# Partition of Amino Acid Requirements of Broilers between Maintenance and Growth. IV. Threonine and Glycine

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**ABSTRACT** : Two experiments were conducted to subdivide threonine (exp. 1) and glycine (exp. 2) requirements of broilers into maintenance and growth requirements. Purified diets containing five graded levels of threonine (exp. 1) and glycine (exp. 2) were fed to growing chicks to estimate threonine (exp. 1) and glycine (exp. 2) requirements for growth and maintenance. A model developed to divide threonine requirement for maintenance from that for growth yielded a requirement for growth of 8.946 mg/g weight gain and 0.341 mg/mg N gain; the maintenance requirement was 0.033 or 0.030 mg per unit of metabolic body size ($Wg^{0.75}$). The plateau of plasma threonine concentration occurred at 279.4 mg threonine intake/day. The total threonine requirement was 289.1 mg/day or 0.69% of the diet, 294.1 mg/day or 0.71% of the diet based on weight gain and nitrogen gain responses, respectively. These estimates were in close agreement with previous estimates of threonine requirements. From the relationship of weight gain to N gain, 5.46% of the retained protein consisted of threonine; the reported threonine content of chick muscle was 4.02%. The glycine requirement for maintenance could not be determined due to failure to obtain data allowing extrapolation to zero response. However, ADG increased slightly up to 0.56% glycine. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 3 : 381-387*)

Key Words : Threonine, Glycine, Requirement, Growth, Maintenance, Chicks

## INTRODUCTION

Threonine has been reported to be a dietary essential amino acid for chicks (Almquist and Grau, 1944 ; Grau, 1947). Almquist and Grau (1944) estimated the amount of threonine necessary to induce optimum growth of growing chicks. They concluded that 1.0% DL-threonine was insufficient for optimum growth whereas 2.0% appeared adequate. Grau (1947) obtained satisfactory growth with an amino acid mixture which contained 1.3% DL-threonine. Many other early reports give estimates of the threonine requirement of growing chicks (Almquist, 1947; Krautmann et al., 1958; Klain et al., 1960; Thomas and Bossard, 1982; Davis and Austic, 1982; Thomas et al., 1986; ARC, 1975; SCA, 1987; NRC, 1984, 1994), but they have not separated the requirement into those for gain and maintenance.

Robbins (1987) reported that the requirement for any indispensable amino acid (expressed as a percent of crude protein) remained constant as dietary crude protein varied between deficiency and adequacy, and so he concluded that the threonine requirement was 3.7% of dietary crude protein, and was little affected by dietary protein content.

The information on the threonine requirement for maintenance is scarce, especially for the broiler chicks. Leveille and Fisher (1960) reported that the maintenance requirement for L - threonine was 74 mg/kg body weight/day, and the minimal maintenance level was 55 mg/kg body weight/day. They also concluded the D-isomer of threonine is not available to the adult rooster.

Almquist and Grau (1944) demonstrated that for maximal chick growth glycine was considered an indispensable amino acid. However, since serine by loss of the $\beta$-carbon atom can be converted to glycine, serine might spare dietary glycine (Baker et al., 1968). The nonessentiality of glycine was also reported by Sugahara and Kandatsu (1976). Wixom et al. (1958) explained that serine could partially replace the need for glycine in chicks fed casein protein. Greene et al. (1960) observed improved body weight gains in chicks when 2.0% glycine was added to a diet containing an amino acid mixture as a sole source of nitrogen. The diet, however, contained no serine and the experiment was conducted on 9-day-old chicks for a period of 5 days. Klain et al. (1960) reported 0.5% glycine to be essential for supporting optimal growth of 7 - day - old chicks when a diet containing 30% of an amino acid mixture without serine was fed for an experimental period of 7 days. Dean and Scott (1965) also observed a dietary glycine requirement of 1.6% when an amino acid mixture devoid of serine was fed to 7 - day - old chicks for the same experimental period.

The glycine + serine requirements recommended by ARC (1975), NRC (1984, 1994) were 1.14%, 1.50% and 1.25%, respectively. No maintenance requirements for glycine alone were given.

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 can vary with response criterion and environmental conditions, nutrient deficiency, or genetic potentials influencing feed intake. It seems desirable to express amino acid requirements for maintenance, as for energy requirements, on the basis of metabolic body size because daily N loss should be a result of surface and

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intestinal protein losses and like basal metabolic rate should be proportional to body weight (Shin, 1990).

Using the model equation developed by Shin et al. (1992), the lysine, methionine and tryptophan requirements for chicks (Kim et al, 1997a,b,c) and the lysine, methionine+cystine and threonine requirements for swine (Yang et al, 1997a,b,c) were successfully subdivided into maintenance and growth.

The objective of the present study was to subdivide the threonine (exp. 1) and glycine (exp. 2) requirements into one part for growth, and another part for maintenance, and to compare those estimates obtained from these studies with previous estimates of total threonine and glycine requirements.

## MATERIALS AND METHODS

A total of 250 male Arbor Acres chicks (125 chicks per experiment) of a broiler strain were used as experimental subjects. Groups of 5 chicks were housed in battery cages made of steel wire in a room with constant light and air ventilation. The chicks were grouped to have uniform mean body weight and alloted to the respective treatment. The experimental diets contained either 25, 50, 75, 100 or 125% of NRC (1994) estimated threonine (exp. 1) and glycine (exp. 2) requirements for growing chicks, with 100% of NRC requirements for all other amino acids. The composition of the basal diet is shown in table 1.

L - threonine (exp. 1) and L - glycine (exp. 2) were substituted with L - glutamic acid on an equal weight basis, respectively, so that all diets had the same amounts of amino acid mixture. During 1 week of pre - experimental periods, the chicks were fed a commercial diet. From the day 8 posthatching the experimental diets were fed to the chicks for 2 weeks. The chicks had *ad libitum* access to fresh water and test diets. Initial body weight was about 135 g. Body weights were measured each week to calculate weight gain and feed intakes were measured daily on a replication basis during the entire experimental period. The experimental feeds were stored at -4℃ throughout the experimental period and any remains in the feeders were discarded daily to avoid any deterioration. Threonine and glycine intakes were calculated by multiplying feed intake with dietary threonine and glycine level, respectively. For the threonine trial, on the final day of the experiment, blood samples from five chicks selected randomly from each treatment were taken by heart puncture (Zimmerman and Scott, 1965). Samples were immediately centrifuged (Hanil, Korea) at 3,000 rpm for 20 minutes in a heparinized tube. Blood plasma was deproteinized with sulfosalycilic acid (Terrlink et al., 1994), stored at -4℃ and analyzed for amino acid concentration using automatic amino acid analyzer (Biochrom 20, Pharmacia Biotech Co., England).

In both trials, five chicks from each treatment were sacrificed by cervical dislocation for carcass analysis. 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 was determined to calculate body nitrogen retention.

**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 |
| AA mixture | 23.397 | L-Histidine · HCl · $H_2O$ | 0.473 |
| Mineral mixture[a] | 5.370 | L-Isoleucine | 0.800 |
| Soy oil | 5.000 | L-Leucine | 1.200 |
| Cellulose | 5.000 | L-Lysine · HCl | 1.374 |
| | | L-Methionine | 0.500 |
| $NaHCO_3$ | 1.500 | L-Cystine | 0.400 |
| Vitamin mixture[b] | 0.200 | L-Phenylalanine | 0.720 |
| Choline chloride | 0.200 | L-Tyrosine | 0.620 |
| | | L-Threonine | variable |
| Tocopheryl acetate | 0.002 | L-Tryptophan | 0.200 |
| | | L-Valine | 0.900 |
| | | L-Proline | 0.600 |
| BHT | 0.003 | L-Glycine | variable |
| Total | 100.00 | L-Glutamic acid | variable |
| | | Total | 23.397 |

a Mineral mixture provided per kilogram of diet: $CaCO_3$, 3.0 g; $Ca_3(PO_4)_2$, 28.0 g; $K_2HPO_4$, 9.0 g; NaCl, 8.8 g; $MgSO_4 \cdot 7H_2O$, 3.5 g; $MnSO_4 \cdot H_2O$, 0.65 g; ferric citrate 0.5 g; $ZnCO_3$, 0.1 g; $CuSO_4 \cdot 5H_2O$, 20.0 mg; $H_3BO_3$, 9.0 mg; $Na_2MoO_4 \cdot 2H_2O$, 9.0 mg; KI, 40.6 mg; $CoSO_4 \cdot 7H_2O$, 1.0 mg; $Na_2SeO_3$, 0.215 mg.

b Vitamin mixture provided per kilogram of diet: thiamin · HCl, 20 mg; niacin, 50 mg; riboflavin, 10 mg; D - Ca pantothenate, 30 mg; Vit $B_{12}$, 0.04 mg; pyridoxine · HCl, 6 mg; biotin, 0.6 mg; folic acid, 4 mg; menadione, 2 mg; Vit C, 250 mg; Vit A, 5,200 IU; Vit D, 600 IU.

c Patterned after NRC (1994).

The mathematical equation for the model to subdivide the threonine 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. (1992). The equation is

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

where,

$I$ = amino acid intake

$R$ = response

$-b/a\ Wg^{0.75}$ = 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). A term covering the plateau portion was not included in the equation estimating the threonine requirement because genetic potential, energy, or some nutrients other than amino acids were found to limit response in that region of the response curve (Shin et al., 1992). The relationship between plasma threonine concentration and daily threonine intake was described by a broken - line model and its breakpoint was determined by solving two equations.

## RESULTS AND DISCUSSION

**Experiment 1**

Responses of chicks fed diets containing five different levels of threonine are shown in table 2. Feed intake, weight gain, nitrogen gain and gain to feed ratio increased rapidly up to 0.60% threonine; beyond 0.60% threonine the responses were minor. It was found that less than 0.2% threonine was required for maintenance.

Water content of chick carcasses increased in the same way as protein content of chick carcasses increased up to 0.60% threonine. Only the group of chicks fed 0.20% threonine diets had a lower protein gain to water gain ratio indicating that threonine deficiency might restrict body protein deposition.

The data for separating threonine requirements into one portion for maintenance and another portion for growth are shown in figure 1. Based on the weight gain response, the estimated growth requirement was 8.946 mg per g weight gain, while the estimated requirement for maintenance was 0.033 mg/day per unit of metabolic body size. The sum of these requirements is the total threonine 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 and 32 g/d,

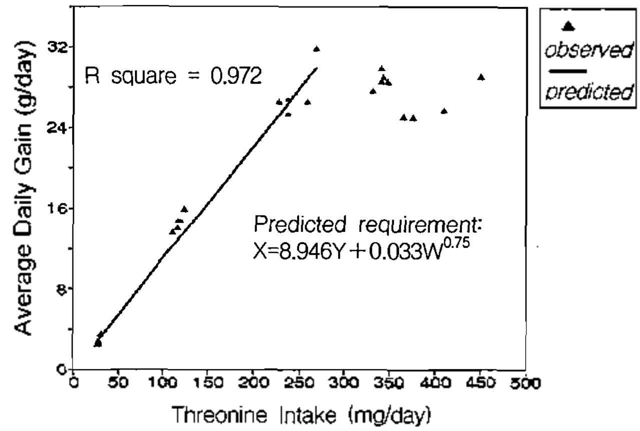


**Figure 1.** Weight gain responses to daily threonine intake

respectively. From the equation in figure 1, the threonine requirement for growth was 286 mg per day, and for maintenance 2.8 mg per day. Thus, the total requirement of threonine was 289 mg per day. At this rate of gain, about 0.98% of total requirement would be utilized for maintenance. With 41.43 g of ADFI (NRC, 1994), the dietary level of threonine needed would be 0.69% of the diet. Previous estimated requirements of growing chicks aging 1~21 days averaged 0.68%±0.03 and are in reasonably close agreement with present estimates as indicated in table 5.

Daily nitrogen gain has been plotted against daily threonine intakes in figure 2. The prediction line and equation also are included. The estimated requirement for nitrogen gain was 0.341 mg per mg nitrogen gain and the estimated requirement for nitrogen maintenance

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

| Dietary level | Mean[2] $Wg^{0.75}$ | Average Daily Feed Intake[3] | Average Daily Gain[3] | Threonine intake[3] | Nitrogen retention[3] | Gain/feed[3] |
|---|---|---|---|---|---|---|
| % | g | g | g | mg/day | % | |
| 0.20 | 43.77±0.31 | 14.11±0.26[d] | 2.83±0.19[d] | 28.22±0.51 | 15.19±0.57 | 0.20±0.01[c] |
| 0.40 | 60.49±0.56 | 29.30±0.49[c] | 14.62±0.39[c] | 117.22±1.97 | 37.55±0.71 | 0.50±0.01[b] |
| 0.60 | 76.90±1.37 | 41.11±1.27[ab] | 27.39±1.13[ab] | 246.69±7.65 | 52.76±1.34 | 0.67±0.02[a] |
| 0.80 | 78.25±0.44 | 42.56±0.32[a] | 28.63±0.34[a] | 340.48±2.60 | 52.84±1.16 | 0.67±0.01[a] |
| 1.00 | 74.91±0.98 | 39.27±1.64[b] | 25.88±0.78[b] | 392.70±16.42 | 53.38±1.25 | 0.66±0.01[a] |

[a,b,c] Means with different superscripts in the same column differ (p<0.05). [1] Average initial weight was 134.79 g.
[2] $Wg^{0.75}$ is {(initial weight+final weight)/2}$^{0.75}$. [3] Values are means±SE of 5 chicks of each treatment.

Table 3. Changes in protein and water contents of chicks fed five graded levels of threonine[1]

| Dietary level | Live body weight | Dry body weight | Water gain | Protein gain | Protein gain /water gain |
|---|---|---|---|---|---|
| % | g | g | g | g | |
| 0.20 | 43.1± 2.1[c] | 11.3±1.7[c] | 31.8± 0.5[c] | 7.2±0.9[c] | 0.227±0.03[b] |
| 0.40 | 169.6±16.2[b] | 59.8±6.0[b] | 109.8±10.9[b] | 28.7±3.1[b] | 0.260±0.01[a] |
| 0.60 | 346.8±22.0[a] | 112.0±9.6[a] | 234.8±12.8[a] | 62.3±4.2[a] | 0.265±0.01[a] |
| 0.80 | 339.7±13.6[a] | 111.9±4.8[a] | 227.8±10.2[a] | 63.1±2.3[a] | 0.278±0.01[a] |
| 1.00 | 327.9±14.0[a] | 111.5±2.3[a] | 216.3±11.8[a] | 62.3±2.3[a] | 0.289±0.01[a] |

[a,b,c] Means with different superscripts in the same column differ (p<0.05).
[1] Values are means±SE of 5 chicks of each treatment.

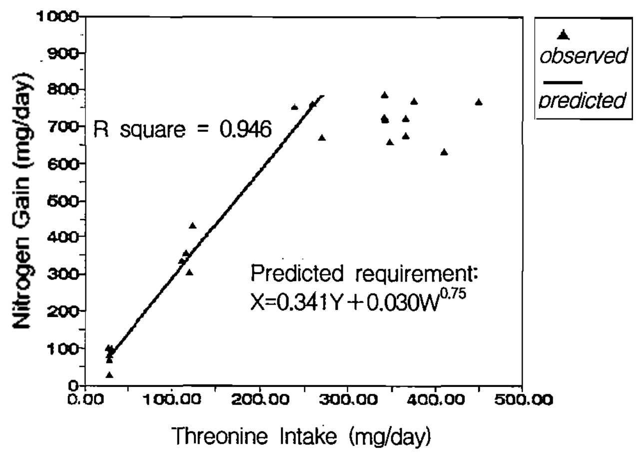


**Figure 2.** Nitrogen gain responses to daily threonine intake

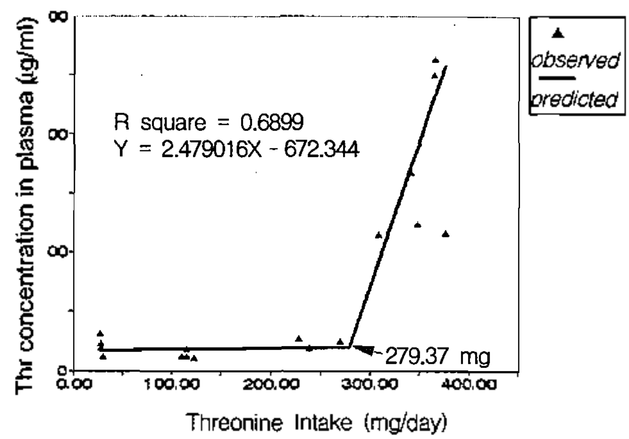


**Figure 3.** Plasma threonine responses to daily threonine intake

is 0.030 mg per unit of metabolic body size. For a chick gaining 855 mg nitrogen per day and weighing 376 g, the estimated requirement for growth was 291.56 mg per day and the requirement for maintenance was 2.56 mg per day. Thus, the total requirement to meet this performance level would be 294 mg per day and represent 0.70% of the diet.

Based on the weight gain and nitrogen gain responses, the maintenance requirement of threonine for a 1 kg chick would be 5.87 mg and 5.33 mg/day, respectively. These estimates are much lower than previously reported (74 mg/kg body weight/day) by Leveille and Fisher (1960). In the report of Leveille and Fisher (1960), because they used White Leghorn roosters at least 12 months old as experimental subjects, the maintenance requirement might be higher. Also, we used 23% crude protein in the basal diet using synthetic amino acids mixture. This level of synthetic amino acids mixture might be higher than chick's actual requirement for crude protein.

The relationship of growth to N gain suggests that weight gain contains 2.62% N ; this equals to 16.4% CP in deposited body weight. As a percentage of deposited CP, this growth requirement equals 5.46% (0.341/6.25) of the retained CP. The reported threonine content of chick muscle CP was 4.02% (Williams et al., 1954). In the report of Williams et al. (1954), it has been concluded that not only the pattern of amino acid composition is comparable within each species at the different stages of growth, but also remarkably similar

**Table 4.** Plasma amino acid concentrations of chicks fed five graded levels of threonine (μg/ml)

| Amino acids | Dietary threonine (%) | | | | | SE[1] |
|---|---|---|---|---|---|---|
| | 0.20 | 0.40 | 0.60 | 0.80 | 1.00 | |
| Threonine[lmr] | 24.88[bc] | 16.22[c] | 33.62[bc] | 87.65[b] | 173.24[a] | 14.61 |
| Valine[m] | 16.59[b] | 18.38[b] | 22.88[ab] | 25.33[ab] | 32.96[a] | 1.77 |
| Methionine | 4.33 | 5.49 | 4.96 | 5.75 | 5.64 | 0.39 |
| Isoleucine[l] | 8.88[b] | 11.51[ab] | 11.77[ab] | 11.27[ab] | 13.94[a] | 0.65 |
| Leucine[m] | 15.02[c] | 17.70[bc] | 20.50[bc] | 23.25[ab] | 27.21[a] | 1.20 |
| Phenylalanine[mq] | 11.48[b] | 11.98[b] | 12.55[b] | 25.32[a] | 28.52[a] | 1.75 |
| Lysine[m] | 102.36[ab] | 140.19[a] | 74.44[b] | 72.50[b] | 51.65[b] | 9.27 |
| Histidine | 23.25[a] | 28.50[a] | 11.78[b] | 22.58[a] | 21.98[a] | 1.62 |
| Arginine | 21.74[b] | 20.01[b] | 35.38[a] | 15.64[b] | 21.45[b] | 2.01 |
| Asparatic acid | 8.74 | 7.43 | 9.08 | 50.27 | 13.11 | 6.99 |
| Serine[q] | 79.66[ab] | 56.73[ab] | 51.48[b] | 71.68[ab] | 81.03[a] | 4.46 |
| Glutamic acid | 77.69[a] | 61.78[ab] | 77.38[a] | 106.75[a] | 18.55[b] | 8.31 |
| Proline | 9.14 | 7.50 | 16.43 | 9.94 | 31.23 | 3.60 |
| Glycine[m] | 24.02[b] | 22.18[b] | 25.32[b] | 37.16[a] | 34.88[a] | 1.65 |
| Alanine | 32.08[b] | 30.28[b] | 52.11[a] | 42.83[ab] | 37.54[ab] | 2.66 |
| Cystine | 40.80 | 34.47 | 36.86 | 72.38 | 73.69 | 7.66 |
| Tyrosine[m] | 18.18[ab] | 19.20[ab] | 23.86[a] | 9.16[bc] | 2.85[c] | 2.31 |
| Total | 415.69 | 359.35 | 438.09 | 489.11 | 415.47 | 22.01 |

[1] Standard error of the mean. [a,b,c] Means with different superscripts in the same row differ ($p<0.05$).
[l] Linear relationship among treatment means ($p<0.05$). [m] Linear relationship among treatment means ($p<0.01$).
[q] Quadratic relationship among treatment means ($p<0.05$). [r] Quadratic relationship among treatment means ($p<0.01$).

Table 5. Comparison of previous estimates of threonine requirements in growing chicks

| Requirement (%) | Age period (days) | Response criteria | Breed | References |
|---|---|---|---|---|
| 0.60 | 10 - 20 | Growth, feed efficiency | Not specified | Almquist, 1947 |
| 0.55 - 0.60 | 7 - 21 | Growth, feed efficiency | Barred Plymouth Rock | Krautmann et al., 1958 |
| 0.58 | 7 - 14 | Growth, feed efficiency | Not specified | Klain et al., 1960 |
| 0.65 | 7 - 14 | Growth, feed efficiency | New Hampshire × Columbian | Dean and Scott, 1965 |
| 0.70 | 1 - 18 | Growth, feed efficiency | New Hampshire × White Leghorn | Bhargava et al., 1971 |
| 0.53 | 7 - 21 | Growth, feed efficiency | Broiler strain | Hewitt and Lewis, 1972 |
| 0.80 | 7 - 14 | Computer model | Not specified | Hurwitz et al., 1978 |
| 0.71 | 14 - 21 | Computer model | Not specified | Hurwitz et al., 1978 |
| 0.73 - 0.75 | 1 - 21 | Growth, feed efficiency | ISA JV 715 | Uzu, 1986 |
| 0.85 | 3 - 14 | Growth, feed efficiency (adjusted to 23% crude protein) | Peterson | Robbins, 1987 |
| 0.72 | 7 - 21 | Growth, feed efficiency | Broiler strain | Thomas et al., 1987 |
| 0.60 | 0 - 4 weeks | | | ARC, 1975 |
| 0.68 | 0 - 4 weeks | | | SCA, 1987 |
| 0.68 | 0 - 3 weeks | | | NRC, 1984 |
| 0.80 | 0 - 3 weeks | | | NRC, 1994 |

Table 6. Responses of chicks fed diets containing five different levels of glycine[1]

| Dietary level | Mean[2] $Wg^{0.75}$ | Average Daily Feed Intake[3] | Average Daily Gain[3] | Glycine intake[3] | Nitrogen retention[3] | Gain/feed[3] |
|---|---|---|---|---|---|---|
| | g | g | g | mg/day | % | |
| 0.19 | 73.0±1.01 | $39.5\pm1.48^{ab}$ | $24.3\pm0.85^{c}$ | 74.1±2.75 | 54.43±2.09 | $0.62\pm0.01^{b}$ |
| 0.38 | 74.2±0.85 | $37.8\pm1.26^{b}$ | $25.3\pm0.62^{bc}$ | 141.7±4.74 | 55.74±2.15 | $0.67\pm0.01^{a}$ |
| 0.56 | 77.2±0.64 | $40.0\pm1.88^{ab}$ | $27.6\pm0.44^{ab}$ | 224.8±10.60 | 60.13±2.24 | $0.70\pm0.03^{a}$ |
| 0.75 | 78.3±0.44 | $42.6\pm0.32^{a}$ | $28.6\pm0.34^{a}$ | 319.2±2.44 | 53.03±1.06 | $0.67\pm0.01^{a}$ |
| 0.98 | 75.2±1.20 | $39.6\pm0.87^{ab}$ | $26.6\pm0.97^{ab}$ | 371.2±8.14 | 49.84±1.87 | $0.67\pm0.01^{a}$ |

a,b,c Means with different superscripts in the same column differ ($p<0.05$). [1] Average initial weight was 134.8 g.
[2] $Wg^{0.75}$ is $\{(\text{initial weight}+\text{final weight})/2\}^{0.75}$. [3] Values are means±SE of 5 chicks in each treatment.

Table 7. Changes in protein and water contents of chicks fed five graded levels of glycine[1]

| Dietary level | Live body weight | Dry body weight | Water gain | Protein gain | Protein gain /water gain |
|---|---|---|---|---|---|
| % | g | g | g | g | |
| 0.19 | $248.0\pm3.8^{b}$ | $78.2\pm20.2^{b}$ | $169.8\pm24.0^{b}$ | $47.4\pm0.4^{c}$ | 0.286±0.04 |
| 0.38 | $263.2\pm21.1^{b}$ | $98.3\pm11.5^{ab}$ | $165.0\pm9.6^{b}$ | $47.9\pm1.6^{c}$ | 0.292±0.03 |
| 0.56 | $305.1\pm27.9^{ab}$ | $112.4\pm12.2^{a}$ | $192.7\pm15.7^{ab}$ | $60.2\pm6.4^{ab}$ | 0.311±0.01 |
| 0.75 | $339.7\pm13.6^{a}$ | $111.9\pm4.8^{a}$ | $227.8\pm10.2^{a}$ | $63.1\pm2.3^{a}$ | 0.278±0.01 |
| 0.98 | $291.2\pm14.3^{ab}$ | $90.4\pm2.0^{ab}$ | $200.8\pm13.6^{ab}$ | $49.9\pm1.6^{bc}$ | 0.251±0.01 |

a,b,c Means with different superscripts in the same column differ ($p<0.05$).
[1] Values are means±SE of 5 chicks of each treatment.

among species. Although their result (4.02%) was different from ours (5.46%), Shin et al. (1994) reported that from the relationship of weight gain and N gain, 5.5% of the retained protein of rat was comprised of threonine, quite similar to our result (5.46%).

Plasma amino acid concentrations of chicks fed graded levels of threonine are presented in table 4 and the response of plasma threonine to daily threonine intake is shown in figure 3. The plasma threonine concentration remained relatively constant up to the breakpoint (279.4 mg/day), then it increased very abruptly. As dietary threonine level increased, plasma valine, isoleucine, leucine, phenylalanine, lysine, glycine and tyrosine levels changed linearly. However, phenylalanine and serine concentrations changed in a quadratic fashion (table 4).

If this breakpoint value was converted to dietary percentage with 41.43 g of ADFI, it would be 0.67% of the diet. This is in close agreement with previous threonine requirements expressed as dietary percentage (0.68%±0.03). Also, this result based on the plasma threonine concentration is in very close agreement with the data from the weight gain and N gain responses. Zimmerman and Scott (1965) and Mitchell et al. (1968) reported that the point at which the amino acid starts to accumulate in plasma coincides with the break in the growth curve. However, in our previous studies, it was shown that plasma obtained at the end of the experiment might underestimate the requirement of amino acid for the experimental period (Kim et al., 1997a,b,c).

**Experiment 2**

Responses of chicks fed diets containing different levels of glycine are shown in table 6. Feed intake, weight gain, nitrogen gain, and gain to feed ratio did not show any significant change beyond 0.56% glycine. However, weight gain, nitrogen gain and gain to feed ratio increased slightly up to 0.56% glycine with negligible responses. From this pattern, the glycine requirement for maintenance could not be separated from requirement for growth. In many reports, the indispensability of glycine in growing chicks was debated. Generally, glycine can be synthesized endogenously from serine or by other routes (Baker, 1977), and glycine may not be required for maintenance. However, Almquist and Grau (1944) suggested that the rate of synthesis of glycine is not sufficiently rapid to meet the demands of high levels of production. The requirement for glycine can be completely eliminated if an appropriate amount of serine is added to the diet (Baker et al., 1968 ; Akrabawi and Kratzer, 1968). Moreover, the need for dietary glycine is reduced considerably if choline, betaine, sarcosine or glycolic acid (Baker and Sugahara, 1970) or threonine (Baker et al., 1972) is added to the diet. It is generally accepted that both serine and sarcosine are direct precursors of glycine. Graber and Baker (1973) reported that excess dietary threonine could be converted to glycine, probably via a one-step reaction involving the enzymatic cleavage (threonine aldolase) of threonine to glycine and acetaldehyde. Although chicks can synthesize both glycine and serine endogenously, as much as 40% of the total physiological requirement of young chicks must be provided orally if maximal growth is to be achieved (Graber and Baker, 1973 ; Baker, 1977).

In this experiment, because only the crystalline amino acids were used without serine, the addition of graded levels of glycine might increase slightly the weight gain up to 0.56% glycine of the diet, while because we supplied sufficient L-glutamic acid as well as L-threonine as putative glycine synthesis precursors (Baker, 1977), chicks might show little responses to the graded levels of glycine.

As shown in the case of weight gain response and nitrogen gain response, the glycine requirement for maintenance could not be determined due to failure to obtain data that would indicate zero response intercept.

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