Growth Performance, Carcass Characteristics, Nutrient Digestibility and Serum Biochemical Parameters of Broilers Fed Low-protein Diets Supplemented with Various Ratios of Threonine to Lysine

L. M. Gong, C. H. Lai, S. Y. Qiao*, Defa Li, Y. X. Ma and Y. L. Liu
National Feed Engineering Technology Research Center, China Agricultural University
No. 2, Yuanmingyuan West Road, Beijing, 100094, P. R. China

ABSTRACT : This study was conducted to evaluate performance, breast (thigh) muscle yield, nutrient digestibility and serum biochemical parameters of broilers fed low-protein diets supplemented with various threonine to lysine ratios (Thr/Lys). Three hundred and twenty four day-old male Arbor Acres broilers were randomly allotted to six dietary treatments with six replicates per treatment and nine broilers per replicate. Six treatments included one control diet [formulated according to NRC (1994)], and five experimental diets (treatments 1-5). In treatments 1-5, the crude protein level was 2% lower than that of the NRC control diet. The Thr/Lys in treatments 1-5 was 0.65, 0.70, 0.75, 0.80 and 0.85 during the starter and grower phases and 0.70, 0.75, 0.80, 0.85 and 0.90 during the finisher phase with other nutrient levels kept consistent. The results showed that: (1) With increasing Thr/Lys, ADG of treatments 1, 3 and 4 were lower ($p<0.05$) than those of the NRC control diet during the starter phase; ADG of treatments 1-5 were lower ($p<0.05$) than those of the NRC control during the grower phase, and ADG of treatment 1 was lower ($p<0.05$) than that of the NRC control during the finisher phase. Average daily feed intake in treatments 1 and 4 were lower ($p<0.05$) than that of broilers on the NRC control diet during the grower phase. Feed/gain (F/G) of the NRC control diet was lowest ($p<0.05$) during the starter phase. F/G in treatments 2 and 5 were higher ($p<0.05$) than that of NRC during the grower phase. (2) Breast muscle proportion on d 21 increased linearly ($p<0.05$) in response to graded levels of Thr/Lys. (3) No differences were detected for dry matter, energy and crude protein digestibility among all seven treatments. (4) On d 21, serum triglyceride of broilers on dietary treatments 3 and 5 was higher ($p<0.05$) than that of broilers in control. The results indicate that the low-protein diets supplemented with an appropriate Thr/Lys could not support the same performance that was achieved by the broilers fed the NRC control diet. ***(Asian-Aust. J. Anim. Sci. 2005. Vol 18, No. 8 : 1164-1170)***

Key Words : Ratio of Threonine to Lysine, Broilers, Low-protein Diets

INTRODUCTION

Threonine (Thr) is an essential amino acid that cannot be synthesized in the animal body and has to be supplemented in the diet. In most plant-based feedstuffs for poultry, threonine is the third or fourth limiting amino acid. In the past ten years, threonine has become one of the main factors limiting animal performance as inclusion of crystalline lysine and methionine in complete diets has increased. Several researchers have found that weight gain, feed conversion ratio (Li and Guo, 2000), carcass characteristics (Dozier et al., 2000) and immunity of broilers (Dozier et al., 2001) could be improved with an increase of threonine in the diet. Broilers fed low-protein, threonine supplemented diets achieved the same high level of growth performance that was achieved by broilers fed high-protein diets (Kidd et al., 1997), while the amount of protein feedstuff and feed cost were both reduced.

As threonine may interact with other amino acids, especially lysine, the Threonine requirement could be affected by the lysine content of diets to some extent. However, little research has been conducted to investigate this interaction, especially regarding the ratio of threonine to lysine (Thr/Lys) in broilers. In the present experiment, growth performance, carcass characteristics, nutrient digestibility and serum biochemical parameters of broilers fed low-protein diets supplemented with various Thr/Lys were determined.

* Corresponding Author: Shiyan Qiao. Tel: +86-10-62893588, Fax: +86-10-62893688, E-mail: qiaoshy@mafic.ac.cn
Received September 26, 2004; Accepted March 7, 2005

MATERIALS AND METHODS

Experimental animals

A total of 324 d-old Arbor Acres male broilers obtained from a commercial hatchery were wing-banded, weighed and randomly assigned to one of six dietary treatments. There were six replicate pens for each treatment and 9 birds per pen. The broilers were raised in a three-floor ladder cage (48 cm×38 cm×38 cm). The room temperature was maintained at 32-36°C from d 1-7, and then gradually reduced 2°C per week until a final temperature of 25°C was reached. Relative humidity was maintained at 55% to 60%. Chicks were exposed to 23 h of light and 1 h of darkness from d 1-4 and 16 h of light and 8 h darkness from d 5-49. Mash feed and water were supplied *ad libitum*.

Experimental diets

The experiment was divided into three phases, including

Table 1. Experimental design

Item	Treatments					
	NRC[1]	1	2	3	4	5
Days 0-21						
ME (kcal/kg)	3,200	2,900	2,900	2,900	2,900	2,900
CP (%)	23	21	21	21	21	21
ME/CP	139	138	138	138	138	138
Thr/Lys	0.73	0.65	0.70	0.75	0.80	0.85
Days 22-42						
ME (kcal/kg)	3,200	2,900	2,900	2,900	2,900	2,900
CP (%)	20	18	18	18	18	18
ME/CP	160	161	161	161	161	161
Thr/Lys	0.74	0.65	0.70	0.75	0.80	0.85
Days 43-49						
ME (kcal/kg)	3,200	2,900	2,900	2,900	2,900	2,900
CP (%)	18	16	16	16	16	16
ME/CP	178	188	188	188	188	188
Thr/Lys	0.80	0.70	0.75	0.80	0.85	0.90

[1] Control diet 1 was formulated according to NRC (1994) recommendations.

Table 2. Diet composition and nutrient levels (%)

Item	Days 0 to 21						Days 22 to 42						Days 43 to 49					
	NRC[1]	1	2	3	4	5	NRC	1	2	3	4	5	NRC	1	2	3	4	5
Ingredients																		
Corn	47.90	59.05	59.15	59.25	59.19	59.13	54.45	66.35	66.44	66.53	66.60	66.56	61.28	71.03	71.13	71.17	71.13	71.08
Soybean meal	38.00	32.80	32.80	32.80	32.80	32.80	35.70	28.90	28.90	28.90	28.90	28.90	30.00	23.50	23.50	23.50	23.50	23.50
Fish meal	4.00	3.00	3.00	3.00	3.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Soy oil	6.00	0.60	0.60	0.60	0.60	0.60	5.50	0.00	0.00	0.00	0.00	0.00	4.70	1.00	1.00	1.00	1.00	1.00
Dicalcium phosphate	1.00	1.20	1.20	1.20	1.20	1.20	1.30	1.40	1.40	1.40	1.40	1.40	1.40	1.50	1.50	1.50	1.50	1.50
Limestone	1.40	1.45	1.45	1.45	1.45	1.45	1.40	1.40	1.40	1.40	1.40	1.40	1.10	1.10	1.10	1.10	1.10	1.10
1.0% premix[2]	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
L-lysine-HCl	0.00	0.20	0.10	0.00	0.00	0.00	0.05	0.25	0.16	0.07	0.00	0.00	0.00	0.30	0.20	0.15	0.15	0.15
DL-methionine	0.40	0.40	0.40	0.40	0.40	0.40	0.30	0.40	0.40	0.40	0.40	0.40	0.20	0.20	0.20	0.20	0.20	0.20
L-threonine	0.00	0.00	0.00	0.00	0.06	0.12	0.00	0.00	0.00	0.00	0.00	0.04	0.02	0.07	0.07	0.08	0.12	0.17
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Nutritional levels[3]																		
ME (kcal/kg)	3,180	2,920	2,920	2,920	2,920	2,920	3,190	2,930	2,930	2,930	2,930	2,930	3,200	3,030	3,030	3,030	3,030	3,030
CP	22.90	21.00	21.00	21.00	21.00	21.00	20.00	18.00	18.00	18.00	18.10	18.10	18.10	16.10	16.10	16.10	16.10	16.10
Ca	1.00	1.01	1.01	1.01	1.01	1.01	0.90	0.91	0.91	0.91	0.91	0.91	0.80	0.81	0.81	0.81	0.81	0.81
Total P	0.61	0.61	0.61	0.61	0.61	0.61	0.55	0.55	0.55	0.56	0.56	0.56	0.55	0.55	0.55	0.55	0.55	0.55
Met	0.73	0.70	0.70	0.70	0.70	0.70	0.56	0.64	0.64	0.64	0.64	0.64	0.44	0.42	0.42	0.42	0.42	0.42
Met+cys	0.99	0.96	0.96	0.96	0.96	0.96	0.81	0.88	0.88	0.88	0.88	0.88	0.68	0.65	0.65	0.65	0.65	0.65
Lys	1.27	1.28	1.20	1.13	1.13	1.13	1.08	1.10	1.03	0.96	0.90	0.90	0.92	1.01	0.94	0.90	0.90	0.90
Thr	0.93	0.84	0.84	0.85	0.90	0.96	0.80	0.72	0.72	0.72	0.72	0.76	0.74	0.71	0.71	0.72	0.76	0.81
Thr/lys	0.73	0.66	0.70	0.75	0.80	0.85	0.74	0.65	0.70	0.75	0.80	0.84	0.80	0.70	0.76	0.80	0.84	0.90

[1] Control diet was formulated according to NRC (1994) recommendation.

[2] Vitamin-mineral premix provides per kg diet: Vitamin A, 10,000 IU; Vitamin D_3, 2,750 IU; Vitamin E, 20 IU; Vitamin B_{12}, 12 mg; riboflavin 6 mg, D-pantothenic acid, 12 mg, niacin, 20 mg, choline chloride, 500 mg, Mn, 75 mg, Zn, 75 mg, Fe, 95 mg, Cu, 10 mg, I, 0.6 mg, Se, 0.3 mg.

[3] All values except ME were analyzed

a starter (d 0-21), grower (d 22-42) and finisher (d 43-49) phase. Six dietary treatments included one control group and five experimental groups (treatments 1-5). The experimental design, dietary composition and nutritional levels are showed in Table 1 and 2. Control diet was formulated to meet NRC (1994) recommendations for all nutrients. The crude protein level of treatments 1-5 was 2% lower than that of the NRC. The Thr/Lys in treatments 1-5 was 0.65, 0.70, 0.75, 0.80 and 0.85, respectively, during the starter and grower phases and 0.70, 0.75, 0.80, 0.85 and 0.90, respectively, during the finisher phase with other nutrient levels kept consistent.

Experimental procedures

At the end of the starter, grower and finisher phases, the broilers were individually weighed, and six broilers per treatment (one broiler per pen) were randomly selected and 5 ml of blood was drawn from the heart of the broilers in order to determine the serum biochemical parameters. Serum was separated by centrifugation (2,500×g for 15 min) and was stored at -80°C until analysis. Following blood sampling, the birds were bled and carcass was

Table 3. Effects of various Thr/lys ratios on broiler performance

Item	Treatments						SEM[2]	P-value of treatments 1-5[3]		P value of all treatments[4]
	NRC[1]	1	2	3	4	5		Linear	Quadratic	
Days 0-21										
ADG[5] (g)	30.9^{b}	28.1^{a}	29.2^{ab}	28.8^{a}	28.0^{a}	29.3^{ab}	0.26	0.510	0.808	0.006
ADFI[6] (g)	44.6	45.8	46.4	44.9	45.0	45.2	0.26	0.808	0.646	0.380
Feed:gain	1.45^{a}	1.63^{b}	1.59^{b}	1.56^{b}	1.61^{b}	1.54^{b}	0.01	0.484	0.669	0.001
Days 22-42										
ADG (g)	65.7^{b}	56.0^{a}	59.1^{a}	58.1^{a}	55.7^{a}	58.8^{a}	0.73	0.235	0.485	0.002
ADFI (g)	136.8^{c}	124.7^{ab}	132.6^{bc}	128.0^{abc}	112.3^{a}	132.2^{bc}	1.28	0.671	0.894	0.030
Feed:gain	2.09^{a}	2.22^{ab}	2.25^{b}	2.20^{ab}	2.20^{ab}	2.25^{b}	0.02	0.653	0.906	0.181
Days 43-49										
ADG (g)	88.4^{b}	73.3^{a}	78.0^{ab}	75.0^{ab}	78.8^{ab}	76.6^{ab}	1.66	0.100	0.266	0.251
ADFI (g)	179.7	166.4	176.5	169.6	166.3	174.6	1.74	0.959	0.841	0.217
Feed:gain	2.10	2.29	2.28	2.27	2.17	2.30	0.04	0.774	0.853	0.818
Days 0-49										
ADG (g)	54.0	46.5	49.0	48.0	47.1	48.7	0.52	0.361	0.592	<0.001
ADFI (g)	103.4	96.8	101.9	98.4	95.5	101.0	0.80	0.806	0.955	0.070
Feed:gain	1.92	2.08	2.08	2.05	2.03	2.07	0.01	0.465	0.536	0.025

[1] Control diet was formulated according to NRC (1994) recommendations.
[2] Standard Error of the Mean. Data are means of six replicate pens of nine birds within each replicate.
[3] Probability of linear and quadratic regression analysis for the effect of increasing Thr/lys on growth parameters in treatments 1-5.
[4] Probability of Duncan's Multiple Comparison among six treatments.
[5] Average daily gain.
[6] Average daily feed intake.
[a, b, c] Values in the same row with different superscripts are different ($p<0.05$).

evaluated. The breast muscle and thigh muscles and the abdominal fat were separated and weighed, and the ratios of each tissue to body weight were calculated. Excreta were collected from d 19 to 21, d 40 to 42 and d 47 to 49, sampled, and dried in an oven to determine digestibility of dry matter, crude protein and energy (AOAC, 1995).

Nutrient content in both the diets and excreta were analyzed according to AOAC (1995) procedures. Serum uric acid, cholesterol and triglyceride (CHOD-PAP method) were measured using a commercially available kit (Beijing Zhongsheng Biotech Company, Beijing, China).

Statistical analysis

Data were analyzed as a randomized complete block design using the GLM procedure of SPSS 10.0 (Lu et al., 2000). If the difference among the seven treatments was significant, then Duncan's Multiple Comparison test was used for post hoc multiple comparisons. Linear and quadratic regression analysis was used to determine the effects of increasing Thr/Lys in treatments 1-5. Pen was used as an experimental unit for the performance and digestibility data, whereas individual bird data were used as the experimental unit for carcass characteristics and serum biochemical parameters. A level of $p\leq 0.05$ was set as the criterion for statistical significance.

RESULTS

Performance

Performance data are presented in Table 3. Regression analysis of treatments 1-5 showed that average daily gain (ADG) during the finisher phase tended to increase with increasing Thr/Lys.

ADG of treatments 1, 3 and 4 were lower ($p<0.05$) when compared to the NRC control during the starter phase. ADG of treatments 1-5 were lower ($p<0.05$) than that of the NRC control during the grower phase, and ADG of treatment 1 was lower ($p<0.05$) than that of the NRC control during the finisher phase. The average daily feed intakes for treatments 1 and 4 were lower ($p<0.05$) than that of the NRC control during the grower phase. Feed/gain (F/G) of the NRC control was lowest ($p<0.05$) during the starter phase. F/G of treatments 2 and 5 were higher ($p<0.05$) than that of the NRC control during the grower phase. However, the performances of the broilers on treatments 1-5 were not different ($p>0.05$). These results indicate that low-protein diets supplemented with an appropriate Thr/Lys could not support the same performance that was achieved by the broilers fed the control NRC diet, although the Thr/Lys in treatments 3-5 was higher than that in the NRC control diet.

Carcass characteristics

The carcass characteristics data of the broilers are shown in Table 4. Regression analysis of treatments 1-5 showed that breast muscle proportion on d 21 increased linearly ($p<0.05$) and quadratically, and the proportion of leg muscle on d 49 linearly increased in response to graded levels of Thr/Lys. There was a 15.08% increase in breast muscle proportion on d 21 and a 28.76% increase on d 49 in

Table 4. Effects of various ratio of Thr/lys on carcass characteristics of broilers (%)

Item	Treatments						SEM[2]	P value of treatments 1-5[3]		P value of all treatments[4]
	NRC[1]	1	2	3	4	5		Linear	Quadratic	
Day 21										
Breast muscle	5.90[a]	5.90[a]	6.46[abc]	6.66[bc]	6.17[ab]	6.79[c]	0.08	0.028	0.073	0.004
Thigh muscle	6.21	6.78	6.46	6.54	6.18	6.35	0.08	0.111	0.231	0.474
Abdominal fat	0.85[a]	0.90[ab]	1.02[ab]	1.06[ab]	1.23[b]	0.98[ab]	0.04	0.310	0.226	0.342
Day 42										
Breast muscle	5.54[b]	4.65[ab]	6.16[b]	4.85[ab]	3.73[a]	5.72[b]	0.23	0.890	0.886	0.086
Thigh muscle	4.42	4.28	4.71	4.49	4.53	4.42	0.09	0.859	0.530	0.432
Abdominal fat	1.01	0.76	0.84	0.69	0.83	0.81	0.05	0.852	0.972	0.856
Day 49										
Breast muscle	5.90	5.00	4.99	5.54	5.32	5.89	0.23	0.288	0.566	0.745
Thigh muscle	6.15	4.66	4.60	5.90	5.17	6.00	0.20	0.065	0.187	0.135
Abdominal fat	0.67	0.81	0.87	0.77	0.81	1.01	0.06	0.571	0.718	0.907

[1] Control diet was formulated according to NRC (1994) recommendations.
[2] Standard Error of the Mean. Data are means of six replicate birds (one bird per replicate).
[3] Probability of linear and quadratic regression analysis for the effect of increasing Thr/lys on growth parameters in treatments 1-5.
[4] Probability of Duncan's Multiple Comparison among six treatments.
[a, b, c] Values in the same row with different superscripts are different ($p<0.05$).

Table 5. Effects of various Thr/lys ratios on nutrient digestibility of broilers (%)

Item	Treatments						SEM[2]	P value of treatments 1-5[3]		P value of all treatments[4]
	NRC[1]	1	2	3	4	5		Linear	Quadratic	
Day 21										
Dry matter	79.44	77.23	82.19	78.75	78.00	76.55	0.62	0.320	0.180	0.289
Energy	83.41	80.57	84.98	81.87	81.26	79.79	0.54	0.270	0.133	0.167
Crude protein	70.24	64.63	74.80	70.39	68.57	67.11	0.98	0.884	0.125	0.169
Day 42										
Dry matter	69.27	66.71	72.29	71.61	68.38	72.22	0.78	0.322	0.480	0.167
Energy	73.90	70.19		74.19	72.64	74.93	0.68	0.241	0.368	0.148
Crude protein	53.59	46.12	55.23	52.55	50.83	59.11	1.37	0.089	0.241	0.216
Day 49										
Dry matter	72.17	69.73	72.30	73.38	77.06	71.71	1.15	0.480	0.408	0.779
Energy	75.50	72.42	74.71	76.03	79.33	74.32	1.04	0.376	0.358	0.748
Crude protein	53.14	45.04	54.72	55.74	58.72	51.57	2.21	0.382	0.261	0.799

[1] Control diet was formulated according to NRC (1994) recommendations.
[2] Standard Error of the Mean. Data are means of six replicate pens.
[3] Probability of linear and quadratic regression analysis for the effect of increasing Thr/lys on growth parameters in treatments 1-5.
[4] Probability of Duncan's Multiple Comparison among six treatments.

the thigh muscle proportion of broilers in dietary treatment 5 in comparison to those consuming treatment 1 diets. This indicates that breast and thigh muscle yield could be improved due to the increase of Thr/Lys.

On d 21, the breast muscle proportions of broilers consuming the dietary treatments 3 and 5 were higher ($p<0.05$) than that of broilers on the NRC control diet. The proportion of abdominal fat in broilers consuming the dietary treatments 1-5 was quantitatively higher than that of broilers on the NRC control diet. A significant difference ($p<0.05$) in the proportion of abdominal fat was observed between treatment 4 and the NRC control. On d 42, the leg muscle proportion of broilers on treatment 4 was significantly lower ($p<0.05$) than that of broilers on the NRC control and on treatments 2 and 5. On d 49, no differences in carcass measurements were observed between treatments.

Nutrient digestibility

The nutrient digestibility data of the broilers are shown in Table 5. In the starter, grower and finisher phases, no treatment differences were detected for dry matter, energy and crude protein digestibility.

Serum biochemical parameter

Serum biochemical parameter data are shown in Table 6. Serum uric acid concentration was not different among all treatments. On d 21, serum triglyceride levels of broilers on dietary treatments 3 and 5 were higher ($p<0.05$) than those of the broilers consuming the NRC control diets.

DISCUSSION

In most plant-based feedstuffs for poultry, Threonine is the third or fourth limiting amino acid. Several authors have

Table 6. Effects of various Thr/Lys ratios on serum biochemical parameters of broilers (%)

Item	Treatments						SEM[2]	P value of treatments 1-5[3]		P value of all treatments[4]
	NRC[1]	1	2	3	4	5		Linear	Quadratic	
Day 21										
Uric acid	5.42	5.73	5.90	5.70	5.60	5.35	0.28	0.576	0.814	0.998
Total cholesterol	124.7^{ab}	131.2^{ab}	131.3^{ab}	144.0^{b}	136.3^{ab}	141.3^{b}	2.62	0.203	0.408	0.109
Triglyceride	26.50^{a}	29.67^{ab}	30.00^{ab}	35.83^{bc}	28.50^{a}	36.68^{c}	1.05	0.132	0.318	0.011
Day 42										
Uric acid	2.08	3.40	2.05	2.60	2.67	2.98	0.19	0.907	0.420	0.443
Total cholesterol	121.7^{ab}	120.0^{ab}	140.2^{c}	140.3^{c}	132.0^{abc}	140.5^{c}	2.41	0.123	0.134	0.045
Triglyceride	19.33	50.17	26.67	43.67	42.50	50.33	4.55	0.709	0.643	0.307
Day 49										
Uric acid	2.78	4.08	2.90	2.80	2.37	2.69	0.20	0.073	0.094	0.431
Total cholesterol	136.7^{ab}	137.2^{ab}	128.2^{a}	135.5^{ab}	154.0^{b}	134.7^{ab}	2.89	0.411	0.682	0.390
Triglyceride	24.17	28.17	22.83	25.00	27.67	23.67	1.34	0.734	0.923	0.939

[1] Control diet 1 was formulated according to NRC (1994) recommendation.
[2] Standard Error of the Mean. Data are means of six replicate birds (one bird per replicate).
[3] Probability of linear and quadratic regression analysis for the effect of increasing Thr/Lys on growth parameters in treatments 1-5.
[4] Probability of Duncan's Multiple Comparison among six treatments.
[a, b, c] Values in the same row with different superscripts are different ($p<0.05$).

reported that growth performance (Li, 2000) and carcass characteristics (Dozier et al., 2000) could be improved with dietary supplementation of Thr. Low-protein, Thr-supplemented diets have been shown to support the same performance levels achieved in broilers fed high-protein diets (Kidd et al., 1997), while the total amount of protein feedstuff required was reduced and the feed cost was lower. In addition, nitrogen excretion from broiler production was reduced.

In our study, ADG during the finisher phase tended to increase with increasing Thr/Lys. Other authors have reported improvement in growth performance in broilers or pigs fed diets with increasing Thr/Lys. Feng and Xu (2003) have reported higher ADG in growing-finishing pigs when the Thr/Lys was increased. In addition, both Li and Guo (2000) and Ciftci and Ceylan (2004), have demonstrated that growth performance was improved with increasing Thr supplementation. In their experiments, the Thr/Lys was increased by supplementation of Thr while the Lys level remained constant in their experiments.

In our experiment, breast muscle proportion on d 21 and thigh muscle proportion on d 49 were both increased in response to graded levels of Thr/Lys, indicating that breast and thigh muscle yield may be improved with increasing Thr/Lys, which is in agreement with Dozier et al. (2000, 2001). In addition, Feng and Xu (2003) and Feng et al. (2001) have reported that both the lean proportion and meat yield of pigs were increased with an increase in Thr/Lys, and that the values were highest when Thr/Lys was 72. Ciftci and Ceylan (2004) reported that incremental increases in dietary Thr increased breast yield of broilers. Collectively, these results indicate that carcass quality or protein deposition was enhanced with an increase in the Thr/Lys.

In our study, serum uric acid concentration tended to decrease linearly and quadratically with increasing Thr/Lys on d 49. In poultry, excess amino acids are metabolized to uric acid, which is then transported into the kidney, where it is excreted. Serum uric acid levels will increase when one or several amino acids are deficient or in excess. In our study, such a modification of serum uric acid concentration was positively correlated with weight gain and protein deposition. This indicated further that, with increasing Thr/Lys, protein metabolism was improved.

The NRC (1994) Thr/Lys ratio recommendations are 0.73, 0.73 and 0.80 during the starter, grower and finisher phases, respectively. In our experiment, increasing the Thr/Lys ratio improved performance and breast and thigh muscle yield, so the ratio of Thr/Lys that may achieve the maximum performance and protein deposition might be higher than the NRC (1994). In this experiment, we were not able to determine the optimal ratio of Thr/Lys that could achieve superior performance and breast and thigh muscle yield. This should be further investigated in subsequent trials.

In the present study, it is clear that broilers fed the low-protein diets supplemented with an appropriate Thr/Lys (treatment 1-5) did not reach the same level of performance achieved by the broilers fed the control diet formulated according to the NRC (1994) recommendations. However, many other authors have reported similar performance in broilers fed low-protein, amino acid supplemented diets. Holsheimer et al. (1994) reported that, for birds fed the low-protein diet (160 g CP/kg) supplemented with essential amino acids (EAA), non-essential amino acids (NEAA) and threonine to the same concentrations resulted in similar performance to that found in birds on the high-protein diet. Deschepper and De Groote (1995) also indicated that it was possible to obtain the same performance levels with low protein diets supplemented with synthetic amino acids, using an ideal amino acid balance. In the present study, the low-protein diets supplemented with various Thr/Lys (treatment 1-5) failed to support the same performance that was achieved by broilers fed the NRC control diet. There could be several explanations for this discrepancy. First, in dietary treatments 1-5, the crude protein levels were lower, which may have resulted in a content of the other amino acids including EAA and NEAA (except lysine, methionine and Thr) that was too low to meet the higher performance requirements although lysine, methionine and Thr were supplemented. Second, some researchers have reported that animals require not only free amino acids, but also small peptides to support growth, and the peptides may be the essential nutrients, and the low-protein, amino acid supplemented diet may have been deficient of these small peptides (Dai, 2002). Indeed, others have also reported performance of animals fed low protein diets supplemented with several essential amino acids was generally inferior to that of birds fed a higher protein diet composed primarily of intact protein (Pinchasov et al., 1990).

In the present experiment, breast muscle proportion on d 21 of broilers in dietary treatments 3 and 5 were higher than that of birds consuming the NRC control, which is not consistent with the results of Kidd et al. (1997) and Alleman et al. (2000). Kidd et al. (1997) showed that low-protein diets [84 and 76% of the NRC (1994) recommendations] decreased breast meat yield compared to high-protein diets [100 and 92% of the NRC (1994) recommendations]. Alleman et al. (2000) also reported that reducing CP concentration always decreased breast muscle proportion. Kidd et al. (1997) reported that diets containing Met, TSAA, Lys, Thr, and Trp at a minimum of 105% NRC (1994) recommendations might support favorable breast meat yield of Large White toms when CP was decreased to 92% of the NRC (1994) recommendation. The reasons for this discrepancy are unknown.

Spencer (1984), Sell et al. (1989) and Sell (1993) suggested that marginal reductions in dietary CP support live performance and carcass quality equal to high CP diets depending on the extent to which CP is reduced and which essential amino acids are supplemented in the low CP diets. Subsequent trials should evaluate the extent to which CP may be reduced while supporting live performance equal to that of higher CP diets.

IMPLICATIONS

Data from this present study demonstrate that performance and breast and thigh muscle yield may be improved with increasing the Thr/Lys in low-protein diets. In addition, the low-protein diets supplemented with an appropriate Thr/Lys was not able to support the same performance that was achieved by the broilers fed the control diet formulated according to NRC (1994) recommendations. Further studies are needed to evaluate the appropriate Thr/Lys that meets the highest performance and carcass quality and the extent to which CP may be reduced such that the diets can support live performance equal to that of the high CP diets.

REFERENCES

Alleman, F., J. Michel, A. M. Chagneau and B. Leclercq. 2000. The effects of dietary protein independent of essential amino acids on growth and body composition in genetically lean and fat chickens. Br. Poult. Sci. 41:214-218.

AOAC. 1995. Official Methods of Analysis. 16th ed. Association of Official Analytical Chemists, Washington, DC.

Ciftci, I. and N. Ceylan. 2004. Effects of dietary threonine and crude protein on growth performance, carcass and meat composition of broiler chickens. Br. Poult. Sci. 45:280-289.

Dai, J. G. 2002. Characteristics of dipeptide transport in small intestinal brush border membrane vesicles of weaned piglets. Ph.D. Dissertation, China Agricultural University, Beijing, China.

Deschepper, K. and G. De Groote. 1995. Effect of dietary protein, essential and non-essential amino acids on the performance and carcass composition of male broiler chickens. Br. Poult. Sci. 36:229-245.

Dozier, W. A., E. T. Jr. Moran and W. T. Kidd. 2000. Response of fast- and slow- feathering male broilers to dietary threonine during 42 to 56 days of age. J. Applied Poul. Res. 9:460-467.

Dozier, W. A., E. T. Jr. Moran and W. T. Kidd. 2001. Male and female responses to low and adequate dietary threonine on nitrogen and energy balance. Poult. Sci. 80:926-930.

Feng, J. and Z. R. Xu. 2003. Effects of different ratios of threonine to lysine on performance and carcass composition of pigs. J. Zhejiang University (Agriculture and life science). 29:14-17.

Feng, J., C. H. Hu, H. Chang and B. Zhou. 2001. The effects of different ratios of threonine to lysine on performance and carcass composition of growing-finishing pigs. Feed Industry, 11:40-41.

Holsheimer, J. P., P. F. Vereijken and J. B. Schutte. 1994. Response of broiler chicks to threonine-supplemented diets to 4 weeks of age. Br. Poult. Sci. 35:551-562.

Kidd, M. T., B. J. Kerr, J. A. England and P. W. Waldroup. 1997. Performance and carcass composition of large white toms as affected by dietary crude protein and threonine supplements. Poult. Sci. 76:1392-1397.

Li, Y. L. and Y. M. Guo. 2000. Threonine and tryptophan requirement of 3-6 week broilers. China J. Anim. Sci. 5:3-5.

Lu, W. D., Y. L. Zhu, J. Sha and H. B. Zhu. 2000. SPSS for windows. Publishing House of Electronics Industry, Beijing.

NRC. 1994. Feeding Standards of poultry. 8th rev. ed. National Academy Press, Washington, DC.

Pinchasov, Y., C. X. Mendonca and L. S. Jensen. 1990. Broiler chick response to low protein diets supplemented with synthetic amino acids. Poult. Sci. 69:1950-1955.

Sell, J. L. 1993. Influence of metabolizable feeding sequence and dietary protein on performance and selected carcass traits of tom turkeys. Poult. Sci. 72:521-534.

Sell, J. L., P. R. Ferket, C. R.Angel, S. E. Scheideler, F. Escribano and I. Zatari. 1989. Performance and carcass characteristics of turkey toms as influenced by dietary protein and metabolizable energy. Nutr. Rep. Int. 40:979-992.

Spencer, G. K. 1984. Minimum protein requirements of turkeys fed adequate levels of lysine and methionine. M.S. Thesis, University of Arkansas, Fayetteville, AR.