Partition of Amino Acid Requirements of Broilers between Maintenance and Growth. V. Isoleucine and Valine

S. H. Bae, J. H. Kim, I. S. Shin[1] and In K. Han*
Department of Animal Science & Technology, College of Agriculture & Life Sciences
Seoul National University, Suweon 441 - 744, Korea

ABSTRACT : Two experiments were conducted to subdivide isoleucine (exp. 1) and valine (exp. 2) requirements for maintenance from the requirements for growth of broilers aged 1 to 3 weeks. Purified diets were used, containing five graded levels of isoleucine and valine. Based on weight gain response, the isoleucine requirement for growth was 7.50 mg/g weight gain and the daily isoleucine need for maintenance (mg) was 0.044 per unit metabolic body size ($Wg^{0.75}$). Based on the N gain response, the isoleucine requirement for growth was 0.317 mg/mg N gain and the daily isoleucine need for maintenance (mg) was 0.040 per unit metabolic body size ($Wg^{0.75}$). Based on weight gain and N gain response, the total isoleucine requirement was calculated 244 mg/day or 0.59% of the diet, 274 mg/day or 0.66% of the diet, respectively. From the relationship of weight gain and N gain, 5.07% of the retained protein was comprised of isoleucine ; the reported isoleucine content of chick muscle was 4.42%. The valine requirement for growth was 9.84 mg/g weight gain and 0.36 mg/mg N gain whereas the maintenance requirement was 0.046 or 0.052 mg per unit of metabolic body size ($Wg^{0.75}$). According to the model developed to estimate valine requirement, the total requirement was 319 mg/day or 0.77% of the diet, 315 mg/day or 0.76% of the diet, respectively. Previous reported valine requirements for growing chicks of 7~24 days old were in close agreement with these estimates. As a percentage of retained protein, valine was calculated to be 5.81% ; the reported valine concentration of crude protein of chicks' body including feathers was 6.72%. *(Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 3 : 388-394)*

Key Words : Isoleucine, Valine, Requirement, Growth, Maintenance, Chicks

INTRODUCTION

Isoleucine, valine and leucine have very similar structures and are commonly named the branched-chain amino acids (BCAA). Practical diets for chicks are rarely, if ever, deficient in leucine, isoleucine or valine. However, much has been written about the BCAA for poultry because of the so - called antagonism that exists among them (Farran and Thomas, 1990 ; Allen and Baker, 1972). With purified diets it has been clearly shown, for example, that an excess of isoleucine impairs leucine and valine utilization. Valine in excess of its requirement does not impair utilization of either isoleucine or leucine (Allen and Baker, 1972 ; Baker, 1977). Chicks fed a valine deficient diet available for *ad libitum* intake in combination with adequate levels of isoleucine and leucine, had poor weight gain associated with a high incidence of feather and leg abnormalities (Farran and Thomas, 1990). Birds fed a diet adequate or deficient in all of the BCAA did not exhibit these symptoms. Therefore, the requirement of broilers for the BCAA, including their maintenance requirement (D'Mello, 1994) is affected by the antagonism among these amino acids. Ousterhout (1960) showed that chicks fed a diet devoid of the three BCAA survived longer and lost less weight than those fed diets devoid of either isoleucine and valine. In other studies (Okumura et al., 1985), chicks fed a leucine - deficient diet grew at a similar rate to those given similar quantities of a standard diet. In contrast, chicks fed either the valine- or isoleucine-deficient diet grew at a markedly poorer rate than control animals. Overall, these observations imply that amino acid antagonisms may operate in deficiency states and point to the dominant role of leucine in its interactions with its structural analogues. These observations also suggest that the maintenance requirements for valine are unlikely to remain constant and may be influenced to an appreciable degree by the relative dietary proportions of the other two BCAAs. For similar reasons, the isoleucine requirement for maintenance may also vary. Burnham and Gous (1992) discounted any such effects of BCAA antagonisms on maintenance isoleucine requirements of adult chickens despite observing an unexpectedly low value for the efficiency of utilization of isoleucine for maintenance.

Isoleucine has been shown to be required for optimum growth in chicks (Almquist and Grau, 1944). The isoleucine requirements estimated by ARC (1975), SCA (1987), NRC (1984, 1994) were 0.70%, 0.57~0.86%, 0.80% and 0.80% of the diet, respectively. And previous studies indicated that the isoleucine requirement is in the range of 0.48~0.81% of the diet (Almquist, 1947 ; Klain et al., 1960 ; Dean and Scott, 1965 ; D'Mello, 1974 ; Woodham and Deans, 1975 ; Baker et al., 1979 ; Farran and Thomas, 1990). However, the isoleucine requirement for maintenance has not been intensively studied. For an adult rooster, Leveille and Fisher (1960) reported that the maintenance requirement for L - isoleucine was found to be approximately 72 mg/kg body weight/day, and the minimal maintenance level 49 mg/kg body weight/day. The estimated isoleucine requirements for maintenance by Owens et al. (1985), using zero response as a criterion, was 203 mg/kg body weight/day.

* Address reprint request to In K. Han.
[1] American Soybean Association, Seoul, Korea.
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In the case of valine, data on requirements are also scanty. Almquist (1947) reported that the valine requirement of growing chicks was 0.80%; other estimates were in the range of 0.69~0.90% of the diet (Klain et al., 1960 ; Dean and Scott, 1965 ; D'Mello, 1974 ; Baker et al., 1979 ; Farran and Thomas, 1990). The valine requirements estimated by ARC (1975), SCA (1987), NRC (1984, 1994) were 0.80%, 0.77~1.06%, 0.82% and 0.90% of the diet, respectively. Little information on maintenance needs is available. Owens et al. (1985) reported that the maintenance requirement of growing chicks was 248 mg/g body weight/day. However, Leveille and Fisher (1960) reported much lower estimates; the maintenance requirement for L- or DL-valine was taken to be 61 mg/g body weight/day and the minimal maintenance level to be 55 mg/g body weight/day.

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 isoleucine (exp. 1) and valine (exp. 2) requirements into one portion for growth, and another portion for maintenance, and to compare these values with previous estimates of total isoleucine and valine requirements.

MATERIALS AND METHODS

A total of 250 male Arbor Acres chicks (125 chicks per experiment) of a commercial 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 experimental groups. The experimental diets contained either 25, 50, 75, 100 and 125% of NRC (1994) estimated isoleucine (exp. 1) and valine (exp. 2) requirements for growing chicks, with 100% of NRC requirement for all other amino acids. The composition of the basal diet is shown in table 1.

L - isoleucine (exp. 1) and L - valine (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 a pre-experimental period, the chicks were fed a commercial diet. From 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 135 g. Body weights were measured each week to calculate weight gain and feed intakes were measured daily on an replication basis during the entire experimental period. The experimental feeds were stored at -4℃ throughout the experimental period and any remaining in the feeder was discarded daily to avoid any deterioration. Isoleucine and valine intakes were calculated by multiplying feed intake with dietary isoleucine and valine level, respectively. For 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 in -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 the amount of body nitrogen.

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	variable
Soy oil	5.000	L-Leucine	1.200
Cellulose	5.000	L-Lysine · HCl	1.374
$NaHCO_3$	1.500	L-Methionine	0.500
		L-Cystine	0.400
Vitamin mixture[b]	0.200	L-Phenylalanine	0.720
Choline chloride	0.200	L-Tyrosine	0.620
Tocopheryl acetate	0.002	L-Threonine	0.800
		L-Tryptophan	0.200
		L-Valine	variable
BHT	0.003	L-Proline	0.600
Total	100.00	L-Glycine	0.750
		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 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 shown in our previous studies (Kim et al., 1997a,b,c)

RESULTS AND DISCUSSION

Experiment 1

Responses of chicks fed diets containing five different levels of isoleucine are shown in table 2. Feed intake, weight gain, nitrogen gain and gain to feed ratio increased rapidly up to 0.60% isoleucine; beyond 0.60%

isoleucine the responses remained relatively constant. It was found that less than 0.20% isoleucine was required for maintenance.

Water content of chick carcasses increased in the same manner as protein content up to 0.60% isoleucine. Protein gain to water gain ratio was not constant, but there were no significant differences. It seemed that the body composition of the chicks was not severely affected by a moderate deficiency or an excess of isoleucine.

The data for separating isoleucine requirements into one portion for maintenance and the other portion for growth are shown in figure 1. Based on the weight gain response, the estimated growth requirement was 7.504 mg per g weight gain, while the estimated requirement for maintenance was 0.044 mg/day per unit of metabolic body size. The sum of these requirements is the total isoleucine requirement. The typical body weight, feed intake and weight gain of 2 weeks old broilers suggested by NRC (1994) are 376 g, 41.43 g/d and 32 g/d, respectively. From the equation in figure 1, the isoleucine requirement for growth was 240 mg per day, and for maintenance 3.76 mg per day. Thus, the total requirement of isoleucine was 244 mg per day. At this rate of gain, about 1.54% of total requirement would be utilized for maintenance. With 41.43 g of ADFI (NRC, 1994), the dietary level of isoleucine needed would be 0.59% of the diet. Previously estimated requirements of isoleucine for growing chicks 7~28 days aged, averaged 0.65%±0.05 (table 4) and are in reasonably close agreement with the present estimates.

Daily nitrogen gain is plotted against daily isoleucine intakes in figure 2 with the prediction line and equation. The estimated requirement for nitrogen gain was 0.317

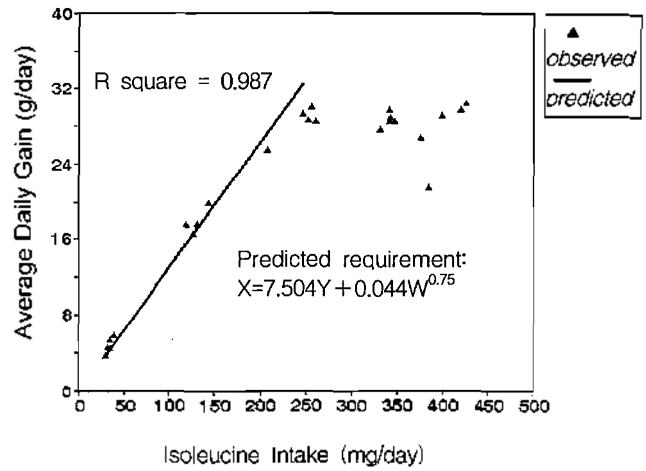

Figure 1. Weight gain responses to daily isoleucine intake

mg per mg nitrogen gain and the estimated requirement for maintenance is 0.040 mg per unit of metabolic body size. Assuming a chick gaining 855 mg nitrogen per day and weighing 376 g, the estimated requirement for growth is 271.04 mg per day and the requirement for maintenance is 3.42 mg per day. Thus, the total requirement needed to meet this performance level would be 274 mg per day, and 0.66% of the diet.

Based on the weight gain and nitrogen gain responses, the maintenance requirement of isoleucine for a chick would be 7.83 and 7.12 mg/kg body weight/day, respectively. These estimated values are much lower than previous estimates (203 mg/kg body weight/day) for broilers by Owens et al. (1985), and (72 mg/kg body weight/day) for adult roosters by Leveille and Fisher

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

Dietary level	Mean[2] $Wg^{0.75}$	Average Daily Feed Intake[3]	Average Daily Gain[3]	Isoleucine intake[3]	Nitrogen retention[3]	Gain/feed[4]
	g	g	g	mg/day	%	
0.20	46.84±0.54	16.95±0.73[c]	4.79±0.36[c]	33.91±1.47	21.53±0.99	0.28±0.01[c]
0.40	64.84±0.65	32.66±1.03[b]	17.82±0.56[b]	130.64±4.11	42.64±1.32	0.55±0.01[b]
0.60	77.99±1.02	40.80±1.60[a]	28.35±0.79[a]	244.79±9.60	54.41±1.34	0.70±0.02[a]
0.80	78.25±0.44	42.56±0.32[a]	28.63±0.34[a]	340.48±2.60	52.78±0.67	0.67±0.01[a]
1.00	76.87±2.03	40.06±0.96[a]	27.42±1.62[a]	400.57±9.58	52.23±4.21	0.68±0.03[a]

[a,b,c] Means with different superscripts in the same column differ ($p<0.05$). [1] Average initial weight was 135.1 g.
[2] $Wg^{0.75}$ is |(initial weight+final weight)/2|$^{0.75}$. [3] Values are means±SE of 5 chicks in each treatment.

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

Dietary level	Live body weight	Dry body weight	Water gain	Protein gain	Protein gain /water gain
%	g	g	g	g	
0.20	58.9±6.4[c]	20.4±2.1[c]	38.5± 4.6[c]	9.1±1.0[c]	0.238±0.02[b]
0.40	247.7±18.9[b]	80.4±4.3[b]	167.3±14.8[b]	44.9±4.7[b]	0.267±0.01[a]
0.60	336.8±30.4[a]	106.7±8.1[a]	230.1±22.7[a]	61.3±6.3[a]	0.265±0.01[ab]
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	316.9±18.7[a]	98.0±9.0[ab]	218.8±10.3[a]	57.2±2.9[ab]	0.261±0.01[ab]

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

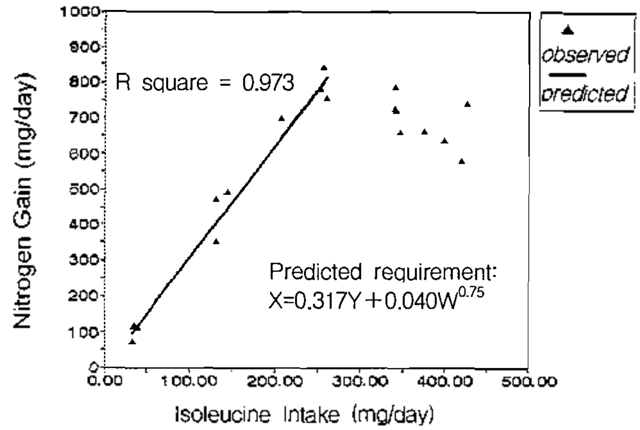

Figure 2. Nitrogen gain responses to daily isoleucine intake

(1960). For adult laying cockerels, Burnham and Gous (1992) reported that the maintenance requirement for isoleucine, calculated as the isoleucine intake required to maintain the body of an adult cockerel at zero nitrogen retention, was estimated to be 60 (±3.2) mg per kg body weight per day. Also, Ishibashi (1973) reported values of 40 and 15 mg/kg body weight/day, respectively, for what he termed the maintenance and the minimum maintenance requirements for isoleucine.

Owens et al. (1985) indicated that the growth requirement for isoleucine was 7.7 mg/g gain. The value obtained by Owens et al. (1985) was in close agreement with our result (7.5 mg/g gain). However, for the maintenance requirement, there is a large difference between Owens et al. (1985) and our estimate, 203 mg/kg body weight/day vs. 7.83 or 7.12 mg/kg body weight/day, respectively. A possible explanation for this difference might be a different age of the chicks. Also, a high level of synthetic amino acids mixture was used in our study. Twenty three percent crude protein supplied by a synthetic amino acids mixture might be much higher than the actual requirement for the chicks. Leveille and Fisher (1960) used experimental procedures and experimental subjects different from ours. Especially, as they used White Leghorn roosters at least 12 months old as experimental subjects, the maintenance requirement might be much higher. In their experiment, Burnham and Gous (1992), not only used adult laying cockerels as experimental subjects, but also used the zero nitrogen retention method. The higher amount of isoleucine required for maintenance suggested by the result of their study might be attributed to the method employed for its estimation.

The relationship of growth to N gain suggests that weight gain contains 2.37% N ; this equals 14.8% CP in deposited body weight. As a percentage of deposited CP, this growth requirement equals 5.07% (0.317/6.25) of the retained CP. The reported isoleucine content of chick muscle CP was 4.42% (Williams et al., 1954).

Experiment 2

Responses of chicks fed diets containing five different levels of valine are shown in table 5. Feed intake, weight gain, nitrogen gain, and gain to feed ratio increased rapidly up to 0.675% valine; beyond 0.675% valine the responses were minor. It was found that less than 0.225% valine was required for maintenance.

Water content of chick carcasses increased in the same manner as protein content up to 0.60% valine (table 6). Protein gain to water gain ratio was not constant.

The data for separating valine requirements into one portion for maintenance and another for growth are shown in figures 3 and 4. Based on the weight gain response, the estimated growth requirement was 9.84 mg per g weight gain, while the estimated requirement for maintenance was 0.046 mg/day per unit of metabolic

Table 4. Comparison of previous estimates of isoleucine requirements in growing chicks

Requirement (%)	Age period (days)	Response criteria	Breed	References
0.60	10 - 24	Growth	Not specified	Almquist, 1947
0.73	8 - 15	Growth	New Hampshire ×Columbian	Klain et al., 1960
0.80	8 - 16	Growth	New Hampshire ×Columbian	Dean and Scott, 1965
≤0.52	7 - 21	Growth, plasma AA levels	Not specified	D'Mello, 1974
0.48	14 - 28	Total protein efficiency	Ross	Woodham and Deans, 1975
0.60	8 - 16	Growth, feed efficiency	New Hampshire ×Columbian	Baker et al., 1979
0.81	7 - 21	Growth, feed efficiency	Ross ×Arbor Acres	Farran and Thomas, 1990
0.70	0 - 4 weeks			ARC, 1975
0.57 - 0.86	0 - 4 weeks			SCA, 1987
0.80	0 - 3 weeks			NRC, 1984
0.80	0 - 3 weeks			NRC, 1994

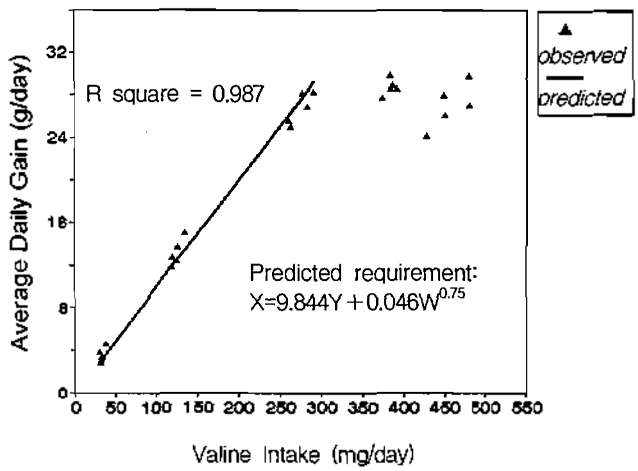

Figure 3. Weight gain responses to daily valine intake

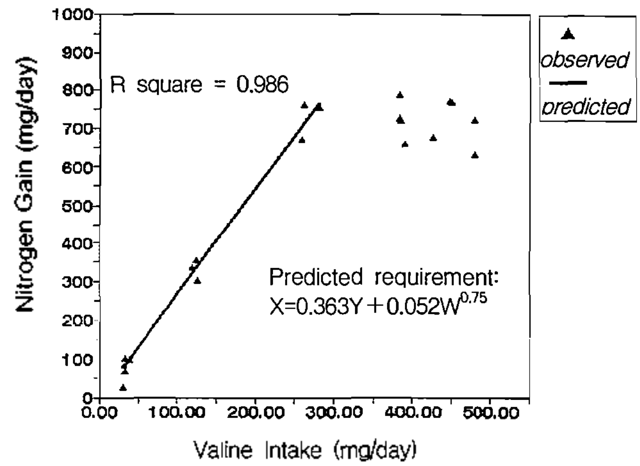

Figure 4. Nitrogen gain responses to daily valine intake

body size. The sum of these requirements is the total valine requirement. The typical body weight, feed intake, and weight gain of 2 weeks old broilers suggested by NRC (1994) are 376 g, 41.43 g/d and 32 g/d, respectively. From the equation in figure 3, the valine requirement for growth was 315 mg per day, and for maintenance 3.93 mg per day. Thus, the total requirement of valine was 319 mg per day. At this rate of gain, about 1.23% of total requirement would be utilized for maintenance. With 41.43 g of ADFI (NRC, 1994), the dietary level of valine needed would be 0.77% of the diet. Previously estimated requirements of valine for growing chicks aging 7~24 days, averaged 0.80%±0.03 (table 7), which were in reasonably close agreement with present estimates.

Daily nitrogen gain is plotted against daily valine intakes in figure 4. The prediction line and equation also are included. The estimated requirement for nitrogen gain was 0.363 mg per mg nitrogen gain and the estimated requirement for nitrogen maintenance is 0.052 mg per unit of metabolic body size. Assuming a chick gaining 855 mg nitrogen per day and weighing 376 g, the estimated requirement for growth is 310 mg per day and the requirement for maintenance is 4.44 mg per day. Thus, the total requirement needed to meet this performance level would be 315 mg per day and 0.76% of the diet.

Based on the weight gain and nitrogen gain responses, the estimated maintenance requirement of valine for a chick would be 9.25 mg/kg body weight/day, 8.18 mg/kg body weight/day, respectively. These values are much lower than previous estimates

Table 5. Responses of chicks fed diets containing five different levels of valine[1]

Dietary level	Mean[2] $Wg^{0.75}$	Average Daily Feed Intake[3]	Average Daily Gain[3]	Valine intake[3]	Nitrogen retention[3]	Gain/feed[3]
	g	g	g	mg/day	%	
0.225	45.00±0.39	14.58±0.59[c]	3.53±0.32[d]	32.79±1.32	18.07±1.56	0.24±0.02[c]
0.450	58.34±0.73	27.81±0.61[b]	13.07±0.57[c]	125.12±2.74	36.64±1.07	0.47±0.01[b]
0.675	76.03±0.85	40.58±0.87[a]	26.72±0.66[a]	273.92±5.87	56.18±1.17	0.66±0.01[a]
0.900	78.25±0.44	42.56±0.32[a]	28.63±0.34[a]	383.04±2.92	55.03±1.07	0.67±0.01[a]
1.125	76.13±1.15	40.56±0.91[a]	26.89±0.93[ab]	456.24±10.20	54.90±1.53	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 134.81 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 6. Changes in protein and water contents of chicks fed five graded levels of valine[1]

Dietary level	Live body weight	Dry body weight	Water gain	Protein gain	Protein gain /water gain
%	g	g	g	g	
0.225	53.3±11.5[d]	20.3±5.8[d]	33.0± 5.8[d]	8.2±1.8[c]	0.253±0.04
0.450	160.8± 6.2[c]	55.4±1.5[c]	105.4± 7.3[c]	28.2±1.0[b]	0.270±0.01
0.675	307.4± 3.7[b]	101.3±2.0[ab]	206.2± 3.4[b]	60.8±2.3[a]	0.295±0.01
0.900	339.7±13.6[a]	111.9±4.8[a]	227.8±10.2[a]	63.1±2.3[a]	0.278±0.01
1.125	297.5± 9.6[b]	97.6±4.0[b]	199.9± 6.5[b]	57.9±2.0[a]	0.290±0.01

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

Table 7. Comparison of previous valine requirements in growing chicks

Requirement (%)	Age period (days)	Response criteria	Breed	References
0.80	10 - 20/24	Growth	Not specified	Almquist, 1947
0.83	8 - 13/15	Growth, feed efficiency	New Hampshire ×Columbian	Klain et al., 1960
0.82	8 - 16	Growth, feed efficiency	New Hampshire ×Columbian	Dean and Scott, 1965
0.75	7 - 21	Growth, plasma AA levels	Not specified	D'Mello, 1974
0.69	8 - 16	Total protein efficiency	New Hampshire ×Columbian	Baker et al., 1979
0.90	7 - 21	Growth, feed efficiency	Ross×Arbor Acres	Farran and Thomas, 1990
0.80	0 - 4 weeks			ARC, 1975
0.77 - 1.06	0 - 4 weeks			SCA, 1987
0.82	0 - 3 weeks			NRC, 1984
0.90	0 - 3 weeks			NRC, 1994

(248 mg/kg body weight/day) for broilers by Owens et al. (1985), and the estimates (61 mg/kg body weight/day) for adult roosters by Leveille and Fisher (1960). For adult laying cockerels, Ishibashi (1973) reported that the maintenance requirement for valine was estimated to be 30 mg per kg body weight per day.

Owens et al. (1985) reported that growth and maintenance requirements of valine were 8.1 mg/g gain and 248 mg/kg body weight/day, respectively. If these values are applied to the model for chick by NRC (1994), this chick requires 259.2 mg and 10.16 mg valine per day for growth and for maintenance, respectively. Therefore, the total valine requirement of this chick is 269 mg and the value can be converted to 0.65% of the diet. This is much lower than our results and other valine requirements of growing chicks (0.77%, 0.76% and 0.80%±0.03%, respectively, table 7). Therefore, direct comparison between the result of Owens et al. (1985) and the present result is not so relevant. In the case 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 than this result. Leveille and Fisher (1960) concluded in their report that D-valine appeared to be completely available for the maintenance of nitrogen equilibrium in the adult rooster. However, it is generally accepted that the relative availability of D-valine is about 70% in the chicks compared with L-valine (Baker, 1994). Therefore, the maintenance requirement of Leveille and Fisher (1960) might be an overestimate.

The relationship of growth to N gain suggests that weight gain contains 2.71% N ; this equals 16.9% CP in deposited body weight. As a percentage of deposited CP, this growth requirement equals 5.81% (0.363/6.25) of the retained CP. The reported valine content of chick muscle CP was 6.72% (Williams et al., 1954).

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