Valine needs in starting and growing Cobb (500) broilers

F. C. Tavernari,* G. R. Lelis,† R. A. Vieira,† H. S. Rostagno,† L. F. T. Albino,† and A. R. Oliveira Neto‡[1]

*Embrapa Swine and Poultry, Concórdia, SC, Brazil, 89700-000; †Viçosa Federal University, Viçosa, MG, Brazil, 35700-000; and ‡Evonik Degussa of Brazil, São Paulo, SP, Brazil, 01404-000

ABSTRACT Two independent experiments were conducted with male Cobb × Cobb 500 broilers to determine the optimal valine-to-digestible-lysine ratio for broiler development. We conducted a randomized block experiment with 7 treatments, each with 8 replicates of 25 starter birds (8 to 21 d of age) and 20 finisher (30 to 43 d of age) birds. To prevent any excess of digestible lysine, 93% of the recommended level of digestible lysine was used to evaluate the valine-to-lysine ratio. The utilized levels of dietary digestible lysine were 10.7 and 9.40 g/kg for the starting and growing phases, respectively. A control diet with 100% of the recommended level of lysine and an adequate valine-to-lysine ratio was also used. The feed intake, weight gain, feed conversion ratio, and carcass parameters were evaluated. The treatments had no significant effect on the feed intakes or carcass parameters in the starter and finisher phases. However, during both of the studied phases, we observed a quadratic effect on weight gain and the feed conversion ratio. The broilers of both phases that were fed test diets with the lower valine-to-lysine (Val/Lys) ratio had poorer performance compared with those broilers fed control diets. However, when higher Val/Lys ratios were used for the starting and growing broilers that were fed test diets, the 2 groups had similar performance. During the starting phase, in broilers that were fed a higher Val/Lys ratio, weight gain, and the feed conversion ratio improved by 5.5% compared with broilers fed the basal diets. The broilers in the growing phase also had improved performance (by 7 to 8%) when the test diets had higher Val/Lys ratios. Based on the analysis of the starter phase data, we concluded that the optimal digestible Val/Lys ratio for Cobb × Cobb 500 broilers is 77%, whereas for birds in the finisher phase (30 to 43 d of age), a digestible Val/Lys ratio of 76% is suggested.

Key words: broiler, carcass, performance, requirement, valine

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INTRODUCTION

Recent studies on broilers have led to a better understanding of the effects of limiting amino acids in corn and soybean meal-based diets and in diets containing animal byproducts. The minimum CP content of broiler diets is variable and depends on the 4th limiting amino acid (Kidd and Hackenhaar, 2005), when industrial methionine, lysine, and threonine are offered, with the goal of achieving the best balance between all amino acids and the lysine content. The principal motivation behind using crystalline amino acids in broiler diets is to reduce the environmental impact of excessive nitrogen. A review of the literature suggests that valine is the 4th limiting amino acid in corn and soybean meal-based diets (Mack et al., 1999; Baker et al., 2002; Corzo et al., 2007, 2008, 2009; Rostagno et al., 2011). Presently, industrial L-valine is available in some countries, and some producers include supplemental valine in swine and broiler diets.

The optimal valine-to-lysine (**Val/Lys**) ratio in the Cobb broiler diet is unknown. Although valine has been proposed to be the 4th limiting amino acid, the best Val/Lys ratio during the different phases of broiler rearing is still being debated. Factors such as environmental temperature and health status can change the amino acid needs, as has been observed for threonine (Corzo et al., 2007) and also for Met + Cys (Williams et al., 1997a,b; Stahly, 1998; Oliveira Neto, 2003); these factors may also change the needs for valine. The relationships among valine, isoleucine, and leucine contribute to the differences in the digestible Val/Lys ratios (Torres et al., 1995; Corzo et al., 2009; Wiltafsky et al., 2010; Corzo et al., 2010; Berres et al., 2010).

Most of the studies that have examined valine requirements were conducted using different strains, such as New Hampshire × Columbian Plymouth Rock broilers (Baker et al., 2002), Ross × Ross 308 broilers (Corzo et al., 2004b, 2007, 2008), or ISA 220 broilers (Mack et al., 1999). No research has examined the valine needs

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[1]Corresponding author: adhemarneto10@hotmail.com

of the Cobb 500 (slow-feathering) broiler strain, despite the importance of this strain in worldwide poultry meat production.

The objective of this study was to determine the optimal digestible Val/Lys ratio for male Cobb × Cobb 500 broilers that were fed diets based on corn, soybean meal, and sorghum. These birds received 10.7 and 9.40 g/kg of digestible lysine at ages 8 to 21 d and 30 to 42 d, respectively.

MATERIALS AND METHODS

Two independent experiments were conducted to determine the optimal Val/Lys ratio during the starter and finisher rearing phases of male Cobb × Cobb 500 broilers. To avoid any residual starting phase effects on the growing phase, each experiment was independently conducted (i.e., different broilers were used to evaluate each phase).

A randomized block experiment was conducted during the starter phase (8 to 21 d), at which time the broilers had an average BW of 161.76 ± 0.24 g. This experiment had 7 treatments, with 8 replicates of 25 birds per experimental unit. Six different ratios of digestible valine (% of lysine) of 69, 72, 75, 78, 81, and 84% were evaluated. The L-valine supplemented in the diets to obtain the desired Val/Lys ratios was a food-grade L-valine with 98.5% purity, supplied by Evonik Degussa. The diets were formulated to supply the broiler nutritional requirements suggested in Rostagno et al. (2011), with the exception of valine and lysine levels. To avoid excessive lysine, 93% digestible lysine (10.7 g/kg) was used. A control diet containing adequate lysine (11.5 g/kg) and valine (8.8 g/kg) levels was also included in the experimental design, in accordance with Rostagno et al. (2011).

For the finisher phase, broilers at 30 to 42 d were examined in a randomized block experiment. Male broilers with an average BW of 1,486.38 ± 1.48 g were included. This experiment had 7 treatments with 8 replicates of 20 birds per experimental unit. Six different ratios of digestible valine (% of lysine) of 71, 74, 77, 80, 83, and 86% were evaluated. The diets were formulated to supply the broiler nutritional requirements suggested in Rostagno et al. (2011), except for valine and lysine levels. To avoid excessive lysine, 93% digestible lysine (9.4 g/kg) was used. A control treatment containing adequate digestible lysine (10.1 g/kg) and valine (8.1 g/kg) levels was also included in the experimental design.

The compositions of the basal diets for both experiments are shown in Table 1. All of the diets were in mashed form and were based on corn, soybean meal, and sorghum. The basal diets contained starch, which was replaced by crystalline amino acids to formulate the different treatment diets. The nutritional and energy compositions of the basal and control diets used during the starter and finisher phases are presented in Table 2. An analysis of the amino acid and protein contents of the experimental diets (Llames and Fontaine, 1994; Fontaine et al., 1998) confirmed the calculated values. Thus, these values were used in further calculations (Table 2).

A total of 2,520 male Cobb 500 broilers that had been sexed by wings and vaccinated against fowl pox and Marek's disease at the hatchery were used in the experiments. During both experiments, the birds were housed in a 3-m-high masonry broiler house with an asbestos monitor roof, concrete floor, 0.40-m-high wire mesh side walls, and plastic curtains to control the house temperature and prevent drafts. The house was divided into 1.0 × 2.0-m pens that were provided with wood-shaving litter, nipple drinkers, and tube feeders. The drinkers, feeders, curtains, and birds were managed according to the recommendations of the manual for this genetic strain (Cobb-Vantress, 2003). Water and feed (mash) were supplied ad libitum during both experiments. Before the beginning of each experimental period, the birds were fed commercial feed. A 24-h light (natural + artificial) regimen was used during the entire experimental period. The chicks were brooded using infrared lamps, and the height was adjusted for bird comfort.

The internal house temperature was measured by maximum-minimum temperature thermometers placed at different bird-height locations inside the poultry house. The following average temperatures were recorded during the experiments: 25°C (22 and 28°C for the minimum and maximum, respectively) for 8 to 21 d and 25°C (21 and 29°C for the minimum and maximum, respectively) for 30 to 43 d.

The birds and their diets were weighed at the beginning and end of each experimental period (8 to 21 d and 30 to 43 d) to calculate the following parameters: feed intake (**FI**), weight gain (**WG**), and the feed conversion ratio (**FCR**). In both experiments, daily mortality was recorded to correct for its effect on FI. The FCR was corrected for mortality and was expressed as the FI for all of the live birds in the pen (in grams) divided by the WG per pen (in grams). At the end of the finisher-phase experiment, 3 birds from each pen that had obtained the average weight for their pen were killed at 44 d of age to determine the carcass, breast, and leg yields.

The data were statistically analyzed using the Sistema de Análises Estatísticas and Genéticas software package (Universidade Federal de Viçosa, 2000). The data were compared using ANOVA, and the Dunnett test ($P < 0.05$) was used to compare the control treatment with the different Val/Lys ratio test diets. The data were also evaluated by regression analyses. Only the quadratic effects are displayed because significance of higher-order polynomials was not observed ($P > 0.05$). When a significant quadratic response ($P < 0.05$) was observed, 95% of the maximum or minimum response was used to avoid overestimating the broiler

Table 1. The ingredient compositions (%, as is) of the basal diets in experiment 1 (8 to 21 d) and experiment 2 (30 to 43 d)

Ingredient	8 to 21 d	30 to 43 d
Corn	45.39	49.01
Soybean meal (45%)	24.60	21.23
Low-tannin sorghum	20.00	20.00
Soybean oil	1.37	3.01
Dicalcium phosphate	1.86	1.54
Limestone	0.91	0.82
Salt	0.29	0.24
$NaHCO_3$	0.30	0.30
L-Lysine HCl (78%)	0.40 (0.50)[1]	0.35 (0.42)[1]
L-Valine (98.5%)	0.00 (0.17)[2]	0.00 (0.14)[2]
DL-Methionine (99%)	0.36	0.32
L-Threonine (98%)	0.19	0.15
Glycine (98%)	0.39	0.18
L-Arginine (98.5%)	0.20	0.17
L-Isoleucine (98.5%)	0.11	0.10
L-Tryptophan (98%)	0.02	0.02
Glutamic acid (98%)	3.0	2.0
Starch	0.30	0.27
Premix[3]	0.35	0.35
Total	100	100

[1]Supplemental lysine HCl (78%) in the control diet.

[2]Supplemental valine (98.5%) in the control diet. The broiler basal diet had no valine supplementation. The test diets were supplemented with L-valine (98.5%), which replaced starch to achieve the desired Val/Lys ratios.

[3]The diets supplied the following compounds (per kg): retinyl acetate, 3.44 mg; cholecalciferol, 50 μg; DL-α-tocopherol, 15 mg; thiamine, 1.63 mg; riboflavin, 4.9 mg; pyridoxine, 3.26 mg; cyanocobalamin, 12 μg; D-pantothenic acid, 9.8 mg; D-biotin, 0.1 mg; menadione, 2.4 mg; folic acid, 0.82 mg; niacinamide, 35 mg; selenium, 0.2 mg; iron, 35 mg; copper, 8 mg; manganese, 60 mg; Zn, 50 mg; I, 1 mg; butyl hydroxy toluene, 80 mg. The broiler basal diets had no valine supplementation. The test diets were supplemented with 98.5% L-valine, which replaced starch to achieve the desired Val/Lys ratios.

valine needs. A linear response plateau (**LRP**) model with a 5% probability level was also used to determine the optimum Val/Lys ratio for each evaluated parameter. When the same variable was presented using both the quadratic (95%) and LRP responses, an average value was calculated to define the best Val/Lys ratio while avoiding overestimation or underestimation.

RESULTS AND DISCUSSION

The purpose of this study was to evaluate the Val/Lys ratio in broiler diets that contained ingredients normally used in the diets produced by feed mills and used by poultry companies. To fine-tune the digestible Val/Lys ratio, the CP in the diet was reduced and in-

Table 2. The nutrient compositions (g/kg) of the basal diets (as is) in experiment 1 (8 to 21 d) and experiment 2 (30 to 43 d)

	8 to 21 d		30 to 43 d	
Nutrient	Control	Basal	Control	Basal
Analyzed composition[1] (g/kg)				
CP	203	204	181	182
Lysine	11.5 (100)[2]	10.3 (100)	10.1 (100)	9.50 (100)
Valine	8.80 (77)	7.10 (69)	8.10 (80)	6.70 (71)
Methionine + Cystine	8.30 (72)	8.00 (78)	7.60 (75)	7.60 (80)
Threonine	7.50 (65)	7.30 (71)	6.60 (65)	6.60 (70)
Tryptophan	2.10 (18)	2.10 (20)	1.80 (17)	1.80 (19)
Arginine	12.0 (104)	12.0 (117)	10.7 (106)	10.7 (113)
Isoleucine	7.70 (67)	7.70 (75)	6.80 (67)	6.80 (72)
Leucine	14.3 (124)	14.3 (139)	13.5 (134)	13.5 (142)
Glycine + Serine	17.5 (152)	17.5 (170)	14.3 (142)	14.3 (150)
Calculated composition				
AME (kcal/kg)	3,000	3,000	3,150	3,150
Calcium (g/kg)	8.84	8.84	7.64	7.64
Available phosphorus (g/kg)	4.42	4.42	3.80	3.80
Sodium (g/kg)	2.14	2.14	1.94	1.94

[1]The feeds were formulated using the total amino acid contents of corn and soybean meal according to near infrared reflectance (NIR).

[2]The values in parentheses indicate the amino acid-to-lysine ratios. The amino acid and other nutrient values are shown as grams per kilogram and not as a percentage of the diets. All of the total dietary amino acid compositions were analytically verified by Evonik Degussa (Hanau, Germany) using wet chemistry (HPLC). The digestibility coefficient from Rostagno et al. (2011) was used to obtain the digestible amino acid levels.

Table 3. The influence of the digestible valine-to-lysine ratio (Val/Lys, %) on weight gain (WG), final weight (FW), feed intake (FI), and feed conversion ratio (FCR) in 8- to 21-d-old broilers[1] (experiment 1)

Val/Lys (%)	BW8	WG	FW	FI	FCR
Control	162	701[a]	863[a]	1,049	1.50[a]
69	162	671[b]	833[b]	1,044	1.56[b]
72	162	685[a]	847[a]	1,046	1.53[a]
75	162	689[a]	851[a]	1,035	1.50[a]
77	162	706[a]	868[a]	1,039	1.47[a]
81	162	708[a]	870[a]	1,050	1.48[a]
84	162	703[a]	865[a]	1,056	1.50[a]
SEM	0.25	2.80	2.63	3.30	0.01
P-value	0.9999	0.001	0.0036	0.720	0.016
Quadratic *P*-value	0.979	0.049	0.001	0.200	0.019

[a,b]Means that do not share a common superscripted letter within a column differ significantly from those of the control treatment, as determined by the Dunnett test ($P < 0.05$).

[1]Each value represents the mean of 8 replicates with 25 birds per pen (200 birds total). BW8: BW at 8 d old.

dustrial amino acids were added. In both experiments (8 to 21 and 30 to 42 d of age), the formulated diets contained corn, soybean meal, and sorghum, and the amino acid contents of all the diets were analyzed to confirm the calculated values. To provide better data on the Val/Lys ratio, the total amino acids were converted to digestible amino acids using Rostagno's digestibility coefficient. This method is consistent with the method of Emmert and Baker (1997), who suggested that digestible amino acid values should be used to avoid any differences in absorption efficiency arising from the ingredient sources. Given that the ideal protein level involves the optimal ratios of all the essential amino acids to lysine, the regression analysis used Val/Lys ratio, not digestible valine. Most studies that have evaluated the Val/Lys ratio have first estimated the optimal valine level and then used this level to find the optimal Val/Lys ratio.

Several studies have addressed the valine needs of broilers in the starting (Han and Baker, 1994; Corzo et al., 2008), growing (Baker et al., 2002; Thornton et al., 2006; Corzo et al., 2008), and finisher (Corzo et al., 2004b) phases. However, differences between these studies should be considered. Baker et al. (2002) and Corzo et al. (2008) conducted 2 well-known studies to determine the valine requirements of broilers. There are notable differences between their studies and the present work. Although the objectives of all these aforementioned studies were the same, the studies used different strains, basal diets, and age periods, which may influence the broiler valine needs. In Baker et al. (2002), a different strain (New Hampshire × Columbian Plymouth Rock) was given a diet using corn gluten meal as the only source of intact protein and was evaluated at 8 to 21 and 22 d. To obtain the optimal digestible amino acid percentages, a large quantity of free-form amino acids (industrial amino acids) were included. However, the levels of free-form amino acids were much higher than those found in practical diets. In addition, the lysine levels were lower (1.07%) than those in the present study, and the authors supplemented the diets with high levels of L-glutamic acid to increase the CP level from 12 to 22.5%. In Corzo et al. (2008), the Ross 308 strain was fed a basal diet containing corn and peanut meal as the main ingredients. The study examined 3 different phases: 1 to 14, 14 to 28, and 28 to 42 d of age. Although peanut meal was appropriate for that study's objectives, it is not a common ingredient in broiler diets. The valine needs during the 3 phases examined by Corzo et al. (2008) were calculated and presented as total or digestible values, not as Val/Lys ratios. However, it is well accepted among researchers and nutritionists that digestible valine levels cannot be used without considering the Val/Lys (ideal protein) ratio. The differing results among Baker et al. (2002), Corzo et al. (2008), and the present study clearly show

Table 4. The regression equations, coefficients of determination, plateaus, and requirements of the 8- to 21-d-old broilers (experiment 1)

Parameter	Equation	R^2	Plateau	Requirement[1,2]
Quadratic regression				
WG	$-615.1 + 32.95$ Val – 0.204 Val^2	0.94	—	77
FCR	$6.01 - 0.12$ Val – 0.00076 Val^2	0.94	—	75
Linear response plateau				
WG	$471.37 + 3.003$ Val	0.90	706 g	79
FCR	2.18 – 0.0093 Val	0.99	1.49 g/g	76

[1]The requirement is expressed as the digestible valine-to-lysine ratio (%).

[2]The digestible valine-to-lysine ratio estimates represent 95% of the maximum or minimum response. FCR: feed conversion ratio; R^2: coefficient of determination; WG: weight gain.

Table 5. The influence of the digestible valine-to-lysine ratio (Val/Lys, %) on weight gain (WG), final weight (FW), feed intake (FI), and the feed conversion ratio (FCR) in 30- to 43-d-old broilers[1] (experiment 2)

Val/Lys (%)	BW30	WG	FW	FI	FCR
Control	1,486	1,214[a]	2,701[a]	2,467	2.03[a]
70	1,487	1,135[b]	2,621[b]	2,466	2.17[b]
73	1,486	1,199[a]	2,685[a]	2,497	2.08[a]
76	1,487	1,229[a]	2,715[a]	2,509	2.04[a]
79	1,486	1,215[a]	2,701[a]	2,480	2.04[a]
82	1,487	1,247[a]	2,734[a]	2,528	2.03[a]
85	1,486	1,189[a]	2,675[a]	2,455	2.07[a]
SEM	1.56	6.80	5.74	9.00	0.01
P-value	0.998	0.001	0.001	0.226	0.001
Quadratic *P*-value	0.998	0.001	0.001	0.070	0.001

[a,b]Means that do not share a common superscripted letter within a column differ significantly from those of the control treatment, as determined by the Dunnett test ($P < 0.05$).

[1]Each value represents the mean of 8 replicates with 20 birds per pen (160 birds total). BW30: BW at 30 d old.

that additional research is necessary to determine the actual valine and Val/Lys ratio requirements of broilers and that these requirements should consider factors such as basal diet, strain, and age.

The influence of the Val/Lys ratio on the outcomes of the 8- to 21-d-old Cobb male broilers is shown in Table 3. The regression equations, coefficients of determination (R^2), and estimated optimal Val/Lys for the starting phase are shown in Table 4.

The Val/Lys ratio had no effect on the FI of the broilers during the starter phase, and there was no difference in FI between the birds fed the control and test diets. In contrast, Corzo et al. (2008) found that valine levels influenced FI. This difference may be due to the different valine ranges used in the 2 studies. Corzo et al. (2008) evaluated Val/Lys ratios ranging from 58 to 88%, whereas our study examined a range from 69 to 84% (intermediate values), which was most likely not sufficient to affect the FI.

The starter broilers fed the test diet containing a 69% digestible Val/Lys ratio had lower WG (4.3%, 671 vs. 701 g) than the birds fed the control diet (Table 3). The control diet contained adequate nutrition according to the recommendations of Rostagno et al. (2011) and contained 11.5 g/kg of digestible lysine and a 77% Val/Lys ratio. The test diets used to evaluate the optimal Val/Lys ratio were similar to the control diet except that the digestible lysine was reduced to 93% of the recommended level (10.3 g/kg of Lys) to avoid any excess digestible lysine that could affect the optimal Val/Lys ratio. The decreased supplemental crystalline lysine in the test diets resulted in increased amino acid-to-lysine ratios in all of the treatments (Table 2). When the WG were analyzed, we found similar values between the broilers fed the control diet and those fed the test diets with Val/Lys ratios higher than 72% (Table 3). This result must be highlighted because experiments may underestimate the amino acid-to-lysine ratios due to the inclusion of crystalline essential amino acids, which may limit the dietary CP content (by maintaining a fixed level of soybean meal) and cause an imbalance between some amino acids and lysine. This effect was evident in the present study; modern broilers should respond to digestible lysine levels higher than 11.5 g/kg during the starter phase, but we did not observe any **WG** or FCR improvements in the broilers fed the control diet (11.5 g/kg digestible lysine) rather than the test diets (10.3 g/kg of digestible lysine) that had Val/Lys ratios greater than or equal to 72%.

The increased Val/Lys ratios affected the WG of the broilers aged 8 to 21 d. Both the quadratic (77%) and linear response plateau (79%) affected the WG, which reached a maximum of 708 g (a 5.5% increase relative to the group fed the 69% Val/Lys basal diet). The LRP (79%) and the quadratic regression (77%) gave an estimated optimal average Val/Lys ratio for WG of 78% for the 8- to 21-d-old broilers. This estimated optimal Val/Lys ratio was similar to those reported by Baker et al. (2002) and Rostagno et al. (2011), who suggested Val/Lys ratios of 77.5 and 77%, respectively, for starter broilers.

The improved WG with constant FI observed at higher Val/Lys ratios suggested that the ratio had a significant effect on feed conversion. When analyzed by

Table 6. The effects of different digestible valine-to-lysine (Val/Lys) ratios on the carcass, breast, and leg yields of 44-d-old broilers (experiment 2)

Val/Lys (%)	Carcass (%)	Breast (%)	Legs (%)
Control	73.24[1]	26.49	30.54
70	73.22	26.54	30.43
73	73.15	27.31	29.90
76	72.71	26.58	30.77
79	72.40	26.80	29.92
82	73.17	26.91	29.73
85	72.47	27.05	30.16
SEM	0.21	0.13	0.12
P-value	0.139	0.363	0.191
Quadratic *P*-value	0.129	0.533	0.514

[1]Each value represents the mean of 8 replicates, with 3 birds per pen used to measure the carcass parameters (24 birds total). Val/Lys: digestible valine-to-lysine ratio (%); Legs: thigh plus drumstick.

Table 7. The regression equations for experiment 2 (30 to 43 d of age)

Parameter	Equation	R^2	Plateau	Requirement[1,2]
Quadratic regression				
WG	$-6{,}268.5 + 189.779\text{Val} + 1.199\text{Val}^2$	0.87	—	75
FCR	$11.5 - 0.239\text{Val} + 0.00148\text{Val}^2$	0.97	—	77
Linear response plateau				
WG	$592.96 + 8.0511\text{Val}$	0.78	1,189 g	75
FCR	$4.295 - 0.0303\text{Val}$	1.00	2.05 g/g	74

[1]The requirement is expressed as the digestible valine-to-lysine ratio (%).

[2]The digestible valine-to-lysine ratio estimates represent 95% of the maximum or minimum response. FCR: feed conversion ratio; R^2: coefficient of determination; WG: weight gain.

quadratic regression and LRP, the optimal Val/Lys ratios for feed conversion were 75% and 76%, respectively. The optimal value for FCR was 76% in the starting phase. This ratio (1.48) represents a 5.5% improvement over that of the valine-deficient basal diet (1.56).

The effects of the various Val/Lys ratios on the performance and carcass parameters of the 30- to 42-d-old male Cobb broilers are shown in Tables 5 and 6. The regression equations, coefficients of determination, and estimated optimal Val/Lys ratios are presented in Table 7.

Similar to the observations in starter broilers, the dietary valine levels did not affect FI in the broilers aged 30 to 43 d. We varied the Val/Lys ratios in the present study from 71 to 86%, which was likely not sufficient to cause any significant changes in FI. In contrast, Corzo et al. (2008) found that valine levels had a linear effect on FI. However, the authors varied the Val/Lys ratios from 58 to 88%. The data presented by Corzo et al. (2008) suggest that at least 1 treatment with a Val/Lys ratio lower than 65% is required to significantly influence broiler FI in the starter and grower phases.

The broilers fed the ideal protein control diet containing 10.3 g/kg digestible lysine had better WG (7%) and FCR (6%) than the broilers fed the test diet (9.5 g/kg Lys) that contained the lowest Val/Lys ratio (71%). When fed the test diets that contained Val/Lys ratios greater than or equal to 74%, however, the broilers' WG or FCR were similar to those of the birds fed the control diet. Similar to observations in the starter phase, increasing the levels of digestible lysine from 9.5 to 10.3 g/kg did not change the WG or FCR in the 30- to 43-d-old birds, although modern commercial broiler lines are capable of responding to much higher lysine levels. Because there were no changes in the quantities of soybean meal, corn, or sorghum (which prevented any changes in the crude dietary protein content), some amino acids were likely marginally deficient in the control diets. The levels of glycine plus serine in the control diet may have been slightly deficient. Recent studies by Corzo et al. (2004a) and Dean et al. (2006) have concluded that the glycine + serine level should be considered in Ross broiler chicks fed vegetable diets. These authors recommended total glycine + serine levels of 1.80% (7 to 20 d) and 2.44% (0 to 17 d). These results may explain why we did not observe any response to lysine in the control vs. test diets when Val/Lys ratios were adequate.

Increasing the Val/Lys ratio from 71 to 86% improved the WG (8%) and FCR (7%) of the finisher broilers. Both parameters had quadratic and LRP responses, and the estimated optimal Val/Lys ratio was the average of the values estimated using each method. The optimal ratio for WG estimated by the quadratic equation (95% of the maximum response) and LRP was 75%. For the FCR, the optimal values were 77 and 74% of the estimated requirement using the quadratic regression and LRP, respectively. The average Val/Lys ratio was 76%. Considering the previously mentioned criteria and the broiler responses observed during the grower phase, we found the optimal Val/Lys ratio for WG and the FCR in the 30- to 43-d-old Cobb x Cobb 500 broilers to be 76%. This recommendation is slightly lower than those of Han and Baker (1994), Mack et al. (1999), Baker et al. (2002), and Corzo et al. (2007, 2008), who suggested Val/Lys ratios of 77, 81, 77.5, 77, and 78, respectively, for New Hampshire x Columbian Plymouth Rock, ISA 220 or Ross x Ross 308 broilers.

The carcass, breast, and leg yields were not affected by the Val/Lys ratios utilized in the present study (Table 6). Additionally, there was no variation in the carcass parameters among the broilers fed the control and test diets, which contained lower digestible lysine levels. Corzo et al. (2004b, 2008) also showed that dietary valine levels did not affect the breast yield of Ross broilers. In our study of Cobb broilers, valine did not significantly affect the carcass and cut yields, although valine did affect WG and the FCR, suggesting that valine promotes a higher growth rate but does not change the composition of the broiler carcass.

From the analysis of the starter phase data, we conclude that the optimal digestible Val/Lys ratio for Cobb x Cobb 500 broilers is 77%. For the broilers in the finisher phase (30 to 43 d of age), a digestible Val/Lys ratio of 76% is suggested.

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