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Determination of the optimum arginine : lysine ratio in broiler diets

O. Sirathonpong[A], Y. Ruangpanit[A], O. Songserm[A], E. J. Koo[B] and S. Attamangkune[A,C]

[A]Department of Animal Science, Faculty of Agriculture at Kamphaeng Saen, Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom 73140, Thailand.
[B]CJ CheilJedang Corporation. CJ CheilJedang Center, 330, Dongho-ro, Jung-gu, Seoul, 04560, Republic of Korea.
[C]Corresponding author. Email: agrsea@yahoo.com

Abstract. The study was conducted to determine the optimum dietary concentration of arginine relative to lysine on the basis of the performance, carcass traits and blood characteristics of 1–35-day-old broilers using a randomised complete block design. One-day-old broilers (n = 1200) were allocated to five dietary treatment groups receiving different arginine : lysine (Arg : Lys) ratios, where the proportion of Arg was progressively increased by increments of 10%, and the concentration of lysine was kept constant; the final ratios were 0.85, 0.95, 1.05, 1.16 and 1.26. Each diet treatment was composed of eight replicates (4 males and 4 females), with 30 chickens each replicate. All broilers were fed in three phases, namely starter, grower and finisher, at 1–10, 11–24 and 25–35 days of age respectively. An increase in the Arg : Lys ratio in the diet from 0.85 to 1.26 linearly ($P < 0.001$) increased bodyweight gain by 7% and improved feed conversion ratio by 6%. Feed intake and mortality were not significantly ($P > 0.05$) different among the treatments. Increasing the Arg : Lys ratio in the diet linearly ($P < 0.0001$) and quadratically ($P < 0.05$) improved the carcass yield and relative chilled carcass weight respectively. The percentages of breast meat and creatinine and insulin-like growth factor-1 concentrations also linearly ($P < 0.0001$) increased by 5.5%, 23.0% and 18.0% respectively, with an increasing dietary Arg : Lys ratio. The results of the present study indicated that the highest dietary Arg : Lys ratio (1.26) improved bodyweight gain, feed conversion ratio, breast meat, creatinine and insulin-like growth factor-1. However, the optimum dietary Arg : Lys ratio to improve carcass yield and weight gain in the grower phase (Days 11–24 of age) was at 1.05.

Additional keywords: carcass, IGF-1, performance, weight gain.

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Introduction

Arginine (Arg) is an essential amino acid for broilers. Birds are completely dependent on dietary Arg to meet their requirements for protein synthesis and other functions (Tamir and Ratner 1963). Arginine is necessary for maintenance, growth performance and immunity and must be adequately available in poultry diets to support protein accretion and maintain physiological and immunological functions. A deficiency in dietary Arg may suppress immune system function in chicks (Al-Daraji and Salih 2012). In addition, Arg is considered the fourth limiting amino acid when the environmental temperature exceeds the thermal comfort zone of broilers, a common situation in commercial production systems in tropical countries (Mendes *et al*. 1997; Veldkamp *et al*. 2000). It is also that the environmental temperature has an effect on growth, feed intake and carcass quality on broiler chickens (Leeson 1986).

Arginine is a powerful secretagogue. It increases the release of insulin, growth hormone and insulin-like growth factor-1 (IGF-1) into the bloodstream (Newsholme *et al*. 2005). Also, Arg is a substrate for the biosynthesis of many molecules, including proteins, nitric oxide, creatine, ornithine, glutamate, polyamines, proline, glutamine, agmatine and dimethylarginines. These molecules serve several important biological and physiological functions in poultry (Khajali and Wideman 2010).

Arginine and lysine (Lys) are similar in structure and are known to compete in intestinal absorption. However, in a study of Mendes *et al*. (1997) in testing Arg : Lys ratios of 1.10–1.40, there were no antagonistic effects on broiler performance, as measured by growth and carcass yield. Szabó *et al*. (2014) confirmed that when the Arg : Lys ratio was increased from 1.05 to 1.75, the excess Arg relative to Lys did not depress bodyweight gain.

Many researchers have found that Arg can be used to enhance the production performance of broilers. Kidd *et al*. (2001) reported that an increase in dietary Arg, with a constant concentration of Lys from the National Research Council (NRC 1994) recommendations, from 1.14 (Arg : Lys = 100%) to 1.36 (Arg : Lys = 120%) improved broiler performance. Similarly, Al-Daraji and Salih (2012) reported that increasing the Arg : Lys ratio from 1.19 to 1.24 improved the live bodyweight, weight gain and the feed conversion ratio (FCR) in broilers. Corzo and Kidd (2003) studied different concentrations of arginine in broiler diets during Days 0–18, and found that male broilers reached their optimum bodyweight at an Arg : Lys ratio of 1.10, whereas an Arg : Lys ratio of 1.22 was observed to be the optimum level to improve FCR.

The present study was designed to determine the optimal Arg : Lys ratio in broiler diets to improve growth, FCR, carcass traits and blood plasma characteristics of broilers fed diets with different Arg : Lys ratios.

Materials and methods

Experimental diet

An experiment was conducted with five dietary treatments of different Arg : Lys ratios. To develop the dietary treatments, a supplement of L-arginine with L-ARGININE (CJ CheilJedang Corporation, Seoul, Korea) was used to provide the different Arg : Lys ratios. The experimental diets were divided into three phases of feeding and were composed of mainly maize and soybean meal. The chickens were fed a starter diet (Days 1–10 of age), grower diet (Days 11–24 of age) and finisher diet (Days 25–35 of age). Coxiril (Huvephama, Sofia, Bulgaria) at 1 grams per ton was added to diets as an anti-coccidial agent. The diet composition is shown in Table 1. The basal diets were formulated to meet recommendations (Aviagen 2016) for all nutrients, except for protein and Arg. The basal diet had an Arg : Lys ratio of 0.85, consisting of 1.22%, 1.10% and 0.98% Arg in the starter, grower and finisher diets relative to Lys respectively. In the remaining four dietary treatments, the Arg : Lys ratio was progressively increased by 10% increments. The Arg : Lys ratios were 0.95, 1.05, 1.16 and 1.26 respectively, as shown in Table 1.

Animals and management

The experimental protocol complied with the guidelines for the animal care and use of Kasetsart University Kamphaeng Saen Campus, Nakhon Pathom, Thailand. In total, 1200 1-day-old broilers (Ross 308), with an average initial bodyweight of 40 g, were randomly allocated into five dietary treatments. Each treatment consisted of eight replicate pens (4 replicate pens of male and 4 replicate pens of females), with 30 broilers per a replicate pen. The broilers were raised in 40-floor pens (6 m^2),

Table 1. Ingredient composition, calculated and analysed chemical composition of experimental diets (g/kg as fed basis)
CP, crude protein

	Starter diet					Grower diet					Finisher diet				
Arginine : lysine ratio	0.85	0.95	1.05	1.16	1.26	0.85	0.95	1.05	1.16	1.26	0.85	0.95	1.05	1.16	1.26
Ingredient (%)															
Maize	428.8	428.4	427.9	427.4	426.9	469.0	468.6	468.1	467.6	467.0	461.6	461.1	460.6	460.1	460.7
Corn gluten meal 62%	79.1	79.1	79.1	79.1	79.1	75.0	75.0	75.0	75.0	75.0	70.2	70.2	70.2	70.2	70.2
Wheat	150.0	150.0	150.0	150.0	150.0	106.8	106.8	106.8	106.8	106.8	180.0	180.0	180.0	180.0	180.0
Dry distiller grains with solubles	40.0	40.0	40.0	40.0	40.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0	60.0
Soybean meal, 46% crude protein	229.5	229.5	229.5	229.5	229.5	179.5	179.5	179.5	179.5	179.5	144.0	144.0	144.0	144.0	144.0
Brewer dried grain	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0
Rice bran oil	20.2	20.2	20.2	20.2	20.2	32.8	32.8	32.8	32.8	32.8	40.4	40.4	40.4	40.4	40.4
Vitamin–mineral premix[A]	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Micro-ingredient[B]	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.8	0.8	0.8	1.0	1.0	1.0	1.0	1.0
Coxiril (coccidiostat)	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0
L-lysine	7.3	7.3	7.3	7.3	7.3	6.7	6.7	6.7	6.7	6.7	6.5	6.5	6.5	6.5	6.5
L-arginine	0.0	0.4	0.9	1.4	1.9	0.0	0.4	0.9	1.4	2.0	0.0	0.5	1.0	1.5	1.9
Calculated chemical composition (%)															
Protein (%)	22.00	22.00	22.00	22.00	22.00	20.50	20.50	20.50	20.50	20.50	18.50	18.50	18.50	18.50	18.50
Energy (MJ/kg)	12.60	12.60	12.60	12.60	12.60	13.00	13.00	13.00	13.00	13.00	13.40	13.40	13.40	13.40	13.40
Moisture (%)	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50	11.50
Fat (%)	5.20	5.20	5.20	5.20	5.20	7.20	7.20	7.20	7.20	7.20	7.50	7.50	7.50	7.50	7.50
Fibre (%)	3.60	3.60	3.60	3.60	3.60	3.90	3.90	3.90	3.90	3.90	4.00	4.00	4.00	4.00	4.00
Lysine (%)	1.44	1.44	1.44	1.44	1.44	1.29	1.29	1.29	1.29	1.29	1.16	1.16	1.16	1.16	1.16
Arginine (%)	1.22	1.37	1.52	1.67	1.82	1.10	1.23	1.37	1.51	1.64	0.98	1.10	1.22	1.34	1.46
Analysed chemical composition (%)															
Protein (%)	22.39	22.23	22.59	22.64	22.70	21.10	21.19	21.25	21.38	21.75	18.28	18.27	18.71	18.83	18.81
Moisture (%)	10.70	10.60	10.50	10.40	10.40	10.50	10.40	10.30	10.60	10.50	10.60	10.60	10.50	10.80	10.70
Fat (%)	4.66	4.89	5.03	5	4.94	6.76	6.78	6.65	6.62	6.40	7.30	7.48	7.31	7.41	7.02
Fibre (%)	3.14	3.09	2.96	2.85	2.96	3.52	3.42	3.50	4.15	3.45	4.75	4.46	4.54	4.98	4.67
Lysine (%)	1.46	1.50	1.32	1.47	1.48	1.44	1.42	1.41	1.38	1.43	1.07	1.06	1.15	1.17	1.17
Arginine (%)	1.31	1.46	1.51	1.72	1.90	1.18	1.33	1.42	1.53	1.69	0.96	1.04	1.22	1.37	1.43

[A]Supplied per kilogram diet: vitamin A, 15 000 IU; vitamin D3, 3750 IU; vitamin E, 18.75 IU; vitamin K3, 1.88 mg; thiamine, 1.88 mg; riboflavin, 6.88 mg; pyridoxine, 2.50 mg; vitamin B12, 0.01 mg; nicotinic acid, 31.25 mg; pantothenic acid, 15 mg; folic acid, 0.63 mg; biotin, 0.15 mg, manganese, 100 mg; zinc, 75 mg; iron, 50 mg; copper, 10 mg; I, 0.63 mg; cobalt, 0.1 mg; selenium, 0.1 mg.

[B]Limestone, monodicalcium phosphate, choline chloride 60%, L-methionine, L-threonine, L-valine.

with rice hulls as the litter material. All birds were housed in an evaporative cooling-system house, with a temperature of 27–30°C and a relative humidity of 75% during the experiment. Feed and water were offered *ad libitum*, and continuous fluorescent lighting was provided throughout the experiment. The broilers were vaccinated against Newcastle disease and infectious bronchitis as per the local commercial veterinary practice.

Measurements and sampling

Blood samples

At 35 days of age, three birds from each pen were randomly selected for blood-sample collection (3 mL/bird) and the blood samples were centrifuged at 2500*g* for 10 min at 25°C to obtain plasma. Plasma samples were used to determine the concentrations of total protein, glucose, triglyceride, creatinine and insulin-like growth factor-1 (IGF-1). IGF-1 was measured by using a commercial test kit (ELISA kit, Catalogue number EKC31945, Biomatik Corporation, Cambridge, ON, Canada). Total protein, glucose and creatinine were measured by using the commercial test kit (Ref. 0018258640, Ref. 0018250840 and Ref.0018257240 respectively, QuantiLab Instrumentation Laboratory, A Warfen Company, MA, USA). Triglyceride was measured by using a commercial analysis with IDDXX VetTest Chemistry Analyzer Specification (IDEXX Europe B.V., North Holland, The Netherlands).

Growth performance

Bodyweight, feed intake and mortality were recorded at 0, 10, 24 and 35 days of age. Bodyweight gain and FCR were calculated at 10, 24 and 35 days of age.

Carcass traits

At the end of the experimental period, five birds from each pen were randomly sacrificed for carcass analysis. All chickens were fasted for 10 h before slaughtering. Internal organs (gizzard, liver and heart) were removed and weighed. The carcass was weighed immediately after slaughtering to determine the carcass yield. The carcasses were then chilled at approximately −7°C for 1 h and weighed to determine the chilled carcass weight. The carcass yield and chilled carcass weight were calculated on the basis of the liveweight. Each carcass was deboned, and divided into breast meat, thigh, drum, wing and abdominal fat. Each individual part was weighed and the weights were recorded. The percentages of the carcass parts were calculated on the basis of the chilled carcass weight.

Chemical analysis

Dry matter (DM), crude protein, crude fat (ether extract), crude fibre and amino acid content of feed samples were analysed. DM was determined by drying the sample at 103°C for 4 h in an oven (ISO 1999, Method no. 6496). Crude protein was determined by the Kjeldahl method with block digestion (ISO 2009; Method no. 5983-2). Crude fat and crude fibre were determined by Soxhlet extraction and fritted glass crucible method respectively (AOAC 2012; Method nos 920.39 and 978.10 respectively). Lys and Arg concentrations were determined by an in-house method based on Official Journal of the European communities L257/16 (Commission Directive 98/64/EC 1998).

Statistical analyses

The experimental design was a randomised complete-block design with a pen as the experimental unit. Sex was defined as the block factor. The growth performance, carcass and plasma data were analysed using the fit model platform in JMP Pro v.14 (SAS 2016). Plotting the growth performance, carcass and plasma data by using a normal quantile plot indicated that the means were normally distributed. The statistical model included a dietary Arg : Lys ratio and a replicate pen. Treatment comparisons were made using orthogonal contrasts to determine linear, quadratic, cubic and quartic effects by the treatments. Mortality data were analysed using a one-way ANOVA. Significance was accepted at $P < 0.05$.

Results

The results (Table 1) showed that the determined values were close to the calculated values.

Performance

The weight gain showed a significant ($P < 0.001$) linear increase with an increasing dietary Arg : Lys ratio from 0.85 to 1.26. Also FCR improved linearly ($P < 0.001$) with an increasing dietary Arg : Lys ratio in the starter diet. There were no differences in feed intake during the starter phase. Similar effects of dietary Arg : Lys ratio were also observed in the grower phase. A significant ($P < 0.05$) quadratic effect of Arg : Lys ratio was observed for weight gain during the growing phase, which reached a plateau at the Arg : Lys ratio of 0.95. Additionally, bodyweight gain increased linearly ($P < 0.001$) in broilers with an increasing Arg : Lys ratio of the diet in the starter phase. There were no significant differences in bodyweight gain, feed intake and FCR among treatments during the finisher phase (Table 2).

The overall growth-performance parameters showed that with an increasing the Arg : Lys ratio of the diet, from 0.85 to 1.26, there was a linear bodyweight gain by 7% and improved FCR by 6%. There was no Arg : Lys ratio effect in feed intake among treatments. Mortality was not significantly ($P < 0.05$) different among the treatments.

Carcass characteristics

Increasing the Arg : Lys ratio in the diet linearly ($P < 0.0001$) and quadratically ($P < 0.001$) improved the carcass yield and chilled carcass weight respectively (Table 3). The percentage of breast meat also showed a significant ($P < 0.0001$) linear improvement with an increasing Arg : Lys ratio. Broilers fed a diet with an Arg : Lys ratio of 0.85 had the lowest carcass yield, chilled carcass weight and breast meat yield. The significant quadratic effect was validated for carcass yield and chilled carcass weight, with maximum values being estimated at Arg : Lys ratios of 1.05,1.16 and 1.26, and showed that the values reached a plateau at an Arg : Lys ratio of 1.05. The percentage of breast meat linearly improved ($P < 0.0001$) by 5.5% with an increase in the dietary Arg : Lys ratio from 0.85 to 1.26.

Table 2. Effects of increasing dietary arginine : lysine (Arg : Lys) ratio on the growth performance of broilers
*, P < 0.05. **, P < 0.001. ***, P < 0.0001. n.d., not determined; n.s., not significantly different (at P = 0.05); FCR, feed conversion ratio; s.e.m., standard error of the mean

Item	Arg : Lys ratio					s.e.m.	Significance (contrast)			
	0.85	0.95	1.05	1.16	1.26		Linear	Quadratic	Cubic	Quartic
Starter phase, 1–10 days										
Weight gain (g)	234	240	244	243	247	2.32	**	n.s.	n.s.	n.s.
Feed intake (g)	314	313	312	309	309	2.84	n.s.	n.s.	n.s.	n.s.
FCR	1.34	1.30	1.28	1.27	1.26	0.014	**	n.s.	n.s.	n.s.
Mortality (%)	0.00	0.40	0.00	0.40	0.80	0.360	n.d.	n.d.	n.d.	n.d.
Grower phase, 11–24 days										
Weight gain (g)	532	573	581	588	599	7.48	**	*	n.s.	n.s.
Feed intake (g)	1041	1059	1065	1077	1090	14.97	n.s.	n.s.	n.s.	n.s.
FCR	1.96	1.85	1.84	1.83	1.82	0.032	*	n.s.	n.s.	n.s.
Mortality (%)	0.40	0.80	0.40	0.80	0.00	0.430	n.d.	n.d.	n.d.	n.d.
Finisher phase, 25–35 days										
Weight gain (g)	1037	1066	1066	1070	1081	14.74	n.s.	n.s.	n.s.	n.s.
Feed intake (g)	1752	1779	1744	1765	1736	27.71	n.s.	n.s.	n.s.	n.s.
FCR	1.70	1.67	1.64	1.66	1.61	0.024	n.s.	n.s.	n.s.	n.s.
Mortality (%)	0.80	1.30	0.00	0.00	0.00	0.460	n.d.	n.d.	n.d.	n.d.
Overall growth phase, 1–35 days										
Weight gain (g)	1802	1894	1891	1902	1927	19.08	**	n.s.	n.s.	n.s.
Feed intake (g)	3107	3150	3120	3151	3136	35.17	n.s.	n.s.	n.s.	n.s.
FCR	1.73	1.66	1.65	1.66	1.63	0.020	*	n.s.	n.s.	n.s.
Mortality (%)	1.30	2.50	0.40	1.20	0.80	0.740	n.d.	n.d.	n.d.	n.d.

Table 3. Effects of increasing dietary arginine : lysine (Arg : Lys) ratio on plasma chemical composition, carcass characteristics and organ weight percentages
Percentage of carcass yield and percentage of chill carcass weight were calculated on the basis of live bodyweight. Internal organs refer to gizzard, liver and heart. *, P < 0.05. ***, P < 0.0001. n.s., not significantly different (at P = 0.05); s.e.m., standard error of the mean

Item	Arg : Lys ratio					s.e.m.	Significance (contrast)			
	0.85	0.95	1.05	1.16	1.26		Linear	Quadratic	Cubic	Quartic
Plasma chemical composition										
Total protein (g/dL)	2.75	2.68	2.66	2.68	2.7	0.046	n.s.	n.s.	n.s.	n.s.
Glucose (mg/dL)	255.25	244.88	247.542	248.92	246.61	18.255	n.s.	n.s.	n.s.	n.s.
Triglycerides (mg/dL)	120.58	121.58	117.17	119.75	119.17	4.080	n.s.	n.s.	n.s.	n.s.
Creatinine (mg/dL)	0.13	0.14	0.13	0.16	0.16	0.005	***	n.s.	n.s.	*
IGF-1 (ng/mL)	0.85	0.91	0.91	0.87	1.00	0.025	*	n.s.	*	n.s.
Carcass characteristic										
Weight (g)	2050.50	2057.10	2064.00	2059.10	2056.10	16.620	n.s.	n.s.	n.s.	n.s.
Carcass yield (%)	83.80	85.00	85.90	86.00	86.30	0.290	***	*	n.s.	n.s.
Chill carcass (%)	82.00	83.10	84.00	84.20	84.50	0.290	***	*	n.s.	n.s.
Internal organ (%)	4.87	4.81	4.79	4.81	4.79	0.076	n.s.	n.s.	n.s.	n.s.
Breast meat (%)	28.70	29.21	29.23	29.81	30.26	0.248	***	n.s.	n.s.	n.s.
Thigh (%)	15.65	15.82	15.94	15.95	16.01	0.107	n.s.	n.s.	n.s.	n.s.
Drum (%)	12.04	12.07	12.14	12.17	12.23	0.084	n.s.	n.s.	n.s.	n.s.
Wing (%)	9.06	9.04	9.04	8.97	8.90	0.059	n.s.	n.s.	n.s.	n.s.
Abdominal fat (%)	1.21	1.11	1.24	1.19	1.25	0.084	n.s.	n.s.	n.s.	n.s.

However, there was no significant (P < 0.05) difference observed among treatments in the percentage of visceral organs, thigh, drumstick, wing and abdominal fat. The overall carcass and breast meat yields showed a positive response with an increasing dietary Arg : Lys ratio in the broiler diet.

Plasma testing

Increasing the Arg : Lys ratio from 0.85 to 1.26 in the diet linearly increased (P < 0.0001) the creatinine concentration by 23 %. The IGF-1 concentration was also linearly improved (P < 0.05) by 18% with an increasing Arg : Lys ratio from 0.85 to 1.26. However, there were no significant (P < 0.05) differences in total protein, glucose and triglycerides among the dietary treatments (Table 3).

Discussion

In the present study, increasing the Arg : Lys ratio from 0.85 to 1.26 resulted in linear improvements in bodyweight gain and FCR during the starter, grower and finisher phases, and overall across all phases. This is in agreement with Al-Daraji and Salih (2012), who found a linear increase ($P < 0.05$) in live bodyweight gain, feed intake and FCR in chickens fed diets containing Arg and Lys at a ratio of 1.20–1.23. In contrast, Szabó *et al*. (2014) suggested that to maximise broiler growth performance at 21–36 days of age, the Arg : Lys ratio should be in the range of 1.40–1.75, with 1.15% Lys in the diet. However, the present study showed that there was a quadratic response in weight gain to an increasing Arg : Lys ratio in the grower phase. Broken-line analysis indicated that the Arg : Lys ratio required for the weight gain response was 0.95–1.26, with the diet consisting of 1.23–1.64% arginine and 1.29% Lys. The optimum Arg : Lys ratio to maximise weight gain in the grower phase was 0.95. In the present study, feed intake in the starter, grower and finisher phases was not affected by the different Arg : Lys ratios of 0.85–1.26 in the diet. However, an improvement was observed in bodyweight gain and feed conversion with an increasing ratio of Arg : Lys in the diet.

The results of the overall growth phase in the present study showed that increasing the Arg : Lys ratio in the diet from 0.85 to 1.26 had a positive effect on broiler growth performance. Increasing the Arg : Lys ratio by increasing the Arg concentration significantly increased bodyweight and weight gain, along with an improvement in feed conversion. These results are in agreement with Brake *et al*. (1998), who reported that feed intake was not affected by Arg : Lys ratio but FCR was improved by the Arg : Lys ratio of 1.36 when compared with the ratio of 1.09 at a circulating hot diurnal temperature (25.5–3.3°C). Mendes *et al*. (1997) reported that increasing the Arg : Lys ratio from 1.10 to 1.40 improved FCR but had no significant ($P > 0.05$) effect on breast meat yield.

Creatinine is a blood chemical molecule generated from creatine, a major molecule used for energy production in muscles. Creatine is an endogenous metabolite of Arg. It is a unique organic compound involved in protein metabolism and participates in the muscle energy-buffering system (Khajali and Wideman 2010; Chen *et al*. 2011). In the present study, there was a linear increase in the creatinine concentration with and increasing Arg : Lys ratio. The highest concentration of creatinine was observed in the plasma of chickens fed with dietary Arg : Lys ratio of 1.26. This could be attributed to high protein synthesis at high Arg : Lys ratios in chickens, resulting in an increased growth performance and meat yield. Supplementation of the diet with L-arginine increased Arg in blood plasma in the form of creatinine. The Arg : Lys ratio had no influence on the total protein and triglyceride concentrations.

There was no significant ($P < 0.05$) difference among the treatments in the percentage of abdominal fat and triglyceride concentration measured from this study. The percentage of abdominal fat is related to triglyceride concentration. Also Santoso *et al*. (1995) found that the triglyceride concentration in the blood is directly associated with fatty acid synthesis in broiler chickens. One of the main functions of abdominal fat cells is the storage of triglycerides synthesised in the liver (Cartwright 1991), which is also related to the results on the percentage of abdominal fat in the present study.

In the present study, there was a significant linear effect of an increased Arg : Lys ratio in the diet on the IGF-1 concentration. It was confirmed that Arg can increase the release of IGF-1 into the bloodstream. IGF-1 promotes cell division and cell growth in the body and is, therefore, important for optimal growth performance and nitrogen balance in the growing animal (Duclos 2005).

The results of the present study clearly showed an improvement in the carcass yield weight, chilled weight and breast meat yield with an increased Arg : Lys ratio in broiler diets. Furthermore, Jiao *et al*. (2010) also demonstrated in broilers that, at 42 days, an increase in Arg concentration of 120% of the recommendation by NRC (Arg : Lys ratio of 1.36) could enhance breast meat. The breast meat yield was increased with dietary Arg : Lys ratio of 1.36.

Internal organ weights were not affected by dietary Arg : Lys ratio in the diet. This result is similar to that of Deng *et al*. (2003), who observed no significant difference in organ weights between starter broilers that had been fed a diet with a low Arg : Lys ratio of 0.75 or 0.79 and those that had received a high dietary ratio of 1.37–1.48.

Amino acid requirement can be affected by many factors. Basoo *et al*. (2012) reported that the requirement for Arg relative to Lys of broilers was different by the environment, broilers at 21–42-day period when exposed to hypobaric condition at high-altitude area. The estimated dietary Arg : Lys ratio requirement for maximising breast meat yield, bodyweight gain and FCR was 1.26, 1.24 and 1.22 respectively at high altitude (exposed to hypobaric hypoxia).

On the basis of the results of the present study, when broilers were reared under tropical environments, the highest Arg : Lys ratio of 1.26 had the greatest effect on broiler growth and percentage of breast meat. For the percentages of carcass yield and chill carcass weight, Arg : Lys ratio of 1.05 was the optimum ratio. However, additional research should be conducted to validate the optimum Arg : Lys ratios for maximising the growth and percentage of breast meat of broilers.

Conclusions

The growth performance of broilers, and blood chemical and carcass characteristics were significantly affected by the Arg : Lys ratio in the diet. Weight gain in the starter phase (Days 1–10 of age) and overall growth phase was linearly affected by increasing the Arg : Lys ratio of the diet from 0.85 to 1.26. An improvements in the FCR in the starter phase (Days 1–10 of age), the grower phase (Days 11–24 of age) and overall growth phase, which were related to the increased IGF-1 and creatinine concentrations, were also linearly affected by the increasing Arg : Lys ratio in the diet.

The results of the present study suggested that an Arg : Lys ratio of 1.05 in the broiler diet would maximise the weight gain in the grower phase (Days 11–24 of age) and also carcass yield. The use of synthetic amino acid to achieve the suggested ratio enabled nutritionists to formulate the diet with the competitive feed-cost saving.

Conflicts of interest

The authors declare no conflicts of interest.

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