Impact of feeding varying grower digestible lysine and energy levels to female Cobb MV × Cobb 500 broilers from 14 to 28 D on 42 D growth performance, processing, and economic return

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Primary Audience: Production Managers, Nutritionists, Primary Breeders

SUMMARY

Previous research in our laboratory has revealed that feeding crumbled diets with various levels of starter digestible Lys (**dLys**) and AME affects early feed conversion ratio (**FCR**) of Cobb MV × Cobb 500 broilers. However, overall performance was not affected, likely due to treatment application occurring in the starter phase. Therefore, the objective of this study was to evaluate a 3 dLys (1.00, 1.08, and 1.18%) × 4 AME (2,937, 3,028, 3,116, and 3,206 kcal/kg) factorial arrangement of pelleted grower diet treatments (**Gdiets**) and their impact on 42-day-old Cobb MV × Cobb 500 females. Significant dLys × AME interactions demonstrated a stepwise decrease in FCR (day 14–28 and 14–35) when dLys increased at 2,937, 3,116, and 3,206 kcal/kg but not at 3,028 kcal/kg AME. A significant dLys × AME interaction was also observed for day 14–28 total Lys intake/bird. Overall data exhibited improvements in BW and BW gain (**BWG**) when feeding Gdiets of 1.08 or 1.18% dLys. Feeding Gdiets of 1.18% dLys or ≥3,028 kcal/kg AME optimized day 14–41 FCR. Processing data demonstrated improved breast yield when feeding Gdiets formulated to ≥1.08% dLys or formulated to 2,937 or 3,028 kcal/kg AME. The most profitable Gdiet was 1.18% dLys +3,028 kcal/kg AME. To determine the best feeding regime for this new cross, future research should evaluate the effects of varying dLys and AME levels during the finisher phase on broiler performance.

Key words: lysine, energy, broiler, live performance, processing yield

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DESCRIPTION OF THE PROBLEM

To optimize performance and consequently meet increasing demand for protein sources, the poultry industry is constantly seeking to improve existing genetic lines, thereby developing new commercial broiler crosses. To achieve the maximum genetic potential of new crosses, research addressing their nutritional specifications is needed (Smith and Pesti, 1998). Evaluating the inclusion of AA and AME could yield nutritional and economic impacts on broiler production because AA are important for muscle

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development (Tesseraud et al., 1996) and AME is crucial for basal metabolic functions (Kleyn, 2013). In addition, feed ingredients that provide AA and AME are the largest expenses in the broiler diet (Zhai et al., 2014).

Maynard et al. (2020a) conducted 2 experiments in which both evaluated the response of Cobb MV × 700 broilers to feeding different AA density (**AAD**) regimens, and they observed a decrease in feed conversion ratio (**FCR**) when birds were provided diets formulated to high AAD from day 0 to 28. Based on the second experiment, they also found an improvement in FCR from day 0 to 46 when birds were fed with diets formulated to high AAD throughout the grow out period (day 0–46) as compared with those fed with diets formulated to high AAD (day 0–14) + medium AAD (day 15–46) and formulated to high AAD (day 0–28) + low AAD (day 29–46) (Maynard et al., 2020a). These studies exhibited some benefits in growth performance when increasing AAD levels and showed that broiler response to different AAD diets varies because of the feeding phase. In addition, energy can also affect feed consumption and broiler body composition (Leeson et al., 1996). Therefore, determining the optimal energy levels is needed to reduce cost and maximize profit. In addition, another study by Maynard et al. (2020b) tested the interactions between sex and dietary energy of Cobb MV × 700 broilers from day 0 to 46, and they found that males and females had similar response to dietary energy levels.

Furthermore, limited information concerning the interaction of dietary AA and energy exists for broiler performance (Maynard et al., 2020b). A previous study conducted in our laboratory aimed to evaluate the effects of a 2 digestible Lys (**dLys**) × 4 AME factorial arrangement of treatments during the starter phase on the performance and yield of Cobb MV × Cobb 500 males at day 42. Improvements in performance at day 14 were observed when feeding starter diets formulated to 1.28% dLys or ≤3,070 kcal/kg AME (Hirai, unpublished data). In addition, a significant interaction between dLys and AME was observed for FCR (uncorrected for mortality), where feeding 1.18% dLys + 3,160 kcal/kg AME during the starter phase demonstrated the lowest FCR (uncorrected for mortality) at day 28 (Hirai, unpublished data). However, no significant interaction or significance for the main effects were observed at the end of rearing period, suggesting that feeding during the initial phase only may not be enough, and the grower phase needs to be investigated. Hence, more research is needed to explore the interaction of dLys and AME on Cobb MV × Cobb 500 broiler performance to determine the best feeding strategy.

Because literature on Cobb MV × Cobb 500 broilers is limited, and broiler response to feeding strategy varies because of several factors (such as genetic line, gender, and age), nutritional specifications for each specific case need to be evaluated for maximum broiler performance. Therefore, the objective of this study was to determine the response of Cobb MV × Cobb 500 female broilers fed varying dLys and AME levels during the grower phase on day 14 to 28 growth performance, as well as the carryover effect of these dietary treatments on 42-day growth performance, processing yield, and economic return.

MATERIALS AND METHODS

Broiler Management

One-day-old female chicks were provided from a commercial hatchery and equally distributed to 96 pens (0.074 m^2/bird, 15 females/pen) (Tyson Hatchery, Sand Mountain, AL). Each pen contained fresh shavings over used litter, a hanging feeder, and 3 nipple drinkers. The research facility was a solid-walled house with forced-air heating, cool cells, and cross-ventilation by negative air pressure. From day 0 to day 14, chicks were fed a common diet in crumbled form. On day 14, all birds were weighed, and pen weights were equalized by block, keeping 13 females per pen (0.086 m^2/bird) that were randomly assigned and then fed experimental pelleted diets until day 28. Common pelleted diets were also provided in the finisher (day 28–41) phase to look at carryover effects of feeding varying dLys × AME diets in the grower phase. The temperature was 32.2°C at placement and slowly decreased until reaching 18.3°C at the end of the grow out period (Cobb-Vantress Inc., 2013). The lighting program followed breeder recommendations, with 24 h of light during the

Table 1. Experimental diet formulations fed during the grower phase (day 14–28).[1]

	1.00% dLys[2]				1.08% dLys				1.18% dLys			
Ingredient name	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME
Corn	68.95	68.29	66.45	64.56	66.45	64.57	62.72	60.84	61.80	59.91	58.07	56.18
SBM (48% CP)	27.93	26.96	27.15	27.34	29.86	30.05	30.24	30.43	33.72	33.91	34.10	34.29
Soybean oil	-	1.53	3.17	4.86	0.45	2.13	3.78	5.47	1.21	2.90	4.54	6.23
Defluorinated phosphate	1.24	1.25	1.26	1.26	1.22	1.23	1.24	1.24	1.20	1.20	1.21	1.21
Calcium carbonate	0.584	0.582	0.578	0.573	0.577	0.572	0.567	0.562	0.563	0.558	0.553	0.548
DL-Met	0.244	0.257	0.260	0.264	0.291	0.294	0.298	0.301	0.338	0.342	0.345	0.349
L-Lys HCL	0.148	0.183	0.181	0.180	0.191	0.189	0.187	0.185	0.198	0.196	0.194	0.192
L-Thr	0.080	0.097	0.098	0.099	0.109	0.110	0.111	0.112	0.125	0.126	0.127	0.128
L-Valine	0.002	0.024	0.026	0.028	0.033	0.035	0.037	0.038	0.046	0.048	0.050	0.052
Phytase[3]	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Salt, NaCl	0.243	0.242	0.241	0.241	0.244	0.244	0.243	0.243	0.247	0.246	0.246	0.245
Sodium S-Carb	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150	0.150
Vitamin-trace mineral	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250	0.250
Choline Cl-60%	0.086	0.092	0.094	0.095	0.078	0.079	0.080	0.082	0.061	0.062	0.063	0.065
Antibiotic[4]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Coccidiostat[5]	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050	0.050
Nutrient name	Calculated nutrients (%)[6]											
AME (kcal/kg)	2,937	3,028	3,116	3,206	2,937	3,028	3,116	3,206	2,937	3,028	3,116	3,206
CP (%)	17.66	17.22	17.18	17.15	18.45	18.42	18.38	18.34	19.95	19.91	19.87	19.83
Crude fat (%)	2.29	3.77	5.36	6.98	2.70	4.32	5.91	7.54	3.39	5.02	6.60	8.23
Linoleic acid (%)	1.42	2.24	3.11	4.01	1.62	2.52	3.39	4.28	1.97	2.86	3.73	4.63
Calcium (%)	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Total phosphorus (%)	0.58	0.57	0.57	0.57	0.58	0.58	0.58	0.57	0.59	0.59	0.59	0.58
Available phosphorus (%)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42
Sodium (%)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Potassium (%)	0.76	0.74	0.73	0.73	0.79	0.79	0.78	0.78	0.85	0.85	0.85	0.84
Chloride (%)	0.22	0.23	0.23	0.23	0.23	0.23	0.23	0.22	0.23	0.23	0.23	0.22
Na + K-Cl (mEq/kg)	227	220	220	220	233	233	233	233	249	249	249	249
Total Lys (%)	1.10	1.10	1.10	1.10	1.19	1.19	1.19	1.19	1.30	1.30	1.30	1.30
Total Met (%)	0.52	0.53	0.53	0.53	0.58	0.58	0.58	0.58	0.64	0.64	0.64	0.66
Total TSAA (%)	0.83	0.83	0.83	0.83	0.89	0.89	0.89	0.89	0.98	0.98	0.98	0.98
Total Trp (%)	0.22	0.21	0.21	0.21	0.23	0.23	0.23	0.23	0.25	0.25	0.25	0.25

continued

Table 1. Continued

Nutrient name	Calculated nutrients (%)[6]											
Total Thr (%)	0.73	0.73	0.73	0.73	0.79	0.79	0.79	0.79	0.87	0.87	0.87	0.87
Total Ile (%)	0.76	0.74	0.74	0.74	0.79	0.79	0.79	0.79	0.86	0.86	0.86	0.86
Total Val (%)	0.85	0.85	0.85	0.85	0.92	0.92	0.92	0.92	1.01	1.01	1.01	1.01
Total Arg (%)	1.16	1.12	1.12	1.12	1.21	1.21	1.21	1.21	1.33	1.33	1.33	1.33
dLys (%)	1.00	1.00	1.00	1.00	1.08	1.08	1.08	1.08	1.18	1.18	1.18	1.18
Digestible Met (%)	0.50	0.51	0.51	0.51	0.56	0.56	0.56	0.56	0.62	0.62	0.62	0.63
Digestible TSAA (%)	0.76	0.76	0.76	0.76	0.82	0.82	0.82	0.82	0.90	0.90	0.90	0.90
Digestible Trp (%)	0.19	0.18	0.18	0.18	0.20	0.20	0.20	0.20	0.22	0.22	0.22	0.22
Digestible Thr (%)	0.65	0.65	0.65	0.65	0.70	0.70	0.70	0.70	0.77	0.77	0.77	0.77
Digestible Ile (%)	0.69	0.67	0.67	0.67	0.72	0.72	0.72	0.72	0.78	0.78	0.78	0.78
Digestible Val (%)	0.77	0.77	0.77	0.77	0.83	0.83	0.83	0.83	0.91	0.91	0.91	0.91
Digestible Arg (%)	1.08	1.05	1.05	1.05	1.13	1.13	1.13	1.13	1.24	1.24	1.24	1.24
Choline (mg/kg)	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543

[1]Three different digestible lysine (dLys) levels and 4 different energy (AME) levels were used to create 12 treatments: Trt 1 = 1.00% dLys + 2,937 kcal/kg AME; Trt 2 = 1.00% dLys + 3,028 kcal/kg AME; Trt 3 = 1.00% dLys + 3,116 kcal/kg AME; Trt 4 = 1.00% dLys + 3,206 kcal/kg AME; Trt 5 = 1.08% dLys + 2,937 kcal/kg AME; Trt 6 = 1.08% dLys + 3,028 kcal/kg AME; Trt 7 = 1.08% dLys + 3,116 kcal/kg AME; Trt 8 = 1.08% dLys + 3,206 kcal/kg AME; Trt 9 = 1.18% dLys + 2,937 kcal/kg AME; Trt 10 = 1.18% dLys + 3,028 kcal/kg AME; Trt 11 = 1.18% dLys + 3,116 kcal/kg AME; Trt 12 = 1.18% dLys + 3,206 kcal/kg AME.

[2]Digestible Lys (%).

[3]Ronozyme HiPhos (GT); DSM, Kaiseraugst, Switzerland.

[4]BMD-50 (bacitracin methylene disalicylate); Zoetis, Parsippany, NJ.

[5]Zoamix 25%; Zoetis, Parsippany, NJ.

[6]Values are calculated based on the results of nutrient composition of corn and SBM at Missouri University labs. Columbia, MO.

Table 2. Analyzed nutrients for each experimental grower diet.[1]

	Average analyzed value[4]											
	1.00% dLys[3]				1.08% dLys				1.18% dLys			
Nutrient name[2]	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME
Lys	1.15	1.11	1.10	1.15	1.16	1.10	1.22	1.22	1.36	1.27	1.31	1.28
Met	0.50	0.49	0.54	0.49	0.53	0.50	0.52	0.53	0.55	0.66	0.52	0.61
Cys	0.35	0.37	0.36	0.34	0.36	0.34	0.34	0.35	0.37	0.39	0.38	0.36
TSAA	0.85	0.86	0.90	0.83	0.88	0.84	0.86	0.88	0.92	1.05	0.90	0.97
Trp	0.22	0.20	0.19	0.20	0.20	0.21	0.21	0.21	0.23	0.21	0.22	0.22
Thr	0.79	0.76	0.76	0.74	0.79	0.73	0.79	0.79	0.82	0.80	0.86	0.88
Ile	0.79	0.68	0.71	0.71	0.75	0.71	0.76	0.77	0.77	0.80	0.85	0.84
Val	0.93	0.87	0.89	0.86	0.89	0.97	0.92	0.90	0.95	0.95	1.01	1.02
Arg	1.34	1.23	1.24	1.19	1.23	1.20	1.28	1.30	1.35	1.37	1.48	1.46
Tau	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.10	0.08	0.09	0.09	0.08
Asp	1.95	1.79	1.81	1.76	1.86	1.73	1.87	1.90	1.96	1.97	2.12	2.14
Ser	0.96	0.89	0.90	0.85	0.92	0.85	0.91	0.92	0.94	0.91	1.01	1.04
Glu	3.48	3.19	3.23	3.11	3.32	3.11	3.29	3.41	3.49	3.55	3.80	3.82
Pro	1.14	1.12	1.08	1.04	1.09	1.05	1.07	1.08	1.17	1.18	1.18	1.25
Gly	0.83	0.76	0.77	0.74	0.77	0.73	0.79	0.81	0.82	0.84	0.89	0.88
Ala	0.96	0.90	0.91	0.88	0.92	0.88	0.93	0.95	0.95	0.97	1.04	1.01
Leu	1.54	1.39	1.43	1.40	1.49	1.41	1.48	1.48	1.53	1.57	1.65	1.67
Tyr	0.52	0.45	0.47	0.46	0.51	0.46	0.53	0.51	0.50	0.52	0.58	0.57
Phe	0.91	0.81	0.83	0.81	0.86	0.81	0.88	0.91	0.90	0.94	1.00	0.98
His	0.52	0.51	0.49	0.49	0.49	0.47	0.51	0.49	0.51	0.52	0.55	0.56
GE (kcal/kg)	3,455	3,504	3,581	3,654	3,471	3,510	3,603	3,680	3,517	3,577	3,647	3,738
CP	19.68	18.18	18.15	18.95	19.65	18.02	19.07	19.22	19.94	20.30	22.09	21.30

[1]Feed samples were analyzed in duplicate at ATC Scientific Labs, North Little Rock, AR. Official Methods of Analysis of AOAC International: AA by performic acid (cysteine and methionine); AA by sodium hydroxide (tryptophan); AA by hydrochloric acid (all other AA). Dietary treatments were formulated to: Trt 1 = 1.00% digestible lysine (dLys) + 2,937 kcal/kg energy (AME); Trt 2 = 1.00% dLys + 3,028 kcal/kg AME; Trt 3 = 1.00% dLys + 3,116 kcal/kg AME; Trt 4 = 1.00% dLys + 3,206 kcal/kg AME; Trt 5 = 1.08% dLys + 2,937 kcal/kg AME; Trt 6 = 1.08% dLys + 3,028 kcal/kg AME; Trt 7 = 1.08% dLys + 3,116 kcal/kg AME; Trt 8 = 1.08% dLys + 3,206 kcal/kg AME; Trt 9 = 1.18% dLys + 2,937 kcal/kg AME; Trt 10 = 1.18% dLys + 3,028 kcal/kg AME; Trt 11 = 1.18% dLys + 3,116 kcal/kg AME; Trt 12 = 1.18% dLys + 3,206 kcal/kg AME.

[2]W/W%.

[3]Digestible Lys (%) goal for experimental diets.

[4]Average of 2 analyzed samples/treatment.

Table 3. Descriptive data: percentage of pellets and fines for each experimental diet fed during the grower phase (day 14–28)[1] and for the common finisher diet (day 28–42).

	1.00% dLys[2]				1.08% dLys				1.18% dLys			
Percent	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME
Pellet[3]	77.62	74.39	71.83	55.41	77.68	78.19	62.34	45.02	67.39	55.18	53.30	29.91
Fine[4]	22.38	25.61	28.17	44.59	22.32	21.81	37.66	54.98	32.61	44.82	46.70	70.09

Percent	Finisher (day 28–42)[5]
Pellet[3]	19.13
Fine[4]	80.87

[1]Three different digestible lysine (dLys) levels and 4 different energy (AME) levels were used to create 12 treatments: Trt 1 = 1.00% dLys + 2,937 kcal/kg AME; Trt 2 = 1.00% dLys + 3,028 kcal/kg AME; Trt 3 = 1.00% dLys + 3,116 kcal/kg AME; Trt 4 = 1.00% dLys + 3,206 kcal/kg AME; Trt 5 = 1.08% dLys + kcal/kg AME; Trt 6 = 1.08% dLys + 3,028 kcal/kg AME; Trt 7 = 1.08% dLys + 3,116 kcal/kg AME; Trt 8 = 1.08% dLys + 3,206 kcal/kg AME; Trt 9 = 1.18% dLys + 2,937 kcal/kg AME; Trt 10 = 1.18% dLys + 3,028 kcal/kg AME; Trt 11 = 1.18% dLys + 3,116 kcal/kg AME; Trt 12 = 1.18% dLys + 3,206 kcal/kg AME.

[2]Digestible Lys (%).

[3]Determined using an American Society of Agricultural Engineers #5 sieve (4750 microns), all samples (∼500 g) were hand sieved for 10 s then the pans were rotated 180° and hand sieved for additional 10 s.

[4]Amount remaining at the bottom of the pan (37 microns).

[5]Common finisher diet fed from day 28 to day 42.

first 7 day of age and 4 h of dark from day 7 to 42. Light intensity was 26.9 lux during the first 10 day of age, gradually decreased until reaching 2.7 lux on day 21, and remained at this intensity until day 42 (Cobb-Vantress Inc., 2013). In addition, temperature and light were monitored daily, and bird mortality was recorded twice a day. Birds were provided with water and feed ad libitum throughout the study.

Experimental Diet Preparations

Diet Formulation Twelve experimental grower diets (**Gdiets**) were formulated to dLys levels of 1.00, 1.08, and 1.18% and AME levels of 2,937, 3,028, 3,116, and 3,206 kcal/kg, which were provided to birds from day 14 to day 28 (Table 1). To ensure the nutrient values of these experimental Gdiets and the 2 common basal diets (starter and finisher) were close to the target, major raw ingredients were scanned in-house using near infrared spectroscopy (FOSS, Hillerød, Denmark) and analyzed for nutrient content at a commercial laboratory (AOAC International, 2006; The University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO; ATC Scientific, North Little Rock, AR). This was carried out before formulation.

Batching Basal diets were manufactured at the Poultry Research Unit, Mississippi State University, in which grower diets were individually batched. A premix for each diet was made for ingredients with inclusions under 0.5% (such as trace minerals, vitamins, and synthetic AA). The appropriate premixes and macroingredients (e.g., corn and soybean meal) were mixed for 5 min in a 0.907-tonne vertical screw mixer (MFP Vertical Mixer; Easy Automation Inc., Welcome, MN). Afterward, each diet had the corresponding soybean oil added and was mixed for an additional 10 min to create a homogenous mix.

Feed Manufacture The pelleting process was performed at the Poultry Research Unit at the USDA in Starkville, MS; all diets were steam conditioned at 81°C with a 262 kPa incoming steam pressure for 10 s (40-horsepower CPM pellet mill with a 4.76 × 38.1 mm pellet die). Experimental diets for the grower phase were pelleted in order of increasing dLys and AME, with whole grain corn being flushed in the mixer between dLys levels to avoid cross contamination. Finished feed samples were collected and sent for laboratory analysis (AOAC International, 2006; The University of Missouri Agricultural Experiment Station Chemical Laboratories, Columbia, MO; ATC Scientific, North Little Rock, AR; Table 2). Particle size and particle size SD of the starter diet were determined to be 1,325 μm ± 1.90 (average of 5 100 g samples) using RO-TAP RX-29 (W.S. Tyler, Mentor, OH) for 10 min (data not shown). To determine the percentage of pellets and fines, representative samples (∼500 g) of each experimental Gdiet, as well as finisher diet, were collected at the mill and hand sieved for 10 s using an American Society of Agricultural Engineers #5 sieve (4,750 microns), then rotated 180° and hand sieved for additional 10 s (Table 3). The common starter was fed as crumbles from day 0 to day14, whereas grower experimental diets and the common finisher diet were fed as pellets for day 14 to 28 and day 28 to 42, respectively.

Measured Variables

Live Performance To calculate FCR corrected for mortality, average BW, BW gain (**BWG**), average feed intake (**FI**)/bird, and pen feed intake and individual bird weights were collected at day 14, 28, 35, and 41. Total Lys intake/bird (g) and GE intake/bird (kcal) were calculated by multiplying the analyzed total Lys or GE of the diet (Table 2) fed from day 14 to day 28 by the FI during this feeding phase. All experimental procedures and animal handling were conducted in accordance with the guidelines from the Institutional Animal Care and Use Committee of Mississippi State University, which was based on the Guide for the Care and Use of Agricultural Animals Research and Teaching (Federation of Animal Science Societies, 1999).

Processing Measurements On day 41, 3 birds/pen within 100 g of average BW/pen were selected and tagged for processing (total of 288 females). After fasting for approximately 10 h, these birds were processed and deboned at the Poultry Processing Plant of Mississippi State University. All broilers were hung by their feet on an automated processing line and electronically stunned before exsanguination via neck

Table 4. Common diets fed during the starter (day 0–14) and finisher (day 28–41) phases.[1]

	Inclusion (%)	
Ingredient name	Starter (day 0–14)	Finisher (day 28–42)
Corn	60.43	63.72
SBM (48% CP)	31.88	24.43
Soybean oil	1.73	3.92
Corn DDGS[2]	-	5.00
Meat and bone meal (57% CP)	3.50	-
Defluorinated phosphate	0.393	0.905
Calcium carbonate	0.388	0.677
DL-Met	0.350	0.237
L-Lys HCl	0.223	0.202
L-Thr	0.177	0.073
L-Val	0.058	-
Phytase[3]	0.011	0.011
Salt, NaCl	0.285	0.270
Sodium S-Carb	0.150	0.150
Vitamin-trace mineral	0.250	0.250
Choline Cl-60%	0.060	0.084
Antibiotic[4]	0.050	0.050
Coccidiostat[5]	0.050	0.050

Nutrient name	Calculated nutrients[6]	Analyzed nutrient[7]	Calculated nutrients	Analyzed nutrient
AME (kcal/kg)	2,977	-	3,151	-
GE (kcal.kg)	-	3,561	-	3,644
CP (%)	20.84	22.61	17.61	18.46
Crude fat (%)	4.17		6.26	
Linoleic acid (%)	2.23		3.66	
Calcium (%)	0.90		0.76	
Total phosphorus (%)	0.60		0.53	
Available phosphorus (%)	0.45		0.38	
Sodium (%)	0.22		0.22	
Potassium (%)	0.82		0.73	
Chloride (%)	0.28		0.25	
Na + K-Cl (mEq/kg)	227		211	
Total Lys (%)	1.34	1.40	1.07	1.08
Total Met (%)	0.67	0.59	0.52	0.52
Total TSAA (%)	1.00	1.00	0.83	0.86
Total Trp (%)	0.25	0.24	0.21	0.17
Total Thr (%)	0.93	0.94	0.71	0.76
Total Ile (%)	0.87	0.85	0.74	0.70
Total Val (%)	1.04	1.07	0.84	0.87
Total Arg (%)	1.37	1.52	1.09	1.10
d[8]Lys (%)	1.22		0.97	
dMet (%)	0.64		0.50	
dTSAA (%)	0.92		0.76	
dTrp (%)	0.22		0.18	
dThr (%)	0.83		0.63	
dIle (%)	0.79		0.67	
dVal (%)	0.94		0.76	

continued

Table 4. Continued

Nutrient name	Calculated nutrients[6]	Analyzed nutrient[7]	Calculated nutrients	Analyzed nutrient
dArg (%)	1.28		1.02	
Choline (mg/kg)	1,543		1,543	

[1]Common diets were provided to birds during starter (day 0–14) and finisher (day 28–41) phases.
[2]Corn distiller's dried grains with solubles.
[3]Ronozyme HiPhos (GT); DSM, Kaiseraugst, Switzerland.
[4]BMD-50 (bacitracin methylene disalicylate); Zoetis, Parsippany, NJ.
[5]Zoamix 25%; Zoetis, Parsippany, NJ.
[6]Values are calculated based on the results of nutrients composition of corn, SBM, corn DDGs, and animal by-product blend. Feed ingredients for starter diet were analyzed at Missouri University labs (Columbia, MO), and ingredients for finisher diet were analyzed at ATC Scientific labs (North Little Rock, AR).
[7]Feed samples were analyzed at ATC Scientific labs. Starter diet was formulated to 1.22% digestible lysine (dLys) + 2,977 kcal/kg energy (AME), and finisher diet was formulated to 0.97% dLys + 3,151 kcal/kg AME; W/W%; Average of 2 analyzed samples/diet.
[8]Digestible.

cutting with a knife. Next, broilers were put under hot water (52°C–66°C) and had their feathers removed by a plucking machine with rubber fingers. Then, their feet were manually removed, and carcasses were rehung on another automated line in which the heads, necks, and viscera were mechanically removed. Each carcass had its abdominal fat pad removed and weighed. Afterward, hot carcasses were pulled off the processing line and weighed. All carcasses were chilled in an ice bath (≤4°C) for 3 h. After chilling, each carcass was deboned on a stationary line by 1 of 3 trained people. To obtain the processing yield relative to carcass weight, the following chicken parts were weighed: boneless skinless breast (pectoralis major), tenders (pectoralis minor), thighs, drumsticks, and wings.

Economic Analysis An economic analysis was conducted to determine the potential gross profit for each dietary treatment, where ingredient prices from Feedstuffs and the USDA (Feedstuffs, 2019; USDA, 2019a) and chicken part values in the market (USDA, 2019b) were used, and the following equations were used for calculation.

Potential gross chicken part values = Processing data (chicken parts wt in kg) * Chicken part value in the market (cents)

Total potential gross chicken part value/bird (cents) = sum of all potential gross chicken part values/bird

Total feed cost/bird (cents) = Average feed intake (kg) * Feed cost (cents/kg)

Total feed cost/bird (dollars) = Total feed cost/bird (cents) / 100

Gross bird profit (cents) = Total potential gross profit/bird (cents) – Total feed cost/bird (cents)

Gross bird profit (dollars; in kg) = Gross bird profit (cents) / 100

Statistical Analysis

A 3 × 4 factorial arrangement of treatments within a randomized complete block design was used in the present study (day 14–42). Each dietary treatment had 8 replicated floor pens with 13 females/pen in which each floor pen was considered an experimental unit. The GLM procedure (two-way ANOVA) in SAS was used to analyze the measured variables (SAS Institute Inc., 2014). Significance level was set at $P \leq 0.05$, and significant mean differences were further explored with Fisher's protected least significant difference. In addition, PROC CORR was used for correlation analysis between total Lys intake/bird (g) or GE intake/bird (kcal) and day 14 to 28 BWG, day 14 to 28 FCR, overall performance data (day 14–41), and processing parameters.

RESULTS AND DISCUSSION

Feed Analysis

Based on the feed analysis results, it was observed that the analyzed values were within the

Table 5. The effect of varying digestible lysine (dLys) and AME levels on day 14 to 28 Cobb MV × Cobb 500 female performance.[1]

Grower dLys level (%)	Grower AME level (kcal/kg)	Day 14 Avg[2] BW[3] (kg)	Day 28 Avg BW (kg)	Day 14–28 BWG[4] (kg)	Day 14–28 Avg FI[5]/bird (kg)	Day 14–28 total lysine intake/bird[6] (g)	Day 14–28 GE intake/bird[7] (kcal)	Day 14–28 FCR[8]	Day 14–28 percent mortality[9] (%)
1.00	2,937	0.4247	1.421	0.996	1.588	18.4[d,e]	5,541	1.595[a]	0
	3,028	0.4240	1.417	0.994	1.533	16.9[f,g]	5,374	1.548[c]	0
	3,116	0.4239	1.407	0.985	1.518	16.6[g]	5,436	1.525[d]	0
	3,206	0.4252	1.425	1.000	1.490	17.1[f]	5,446	1.491[e,f]	0
1.08	2,937	0.4244	1.415	0.990	1.557	18.1[d,e]	5,405	1.573[b]	0
	3,028	0.4245	1.424	1.000	1.535	17.0[f,g]	5,389	1.536[c,d]	0
	3,116	0.4242	1.444	1.020	1.503	18.3[d,e]	5,416	1.476[f]	0
	3,206	0.4227	1.446	1.023	1.466	17.9[e]	5,395	1.433[g]	0
1.18	2,937	0.4227	1.440	1.017	1.520	20.4[a]	5,347	1.496[e]	0
	3,028	0.4226	1.473	1.049	1.497	19.0[b,c]	5,354	1.426[g]	0
	3,116	0.4248	1.468	1.044	1.467	19.2[b]	5,348	1.397[h]	0
	3,206	0.4231	1.466	1.043	1.451	18.6[c,d]	5,326	1.377[i]	0
SEM[10]		0.00072	0.0110	0.0110	0.0150	0.20	54	0.0068	-
Marginal means – grower dLys level									
1.00%		0.4240	1.417[b]	0.993[b]	1.535[a]	17.3	5457[a]	1.539	0
1.08%		0.4239	1.432[b]	1.008[b]	1.516[a]	17.9	5401[a,b]	1.505	0
1.18%		0.4229	1.461[a]	1.037[a]	1.484[b]	19.1	5345[b]	1.424	0
SEM		0.00036	0.0054	0.0055	0.0076	0.10	26	0.0034	-
Marginal means – grower AME level									
2,937 kcal/kg		0.4231	1.425	1.001	1.556[a]	18.6	5,431	1.552	0
3,028 kcal/kg		0.4235	1.440	1.016	1.522[b]	17.7	5,375	1.503	0
3,116 kcal/kg		0.4245	1.437	1.013	1.496[c]	18.0	5,402	1.465	0
3,206 kcal/kg		0.4234	1.444	1.021	1.469[d]	17.9	5,394	1.434	0
SEM		0.00041	0.0063	0.0063	0.0088	0.11	31	0.0039	-
P-values									
dLys[11]		0.1295	<0.0001	<0.0001	<0.0001	<0.0001	0.0302	<0.0001	-
AME[12]		0.7198	0.1353	0.1268	<0.0001	<0.0001	0.5857	<0.0001	-
dLys × AME[13]		0.0981	0.2880	0.3636	0.8935	<0.0001	0.7639	0.0016	-

[a–c]Values within columns with different superscripts differ significantly ($P < 0.05$).
[1]Dietary treatments were formulated to Trt 1 = 1.00% dLys + 2,937 kcal/kg AME; Trt 2 = 1.00% dLys + 3,028 kcal/kg AME; Trt 3 = 1.00% dLys + 3,116 kcal/kg AME; Trt 4 = 1.00% dLys + 3,206 kcal/kg AME; Trt 5 = 1.08% dLys + 2,937 kcal/kg AME; Trt 6 = 1.08% dLys + 3,028 kcal/kg AME; Trt 7 = 1.08% dLys + 3,116 kcal/kg AME; Trt 8 = 1.08% dLys + 3,206 kcal/kg AME; Trt 9 = 1.18% dLys + 2,937 kcal/kg AME; Trt 10 = 1.18% dLys + 3,028 kcal/kg AME; Trt 11 = 1.18% dLys + 3,116 kcal/kg AME; Trt 12 = 1.18% dLys + 3,206 kcal/kg AME.
[2]Average.
[3]BW (kg).
[4]BW Gain (kg).
[5]Feed Intake/bird (kg).
[6]Total Lys intake/bird on day 14 to 28 (g), which was calculated using day 14 to 28 feed intake/bird and analyzed Lys/diet.
[7]GE intake/bird on day 14 to 28 (kcal), which was calculated using day 14 to 28 feed intake/bird and analyzed GE/diet.
[8]Feed conversion ratio (feed:gain) was adjusted with mortality weight.
[9]Percent mortality is based on a beginning pen number of 13 birds.
[10]SEM, an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.
[11]P-values for dLys main effect; alpha set at $P \leq 0.05$.
[12]P-values for AME main effect; alpha set at $P \leq 0.05$.
[13]P-values for dLys × AME interaction; alpha set at $P \leq 0.05$.

expected ranges for total AA, CP, and GE (Tables 2 and 4). In addition, it is important to mention that despite the overlap in total Lys levels observed in diets formulated to different dLys levels, each experimental diet was analyzed twice, and the average of total Lys content was calculated; the laboratory used reports a SD of 0.055% for total Lys content (the AAFCO Proficiency Testing Program; Champaign, IL).

Descriptive data for pellet quality in Table 3 demonstrate a general decrease in percent pellets when increasing dLys or AME. The most dramatic decrease in percent pellets was obtained from diets that required increased supplemental fat, as all fat was applied at the mixer. The concept of increased mixer-added fat decreasing pellet quality is supported by previous research (Rigby et al., 2018). Formulated Gdiets to lower levels of dLys and AME had higher percent pellets, although as discussed further under "Broiler Performance," birds fed these diets did not outperform those fed Gdiets formulated to higher dLys and AME (which has lower percent pellets.) This is noteworthy, as previous research by McKinney and Teeter (2004) demonstrated that pellet quality may affect the energy used for maintenance or the bioavailability of energy in which birds fed diets with higher pellet quality may be fed reduced energy diets, without negatively affecting growth performance. In addition, the authors acknowledge that increased pellet quality enhances the performance of broilers (Cutlip et al., 2008; Lilly et al., 2011). Given this previous research reported with higher pellet quality diets and resulting performance, as well as the results of the present study demonstrating performance benefits (which will be further elucidated in the following paragraphs) for birds fed Gdiets associated with lower pellet quality, the authors feel that if feed quality had been maintained across Gdiets, the differences observed would have a similar, if not more dramatic.

Broiler Performance

As expected, no significant differences were observed for any measured variables during the starter phase (day 0–14; $P > 0.05$): average BW = 0.423 kg, BWG = 0.383 kg, FI = 0.480 kg, FCR = 1.252, and percent mortality = 1.736% (data not shown). In addition,

Table 6. The carryover effect of feeding grower (day 14 to 28) diets varying in digestible lysine (dLys) and AME levels on day 14–35 Cobb MV × Cobb 500 female broiler performance.[1]

Grower dLys level (%)	Grower AME level (kcal/kg)	Day 35 Avg[2] BW[3] (kg)	Day 14–35 BWG[4] (kg)	Day 14–35 Avg FI[5]/bird (kg)	Day 14–35 FCR[6]	Day 14–35 percent Mortality[7] (%)
1.00	2,937	1.95	1.52	2.59	1.699[a]	0
	3,028	1.94	1.51	2.49	1.654[b,c]	0
	3,116	1.94	1.52	2.48	1.639[c,d]	0
	3,206	1.95	1.52	2.46	1.617[e]	0
1.08	2,937	1.94	1.52	2.55	1.670[b]	1
	3,028	1.95	1.53	2.51	1.645[c,d]	0
	3,116	1.96	1.54	2.47	1.615[e]	1
	3,206	1.97	1.54	2.43	1.577[f]	0
1.18	2,937	1.94	1.52	2.49	1.631[d,e]	0
	3,028	1.99	1.57	2.47	1.574[f,g]	0
	3,116	1.98	1.56	2.43	1.564[f,g]	0
	3,206	1.98	1.55	2.45	1.556[g]	0
SEM[8]		0.018	0.018	0.026	0.0070	0.40
Marginal means – grower dLys level						
1.00%		1.94	1.52[b]	2.51[a]	1.651	0
1.08%		1.96	1.53[a,b]	2.49[a,b]	1.626	0.5
1.18%		1.97	1.55[a]	2.46[b]	1.578	0
SEM		0.010	0.010	0.013	0.0035	0.20
Marginal means – grower AME level						
2,937 kcal/kg		1.94	1.52	2.54[a]	1.667	0.3
3,028 kcal/kg		1.96	1.54	2.49[b]	1.624	0
3,116 kcal/kg		1.96	1.53	2.46[b,c]	1.606	0.3
3,206 kcal/kg		1.96	1.54	2.45[c]	1.585	0
SEM		0.010	0.010	0.015	0.0040	0.23
P-values						
Grower dLys[9]		0.0523	0.0471	0.0421	<0.0001	0.1458
Grower AME[10]		0.5090	0.4940	<0.0001	<0.0001	0.5803
Grower dLys × AME[11]		0.6158	0.6613	0.4832	0.0427	0.6835

[a-c]Values within columns with different superscripts differ significantly ($P < 0.05$).

[1]Common diets were fed to all birds from day 0–14 and 28–41; therefore day 14–35 includes a carryover effect of feeding diets varying in dLys and AME levels from day 14-28. Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME.

[2]Average.

[3]BW (kg).

[4]BW gain (kg).

[5]Feed Intake/bird (kg).

[6]Feed conversion ratio (feed:gain) was adjusted with mortality weight.

[7]Percent mortality is based on a beginning pen number of 13 birds.

[8]SEM, an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.

[9]*P*-values for dLys main effect; alpha set at $P \leq 0.05$.

[10]*P*-values for AME main effect; alpha set at $P \leq 0.05$.

[11]*P*-values for dLys × AME interaction; alpha set at $P \leq 0.05$.

no Gdiet dLys × AME interaction was observed for BW, BWG, FI, and percent mortality throughout the study ($P > 0.05$; Tables 5–7). No significant difference was established for the main effect of Gdiet AME for BW, BWG, and percent mortality during the rearing period ($P > 0.05$; Tables 5–7). In addition, no significance for the main effect of Gdiet dLys was found for

Table 7. The carryover effect of feeding grower (day 14–28) diets varying in digestible lysine (dLys) and AME levels on day 14 to 41 Cobb MV × Cobb 500 female broiler performance.[1]

Grower dLys level (%)	Grower AME level (kcal/kg)	Day 41 Avg[2] BW[3] (kg)	Day 14–41 BWG[4] (kg)	Day 14–41 Avg FI[5]/bird (kg)	Day 14–41 FCR[6]	Day 14–41 percent mortality[7] (%)
1.00	2,937	2.32	1.90	3.41	1.803	1.0
	3,028	2.34	1.91	3.36	1.756	1.0
	3,116	2.26	1.84	3.31	1.779	0.0
	3,206	2.30	1.88	3.30	1.759	0.0
1.08	2,937	2.34	1.91	3.44	1.790	1.0
	3,028	2.35	1.93	3.39	1.756	0.0
	3,116	2.36	1.94	3.38	1.741	1.0
	3,206	2.37	1.95	3.34	1.713	1.0
1.18	2,937	2.34	1.92	3.40	1.763	1.0
	3,028	2.40	1.98	3.36	1.701	1.0
	3,116	2.35	1.93	3.30	1.719	0.0
	3,206	2.34	1.92	3.30	1.721	0.0
SEM[8]		0.031	0.031	0.045	0.0106	0.69
Marginal means – grower dLys level						
1.00%		2.30[b]	1.88[b]	3.35	1.773[a]	0.5
1.08%		2.36[a]	1.93[a]	3.39	1.750[b]	0.5
1.18%		2.36[a]	1.94[a]	3.34	1.727[c]	0.5
SEM		0.016	0.016	0.022	0.0053	0.35
Marginal means – grower AME level						
2,937 kcal/kg		2.33	1.91	3.43[a]	1.784[a]	1.0
3,028 kcal/kg		2.36	1.94	3.37[a,b]	1.737[b]	0.6
3,116 kcal/kg		2.32	1.90	3.33[b]	1.749[b]	0.3
3,206 kcal/kg		2.34	1.92	3.31[b]	1.733[b]	0.0
SEM		0.018	0.018	0.026	0.0061	0.40
P-values						
Grower dLys[9]		0.0293	0.0287	0.2801	<0.0001	1.0000
Grower AME[10]		0.4873	0.4989	0.0238	<0.0001	0.3633
Grower dLys × AME[11]		0.7317	0.7548	0.9952	0.0985	0.8558

[a-c]Values within columns with different superscripts differ significantly ($P < 0.05$).

[1]Common diets were fed to all birds from day 0 to 14 and 28 to 41; therefore day 14 to 41 includes a carryover effect of feeding diets varying in dLys and AME levels from day 14 to 28. Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME.

[2]Average.

[3]BW (kg).

[4]BW gain (kg).

[5]Feed Intake/bird (kg).

[6]Feed conversion ratio (feed:gain) was adjusted with mortality weight.

[7]Percent mortality is based on a beginning pen number of 13 birds.

[8]SEM, an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.

[9]*P*-values for dLys main effect; alpha set at $P \leq 0.05$.

[10]*P*-values for AME main effect; alpha set at $P \leq 0.05$.

[11]*P*-values for dLys × AME interaction; alpha set at $P \leq 0.05$.

day 35 BW ($P > 0.05$; Table 6), and in agreement with this, a previous study has reported no response for day 35 BW when Cobb × Cobb 700 straight-run broilers were fed high dietary AAD during different feeding phases (Zhai et al., 2013).

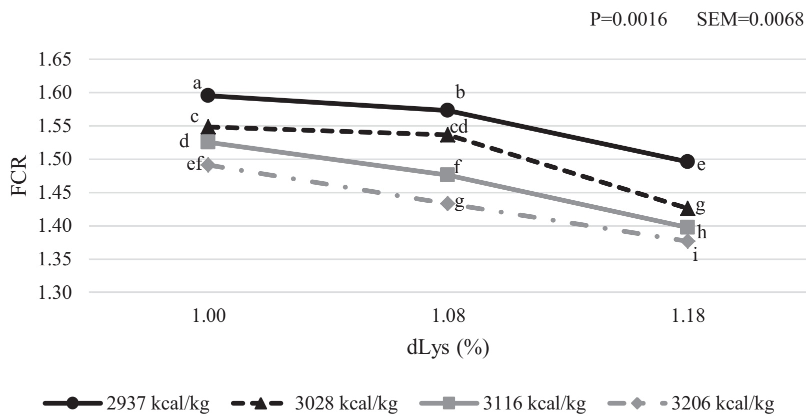

Figure 1. Digestible lysine (dLys) × AME interaction for day 14 to 28 feed conversion ratio (FCR). Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME. [a-c]Means within a column not sharing a common superscript differ ($P < 0.05$).

Feed Conversion Ratio Results demonstrated that there was a significant dLys × AME interaction for day 14 to 28 and 14 to 35 FCR (P = 0.0016 and P = 0.0427, respectively; Tables 5 and 6; Figures 1 and 2). For this, there was a stepwise decrease in FCR as dLys increased for AME level at 2,937, 3,116, and 3,206 kcal/kg AME but not 3,028 kcal/kg AME. However, by the end of the study, interactions for FCR that were previously obtained were lost ($P > 0.05$; Table 7). The main reason for this dLys × AME interaction was the increase of day 14 to 28 FCR when feeding 1.00 or 1.08% dLys with 2,937 kcal/kg AME, which was caused by increased FI. For this result, it is likely that birds were eating more to compensate for the lower nutrient levels in these diets (Leeson et al., 1996; Zhai et al., 2013). Significant differences for the main effect of dLys for day 14 to 41 FCR were observed in which there

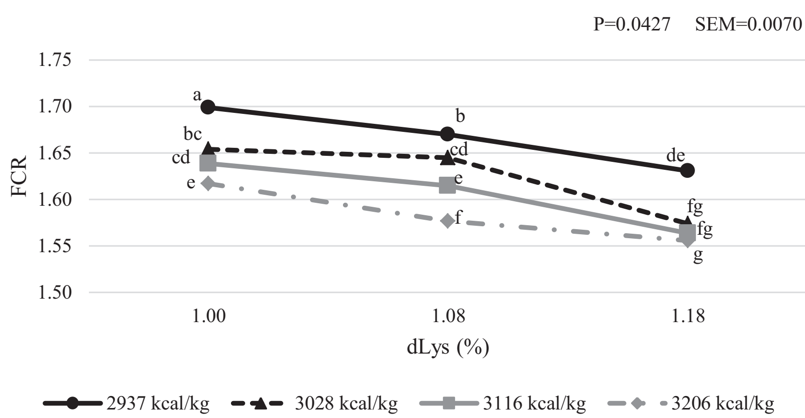

Figure 2. Digestible lysine (dLys) × AME interaction for day 14 to 35 feed conversion ratio (FCR). Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME. [a-c]Means within a column not sharing a common superscript differ ($P < 0.05$).

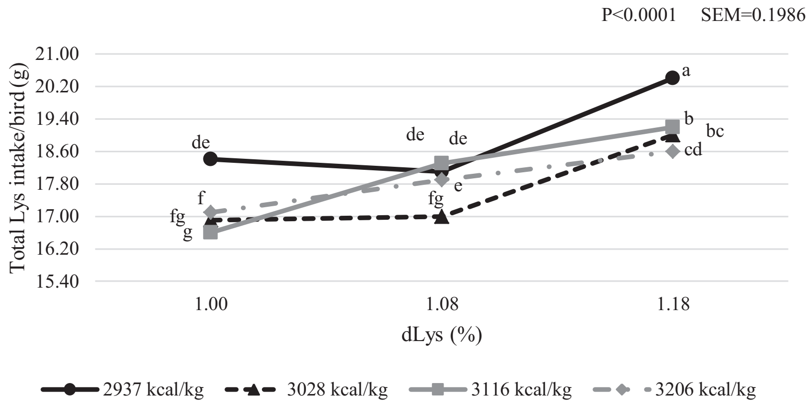

Figure 3. Digestible lysine (dLys) × AME interaction for day 14 to 28 total lysine (Lys) intake/bird (g). Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME. [a-c] Means within a column not sharing a common superscript differ ($P < 0.05$).

was a stepwise decrease in FCR when increasing dLys during the grower phase ($P < 0.0001$; Table 7). In partial agreement with these results, previous research did not find significant dLys × AME interactions for FCR throughout the rearing period (day 0–54) (Zhai et al., 2014). However, an improvement in day 28 FCR was observed when Cobb × Cobb 700 straight-run broilers received diets with higher AAD during the grower phase (day 14–48) (Zhai et al., 2013, 2014). In addition, feeding grower diets formulated to ≥3,028 kcal/kg AME decreased day 14 to 41 FCR ($P < 0.0001$; Table 7). This result is consistent with previous literature, whereas a decrease in FCR was reported when feeding a higher ME level (Leeson et al., 1996).

BW and BWG Birds receiving diets formulated to 1.18% dLys had the highest day 28 BW ($P < 0.0001$; Table 5). In addition, birds fed Gdiets formulated to 1.08 and 1.18% dLys yielded improved day 41 BW as compared with birds fed Gdiets formulated to 1.00% dLys ($P = 0.0293$; Table 7). Performance data also revealed that birds fed 1.18% dLys had the highest day 14 to 28 BWG during the grower phase ($P < 0.0001$; Table 5). In addition, there was an improvement in day 14 to 35 BWG when broilers were fed Gdiets formulated to 1.18% dLys as compared with those fed Gdiets of 1.00% dLys; birds fed 1.08% grower dLys had similar and intermediate BWG ($P = 0.0471$; Table 6). Overall data showed that feeding 1.08 and 1.18% dLys during the grower phase improved day 14 to 41 BWG ($P = 0.0287$; Table 7).

Average FI/Bird Significant differences for the main effect of dLys were established for day 14 to 28 and 14 to 35 FI ($P < 0.0001$ and $P = 0.0421$, respectively; Tables 5 and 6). Birds fed Gdiets formulated to 1.18% dLys had a lower day 14 to 28 FI than birds fed Gdiets formulated to 1.00 and 1.08% dLys. From day 14 to day 35, birds receiving Gdiets of 1.18% dLys had a lower FI than those fed Gdiets formulated to 1.00% dLys, with birds fed 1.08% grower dLys having a similar and intermediate FI. In agreement with the present study, a decrease in day 28 and 35 FI of Cobb × Cobb 700 straight-run broilers when feeding a higher dietary AAD throughout the experimental period (day 0–56) has been previously reported (Zhai et al., 2013). As reported earlier, these results agree with previous literature, whereas diets containing higher levels of nutrient density may have inhibited feed consumption vs. those with lower nutrient densities (Leeson et al., 1996; Zhai et al., 2013).

In addition, significant differences for the main effect of AME were found throughout the experimental period. A stepwise decrease in day

Table 8. Correlations between total lysine intake/bird as well as GE intake/bird and performance parameters.[1]

Day 14–28 total Lys intake/bird[2]	Day 14–28 BWG[3]	Day 14–28 FCR[4]	Day 14–41 BWG	Day 14–41 FCR	Carcass weight	Breast	Tender	Drumstick	Thigh	Wing	Fat pad
r	0.65	−0.47	0.38	−0.32	0.42	0.53	0.18	0.36	0.34	0.38	0.01
P-values	<0.0001	<0.0001	0.0003	0.0025	<0.0001	<0.0001	0.1067	0.0007	0.0013	0.0003	0.9473
Day 14–28 GE intake/bird[5]	Day 14–28 BWG	Day 14–28 FCR	Day 14–41 BWG	Day 14–41 FCR	Carcass weight	Breast	Tender	Drumstick	Thigh	Wing	Fat pad
r	0.62	0.04	0.68	−0.10	0.55	0.42	0.30	0.54	0.44	0.54	0.15
P-values	<0.0001	0.7070	<0.0001	0.3383	<0.0001	<0.0001	0.0058	<0.0001	<0.0001	<0.0001	0.1697

[1]Total lysine (Lys) intake/bird (g) and GE intake/bird (kcal) were calculated using the analyzed total lysine and GE of the diet (Table 2) fed from day 14 to day 28 and multiplying it by the intake during this feeding period on a per bird basis.
[2]Total Lys intake/bird on day 14 to 28 (g), which was calculated using day 14 to 28 feed intake/bird and analyzed Lys/diet.
[3]BW Gain (kg).
[4]Feed conversion ratio (corrected for mortality).
[5]GE intake/bird on day 14 to 28 (kcal), which was calculated using day 14 to 28 feed intake/bird and analyzed GE/diet.

14 to 28 FI was observed when increasing dietary AME levels during the grower phase ($P < 0.0001$; Table 5). Results for day 14 to 35 FI showed that birds fed Gdiets formulated to 3,206 kcal/kg AME had the lowest FI, with birds receiving Gdiets formulated to 3,116 kcal/kg AME having a similar and intermediate FI ($P < 0.0001$; Table 6). Overall data (day 14–41) demonstrated that feeding Gdiets formulated to 3,116 and 3,206 kcal/kg AME had decreased FI, with birds fed Gdiets of 3,028 kcal/kg AME having a similar and intermediate FI ($P = 0.0238$; Table 7). As previously mentioned, this is likely because of the ability of the bird to adjust its feed intake based on the diet nutrient density.

Total Lys Intake/Bird (day 14–28) and Correlation Analysis Owing to the observed result of FI being influenced by dLys, it was of interest to determine the total Lys intake/bird. This resulted in a significant dLys × AME interaction being observed for day 14 to 28 total Lys intake/bird ($P < 0.0001$; Table 5; Figure 3). Birds fed 1.18% dLys +2,937 kcal/kg AME had the highest day 14 to 28 total Lys intake/bird as compared with those fed the remaining treatments. Birds fed Gdiets formulated to 1.18% dLys +3,028 kcal/kg AME had a similar total Lys intake/bird as those fed Gdiets formulated to 1.18% dLys with 3,116 or 3,206 kcal/kg AME. Broilers fed 1.18% dLys +3,206 kcal/kg AME had a similar total Lys intake/bird as those fed Gdiets formulated to 1.08% dLys with 2,937 or 3,116 kcal/kg AME and Gdiets formulated to 1.00% dLys +2,937 kcal/kg AME. Birds receiving Gdiets formulated to 1.08% dLys +3,206 kcal/kg AME had a similar total Lys intake/bird as those fed Gdiets formulated to 1.00% dLys +2,937 kcal/kg AME and 1.08% dLys with 2,937 or 3,116 kcal/kg AME. Broilers fed 1.00% dLys +3,206 kcal/kg AME had a similar total Lys intake/bird as those fed Gdiets formulated to 3,028 kcal/kg AME with 1.00 or 1.08% dLys. The lowest total day 14 to 28 Lys intake/bird was observed when feeding Gdiets formulated to 1.00% dLys +3,116 kcal/kg AME, with birds fed Gdiets formulated to 3,028 kcal/kg AME with 1.00 or 1.08% dLys performing similar. Driving this interaction is the lack of increased intake for birds fed 1.08% dLys with 2,937 and 3,028 kcal/kg AME diets.

Table 9. The effect of varying digestible lysine (dLys) and AME levels from day 14 to 28 on day 42 processing characteristics reported as average yield relative to day 42 carcass weight.[1]

Grower dLys level (%)	Grower AME level (kcal/kg)	Carcass wt[2] (kg)	Yield relative to day 42 carcass weight[3] (%)					
			Breast[4]	Tender[5]	Drumstick	Thigh	Wing	Fat pad
1.00	2,937	1.63	25.0	5.94	13.94	17.4	11.40	2.49
	3,028	1.62	24.7	6.08	13.72	17.2	11.44	2.22
	3,116	1.61	24.7	5.84	13.91	17.1	11.47	2.42
	3,206	1.62	24.4	6.00	13.66	17.1	11.29	2.55
1.08	2,937	1.64	25.7	5.96	13.41	16.9	11.37	2.27
	3,028	1.66	25.8	5.90	13.42	16.9	11.33	2.36
	3,116	1.63	25.3	6.01	13.53	17.4	11.36	2.63
	3,206	1.66	25.4	5.86	13.42	17.5	11.34	2.48
1.18	2,937	1.65	26.5	6.01	13.33	16.8	11.13	2.25
	3,028	1.71	26.6	5.94	13.38	17.1	11.32	2.21
	3,116	1.67	25.8	5.98	13.71	17.6	11.32	2.12
	3,206	1.66	25.0	5.92	13.74	17.2	11.54	2.25
SEM[6]		0.024	0.38	0.096	0.160	0.24	0.126	0.102
Marginal means – grower dLys level								
1.00%		1.62[b]	24.7[b]	5.96	13.80[a]	17.2	11.40	2.42[a]
1.08%		1.65[a,b]	25.6[a]	5.94	13.44[b]	17.2	11.35	2.44[a]
1.18%		1.67[a]	26.0[a]	5.96	13.54[b]	17.2	11.33	2.20[b]
SEM		0.012	0.19	0.048	0.081	0.12	0.063	0.051
Marginal means – grower AME level								
2,937 kcal/kg		1.64	25.8[a]	5.97	13.56	17.1	11.30	2.34
3,028 kcal/kg		1.66	25.7[a]	5.97	13.51	17.1	11.36	2.26
3,116 kcal/kg		1.64	25.3[a,b]	5.94	13.71	17.4	11.38	2.39
3,206 kcal/kg		1.64	24.9[b]	5.92	13.60	17.3	11.39	2.42
SEM		0.014	0.22	0.055	0.094	0.14	0.073	0.059
P-values								
Grower dLys[7]		0.0137	<0.0001	0.8991	0.0062	0.9832	0.7178	0.0027
Grower AME[8]		0.6017	0.0296	0.9188	0.4447	0.3004	0.8189	0.2371
Grower dLys × AME[9]		0.8697	0.5489	0.5459	0.5382	0.2484	0.4757	0.1503

[a-c]Values within columns with different superscripts differ significantly ($P < 0.05$).

[1]Common diets were fed to all birds from day 0 to 14 and 28 to 41; therefore processing characteristics at day 42 (reported as average yield relative to carcass weight) are a carryover effect of feeding diets varying in dLys and AME levels from day 14 to 28. Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME.

[2]Carcass weight (kg).

[3]Yield relative to carcass weight (%).

[4]Breast refers to the pectoralis major.

[5]Tender refers to the pectoralis minor.

[6]SEM, an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.

[7]*P*-values for dLys main effect; alpha set at $P \leq 0.05$.

[8]*P*-values for AME main effect; alpha set at $P \leq 0.05$.

[9]*P*-values for dLys × AME interaction; alpha set at $P \leq 0.05$.

In partial agreement with these data, a previous study evaluating the interaction of feed form and dietary Lys on the performance of Ross × Ross 708 males from 0 to 18 D found that Lys intake increased as dLys levels increased (from 0.85–1.25% dLys; Corzo et al., 2012).

No correlations were observed for day 14–28 total Lys intake/bird and tender weight, as well as fat pad weight ($P > 0.05$; Table 8).

Table 10. The effect of varying digestible lysine (dLys) and AME levels from day 14 to day 28 on day 42 processing characteristics reported as average weight.[1]

Grower dLys level (%)	Grower AME level (kcal/kg)	Avg[2] weight (kg)					
		Breast[3]	Tender[4]	Drumstick	Thigh	Wing	Fat pad
1.00	2,937	0.408	0.097	0.227	0.283	0.185	0.041
	3,028	0.399	0.098	0.222	0.278	0.184	0.036
	3,116	0.398	0.094	0.224	0.276	0.185	0.039
	3,206	0.395	0.097	0.221	0.277	0.183	0.041
1.08	2,937	0.426	0.098	0.221	0.280	0.186	0.037
	3,028	0.428	0.098	0.223	0.280	0.188	0.039
	3,116	0.411	0.097	0.219	0.284	0.184	0.043
	3,206	0.421	0.097	0.222	0.290	0.188	0.041
1.18	2,937	0.439	0.099	0.220	0.278	0.184	0.037
	3,028	0.456	0.101	0.228	0.292	0.193	0.038
	3,116	0.429	0.099	0.228	0.293	0.188	0.037
	3,206	0.415	0.099	0.225	0.285	0.190	0.037
SEM[5]		0.0099	0.0021	0.0033	0.0049	0.0026	0.0017
Marginal means – grower dLys level							
1.00%		0.400[c]	0.096	0.223	0.279	0.184	0.039[a,b]
1.08%		0.422[b]	0.098	0.221	0.283	0.187	0.040[a]
1.18%		0.436[a]	0.100	0.225	0.287	0.189	0.037[b]
SEM		0.0049	0.0010	0.0016	0.0024	0.0013	0.0010
Marginal means – grower AME level							
2,937 kcal/kg		0.424	0.098	0.223	0.280	0.185	0.038
3,028 kcal/kg		0.427	0.099	0.224	0.283	0.188	0.037
3,116 kcal/kg		0.412	0.097	0.224	0.284	0.186	0.039
3,206 kcal/kg		0.411	0.098	0.223	0.284	0.187	0.040
SEM		0.0057	0.0012	0.0019	0.0029	0.0015	0.0010
P-values							
Grower dLys[6]		<0.0001	0.0868	0.1908	0.0529	0.0549	0.0462
Grower AME[7]		0.0975	0.5590	0.9147	0.7411	0.4254	0.3747
Grower dLys × AME[8]		0.5429	0.9720	0.4284	0.2244	0.4651	0.1537

[1]Common diets were fed to all birds from day 0 to 14 and 28–41; therefore processing characteristics at day 42 (reported as average weight) are a carryover effect of feeding diets varying in dLys and AME levels from day 14 to 28. Dietary treatments were formulated to Trt 1 = 1.00% dLys +2,937 kcal/kg AME; Trt 2 = 1.00% dLys +3,028 kcal/kg AME; Trt 3 = 1.00% dLys +3,116 kcal/kg AME; Trt 4 = 1.00% dLys +3,206 kcal/kg AME; Trt 5 = 1.08% dLys +2,937 kcal/kg AME; Trt 6 = 1.08% dLys +3,028 kcal/kg AME; Trt 7 = 1.08% dLys +3,116 kcal/kg AME; Trt 8 = 1.08% dLys +3,206 kcal/kg AME; Trt 9 = 1.18% dLys +2,937 kcal/kg AME; Trt 10 = 1.18% dLys +3,028 kcal/kg AME; Trt 11 = 1.18% dLys +3,116 kcal/kg AME; Trt 12 = 1.18% dLys +3,206 kcal/kg AME.
[2]Average.
[3]Breast refers to the pectoralis major.
[4]Tender refers to the pectoralis minor.
[5]SEM, an estimate of the amount that an obtained mean may be expected to differ by chance from the true mean.
[6]*P*-values for dLys main effect; alpha set at $P \leq 0.05$.
[7]*P*-values for AME main effect; alpha set at $P \leq 0.05$.
[8]*P*-values for dLys × AME interaction; alpha set at $P \leq 0.05$.

Significant correlations were observed for day 14 to 28 total Lys intake/bird and BWG, as well as FCR at day 14 to 28 ($P < 0.0001$; r = 0.65 and −0.47, respectively) and day 14 to 41 (P = 0.0003 and 0.0025; r = 0.38 and −0.32, respectively; Table 8); these metrics improved as total 14 to 28 D Lys intake/bird increased. In addition, similar significant correlations were observed for day 14 to 28 total Lys intake/bird and the following processing weights: carcass ($P < 0.0001$ and r = 0.42), breast ($P < 0.0001$ and r = 0.53), drumstick (P = 0.0007 and r = 0.36), thigh (P = 0.0013 and r = 0.34), and wing (P = 0.0003 and r = 0.38; Table 8).

GE Intake/Bird (day 14–28) and Correlation Analysis No dLys × AME interaction or

Table 11. Potential gross bird profit or potential saving for each grower digestible lysine (dLys) and AME level.[1]

Potential gross chicken part values[2] using processing data (chicken parts weight in kg) and chicken part values in the market (cents)[3]	1.00% dLys[4]				1.08% dLys				1.18% dLys			
	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME	2,937 kcal/kg AME	3,028 kcal/kg AME	3,116 kcal/kg AME	3,206 kcal/kg AME
Breast	95.98	93.88	93.65	93.10	100.34	100.81	96.66	99.20	103.36	107.31	101.00	97.72
Wing	63.69	63.48	63.67	62.86	64.20	64.69	63.48	64.66	63.25	66.47	64.80	65.39
Tender	37.19	37.82	36.07	37.29	37.73	37.73	37.31	37.40	38.16	38.90	38.23	38.11
Thigh	22.26	21.81	21.70	21.75	21.96	22.04	22.35	22.75	21.86	22.94	23.01	22.41
Drumstick	12.66	12.40	12.49	12.35	12.35	12.43	12.24	12.40	12.29	12.75	12.75	12.58
Total potential gross chicken part values/bird (cents)[5]	231.78	229.39	227.59	227.35	236.57	237.69	232.05	236.40	238.92	248.36	239.79	236.21
Total feed costs/bird (cents)[6]	91.23	90.62	91.61	92.95	93.191	93.68	78.72	95.14	94.24	94.97	94.53	98.05
Total feed costs/bird (dollars)[7]	0.912	0.906	0.916	0.930	0.932	0.937	0.787	0.951	0.942	0.950	0.945	0.981
Gross bird profit (profit processing-feed costs/bird; cents)[8]	140.55	138.77	135.98	134.40	143.38	144.00	153.33	141.26	144.69	153.39	145.26	138.16
Gross bird profit (profit processing-feed costs/bird; dollars; kg)[9]	1.406	1.388	1.360	1.344	1.434	1.440	1.533	1.413	1.447	1.534	1.453	1.382

[a-c]Values within columns with different superscripts differ significantly ($P < 0.05$).

[1]Dietary treatments were formulated to Trt 1 = 1.00% dLys + 2,937 kcal/kg AME; Trt 2 = 1.00% dLys + 3,028 kcal/kg AME; Trt 3 = 1.00% dLys + 3,116 kcal/kg AME; Trt 4 = 1.00% dLys + 3,206 kcal/kg AME; Trt 5 = 1.08% dLys + 2,937 kcal/kg AME; Trt 6 = 1.08% dLys + 3,028 kcal/kg AME; Trt 7 = 1.08% dLys + 3,116 kcal/kg AME; Trt 8 = 1.08% dLys + 3,206 kcal/kg AME; Trt 9 = 1.18% dLys + 2,937 kcal/kg AME; Trt 10 = 1.18% dLys + 3,028 kcal/kg AME; Trt 11 = 1.18% dLys + 3,116 kcal/kg AME; Trt 12 = 1.18% dLys + 3,206 kcal/kg AME. These dietary treatments were provided to birds during the grower phase (day 14–28), and common starter and finisher diets were fed to all birds from day 0 to 14 and 28 to 41, respectively.

[2]Potential gross chicken part values = Processing data (chicken parts wt in kg)*Chicken part value in the market (cents).

[3]USDA (2019b). Chicken part prices (cents/kg): breast = 235.44, wings = 344.36,; tenderloins = 384.60, thighs = 78.57, drumsticks = 55.84).

[4]Digestible Lys (%).

[5]Total potential gross chicken part value/bird (cents) = sum of the potential gross chicken part values (breast, wings, tenders, thighs, and drumsticks) per bird.

[6]Total feed cost/bird (cents) = Average feed intake (kg)*Feed cost (cents/kg; ingredient prices were based from Feedstuffs (2019) and USDA (2019a) [$/ton]: corn = $149.60; SBM = $309.00; deflourinated phosphate = $1,675.51; calcium carbonate = $233.69; salt = $65.00; soybean oil = $747.79; sodium S-carb = $557.77; vitamin-trace mineral = $2,336.90; DL-methionine = $2,744.75; L-lysine = $1,741.65; L-threonine = $2,006.20; L-valine = $10,913.07; phytase = $9,146.60; antibiotic = $8,664.16; coccidiostat = $989.60).

[7]Total feed cost/bird (dollars) = Total feed cost/bird (cents)/100.

[8]Gross bird profit (cents) = Total potential gross profit/bird (cents)–Total feed cost/bird (cents).

[9]Gross bird profit (dollars; in kg) = Gross bird profit (cents)/100.

differences for the main effect of AME were observed for day 14 to 28 GE intake/bird ($P > 0.05$; Table 5). However, a significant difference for the main effect of dLys for day 14 to 28 GE intake/bird was observed ($P = 0.0302$; Table 5). This revealed that broilers fed Gdiets formulated to 1.00% dLys had a higher GE intake/bird as compared with those fed Gdiets formulated to 1.18% dLys, with birds receiving 1.08% dLys having a similar and intermediate GE intake/bird. This result was likely because of the increased 14 to 28 D FI when birds were fed decreased dLys levels. Although in the present study, AME did not affect GE intake/bird, a previous study testing the effects of varying ME levels of diets on broiler performance reported an increase in ME intake, while also a linear decrease in average daily FI and FCR when increasing ME levels in the diets (Abouelezz et al., 2019).

No correlations were observed for day 14 to 28 GE intake/bird and day 14 to 28 FCR, day 14 to 41 FCR, or fat pad weight ($P > 0.05$; Table 8). Significant correlations were observed for day 14 to 28 GE intake/bird and day 14 to 28 BWG ($P < 0.0001$; r = 0.62), as well as day 14 to 41 BWG ($P < 0.0001$; r = 0.68; Table 8), demonstrating improved performance as 14 to 28 GE intake increased. Significant correlations were also found for day 14 to 28 GE intake/bird and the following processing characteristics: carcass weight ($P < 0.0001$ and r = 0.55), breast weight ($P < 0.0001$ and r = 0.42), tender weight ($P = 0.0058$ and r = 0.30), drumstick weight ($P < 0.0001$ and r = 0.54), thigh weight ($P < 0.0001$ and r = 0.44), and wing weight ($P < 0.0001$ and r = 0.54; Table 8).

Processing (D 42). In general, processing data demonstrated no significant Gdiet dLys × AME interactions for any measured variable ($P > 0.05$). In addition, no significant difference was established for the main effect of Gdiet dLys for carcass weight, tender, thigh, and abdominal fat pad yields (relative to day 42 carcass weight), as well as tender, drumstick, thigh, and wing weights ($P > 0.05$; Tables 9 and 10). In addition, no significant differences for the main effect of Gdiet AME were observed for carcass, tender, drumstick, thigh, wing, and abdominal fat pad weights or yields (relative to day 42 carcass weight); ($P > 0.05$; Tables 9 and 10). In disagreement with these data, a previous study using Cobb 700 straight-run broilers reported an increase in fat pad yield (relative to BW), a decrease in wing yield (relative to BW), as well as an increase in drumstick, thigh, and fat pad weights when feeding higher AME diets (difference of ∼55 kcal/kg throughout; Zhai et al., 2014). They also observed an increase in fat deposition when birds were fed an increased AME level. This was likely because of the dietary energy level associated to the activity of enzymes that produce fatty acids from acetyl-CoA in the chicken liver (hepatic de novo lipogenesis; Tanaka et al., 1983). Among these enzymes, the activity of fatty acid synthase is important for hepatic lipogenesis, as it controls the ability of birds to produce fatty acid deposits in the body (Back et al., 1986).

It was observed that feeding 1.18% dLys during the grower phase improved carcass weight as compared with 1.00% grower dLys, with birds fed 1.08% grower dLys having a similar and intermediate carcass weight ($P = 0.0137$; Table 10). Results also showed an improvement in breast yield (relative to day 42 carcass weight) when birds were fed 1.08 and 1.18% dLys from day 14 to day 28, as compared with those fed Gdiets formulated to 1.00% dLys ($P < 0.0001$; Table 9). There was a stepwise increase in day 42 breast weight when increasing dLys during the grower phase ($P < 0.0001$; Table 10). Broilers fed Gdiets formulated to 2,937 and 3,028 kcal/kg AME had greater breast yield (relative to day 42 carcass weight) than those fed Gdiets formulated to 3,206 kcal/kg AME, with broilers fed Gdiets of 3,116 kcal/kg AME having a similar and intermediate breast yield ($P = 0.0296$; Table 9).

Birds fed Gdiets formulated to 1.00% dLys had the highest drumstick yield (relative to day 42 carcass weight; $P = 0.0062$; Table 9). Birds receiving 1.18% dLys during the grower phase had the lowest abdominal fat pad yield (relative to day 42 carcass weight; $P = 0.0027$; Table 9). In addition, feeding Gdiets formulated to 1.18% dLys provided a lower abdominal fat pad weight than 1.08% grower dLys, with birds fed Gdiets of 1.00% dLys having a similar and intermediate abdominal fat pad weight ($P = 0.0462$; Table 10). These results are in partial agreement with a previous study, which reported a decrease in fat pad yield (relative to BW) and fat pad weight when feeding a higher AAD level (Tesseraud et at., 1996). This is likely because some AA can regulate lipid metabolism and fat deposition in the bird; also, the addition of Lys improves the production of lean meat (Fouad and El-Senousey, 2014).

Economic Analysis

Based on economic return that was calculated only during a specific period of time (January 2019) (Feedstuffs, 2019; USDA, 2019a,b), the lowest potential cost saving/gross profit per bird was observed when feeding Gdiets formulated to 1.00% dLys +3,206 kcal/kg AME, whereas the highest potential cost saving/gross profit per bird was found when birds were fed Gdiets at 1.18% dLys +3,028 kcal/kg AME, with an increase of \$0.19 in potential cost saving/gross profit per bird (Table 11). In addition, feeding Gdiets of 1.18% dLys +3,028 kcal/kg AME demonstrated an increase of \$0.09 in potential cost saving/gross profit per bird in comparison with the Gdiets 1.08% dLys +3,028 kcal/kg AME that is closer to the breeder recommendations (Cobb-Vantress Inc., 2013, 2015). However, it is important to continuously reevaluate the relationship between feed costs and processing yield due to the constant change in the costs of feed ingredients and chicken part values.

CONCLUSION AND APPLICATIONS

1. A significant dLys × AME interaction was observed for day 14 to 28 and 14 to 35 FCR. There was a stepwise decrease in FCR of Cobb MV × Cobb 500 females when increasing dLys at 2,937, 3,116, and 3,206 kcal/kg AME but not at 3028 kcal/kg AME. However, this interaction was lost at the end of the grow out period.
2. For the main effect of dLys, it was observed that Cobb MV × Cobb 500 females fed Gdiets formulated to 1.18% dLys had improvements in day 28 BW, day 14 to 28 BWG, and FI; day 14 to 35 BWG and FCR; and day 14 to 41 FCR. In addition, feeding ≥1.08% dLys during the grower phase (day 14–28) improved day 14 to 41 BW.
3. For the main effect of AME, feeding Gdiets formulated to 3,206 kcal/kg AME resulted in the lowest day 14 to 28 and 14 to 35 FI. In addition, feeding Cobb MV × Cobb 500 females the Gdiets formulated to ≤3,028 kcal/kg AME during the grower phase improved day 14 to 41 FI and FCR.
4. Feeding Cobb MV × Cobb 500 females the Gdiets formulated to ≥1.08% dLys or ≤3,116 kcal/kg AME optimized breast yield (relative to day 42 carcass weight). Moreover, there was a stepwise increase in day 42 breast weight when increasing grower dLys levels from 1.00 to 1.18%.
5. Based on our economic analysis using the market prices for chicken parts and feed ingredients (January 2019), feeding Cobb MV × Cobb 500 female broilers the Gdiet formulated to 1.18% dLys + 3,028 kcal/kg AME (fed from 14–28 D) was the most profitable at the end of the grow out period (day 42).

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