Evaluating the digestible lysine requirements of male Cobb MV × Cobb 500 broilers during the first fourteen days of age and the carryover effect of feeding varying levels of digestible lysine on performance and processing

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Primary Audience: Jel Codes: Production Managers, Nutritionists, Primary Breeders

SUMMARY

Digestible lysine (**dLys**) requirements in broilers is heavily researched due to lysine's importance in diet formulation, body protein accretion, and dietary protein cost. As such, when novel broiler strains are established, it is important to evaluate their dLys requirements. The current objective was to determine the dLys requirement of male Cobb MV × Cobb 500 broilers from d 0 to 14 and evaluate the carryover effect (d 14−41) of feeding varying starter levels of dLys. Two basal diets were formulated (0.88% dLys and 1.44% dLys), then blended to create 6 intermediate dLys treatments (ranging from 0.96 to 1.36% dLys), creating a total of 8 dLys experimental diets. A control diet (treatment 9−1.28% dLys) was separately made to confirm blending techniques. Treatments were arranged as a randomized complete block design (**RCBD**) to 96 pens, with each pen having 14 male chicks. In general, increasing dLys resulted in improvements in performance metrics and processing weights. From d 0 to 14, feeding ≥1.20% dLys increased BW and BWG, feeding ≥0.96% dLys increased FI, with an exception in birds fed 1.44% dLys; stepwise reductions in FCR were observed as dLys increased from 0.88 until 1.20% dLys. Estimated dLys requirements ranged from 1.17 to 1.30% for BWG and 1.29 to 1.49% for FCR (using multiple regression methods). In general, carryover effect data (d 0−41) demonstrated that increasing starter dLys improved performance and d 42 processing. Future research should evaluate higher dLys levels than those used in this study and the dLys requirements of female Cobb MV × Cobb 500 broilers during the starter phase.

Key words: new commercial broiler strain, digestible lysine requirement, live performance

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DESCRIPTION OF PROBLEM

To improve the male line, Cobb developed a new broiler breeder product, the Cobb MV male, which was introduced to the market in 2017 (Cobb Focus One, Cobb-Vantress Inc., 2017). This has led to the production of a new commercial broiler strain, the Cobb MV × Cobb 500. Due to the bird's nutritional requirements being influenced by several factors, research on the nutritional requirements of this new strain is justified to optimize performance, production, and economic return (Baker et al., 2002).

Furthermore, literature has found that amino acids (**AA**) are vital for muscle growth (Tesseraud et al., 1996); thus, to optimize growth performance and meat yield, it is necessary to define the digestible AA requirements of each specific case (Munks et al., 1945). Among all AA, lysine (**Lys**) is the second limiting AA in corn-soybean meal based diets for broilers (Dozier and Payne, 2012). Supplementation of adequate dietary Lys provides proper muscle development and growth performance (Cemin et al., 2017). Noteworthy, the composition of Lys in the breast muscle is greater than other AA, as the breast represents ~7% of the total body protein content (Munks et al., 1945). Therefore, a lysine deficiency in the diet has the potential to reduce breast meat yield (Hamm, 1981; Vieira and Angel, 2012), ultimately impacting economic return.

In modern least-cost diet formulation, digestible AA values are now used rather than crude protein or total amino acid values, which allows for more precise formulation and reduces the amount of crude protein in the diet (Rostagno et al., 1995). Furthermore, the ideal protein concept states that birds require a precise balance of AA to maximize growth potential. Although the requirement for AA can vary depending on several factors, the ratios between these AA tend to remain relatively similar (Baker and Han, 1994). Lysine is used as the reference AA in modern least-cost formulation because it is almost exclusively used for body protein accretion and has little to no metabolic interactions with other AA (Baker and Han, 1994). Therefore, all other essential AA are supplied in the diet as a ratio to lysine. Theapplication of this ratio makes determining the dLys requirement a great starting point for novel broilers strains since all other AA are expressed as a ratio to lysine during diet formulation.

Due to the lack of data involving the Cobb MV × Cobb 500, nutritionists must rely on requirement data derived from other strains, which may result in the over or under-feeding of AA, ultimately impacting broiler performance, processing, nitrogenous waste, and economic return. Previous research has shown the dLys requirement during the starter phase to range from 1.07 to 1.28% (Baker et al., 2002; Cemin et al., 2017; Dozier and Payne, 2012; Garcia and Batal, 2005; Han and Baker, 1991; Knowles and Southern, 1998; Labadan et al., 2001); however, it is important to note that these publications use varying strains, sexes, diet compositions, rearing environments, and ages. For these reasons, it is paramount to determine the dLys requirement of novel strains to optimize performance, processing, and economics.

Furthermore, research has been conducted evaluating the impact of feeding varying levels of digestible lysine in different dietary phases (Corzo et al., 2005, 2010; Butler et al., 2020; Dozier et al., 2008; Hirai et al., 2019, 2020a, 2020b; Johnson et al., 2020; Kidd et al., 2005). While these data are valuable, data identifying the impact of manipulating AA density within a particular growth phase on overall performance is also needed. The starter phase specifically lends itself as a good starting point, as feed intake is relatively low and growth rate is high during this time (Vieira and Angel, 2012). Kang et al. (1985) reported that breast muscle deposition is as high as 68% during the first week and only 23% at 6 wk of age. Therefore, investment in increasing AA density early in a broiler's life may be warranted if potential improvements in performance and processing metrics can be detected in later phases. The objectives of the current study were 1) to evaluate the dLys requirement of male broilers of a new commercial strain (Cobb MV × Cobb 500) during the first 14 d of age; 2) to determine the impact of feeding varying levels of dLys on d 0 to 14 growth performance and the carryover effect in subsequent dietary phases.

MATERIALS AND METHODS

Broiler Management

The current study was conducted at the Mississippi State University Poultry Research Unit in agreement with the Mississippi State University Institutional Animal Care and Use Committee. Day old Cobb MV × Cobb 500 male chicks were procured from a commercial hatchery (Tyson Foods, Inc., Stillwell, OK) and equally allotted into 96 floor pens (0.91×1.22 m; 14 birds/pen; 0.079 m^2/bird) that were top-dressed with fresh pine shavings over used litter (litter ∼11 years old, with ∼45 flocks reared on it). The experimental house was solid-walled with evaporative cooling cells, 2 forced-air heaters, 2 exhaust fans, and 2 tunnel fans. Feed and water were provided ad libitum using a hanging feeder (16.0 kg capacity) and 3 nipple drinkers per pen.

Birds were provided with 24 h of light from d 0 to 7, and then 20 h of light from d 7 until the end of the study at d 42. The light intensity was 26.9 lux from d 0 to 10 and gradually decreased until reaching 2.7 lux on d 21, which was maintained until d 42 (Cobb 500 Broiler Management Guide, Cobb-Vantress, Inc., 2018). The house temperature was set at 32.2˚C on d 0 and incrementally reduced until reaching 18.3˚C on d 35 and maintained until d 42 (Cobb 500 Broiler Management Guide, Cobb-Vantress, Inc., 2018).

Diet Preparations

Prior to diet formulation, all major ingredients, such as corn and soybean meal, were analyzed for proximate analysis and total AA content (AOAC 982.30 mod, 994.12 mod, 988.15 mod; University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO). These samples were also scanned using Near Infrared Spectroscopy (**FOSS NIR**) for proximate analysis, total AA concentration, and AA digestibility coefficients (PNE; Adisseo NIR Service) to allow for more accurate formulation. All diets contained a commercially available phytase (Quantum Blue − *E. coli* derived; AB Vista, Plantation, FL), an antibiotic (BMD-50; finished feed containing 50 g/ton bacitracin methylene disalicylate; Zoetis Inc., Parsippany, NJ), and a coccidiostat (Nicarb 25%; finished feed containing 0.01 to 0.02% nicarbazin; Phibro Animal Health Corporation, Teaneck, NJ). All basal diets were batched at the Mississippi State University Poultry Research Unit (Mississippi State, MS). Dry ingredients were mixed first for 5 min, and after the inclusion of the soybean oil, diets were then mixed again for 10 min in a 0.907 tonne vertical screw mixer (Jacobson Machine Works, Minneapolis, MN). After batching, diets were pelleted at the USDA Poultry Research Unit (Starkville, MS). Feed was conditioned for 10 s at 81˚C with steam pressure at 262 kPa and then pelleted using a 40 horsepower California Pellet Mill (Crawfordsville, IN).

Experimental (Starter) Diets. Initially, 2 basal diets were formulated (Table 1); the LOW basal diet represented Trt 1 and was formulated to 0.88% dLys, and the HIGH basal diet represented Trt 8 and was formulated to 1.44% dLys. The LOW and HIGH basal diets were formulated with minimum dLys levels but similar key AA to dLys ratios (SAA:77%, Thr: 67%, Trp: 18% (LOW) or 19% (HIGH), Ile: 69%, Val: 78% (LOW) or 77% (HIGH), Arg: 108% (LOW) or 110% (HIGH)). Intermediate dLys treatments (Trts 2 to 7 − 0.96, 1.04, 1.12, 1.20, 1.28, and 1.36% dLys, respectively) were created by mixing Trts 1 and 8 in different ratios prior pelleting (Table 1). To verify the blending calculations and technique, Trt 9, or the practical control (PRAC-CON; 1.28% dLys) diet, was separately formulated, batched, and manufactured. This diet was used as a comparison with Trt 6, or the blended control (BLEND-CON) diet, which consisted of a blended proportion of LOW and HIGH basal diets to equal 1.28% dLys. All experimental diets were provided as a crumble from d 0 to 14. Feed samples were also collected after pelleting, and samples were then homogenized and shipped to a third-party laboratory for nutrient analysis (University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO). Diet formulations and calculated nutrient content for the experimental starter basal diets are presented in Table 1. All analyzed nutrient values for the 9 tested treatments were within expected ranges and are presented in Table 2.

Table 1. Diet formulations and calculated nutrient content of the experimental starter diets fed to male Cobb MV × Cobb 500 broilers from d 0 to 14.

Ingredient/Nutrient	LOW (Trt 1) %	HIGH (Trt 8) %	PRAC-CON[1] (Trt 9) %
Corn	73.50	46.20	54.00
Soybean meal (48% CP)	22.30	45.20	38.60
Soybean oil	0.99	5.30	4.06
L-Lysine HCl	0.16	0.15	0.15
DL-Methionine	0.19	0.45	0.24
L-Threonine	0.08	0.16	0.14
L-Valine	0.00	0.05	0.03
Salt	0.23	0.24	0.38
Defluorinated phosphate	1.43	1.27	1.32
Calcium carbonate	0.59	0.51	0.54
Phytase[2]	0.01	0.01	0.01
Sodium S-Carb	0.15	0.15	0.15
Vitamin-trace mineral	0.25	0.25	0.25
Selenium premix 0.06%	0.02	0.02	0.02
Choline Cl-70%	0.10	0.01	0.04
Antibiotic[3]	0.05	0.05	0.05
Coccidiostat[4]	0.04	0.04	0.04
Calculated nutrient content[5] (%)			
AME (kcal/kg)	3,051.72	3,051.72	3,051.72
Crude protein	16.10	25.00	22.50
Crude fat	3.30	7.10	6.10
Calcium	0.90	0.90	0.90
Total phosphorus	0.59	0.64	0.63
Available phosphorus	0.45	0.45	0.45
Sodium	0.22	0.22	0.22
Potassium	0.66	1.03	0.92
Chloride	0.22	0.21	0.21
Digestible lysine	0.88	1.44	1.28
Digestible methionine	0.44	0.79	0.69
Digestible SAA	0.68	1.11	0.99
Digestible threonine	0.59	0.96	0.86
Digestible tryptophan	0.16	0.28	0.24
Digestible isoleucine	0.61	0.99	0.88
Digestible valine	0.69	1.11	0.99
Digestible arginine	0.95	1.58	1.40

[1]Trt 9 (PRAC-CON; 1.28% dLys) was made as a comparison to the Trt 6 (BLEND-CON; 1.28% dLys). Trt 1 (LOW; 0.88% dLys) and Trt 8 (HIGH; 1.44% dLys) basal diets were batched and mixed in different ratios prior to pelleting for the creation of all intermediate dLys treatments and can be found as.

- Trt 1 (0.88% dLys) – 100:0 (LOW:HIGH).
- Trt 2 (0.96% dLys) – 85:15 (LOW:HIGH).
- Trt 3 (1.04% dLys) – 70:30 (LOW:HIGH).
- Trt 4 (1.12% dLys) – 57:43 (LOW:HIGH).
- Trt 5 (1.20% dLys) – 42:58 (LOW:HIGH).
- Trt 6 (BLEND-CON; 1.28% dLys) – 28:72 (LOW:HIGH).
- Trt 7 (1.36% dLys) – 15:85 (LOW:HIGH).
- Trt 8 (1.44% dLys) – 0:100 (LOW:HIGH).

[2]Quantum Blue (*E.Coli* phytase) at 500 FTU/kg. AB Vista, Plantation, FL.
[3]BMD-50 (bacitracin methylene disalicylate). Zoetis, Parsippany, NJ.
[4]Nicarb 25% (Nicarbazin). Phibro, Teaneck, NJ.
[5]Values are calculated based on the analyzed nutrient composition of corn and soybean meal

Common Grower and Finisher Diets. Common grower and finisher diets (corn and soybean meal based) were fed from d 14 to 41 so that any potential carryover effect of feeding varying levels of dLys during the starter phase could be evaluated. Grower diets were fed from d 14 to 28, and the finisher diets were fed from d 28 to 41 and presented as a pellet. Diet specifications for these diets were based on breeder recommendations, as well as internal data from previous research (Cobb 500 Broiler Management Guide, Cobb-

Table 2. Analyzed nutrient content of the experimental starter diets fed to male Cobb MV × Cobb 500 broilers from d 0 to 14.*

Nutrient (%)	Trt 1 0.88% dLys	Trt 2 0.96% dLys	Trt 3 1.04% dLys	Trt 4 1.12% dLys	Trt 5 1.20% dLys	Trt 6 1.28% dLys BLEND-CON[1]	Trt 7 1.36% dLys	Trt 8 1.44% dLys	Trt 9 1.28% dLys PRAC-CON[1]
	Analyzed nutrient content								
Gross energy (kcal/kg)	3,463.51	3,521.73	3,550.80	3,566.12	3,566.26	3,576.13	3,600.46	3,621.63	3,588.69
Crude protein[2]	16.79	18.14	19.18	20.10	21.49	22.61	24.13	25.50	23.07
Total lysine[3]	1.05	1.15	1.23	1.25	1.40	1.37	1.57	1.64	1.49
Total methionine[4]	0.44	0.50	0.55	0.60	0.66	0.66	0.73	0.79	0.70
Total cysteine[4]	0.30	0.33	0.35	0.34	0.37	0.35	0.40	0.40	0.38
Total SAA	0.74	0.83	0.90	0.94	1.03	1.01	1.13	1.19	1.08
Total threonine[3]	0.70	0.77	0.85	0.84	0.92	0.93	1.04	1.08	0.98
Total tryptophan[5]	0.23	0.25	0.26	0.28	0.30	0.30	0.33	0.35	0.32
Total isoleucine[3]	0.78	0.85	0.90	0.91	1.01	1.00	1.14	1.17	1.08
Total valine[3]	0.88	0.94	1.01	1.02	1.12	1.11	1.27	1.30	1.20
Total arginine[3]	1.10	1.22	1.29	1.31	1.44	1.43	1.66	1.72	1.54
Total leucine[3]	1.54	1.64	1.71	1.71	1.84	1.82	2.00	2.04	1.95
Total phenylalanine[3]	0.86	0.94	0.99	0.99	1.09	1.08	1.23	1.26	1.18
Total histidine[3]	0.47	0.50	0.53	0.53	0.58	0.58	0.65	0.66	0.62

*All feed samples were analyzed by the University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO.

[1]PRAC-CON was a practical control diet that was separately formulated and batched. This diet was used as a comparison with the BLEND-CON, which was obtained by blending calculated proportions of the LOW and HIGH basal diets, so that blending technique could be verified. Both control diets were formulated to 1.28% dLys.

[2]AOAC 990.03 mod.

[3]AOAC 982.30 mod.

[4]AOAC 994.12 mod.

[5]AOAC 988.15 mod.

Table 3. Diet formulations and calculated nutrient content of the common grower and finisher diets fed to male Cobb MV × Cobb 500 broilers from d 14 to 41.[1]

Ingredient/Nutrient	Grower (d 14−28) %	Finisher (d 28−41) %
Corn	65.30	66.80
Soybean meal (48% CP)	29.10	26.90
Soybean oil	2.59	3.54
L-Lysine HCl	0.13	0.08
DL-Methionine	0.24	0.21
L-Threonine	0.08	0.06
Salt	0.20	0.23
Defluorinated phosphate	1.21	1.00
Calcium carbonate	0.56	0.54
Phytase[2]	0.01	0.01
Sodium S-Carb	0.15	0.15
Vitamin-trace mineral	0.25	0.25
Selenium premix 0.06%	0.02	0.02
Choline Cl-70%	0.07	0.08
Antibiotic[3]	0.05	0.05
Coccidiostat[4]	0.03	0.03
Calculated nutrient content[5] (%)		
AME (kcal/kg)	3,086.47	3,170.25
Crude protein	19.50	18.50
Crude fat	4.80	5.70
Calcium	0.84	0.76
Total phosphorus	0.58	0.53
Available phosphorus	0.42	0.38
Sodium	0.20	0.20
Potassium	0.77	0.73
Chloride	0.20	0.21
Digestible lysine	1.05	0.95
Digestible methionine	0.52	0.48
Digestible SAA	0.80	0.74
Digestible threonine	0.69	0.65
Digestible tryptophan	0.20	0.19
Digestible isoleucine	0.74	0.70
Digestible valine	0.82	0.78
Digestible arginine	1.17	1.11

[1]Common grower and finisher diets were provided to broilers from d 14 to 28 and d 28 to 41, respectively.
[2]Quantum Blue (*E.Coli* phytase) at 500 FTU/kg. AB Vista, Plantation, FL.
[3]BMD-50 (bacitracin methylene disalicylate). Zoetis, Parsippany, NJ.
[4]Nicarb 25% (Nicarbazin). Phibro, Teaneck, NJ.
[5]Values are calculated based on the analyzed nutrient composition of corn and soybean meal.

Vantress, Inc., 2018; Hirai et al., 2019). Diet formulations and calculated nutrient content for the common grower and finisher diets are presented in Table 3; analyzed nutrient values for these diets were also within expected ranges and are presented in Table 4.

Measured Variables

Live Performance. Each bird and feeder were weighed on d 7, 11, 14, 28, and 41; average BW, BW gain (**BWG**), feed intake (**FI**), and FCR (adjusted for mortality) from d 0 to 7, 0 to 11, 0 to 14, 0 to 28, and 0 to 41 were calculated.

Processing. On d 41, three birds per pen (± 100 g BW/pen; n = 288 broilers) were weighed and wing tagged for processing on d 42. Birds were withdrawn from feed 10 h prior to processing. Measured processing variables included live bird, hot carcass, abdominal fat pad, breast, tender, thigh, drumstick, and wing weights. Hot carcass and abdominal fat pad weights were obtained from the hot carcass, while all other part weights were obtained post chill (≤4°C for 3 h) and debone. All weights were recorded and then used to calculate part yield relative to live weight and carcass weight. Statistical differences ($P \leq 0.05$) were only observed for processing weights, while no differences ($P > 0.05$) were

Table 4. Analyzed nutrient content of the common grower and finisher diets fed to male Cobb MV × Cobb 500 broilers from d 14 to 41.*

	Grower(d 14−28)[1]	Finisher(d 28−41)[1]
Nutrient (%)	Analyzed nutrient content	
Gross energy (kcal/kg)	4,079.43	4,121.70
Crude protein[2]	19.31	18.60
Total lysine[3]	1.16	1.07
Total methionine[4]	0.52	0.49
Total cysteine[4]	0.32	0.31
Total SAA	0.84	0.80
Total threonine[3]	0.79	0.74
Total tryptophan[5]	0.24	0.23
Total isoleucine[3]	0.85	0.87
Total valine[3]	0.91	0.87
Total arginine[3]	1.18	1.14
Total leucine[3]	1.64	1.61
Total phenylalanine[3]	0.96	0.92
Total histidine[3]	0.49	0.47

*All feed samples were analyzed by the University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO.

[1]Common grower and finisher diets were provided to broilers from d 14 to 28 and d 28 to 41, respectively. This was done so that any potential carryover effect of feeding varying levels of dLys in the starter phase could be evaluated.

[2]AOAC 990.03 mod.

[3]AOAC 982.30 mod.

[4]AOAC 994.12 mod.

[5]AOAC 988.15 mod.

detected for processing yield relative to live weight and carcass weight. Therefore, only processing weights will be discussed and presented.

Statistical Analysis

All treatments were randomly assigned to floor pen by location within the house in an unbalanced RCBD and each pen was considered the experimental unit. Due to pen number constraints, treatments 1, 2, and 9 were replicated within 10 floor pens, while treatments 3 to 8 had an additional replication (block; n = 11 replications/treatment). The experimental diets were fed from d 0 to 14; the experimental period was from d 0 to 14 and 14 to 41 (carryover effect), and processing occurred on d 42. Formulated dLys values were used in statistical analysis, as total analyzed Lys values were in agreement with formulated values. ANOVA was performed for all measured variables using the GLM procedure in SAS (SAS Institute Inc., Cary, NC); means were separated using Fisher's least significant difference when *P*-values were ≤0.05.

Only treatments constituting the titration curve (Trts 1-8) were utilized during regression analysis; the PRAC-CON diet (Trt 9) was omitted from this analysis. LS Means were subjected to multiple regression models to estimate the dLys requirement for BWG and FCR. Linear broken line (**LBL**) and quadratic broken line (**QBL**) models were utilized using the Practical Program for Modeling (Garcia-Neto et al., 2015) and then confirmed using the PROC NLIN option of SAS (SAS Institute Inc., Cary, NC; Robbins et al., 2006). In addition, data were analyzed using PROC REG function in SAS (SAS Institute Inc.). The dLys requirement was then estimated using the quadratic polynomial (**QP**) model, in which the dLys requirement was calculated at 95% of the vertex when significance was detected ($P \leq 0.05$; Robbins et al., 2006).

RESULTS AND DISCUSSION

Starter Phase

Multiple Comparison. No significant differences were observed for mortality throughout the starter phase (d 0−7, 0−11, 0−14; P >

0.05); therefore, mortality data during these phases are not presented. This is in agreement with previous research, demonstrating d 0 to 14 mortality was not affected by different dLys concentrations (ranging from 0.95 to 1.43%) in 2 experiments using 2 different strains (Ross × Ross 708 and Hubbard × Cobb 500; Dozier and Payne, 2012).

Data from 0 to 7 d demonstrated that feeding varying dLys levels had no significant effect on FI ($P > 0.05$; Table 5); however, birds receiving diets formulated to ≥1.12% dLys (Trts 4-9) improved d 0 to 7 BW, BWG, and FCR when compared to birds fed ≤1.04% dLys (Trts 1-3) ($P < 0.0001$; Table 5). Similar broiler performance was also observed in broilers fed the PRAC-CON and BLEND-CON diets (1.28% dLys). Additionally, BW and BWG were the lowest, and FCR was highest in broilers fed 0.88% dLys (Trt 1; $P < 0.05$; Table 5). Furthermore, broilers fed 0.96 and 1.04% dLys (Trts 2 and 3, respectively) had improved BW, BWG, and FCR when compared to those fed 0.88% dLys (Trt 1; $P < 0.05$; Table 5). Similar to the current study, in general, improvements in d 0 to 7 BW, BWG, and FCR were observed when providing increased % dLys to either Ross × Ross 708 or Hubbard × Cobb 500 female broilers (Dozier and Payne, 2012). Interestingly, the same study found no difference for d 0 to 7 FI in the Ross × Ross 708 broilers; however, a significant difference was detected in the Hubbard × Cobb 500 broilers, whereas an increase in FI was observed until 1.35% dLys.

From d 0 to 11, significant differences were observed for BW, BWG, FI, and FCR ($P < 0.05$; Table 5). Birds fed the PRAC-CON diet (1.28% dLys; Trt 9) demonstrated greater BW and BWG when compared to birds fed ≤1.12% (Trts 1-4) and the BLEND-CON (1.28% dLys; Trt 6), but were similar to broilers provided 1.20, 1.36, and 1.44% dLys (Trts 5, 7, and 8, respectively; $P < 0.0001$; Table 5). Differences between the PRAC-CON (1.28% dLys) and BLEND-CON (1.28% dLys) may be attributed to the AA in the PRAC-CON coming more from intact protein while the BLEND-CON diet utilized more synthetic AA (Chung and Baker, 1992; Selle et al., 2020). Furthermore, improvements were observed for d 0 to 11 BW and BWG as dLys in the diet increased from 0.88 to 1.12% (Trt 1-4; $P < 0.0001$; Table 5). For d 0 to 11 FI, feeding birds 1.44% dLys resulted in the lowest FI, but similar to broilers fed 0.88% dLys and BLEND-CON (1.28% dLys) (Trts 1 and 6, respectively; $P = 0.0006$; Table 5). Additionally, broilers fed 1.12% dLys (Trt 4) had the highest d 0 to 11 FI but were similar to birds fed 1.04, 1.20% dLys, and PRAC-CON (1.28% dLys; Trts 3, 5, and 9, respectively; $P = 0.0006$; Table 5). For d 0 to 11 FCR, stepwise improvements were observed as the % dLys increased from 0.88 until 1.20% (Trts 1-5; $P < 0.0001$; Table 5). The lowest FCR from d 0 to 11 was observed in broilers provided 1.28% (PRAC-CON; Trt 9) and 1.44% dLys (Trt 8; $P < 0.0001$; Table 5).

Considering the entire starter phase (d 0 −14), birds receiving ≥1.20% dLys (Trts 5-9) demonstrated greater BW and BWG when compared to birds fed ≤1.12% dLys (Trts 1-4; $P < 0.0001$; Table 5). The lowest BW and BWG from d 0 to 14 was observed in broilers provided 0.88% dLys (Trt 1; $P < 0.0001$; Table 5). Stepwise increases in BW and BWG were demonstrated as the % dLys in the diet increased from 0.88% (Trt 1) to 0.96% and 1.04% (Trt 2 and 3, respectively) and finally to 1.12% (Trt 4; $P < 0.0001$; Table 5). For d 0 to 14 FI, birds fed diets formulated to 0.88% dLys (Trt 1) and 1.44% dLys (Trt 8) had lower FI than those fed the remaining dLys levels (Trt 2-7 and 9; $P < 0.0001$; Table 5). Birds fed diets formulated to 1.44% dLys (Trt 8) demonstrated the lowest d 0 to 14 FCR, with birds fed 1.28% dLys (PRAC-CON; Trt 9) performing similar ($P < 0.0001$; Table 5). Furthermore, stepwise improvements in d 0 to 14 FCR were found as dLys level fed increased from 0.88% (Trt 1) to 1.28% (BLEND-CON; Trt 6), with broilers fed the BLEND-CON performing similar to those fed 1.36% dLys (Trt 7; $P < 0.0001$; Table 5). It is important to note the broilers provided the BLEND-CON from d 0 to 14 had a greater FCR than those fed the PRAC-CON. As previously mentioned, this result may be due to the increased intact protein provided within the PRAC-CON diet as compared to the BLEND-CON (Chung and Baker, 1992; Selle et al., 2020).

It is well documented that increasing the dLys in the diet during the starter phase results in improvements in performance metrics

Table 5. The effect of feeding varying levels of dLys from d 0 to 14 on male Cobb MV × Cobb 500 performance parameters at d 7, 11, and 14.

Treatments		d 0−7			
Trt #	dLys (%)	BW[1] (kg)	BWG[2] (kg)	AFI[3] (kg/bird)	FCR[4] (Feed:Gain)
1	0.88	0.158[c]	0.112[c]	0.140	1.221[a]
2	0.96	0.168[b]	0.123[b]	0.142	1.153[b]
3	1.04	0.170[b]	0.124[b]	0.143	1.150[b]
4	1.12	0.179[a]	0.134[a]	0.146	1.095[c]
5	1.20	0.178[a]	0.132[a]	0.142	1.078[cd]
6	1.28 – BLEND-CON[5]	0.179[a]	0.134[a]	0.143	1.071[cd]
7	1.36	0.182[a]	0.137[a]	0.144	1.069[cd]
8	1.44	0.179[a]	0.133[a]	0.140	1.059[cd]
9	1.28 – PRAC-CON[5]	0.181[a]	0.136[a]	0.142	1.049[d]
	SEM[6]	0.0018	0.0018	0.0018	0.0165
	P-value	<0.0001	<0.0001	0.3491	<0.0001
Treatments		d 0−11			
Trt #	dLys (%)	BW[1] (kg)	BWG[2] (kg)	AFI[3] (kg/bird)	FCR[4] (Feed:Gain)
1	0.88	0.283[f]	0.237[f]	0.320[de]	1.314[a]
2	0.96	0.305[e]	0.259[e]	0.328[bcd]	1.271[b]
3	1.04	0.314[d]	0.268[d]	0.332[abc]	1.233[c]
4	1.12	0.328[c]	0.282[c]	0.336[a]	1.193[d]
5	1.20	0.336[ab]	0.291[ab]	0.333[ab]	1.144[e]
6	1.28 – BLEND-CON[5]	0.331[bc]	0.285[bc]	0.325[cde]	1.138[e]
7	1.36	0.333[abc]	0.288[abc]	0.327[bcd]	1.136[e]
8	1.44	0.335[ab]	0.290[ab]	0.320[e]	1.102[f]
9	1.28 – PRAC-CON[5]	0.338[a]	0.293[a]	0.328[abcd]	1.113[f]
	SEM[6]	0.0025	0.0025	0.0027	0.0074
	P-value	<0.0001	<0.0001	0.0006	<0.0001
Treatments		d 0−14			
Trt #	dLys (%)	BW[1] (kg)	BWG[2] (kg)	AFI[3] (kg/bird)	FCR[4] (Feed:Gain)
1	0.88	0.410[d]	0.365[d]	0.513[c]	1.384[a]
2	0.96	0.449[c]	0.403[c]	0.537[ab]	1.333[b]
3	1.04	0.460[c]	0.415[c]	0.536[ab]	1.289[c]
4	1.12	0.481[b]	0.436[b]	0.542[a]	1.240[d]
5	1.20	0.500[a]	0.454[a]	0.540[ab]	1.190[e]
6	1.28 – BLEND-CON[5]	0.498[a]	0.453[a]	0.531[ab]	1.173[f]
7	1.36	0.504[a]	0.458[a]	0.530[b]	1.158[fg]
8	1.44	0.497[a]	0.452[a]	0.515[c]	1.133[h]
9	1.28 – PRAC-CON[5]	0.505[a]	0.460[a]	0.531[ab]	1.150[gh]
	SEM[6]	0.0045	0.0045	0.0043	0.0064
	P-value	<0.0001	<0.0001	<0.0001	<0.0001

[a,b,c,d,e,f,g,h]Means within a column not sharing common superscripts are significantly different ($P \leq 0.05$).
[1]Average body weight for d 7, 11, and 14 (kg).
[2]Average body weight gain (kg).
[3]Average Feed Intake (kg) per bird.
[4]Mortality corrected feed conversion ratio.
[5]PRAC-CON was a practical control diet that was separately formulated and batched. This diet was used as a comparison with the BLEND-CON, which was obtained by blending calculated proportions of the LOW and HIGH basal diets, so that blending technique could be verified. Both control diets were formulated to 1.28% dLys.
[6]Standard error of the mean.

(Butler et al., 2020; Corzo et al., 2005; Dozier and Payne, 2012; Johnson et al., 2020; Kidd et al., 2004;). Johnson et al. (2020) fed 5 varying levels of dLys (ranging from 1.24 to 1.42% dLys) from d 0 to 12 to Cobb MV × Cobb 700 male and female broilers and reported improvements in both BW and FCR. However, unlike the current study, they observed no differences in FI. This may likely be attributed to the difference in strains, whereas the Cobb 500 is marketed as an efficient and fast growing broiler, while the Cobb 700 is marketed as a high yielding, slower growing bird (Cobb 500 and Cobb 700 Product Description, Cobb-Vantress, Inc., 2020). In a separate study, male Cobb 500 × Cobb broilers were fed varying dLys levels (ranging from 0.97 to 1.37%) from d 0 to 12 (Cemin et al., 2017). They reported quadratic responses for d 0 to 12 BWG and FCR as the dLys level increased. Similar to the current study's data, Cobb MV × 500 males demonstrated improvements in BWG from d 0 to 14; stepwise increases were observed for BWG as the dLys concentration increased from 0.88% until 1.20% and then plateaued. Furthermore, stepwise increases were observed for d 0 to 14 FCR, whereas decreases in FCR were observed as the dLys level increased from 0.88% until 1.44%. These data suggest that fast growing broilers may be more sensitive to varying dLys levels during the starter phase as compared to slower growing strains.

Regression Analysis. Again, the regression analysis was conducted only using treatments 1−8, or the titration curve. The PRAC-CON (Trt 9) diet was not included in any of the regression analysis. Significant LBL (linear broken line), QBL (quadratic broken line), and QP (quadratic polynomial) responses ($P < 0.0001$) were observed as increased dietary dLys levels were fed from 0 to 14 d (starter phase) for BWG and FCR (Table 6; Figures 1 and 2). For BWG, data suggests that the dLys requirement for male Cobb MV × Cobb 500 broilers from d 0 to 14 was 1.172% based on LBL ($P < 0.0001$; $R^2 = 0.808$); 1.299% based on QBL ($P < 0.0001$; $R^2 = 0.819$); and 1.250% based on QP ($P < 0.0001$; $R^2 = 0.788$). Using LBL model, the dLys requirement for FCR was approximately 1.293% ($P < 0.0001$; $R^2 = 0.924$) and when using the QP model, the estimated dLys requirement for FCR was 1.415% ($P < 0.0001$; $R^2 = 0.931$). However, the dLys requirement for FCR was estimated using QBL model to be 1.49% ($P < 0.0001$; $R^2 = 0.935$). It is important to note that the estimated FCR dLys requirement using the QBL model was higher than those tested during this study, indicating the need for further research.

In agreement with the current data, previous research has reported estimated dLys requirement variations among response metrics evaluated and statistical models used (Han and Baker, 1991; Vazquez and Pesti, 1997), even in the starter phase (Dozier and Payne, 2012). In addition, when comparing similar statistical models, it has been noted that the dLys requirement to optimize FCR is higher than BWG for overall performance (Baker and Han, 1991; Vazquez and Pesti, 1997), as well as in the starter phase (Cemin et al., 2017; Dozier and Payne, 2012). Previous research has hypothesized that as the dLys concentration exceeds the requirement for optimal BWG, growth rate is maintained. At the same time, FI decreases, resulting in higher estimated requirements for FCR than BWG (Baker et al., 2002).

Cemin et al. (2017) estimated the dLys requirement for male Cobb 500 × Cobb BWG

Table 6. Digestible lysine requirements of Cobb MV × Cobb 500 male broilers from 0 to 14 d of age based on linear broken line, quadratic broken line, and quadratic polynomial models.

Model	Response variable	Estimated dLys requirement	*P*-value	R^2
Linear broken line[1]	BWG[2]	1.172	<0.0001	0.808
	FCR[3]	1.293	<0.0001	0.924
Quadratic broken line[4]	BWG	1.299	<0.0001	0.819
	FCR	1.494	<0.0001	0.935
Quadratic polynomial[5]	BWG	1.250	<0.0001	0.788
	FCR	1.415	<0.0001	0.931

[1]Linear broken line model.
[2]Body weight gain (kg).
[3]Feed Conversion Ratio (Feed:Gain) was adjusted with mortality weight.
[4]Quadratic broken line model.
[5]Quadratic polynomial model, in which the dLys requirement was calculated by 95% of the asymptote.

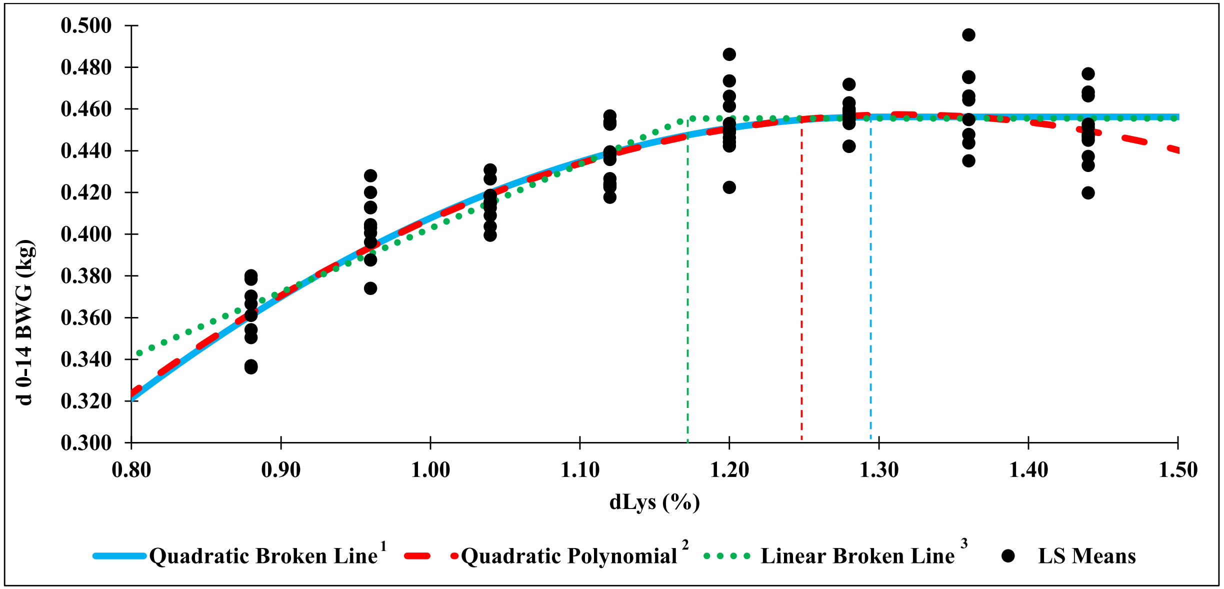

Figure 1. Comparison of LBL, QBL, and QP dLys Req estimates for d 0−14 BWG for Cobb MV × Cobb 500 male broilers. [1]Quadratic broken line: Req represented by the blue solid line: Estimated dLys Req = 1.299%; *P*-value = <0.0001; Sum of Squares Error = 0.0196; R^2 = 0.819. [2]Quadratic regression: Req represented by the red dotted line: Estimated dLys Req = 1.250% (95% of vertex); *P*-value = <0.0001; Sum of squares error = 0.0230; R^2 = 0.788. Calculated values were derived using the regression equation: $y = -0.50229x^2 + 1.32175x - 0.41224$, where y = BWG and x = % dLys. [3]Linear broken line: Req represented by the green dotted line: Estimated dLys Req = 1.172%; *P*-value = <0.0001; Sum of Squares Error = 0.0208; R^2 = 0.808.

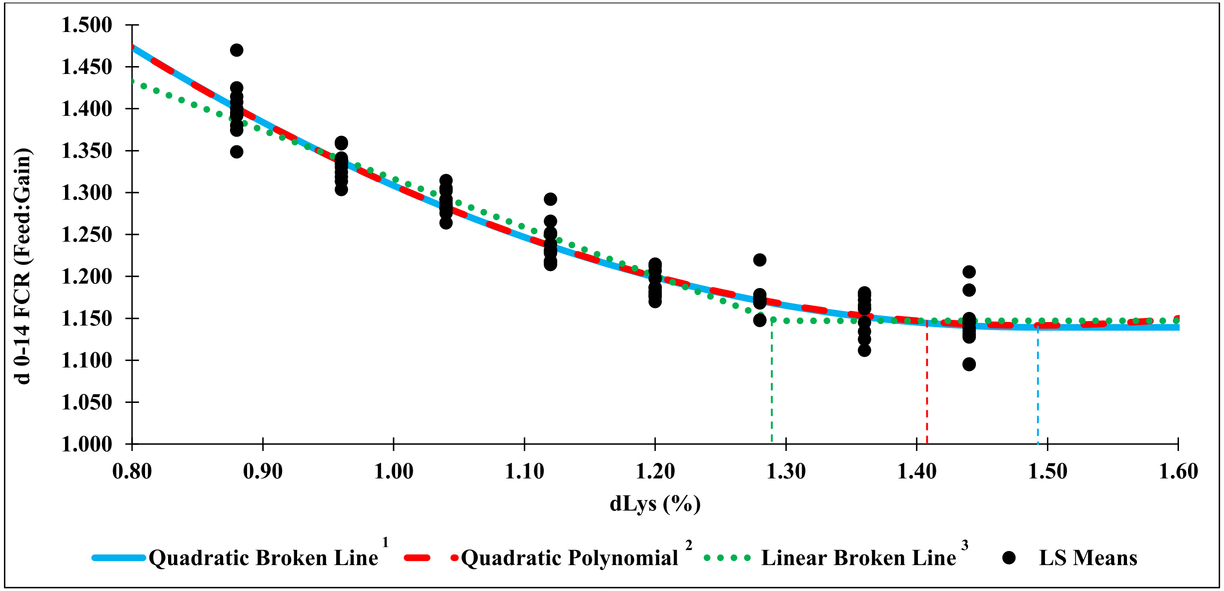

Figure 2. Comparison of LBL, QBL, and QP dLys Req estimates for d 0–14 FCR for Cobb MV × Cobb 500 male broilers. [1]Quadratic broken line: Req represented by the blue solid line: Estimated dLys Req = 1.494%; *P*-value = <0.0001; Sum of Squares Error = 0.0003; R^2 = 0.935. [2]Quadratic regression: Req represented by the red dotted line: Estimated dLys Req = 1.415% (95% of vertex); *P*-value = <0.0001; Sum of Squares Error = 0.0464; R^2 = 0.931. Calculated values were derived using the regression equation: $y = 0.69671x^2 - 2.07548x + 2.68708$, where y = FCR and x = % dLys. [3]Linear broken line: Req represented by the green dotted line: Estimated dLys Req = 1.293%; *P*-value = <0.0001; Sum of Squares Error = 0.0008; R^2 = 0.924.

(d 0−12) to range from 1.036 to 1.207%, depending upon the statistical model implemented. These estimations were much lower than the current study, which ranged from 1.17 to 1.30% (Table 6). For FCR, Cemin et al. (2017) estimated the dLys requirement to range from 1.027 to 1.190%, which were also much lower than our estimated requirement for FCR (ranging from 1.29 to 1.49% dLys; Table 6).

Overall, the dLys requirement estimates for Cobb MV × Cobb 500 are higher than those reported in previous literature (Cemin et al., 2017; Dozier and Payne, 2012) and Cobb 500 recommendations (Cobb 500 Broiler Management Guide, Cobb-Vantress, Inc., 2018). However, it is important to note that these studies utilized varying strains, sexes, dietary phases, and environmental conditions. Ultimately, these data show the importance of evaluating dLys requirements in novel broiler strains.

Carryover Effect

As previously mentioned, numerous studies evaluated the effects of varying AA densities in all dietary phases on broiler performance and processing when utilizing various strains and sexes (Butler et al., 2020; Corzo et al., 2005, 2010; Johnson et al., 2020; Kidd et al., 2004, 2005). These factors (especially the varying AA densities throughout) make comparing results from these studies and the current study difficult. The current study aimed to isolate the starter period as a potential phase of investment for increasing dLys by determining the carryover effect in subsequent growth phases. The authors hypothesize that due the increased rate of growth and decreased feed intake, increasing the cost of starter feed via increased AA density may be warranted (Kang et al., 1985; Vieira and Angel, 2012).

Mortality. A significant effect was detected for d 0 to 28 and 0 to 41 % mortality whereas treatments with dLys levels ≤1.12% dLys generally showed high levels of mortality beyond d 14, suggesting that these levels are likely below a practical range of dLys. In contrast to the current study, 2 experiments using male Ross × Ross 508 broilers (d 0−41 and 0 −42) found that mortality was not affected by varying levels of dLys from d 1 to 18 (Kidd and Fancher, 2001). While there could be many factors contributing to that result (e.g., litter age, length of starter, diet components, etc.), broiler strain may have also been a factor leading to the observed mortality differences. This may be an area of research interest, as a reduction in mortality may lead to improved profitability, as well as improved animal welfare.

Body Weight and Body Weight Gain. For d 0 to 28 BW and BWG, birds receiving starter diets formulated to 1.36% (Trt 7) had greater BW and BWG when compared to broilers fed 0.88 to 1.12% dLys (Trts 1-4), but were similar to all other dLys levels (Trts 5, 6, 8, and 9; $P <$ 0.0001; Table 7). Starter dLys concentrations also significantly affected d 0 to 41 BW and BWG. More specifically, broilers fed 1.20% dLys had the greatest BW and BWG but were similar to those fed 0.96%, 1.12%, BLEND-CON (1.28%), 1.36%, and 1.44% dLys (P = 0.0409 for both, Table 7). These results are in agreement with data published by Kidd and Fancher (2001), where they reported feeding ≥1.10% dLys from d 0 to 18, then providing common grower and finisher diets improved BW and BWG at d 41 and 42. These improvements in BW and BWG may be due to increased protein accretion, particularly breast meat, during the starter phase from feeding increasing levels of dLys (Hamm, 1981; Kang et al., 1985; Vieira and Angel, 2012).

Feed Intake. For d 0 to 28 FI, broilers fed 1.36% dLys (Trt 7) had the greatest d 0 to 28 FI when compared to birds fed starter diets formulated to 0.88% (Trt 1), 0.96% (Trt 2), and 1.04% (Trt 3), 1.12% (Trt 4), and PRAC-CON (1.28%; Trt 9); though were similar to birds fed starter diets formulated to 1.20% dLys (Trt 5), BLEND-CON (1.28% dLys; Trt 6), and 1.44% (Trt 8; P = 0.0005; Table 7). Differences were also detected for d 0 to 41 FI, whereas birds fed 0.88% (Trt 1), 1.04% (Trt 3), and PRAC-CON (1.28%; Trt 9) starter dLys had the lowest FI when compared to broilers fed 1.20 and 1.36% starter dLys (P = 0.0259; Table 7). In contrast to the current study, Hirai et al. (2020) reported no differences in d 0 to 28 or 0 to 41 FI in male Cobb MV × Cobb 500 broilers fed 2 different levels of AA (1.18 and 1.28% dLys) from d 0 to 14. It is possible that the current study was able

Table 7. The carryover effect of feeding varying levels of dLys from d 0 to 14 on male Cobb MV × Cobb 500 performance parameters at d 28 and 41.

Treatments		d 0−28				
Trt #	dLys (%)	BW[1] (kg)	BWG[2] (kg)	AFI[3] (kg/bird)	FCR[4] (Feed:Gain)	Mortality[5] (%)
1	0.88	1.500[d]	1.455[d]	2.145[d]	1.448	7.208[a]
2	0.96	1.569[c]	1.523[c]	2.215[bc]	1.445	4.351[ab]
3	1.04	1.570[c]	1.524[c]	2.190[cd]	1.437	3.247[bc]
4	1.12	1.588[bc]	1.542[bc]	2.212[bc]	1.432	2.597[bc]
5	1.20	1.628[ab]	1.582[ab]	2.260[ab]	1.431	0.649[c]
6	1.28 − BLEND-CON[6]	1.605[abc]	1.559[abc]	2.227[abc]	1.430	0.649[c]
7	1.36	1.641[a]	1.595[a]	2.277[a]	1.425	1.948[bc]
8	1.44	1.627[ab]	1.582[ab]	2.253[ab]	1.422	1.299[bc]
9	1.28 − PRAC-CON[6]	1.591[abc]	1.546[abc]	2.212[bc]	1.424	1.494[bc]
	SEM[7]	0.0165	0.0165	0.0184	0.0064	1.2832
	P-value	<0.0001	<0.0001	0.0005	0.0920	0.0149
Treatments		d 0−41				
Trt #	dLys (%)	BW[1] (kg)	BWG[2] (kg)	AFI[3] (kg/bird)	FCR[4] (Feed:Gain)	Mortality[5] (%)
1	0.88	2.467[c]	2.422[c]	4.102[c]	1.651	9.297[a]
2	0.96	2.559[abc]	2.513[abc]	4.150[bc]	1.637	4.297[bc]
3	1.04	2.543[bc]	2.497[bc]	4.126[c]	1.629	4.545[bc]
4	1.12	2.559[abc]	2.513[abc]	4.222[abc]	1.634	5.844[ab]
5	1.20	2.666[a]	2.621[a]	4.296[ab]	1.632	1.948[bc]
6	1.28 − BLEND-CON[6]	2.578[abc]	2.533[abc]	4.190[bc]	1.652	1.299[c]
7	1.36	2.632[ab]	2.587[ab]	4.373[a]	1.630	5.195[abc]
8	1.44	2.649[ab]	2.604[ab]	4.265[abc]	1.631	1.948[bc]
9	1.28 − PRAC-CON[6]	2.539[bc]	2.494[bc]	4.113[c]	1.629	2.868[bc]
	SEM[7]	0.0409	0.0409	0.0583	0.0120	1.6291
	P-value	0.0262	0.0261	0.0259	0.7916	0.0288

[a,b,c,d]Means within a column not sharing common superscripts are significantly different ($P \leq 0.05$).
[1]Average body weight (kg).
[2]Average body weight gain (kg).
[3]Average feed intake (kg) per bird.
[4]Mortality corrected feed conversion ratio.
[5]Mortality percentage based on starting bird number per pen (14 birds/pen).
[6]PRAC-CON was a practical control diet that was separately formulated and batched. This diet was used as a comparison with the BLEND-CON, which was obtained by blending calculated proportions of the LOW and HIGH basal diets, so that blending technique could be verified. Both control diets were formulated to 1.28% dLys.
[7]Standard error of the mean.

to detect differences in FI from d 0 to 28 and 0 to 41 due to feeding a larger variation of dLys levels during the starter phase (d 0−14). Additionally, in partial agreement with our results, it was previously reported that feeding higher levels of dLys from d 1 to 14 increased FI from d 0 to 42 (Corzo et al., 2010); however, variations in FI may have been attributed to these researchers continuing to increase AA density as the birds grew.

Feed Conversion Ratio. No significant differences were observed for FCR from d 0 to 28 or 0 to 41 ($P > 0.05$; Table 7). Similar to the current study, a previous study conducted by Kidd and Fancher (2001) reported that varying levels of dLys (ranging from 0.88 to 1.43% dLys) from d 1 to 18, then feeding common grower and finisher diets, did not affect FCR at d 41 and 42. These results may be explained by all birds receiving similar grower and finisher diets. It is well documented that modern broilers have feed conversion responses to varying AA density levels (Butler et al., 2020; Corzo et al., 2005, 2010; Dozier et al., 2008; Johnson et al, 2020; Kidd et al., 2005; Sterling et al., 2005). However, since all birds in the current study were only provided varying AA density during the starter phase, in which a significant FCR response was detected, it is possible that broilers were able to compensate

Table 8. The carryover effect of feeding varying levels of dLys from d 0 to 14 on male Cobb MV × Cobb 500 processing parameters at d 42.

Treatments		d 42 Processing weights (kg)							
Trt #	dLys (%)	Live weight[1]	Carcass[2]	Breast[3]	Fat pad[2]	Tender[3]	Drumstick[3]	Thigh[3]	Wing[3]
1	0.88	2.484[c]	1.802[c]	0.480[c]	0.029	0.098[c]	0.237	0.305	0.197[c]
2	0.96	2.593[abc]	1.877[abc]	0.508[abc]	0.029	0.104[bc]	0.249	0.317	0.207[b]
3	1.04	2.529[bc]	1.846[bc]	0.498[bc]	0.027	0.102[bc]	0.250	0.318	0.205[bc]
4	1.12	2.571[abc]	1.877[abc]	0.518[ab]	0.027	0.103[bc]	0.244	0.314	0.205[bc]
5	1.20	2.675[a]	1.951[a]	0.543[a]	0.030	0.112[a]	0.254	0.330	0.217[a]
6	1.28 – BLEND-CON[4]	2.580[abc]	1.869[abc]	0.510[abc]	0.030	0.102[bc]	0.245	0.319	0.210[ab]
7	1.36	2.638[ab]	1.917[ab]	0.540[a]	0.029	0.108[ab]	0.259	0.332	0.214[ab]
8	1.44	2.641[ab]	1.921[ab]	0.531[ab]	0.029	0.105[abc]	0.245	0.323	0.212[ab]
9	1.28 – PRAC-CON[4]	2.578[abc]	1.917[ab]	0.521[ab]	0.031	0.102[c]	0.245	0.315	0.209[ab]
	SEM[5]	0.0440	0.0317	0.0132	0.0015	0.0024	0.0046	0.0071	0.0032
	P-value	0.0420	0.0362	0.0236	0.5372	0.0149	0.0920	0.3819	0.0030

[a,b,c]Means within a column not sharing common superscripts are significantly different ($P \leq 0.05$).

[1]Average Live Weight (d 41) of birds selected for processing at d 42 (kg).

[2]Average weight obtained from the hot carcass (kg).

[3]Average weight obtained from the chilled carcass (kg).

[4]PRAC-CON was a practical control diet that was separately formulated and batched. This diet was used as a comparison with the BLEND-CON, which was obtained by blending calculated proportions of the LOW and HIGH basal diets, so that blending technique could be verified. Both control diets were formulated to 1.28% dLys.

[5]Standard error of the mean.

for these variations in the grower and finisher phases by adjusting their feed intake.

Processing. For d 42 processing weights, data demonstrated no significant differences for drumstick, thigh, and abdominal fat pad weights ($P > 0.05$; Table 8). There was an improvement in the average live weight of birds selected for processing, similar to that of d 41 average live BW. More specifically, broilers fed diets formulated to 1.20% dLys (Trt 5) from d 0 to 14 had the highest live weight (of birds chosen for processing) compared to birds fed 0.88 and 1.44% dLys, with all remaining treatments performing similar ($P = 0.042$; Table 8). A similar response was observed for carcass weight, whereas feeding broilers diets formulated to 1.20% dLys (Trt 5) during the starter phase improved d 42 carcass weight, but were similar to broilers fed 0.96, 1.12, 1.28, 1.3, and 1.44% dLys (Trts 2, 4-9, respectively; $P = 0.0362$; Table 8). Improvements in wing weight were also observed as the dLys level in the diet increased from 0.88 to 1.20% (Trt 1 until Trt 5; $P = 0.0032$; Table 8). Furthermore, broilers fed 1.20% dLys from d 0 to 14 had the highest d 42 wing weight, though similar to broilers fed 1.28% (BLEND-CON and PRAC-CON; Trt 6 and 9, respectively), 1.36% (Trt 7), and 1.44% starter dLys (Trt 8). Additionally, data showed that broilers fed 1.20% (Trt 5) starter dLys had greater tender weight when compared to broilers fed ≤1.12% (Trt 4), 1.28% (Trt 9; PRAC-CON), and 1.28% starter dLys (Trt 6; BLEND-CON; $P = 0.0149$; Table 8). For d 42 breast weight, the highest weights were observed in broilers fed 1.20% (Trt 5) and 1.36% starter dLys (Trt 7); however, these birds had similar breast weights as broilers fed 0.96, 1.12, 1.28, and 1.44% starter dLys (Trt 2; 4; 6, BLEND-CON; 9, PRAC-CON; and 8, respectively; $P = 0.0132$; Table 8).

While the current study did not determine differences in fat pad weight ($P > 0.05$; Table 8), it has been found in previous starter dLys carryover effect research (Kidd and Fancher, 2001); however, they fed on average, diets 56 kcal/kg higher in AME than that of the current study. The lower AME fed in the current study may explain the lack of a fat pad response, as fat deposition is controlled mainly by dietary energy and energy intake (Mabray and Waldroup, 1981; Leeson et al., 1996). In agreement with the current study, improvements in d 41 and d 42 carcass and breast weight were observed when starter phase (d 0−18) dLys was increased (Kidd and Fancher, 2001). Since AA play a vital role in the growth and development of young broilers, it can be expected that these differences may be observed. Furthermore, diets deficient in dLys can limit breast muscle formation early in development by reducing protein synthesis while increasing protein degradation (Hamm, 1981; Dozier et al., 2008; Vieira and Angel, 2012). Overall, the current study demonstrates the importance of evaluating starter dLys requirements in novel broiler strains, such as the Cobb MV × Cobb 500, as well as the overall impact of starter dLys on broiler performance and processing.

CONCLUSIONS AND APPLICATIONS

1) From d 0 to 14, data demonstrated that birds fed diets formulated to ≥1.20% dLys had greater BW and BWG when compared to those fed diets formulated to ≤1.12% dLys; in general, stepwise improvements were observed for d 0 to 14 FCR as dLys increased.
2) The d 0 to 14 dLys requirements for BWG were estimated using LBL, QBL, and QP models, and ranged from 1.172 to 1.299%, depending upon regression model utilized.
3) The estimated dLys requirement for FCR using LBL was 1.293%; when using QBL and QP, the requirement was estimated to be 1.494 and 1.415%, respectively, which is greater than the maximum level fed, indicating the need for future research testing higher % dLys during the starter phase.
4) Carryover performance data demonstrated that feeding ≥1.20% dLys in the starter phase improved d 28 and 41 BW, as well as d 0−28 and 0−41 BWG of Cobb MV × Cobb 500 male broilers. D 42 processing data demonstrated improvements in carcass, breast, tender, and wing weights when feeding starter dLys level of 1.20%. These data suggest that starter phase nutrition (i.e., dLys) can impact overall performance and ultimately return on investment for this novel strain.

DISCLOSURES

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REFERENCES

Han, Y., and D. H. Baker. 1991. Lysine requirements of fast- and slow-growing broiler chicks. Poult. Sci. 70:2108–2114.

Baker, D. H., and Y. Han. 1994. Ideal amino acid profile for chicks during the first three weeks posthatching. Poult. Sci. 73:1441–1447.

Baker, D. H., A. B. Batal, T. M. Parr, N. R. Augspurger, and C. M. Parsons. 2002. Ideal ratio (relative to lysine) of tryptophan, threonine, isoleucine, and valine for chicks during the second and third weeks posthatch. Poult. Sci 81:485–494.

Butler, L. D., C. G. Scanes, S. J. rochell, A. Mauromoustakos, J. V. Caldas, C. A. Keen, C. W. Maynard, S. A. Bolden, R. D. Brister, P. A. Smith, R. E. Latham, C. M. Owens, and M. T. Kidd. 2020. Cobb 700 response to increasing lysine by growth phase. J. Appl. Poult. Res. 29:479–488.

Cemin, H. S., S. L. Vieira, C. Stefanello, M. Kipper, L. Kindlein, and A. Helmbrecht. 2017. Digestible lysine requirements of male broilers from 1 to 42 days of age reassessed. PLOS One 12:e0179665.

Chung, T. K., and D. H. Baker. 1992. Apparent and true amino acid digestibility of a crystalline amino acid mixture and of casein: comparison of values obtained with ileal-canulated pigs and cecectomized cockerels. J. Anim. Sci. 70:3781–3790.

Cobb Focus One. 2017. Issue 1. Winter 2017. Cobb-Vantress Inc., Siloam Springs, AR. Accessed Aug. 2021. http://www.cobb-vantress.com/docs/default-source/cobb-focus-2017/CobbFocusOne2017English.pdf?sfvrsn=2.

Cobb 500 Broiler Management Guide. 2018. Cobb-Vantress Inc., Siloam Springs, AR. Accessed Aug. 2021. https://www.cobb-vantress.com/assets/Cobb-Files/product-guides/bdc20a5443/70dec630-0abf-11e9-9c88-c51e407c53ab.pdf.

Cobb 700 Product Description. 2020. Cobb-Vantress, Inc., Siloam Springs, AR. Accessed Aug. 2021. https://www.cobb-vantress.com/en_US/products/cobb700/.

Corzo, A., M. T. Kidd, D. J. Burnham, E. R. Miller, S. L. Branton, and R. Gonzalez-Esquerra. 2005. Dietary amino acid density effects on growth and carcass of broilers differing in strain cross and sex. J. Appl. Poult. Res. 14:1–9.

Corzo, A., M. W. Schilling, R. E. Loar II, L. Mejia, L. C. G. S. Barbosa, and M. T. Kidd. 2010. Responses of Cobb × Cobb 500 broilers to dietary amino acid density regimens. J. Appl. Poult. Res. 19:227–236.

Dozier, W. A. III, M. T. Kidd, and A. Corzo. 2008. Dietary amino acid responses of broiler chickens. J. Appl. Poult. Res. 17:157–167.

Dozier, W. A. III, and R. L. Payne. 2012. Digestible lysine requirements of female broilers from 1 to 15 days of age. J. Appl. Poult. Res. 21:348–357.

Garcia, A., and A. B. Batal. 2005. Changes in the digestible lysine and sulfur amino acid needs of broiler chicks during the first three weeks posthatching. Poult. Sci. 84:1350–1355.

Garcia-Neto, M., and S. H. V. Perri. 2015. PPM: practical program for modeling. Accessed Aug. 2021. https://sites.google.com/site/programapraticodemodelagem/home.

Hamm, D. 1981. Amino acid composition of breast and thigh meat from broilers produced in four locations of the United States. J. Food Sci. 46:1122–1124.

Han, Y., and D. H. Baker. 1991. Lysine requirements of fast- and slow-growing broiler chicks. Poult. Sci. 73:1739–1745.

Hirai, R. A., L. Mejia, C. Coto, J. Caldas, C. D. McDaniel, and K. G. S. Wamsley. 2019. Evaluating the response of Cobb MV x Cobb 500 broilers to varying amino acid density regimens for a small bird program. J. Appl. Poult. Res. 28:943–962.

Hirai, R. A., L. Mejia, C. Coto, J. Caldas, C. D. McDaniel, and K. G. S. Wamsley. 2020a. Impact of varying starter amino acid density and energy on 42 d male Cobb MV × Cobb 500 broiler performance and processing. J. Appl. Poult. Res. 29:1004–1019.

Hirai, R. A., L. Mejia, C. Coto, J. Caldas, C. D. McDaniel, and K. G. S. Wamsley. 2020b. Impact of feeding varying grower digestible lysine and energy levels to female Cobb MV x Cobb 500 broilers from 14 to 28 D on 42 D growth performance, processing, and economic return. J. Appl. Poult. Res. 29:600–621.

Johnson, C. A., T. Duong, R. E. Latham, R. B. Shirley, and J. T. Lee. 2020. Increasing amino acid density improves growth performance and processing yield in Cobb 700 × MV broilers. J. Appl. Poult. Res. 29:465–478.

Kang, C. W., M. L. Sunde, and R. W. Swick. 1985. Growth and protein turnover in the skeletal muscles of broiler chicks. Poult. Sci. 64:370–379.

Kidd, M. T., and B. I. Fancher. 2001. Lysine needs of starting chicks and subsequent effects during the growing period. J. Appl. Poult. Res. 10:385–393.

Kidd, M. T., C. D. McDaniel, S. L. Branton, E. R. Miller, B. B. Boren, and B. I. Fancher. 2004. Increasing amino acid density improves live performance and carcass yields of commercial broilers. J. Appl. Poult. Res. 13:593–604.

Kidd, M. T., A. Corzo, D. Hoehler, E. R. Miller, and W. A. Dozier III. 2005. Broiler responsiveness (Ross × 708) to diets varying in amino acid density. Poult. Sci. 84:1389–1396.

Knowles, T. A., and L. L. Southern. 1998. The lysine requirement and ratio of total sulfur amino acids to lysine for chicks fed adequate or inadequate lysine. Poult. Sci. 77:564–569.

Labadan, M. C., K. N. Hsu, and R. E. Austic. 2001. Lysine and arginine requirements of broiler chickens at two-to three-week intervals to eight weeks of age. Poult. Sci. 80:599–606.

Leeson, S., L. Caston, and J. D. Summers. 1996. Broiler response to diet energy. Poult. Sci. 75:529–535.

Mabray, C. J., and P. W. Waldroup. 1981. The influence of dietary energy and amino acid levels on abdominal fat pad development of the broiler chicken. Poult. Sci. 60:151–159.

Munks, B., A. Robinson, E. F. Beach, and H. H. Williams. 1945. Amino acids in the production of chicken egg and muscle. Poult. Sci 24:459–464.

Robbins, K. R., A. M. Saxton, and L. L. Southern. 2006. Estimation of nutrient requirements using broken-line regression analysis. J. Anim. Sci 84: E155–E165.

Rostagno, H., J. Pupa, and M. Pack. 1995. Diet formulation for broilers based on total versus digestible amino acids. J. Appl. Poult. Res. 4:293–299.

Selle, P. H., J. C. P. Dorigam, A. Lemme, P. V. Chrystal, and S. Y. Liu. 2020. Synthetic and crystalline amino acids: alternatives to soybean meal in chicken-meat production. Animals 10:729.

Sterling, K. G., D. V. Vedenov, G. M. Pesti, and R. I. Bakalli. 2005. Economically optimal dietary crude protein and lysine levels for starting broiler chicks. Poult. Sci. 84:29–36.

Tesseraud, S., N. Maaa, R. Peresson, and A. M. Chagneau. 1996. Relative responses of protein turnover in three different skeletal muscles to dietary skeletal muscles to dietary lysine deficiency in chicks. Poult. Sci 37:641–650.

Vazquez, M., and G. M. Pesti. 1997. Estimation of the lysine requirement of broiler chicks for maximum body gain and feed efficiency. J. Appl. Poult. Res. 6:241–246.

Vieira, S., and C. Angel. 2012. Optimizing broiler performance using different amino acid density diets: what are the limits? J. Appl. Poult. Res. 21:149–155.