	10-20	Growth	Not specified	0.90
Edwards et al. 1956	1-28	Growth, feed efficiency	Rhode Island Red × Barred Plymouth Rock	1.10
Klain et al. 1960	7-14	Growth, feed efficiency	Not specified	1.01
Zimmerman and Scott, 1965	7-14	Growth, feed efficiency, plasma amino acids	New Hampshire × Columbian	0.83
Zimmerman and Scott, 1965	14-21	Growth, feed efficiency, plasma amino acids	New Hampshire × Columbian	0.70
Boomgaardt and Baker, 1973a	14-28	Growth, feed efficiency	New Hampshire × Columbian	1.05
Boomgaardt and Baker, 1973b	14-21	Growth, feed efficiency	New Hampshire × Columbian	1.06
Hurwitz et al. 1978	7-14	Computer model	Not specified	1.18
Hurwitz et al. 1978	14-21	Computer model	Not specified	1.00
Attia and Latshaw, 1979	1-21	Growth, feed efficiency	Broiler strain	1.18
Burton and Waldroup, 1979	1-28	Growth, feed efficiency	Broiler strain	1.10

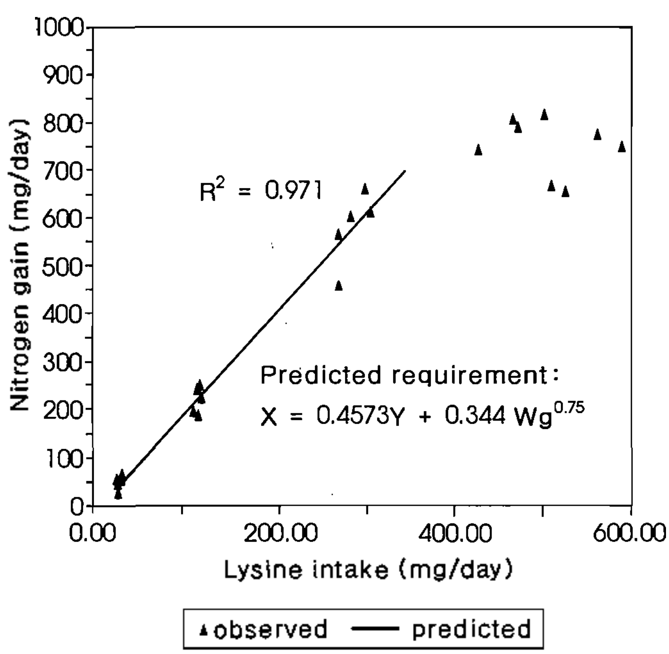

Figure 2. Nitrogen gain responses to daily lysine intake.

For a chick gaining 855 mg nitrogen per day and weighing 376 g, the estimated requirement for growth was 390.74 mg per day and the requirement for maintenance was 29.37 mg per day. Thus, the total lysine requirement was 420.11 mg per day, and this turned out to be 1.01% of the diet. This value is in close agreement with estimates reported previously. Based on the nitrogen gain response, the maintenance requirement of lysine for 1 kg chick would be 61.17 mg per day, which is considerably higher than the the previously estimated value (29 mg/kg body weight/day) by Leveille and Fisher (1959), but lower than the reported value (99 mg/kg body weight/day) by Owens et al. (1985). However, since Leveille and Fisher (1959) used nitrogen balance as a response criteria and in their study, at the level of 29 mg, the chicks were losing body weight, when using zero response as a criteria, the maintenance needs for lysine would be expected to be higher than 29 mg/kg body weight/day. Also it should be noted that our estimates was obtained with the chicks weighing from about 100 g to 600 g, thus it may not be accurate to extrapolate the results to 1 kg chicks. From the relationship of weight gain to nitrogen gain response, the nitrogen content of weight gain would be 2.64%, which equals 16.5% crude protein in gained weight. As a percentage of retained CP, the lysine requirement was calculated to be 7.3%; this can be compared with the mean value (7.46%) of lysine concentration of whole muscle crude protein of chicks (Williams et al., 1954).

Plasma amino acid concentrations of growing chicks fed diets containing five graded levels of lysine are presented in table 4 and the response of plasma lysine to daily lysine intake is shown in figure 3. The plasma lysine concentration remained relatively constant up to the breakpoint (354.75 mg/day), then it increased abruptly. If this breakpoint value was converted to a percentage of the diet with 41.43 g of ADFI, it would be 0.86% of the diet, considerably below the mean value of the previous estimates of 1.01 ± 0.14. The estimated value would be in close agreement with the result by Zimmerman and Scott (1965) who used plasma amino acid concentration as response criteria. However, plasma samples were collected at the end of the study, not the midpoint of the study and thereby may be lower.

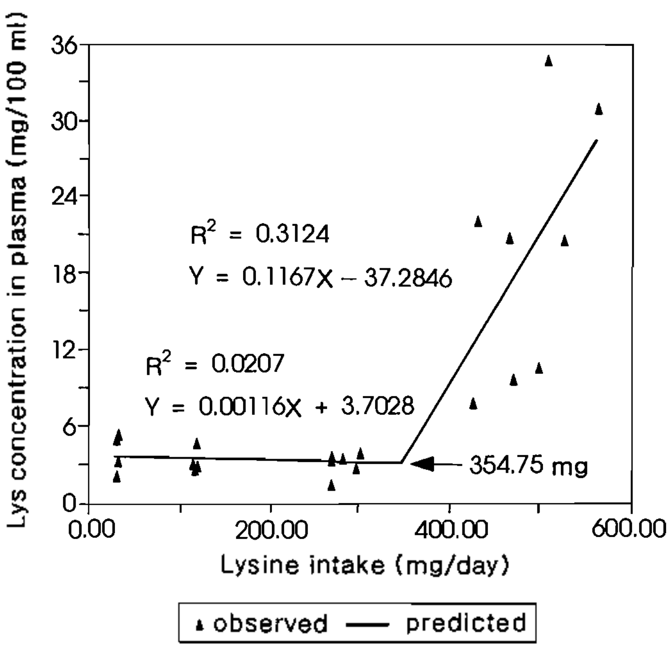

Figure 3. Plasma lysine responses to daily lysine intake.

As dietary lysine supply was increased, plasma asparagine, glutamic acid, alanine, and arginine were increased linearly ($p < 0.05$), while plasma histidine was changed in quadratic fashion ($p < 0.05$). However, plasma free threonine and glycine were decreased in linear fashion, as dietary lysine supply was increased. Zimmerman and Scott (1965) also reported that severe deficiency of lysine markedly increased plasma threonine. As for other amino acids, the results were so variable. In general, it has been known that well balanced protein would tend to minimize the accumulation of free amino acid nitrogen in blood plasma (Zimmerman and Scott, 1965).

Collectively, the equation tested in this study appeared to be useful to estimate a single amino acids requirements for growth and maintenance. However, the results obtained was limited to a chick weighing from 100 g to 600 g, thus it needs further study to extrapolate the equation to practical industry. It should be noticed that the results was obtained only with male growing broilers.

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