Impact of varying starter amino acid density and energy on 42 d male Cobb MV × Cobb 500 broiler performance and processing

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Primary Audience: Production Managers, Nutritionists, Primary Breeders

SUMMARY

Previous research has shown that feeding high amino acid density (**AAD**) diets or increased AME improved broiler performance, though the relationship between AAD and AME on performance needs to be further explored. Therefore, the objective of this study was to evaluate the impact of feeding 2 AAD and 4 AME levels from day 0 to 14 on performance and yield of 42-day-old Cobb MV × Cobb 500 males. Starter diets were formulated to medium or high AAD (**HAA**), and very low (**VLE**), low (**LE**), medium (**ME**), or high (**HE**) AME. Common diets were provided from day 15 to 41. A 2 × 4 factorial arrangement of treatments was used, with day 0 BW considered as a covariant. On day 0 to 14, birds receiving HAA had the lowest feed conversion ratio (**FCR**) corrected and uncorrected for mortality (**uFCR**). Birds receiving VLE diets had the highest day 0 to 14 FCR when compared to birds fed other AME levels. Feeding LE diets resulted in higher day 0 to 14 FCR when compared to ME and HE diets. An AAD × AME interaction for day 0 to 14 total Lys intake/bird found that Lys intake/bird decreased when increasing dietary AME for HAA diets. An AAD × AME interaction was observed for day 0 to 28 uFCR whereas increasing starter AAD in diets formulated to ME and HE increased day 0 to 28 uFCR; no change was observed for VLE and LE diets. However, overall performance and processing was not affected by varying starter AAD and AME levels. Further research should investigate similar feeding strategies, but in other feeding phases.

Key words: lysine, amino acid density, AME, live performance, processing yield

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DESCRIPTION OF PROBLEM

Primary breeder companies are continuously improving existing broiler crosses in terms of efficiency to meet consumer demand for chicken meat and reduce production cost. In 2017, a new broiler breeder product, Cobb MV male, was introduced to the market (Cobb-Vantress Inc., 2017), and this led to the production of new commercial broiler crosses (Cobb MV × Cobb 500 and Cobb MV × Cobb 700). To fully achieve the genetic potential of these new broiler crosses, their response to different feeding strategies (i.e., optimal amino acid [**AA**] density [**AAD**] and AME) must be evaluated.

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Previous research conducted in our laboratory evaluated the impact of varing 4 AAD regimens on the growth performance, processing yield, and economic return of Cobb MV × Cobb 500 broilers (Hirai et al., 2019). Feeding higher AAD diets demonstrated improvements in performance at day 32 and 35. Processing and economic responses of this new commercial broiler cross to AAD diets varied depending upon age (Hirai et al., 2019). In agreement with this, literature has reported that feeding high AAD (**HAA**) regimens improved growth performance of broilers (Vieira and Angel, 2012). Also, improvements were previously observed in growth performance and white meat yield of a high-yield cross and 2 multipurpose crosses when increasing AAD levels (Corzo et al., 2005).

While feed costs represent the highest expense associated with a broiler grow out, providing a diet with an enhanced nutritional profile during the starter and/or grower phase may be economically feasible by the end of grow out (Hidalgo et al., 2004). This is due to the relatively low amount of feed consumed during these feeding phases (as opposed to the finishing phases) (Dozier et al., 2008), as well as the rapid growth rate during this period (Kidd et al., 2004). Also, maximizing growth performance in these phases may result in improved overall performance.

One of the strategies to enhance the nutritional profile of the diets is via enhanced AAD and optimizing AME. These strategies are also of interest because ingredients providing AA and AME are the main contributors to feed cost (Zhai et al., 2014). The AAD of diets can be altered in various ways, one of which is by increasing digestible Lys (**dLys**) while keeping the same ratios for all other AA of interest. This is because Lys is the reference AA used for the ideal protein concept, whereas all the other AA are calculated as a ratio to Lys (Dozier et al., 2009). Previous research reported improvements in digestible AA intake and total breast weight of Ross × Ross 708 male broilers when feeding increased digestible AAD diets during the starter phase (Cloft et al., 2019).

The impact of varying AME levels on the performance of modern broiler crosses has not been explored as thoroughly as AAD; additionally, there are some discrepancies that exist within the research that has been done. Previous literature observed no differences in feed intake when Ross × Ross 308 male and female broilers were provided with diets varying from 2,976 to 3,197 kcal/kg AME during the starter phase (day 0–17; Hidalgo et al., 2004). They also did not have any differences in carcass weight or yield when varying AME levels during day 0 to 38 (Hidalgo et al., 2004). In contrast, feed intake and feed conversion ratio (**FCR**) of Ross × Ross 308 broilers decreased when providing diets with increased levels of AME from day 30 to 47 and from day 30 to 59 (Dozier et al., 2006). These discrepancies, as well as the lack of research with this relatively new Cobb MV broiler cross, warrant further research in this area, especially at different phases of growth.

As previously mentioned, interactions have been documented in the performance response of broilers to various dietary levels of AAD and AME (Zhai et al., 2014). These data suggest that there may be an optimum AA level at a particular AME (Zhai et al., 2014). For example, poor growth performance was observed when feeding low-density diets (in terms of AME_n and AA) during the starter phase (day 0–17) to Ross × Ross 308 male and female broilers as compared with those fed high-density diets (Hidalgo et al., 2004).

Currently, there are no published data on the response of Cobb MV × Cobb 500 broilers to varying AAD and AME levels. Therefore, the objective of the current study was to evaluate the impact of feeding 2 levels of AAD (medium AAD [**MAA**] and HAA) and 4 AME levels (very low [**VLE**], low [**LE**], medium [**ME**], or high [**HE**]) during the starter phase on day 0 to 14 growth performance, as well as the carryover effect of varying starter AAD and AME levels on 42-d performance and processing yield of male Cobb MV × Cobb 500 broilers.

MATERIALS AND METHODS

Broiler Management

On day 0, Cobb MV × Cobb 500 male chicks were obtained from a commercial hatchery (Tyson Hatchery, Stillwell, OK),

Table 1. Experimental diet formulations fed during the starter phase (day 0–14).[1]

	MAA				HAA			
Ingredient name	VLE	LE	ME	HE	VLE	LE	ME	HE
Corn	60.60	58.50	56.50	54.40	57.50	55.50	53.50	51.40
Soybean meal (48% CP)	35.80	36.10	36.50	36.80	38.20	38.50	38.90	39.20
Soybean oil	0.48	2.19	3.90	5.61	1.00	2.70	4.41	6.12
Defluorinated phosphate	1.32	1.33	1.33	1.34	1.31	1.31	1.32	1.32
Calcium carbonate	0.55	0.55	0.54	0.54	0.55	0.54	0.54	0.53
DL-Met	0.29	0.29	0.29	0.30	0.35	0.35	0.35	0.35
L-Lys HCL	0.10	0.10	0.09	0.08	0.15	0.15	0.14	0.14
L-Thr	0.08	0.08	0.08	0.07	0.11	0.11	0.11	0.11
Phytase[2]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Salt, NaCl	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Sodium S-carb	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin-trace mineral	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Selenium	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Choline Cl-60%	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.04
Antibiotic[3]	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Coccidiostat[4]	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Nutrient name	Calculated nutrients (%)[5]							
AME (kcal/kg)	2,890	2,980	3,070	3,160	2,890	2,980	3,070	3,160
CP (%)	21.50	21.50	21.50	21.50	22.50	22.50	22.50	22.50
Crude fat (%)	2.70	4.30	6.00	7.60	3.10	4.80	6.40	8.10
Linoleic acid (%)	1.30	1.30	1.20	1.20	1.20	1.20	1.20	1.10
Calcium (%)	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Total phosphorus (%)	0.63	0.63	0.62	0.62	0.63	0.63	0.63	0.63
Available phosphorus (%)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Sodium (%)	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
Potassium (%)	0.89	0.89	0.89	0.89	0.93	0.93	0.93	0.93
Chloride (%)	0.21	0.20	0.20	0.20	0.21	0.21	0.21	0.21
Na + K-Cl (mEq/kg)	264.80	265.60	266.40	267.20	272.20	273.00	273.80	274.60
dLys (%)[6]	1.18	1.18	1.18	1.18	1.28	1.28	1.28	1.28
Digestible Met (%)	0.59	0.59	0.59	0.59	0.66	0.66	0.66	0.66
Digestible Total Sulfur Amino Acid (Met+Cys; %)	0.89	0.89	0.89	0.89	0.96	0.96	0.96	0.96
Digestible Trp (%)	0.23	0.23	0.23	0.23	0.24	0.24	0.25	0.25
Digestible Thr (%)	0.77	0.77	0.77	0.77	0.83	0.83	0.83	0.83
Digestible Ile (%)	0.84	0.85	0.85	0.85	0.88	0.89	0.89	0.89
Digestible Val (%)	0.92	0.92	0.92	0.92	0.96	0.96	0.96	0.96
Digestible Arg (%)	1.34	1.34	1.34	1.35	1.40	1.41	1.41	1.41
Choline (mg/kg)	1,543	1,543	1,543	1,543	1,543	1,543	1,543	1,543

Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Two AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME, were used to create 8 diets.

[2]Ronozyme HiPhos (GT, 6-phytase, *Aspergillus oryzae*; DSM, Parsippany, NJ).

[3]BMD-50 (bacitracin methylene disalicylate; contains 50 grams(11%) bacitracin per lb of premix; Zoetis, Parsippany, NJ).

[4]Nicarb 25% (active drug ingredient was 25% nicarbazin; Phibro, Teaneck, NJ).

[5]Values are calculated based on the results of nutrient composition of corn and soybean meal at Missouri University Laboratories, Columbia, MO.

[6]Digestible Lys (%).

weighed in groups, and then randomly distributed into 96 pens (0.08 m^2/bird, 14 males per pen). The experimental house was a solid-walled house with cool cell pads, a forced-air heating system, and cross ventilation. Each pen had a hanging-type feeder, 3 nipple drinkers, and used litter (covered with fresh shavings). The temperature and lighting programs were monitored daily and followed breeder recommendations (Cobb-Vantress Inc.,

Table 2. Analyzed nutrients for each starter feed treatment.[1]

	MAA[3]				HAA[4]			
	VLE[5]	LE[6]	ME[7]	HE[8]	VLE	LE	ME	HE
Nutrient name[2]	Avg analyzed value[9]							
Lys[10]	1.36	1.38	1.37	1.34	1.52	1.43	1.45	1.44
Met	0.56	0.62	0.68	0.62	0.65	0.67	0.63	0.70
Cys	0.36	0.38	0.38	0.37	0.39	0.36	0.37	0.37
TSAA	0.92	1.00	1.05	0.98	1.04	1.03	0.99	1.06
Trp	0.31	0.31	0.29	0.29	0.32	0.30	0.31	0.30
Thr	0.89	0.90	0.90	0.90	0.98	0.92	0.93	0.95
Ile	1.04	1.04	1.03	0.99	1.10	1.05	1.04	1.03
Val	1.13	1.13	1.11	1.08	1.19	1.14	1.13	1.12
Arg	1.46	1.49	1.47	1.46	1.59	1.48	1.50	1.50
Tau	0.17	0.17	0.17	0.16	0.17	0.17	0.17	0.16
Asp	2.25	2.27	2.25	2.21	2.42	2.27	2.28	2.28
Ser	0.92	0.91	0.93	0.94	0.96	0.89	0.92	0.96
Glu	4.02	4.00	3.92	3.82	4.21	3.98	3.98	3.95
Pro	1.28	1.26	1.24	1.20	1.31	1.25	1.25	1.22
Gly	0.93	0.93	0.92	0.91	1.00	0.94	0.94	0.94
Ala	1.13	1.12	1.10	1.07	1.17	1.10	1.11	1.09
Leu	1.92	1.92	1.88	1.83	1.98	1.89	1.89	1.87
Tyr	0.72	0.73	0.72	0.73	0.77	0.72	0.74	0.74
Phe	1.13	1.14	1.12	1.10	1.20	1.13	1.13	1.13
His	0.60	0.60	0.59	0.58	0.63	0.59	0.60	0.59
Gross energy (kcal/kg)	3,956.99	4,042.00	4,105.59	4,167.96	4,008.71	4,068.20	4,147.36	4,204.01
CP	23.01	23.25	22.28	22.15	23.65	22.80	23.24	22.72

Abbreviations: AAD, amino acid density; Avg, average; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME; TSAA, total sulfur amino acid (met + cys).

[1]Feed samples were analyzed in duplicate at Missouri University Laboratories, Columbia, MO. Official Methods of Analysis of AOAC International: Amino acid (AA) by Performic acid (Cysteine and Methionine); AA by Sodium hydroxide (Tryptophan); AA by Hydrochloric acid (all other AA).

[2]W/W%.

[3]Medium AAD = 1.18% dLys.

[4]High AAD = 1.28% dLys.

[5]VLE = 2,890 kcal/kg AME.

[6]LE = 2,980 kcal/kg AME.

[7]ME = 3,070 kcal/kg AME.

[8]HE = 3,160 kcal/kg AME.

[9]Average of 2 analyzed samples or treatment.

[10]According to ATC Scientific (North Little Rock, AR), the standard deviation for total Lys is 0.055%.

2013). The temperature at placement was 32.2°C and was gradually decreased to 18.3°C on day 42. Birds were provided with 24 h of light during the first 7 d of age, then decreased to 20 h of light from day 7 to the end of the study. The intensity was set to 26.9 lux from day 0 to 10, with a gradual decrease to 2.7 lux on day 21, which was maintained for the remaining part of the study (Cobb-Vantress Inc., 2013). In addition, birds were observed at least twice a day; any mortality was weighed and noted. Feed and water were provided ad libitum from day 0 to 42, during which birds were fed with dietary treatments during the first 14 d of age (starter phase), and common grower and finisher diets thereafter (day 14–28 and 28–41, respectively).

Experimental Diet Preparations

Diet Formulation. Starter diets were formulated with 2 different AAD (MAA = 1.18% dLys or HAA = 1.28% dLys) and 4 AME levels (VLE = 2,890 kcal/kg, LE = 2,980 kcal/kg, ME = 3,070 kcal/kg, and HE = 3,160 kcal/kg; Table 1), where MAA was

Table 3. Common diets fed during the grower (day 14–28) and finisher (day 28–41) phases.[1]

Ingredient name	Common diet: Grower (day 14–28)	Common diet: Finisher (day 28–41)
Corn	65.30	66.80
Soybean meal (48% CP)	29.10	26.90
Soybean oil	2.59	3.54
Defluorinated phosphate	1.21	1.00
Calcium carbonate	0.56	0.54
Salt, NaCl	0.20	0.23
L-Lys HCl	0.13	0.08
L-Thr	0.08	0.06
DL-Met	0.24	0.21
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
Nutrient name	**Calculated nutrients (%)[5]**	
AME (kcal/kg)	3,086.47	3,170.25
CP (%)	19.50	18.50
Crude fat (%)	4.80	5.70
Linoleic acid (%)	1.35	1.37
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
Na + K-Cl (mEq/kg)	228.00	216.00
dLys (%)	1.05	0.95
Digestible Met (%)	0.52	0.48
Digestible Total Sulfur Amino Acid (Met+Cys; %)	0.80	0.74
Digestible Trp (%)	0.20	0.19
Digestible Thr (%)	0.69	0.65
Digestible Ile (%)	0.74	0.70
Digestible Val (%)	0.82	0.78
Digestible Arg (%)	1.17	1.11
Choline (mg/kg)	1,543	1,543

Abbreviation: dLys, digestible Lys.

[1]All birds were fed with a common diet in grower (day 14–28) and finisher (day 28–41) phases.

[2]Quantum Blue (*Escherichia coli* phytase; AB Vista, Plantation, FL).

[3]BMD-50 (bacitracin methylene disalicylate; contains 50 grams(11%) bacitracin per lb of premix; Zoetis, Parsippany, NJ).

[4]Nicarb 25% (active drug ingredient was 25% nicarbazin; Phibro, Teaneck, NJ).

[5]Values are calculated based on the analyzed nutrient composition of corn and soybean meal at Missouri University Laboratories, Columbia, MO.

based on a previous study conducted in our laboratory (Hirai et al., 2019) and breeder recommendations (Cobb-Vantress Inc., 2018), while HAA was based on Lys levels fed around the world. To determine AME levels, 2 recommended AME levels (day 0–10 and 11–22; Cobb-Vantress Inc., 2018) were averaged, resulting in one ME level (3,070 kcal/kg); then the other AME levels were deduced by reducing or increasing 90 kcal from 3,070 kcal/kg AME, which are levels currently fed in the United States and other regions of the world.

Table 4. Analyzed nutrients for common diets fed during the grower (day 14–28) and finisher (day 28–41) phases.[1]

	Common diet	
	Grower (day 14–28)	Finisher (day 28–41)
Nutrient name[2]	Avg analyzed value[3]	
Lys	1.16	1.07
Met	0.52	0.49
Cys	0.32	0.31
TSAA	0.84	0.80
Trp	0.24	0.23
Thr	0.79	0.74
Ile	0.85	0.87
Val	0.91	0.87
Arg	1.18	1.14
Tau	0.20	0.20
Asp	1.83	1.74
Ser	0.79	0.78
Glu	3.32	3.23
Pro	1.08	1.09
Gly	0.77	0.75
Ala	0.95	0.95
Leu	1.64	1.61
Tyr	0.61	0.60
Phe	0.96	0.92
His	0.49	0.47
Gross energy (kcal/kg)	4,079.43	4,121.70
CP	19.31	18.60

Abbreviations: Avg, average; dLys, digestible Lys; TSAA, total sulfur amino acid (met + cys).

[1]Feed samples were analyzed in duplicate at Missouri University Laboratories, Columbia, MO. Grower diet was formulated to 1.05% dLys + 3086.47 kcal/kg energy (AME), and finisher diet was formulated to 0.95% dLys + 3170.25 kcal/kg AME.

[2]W/W%.

[3]Average of 2 analyzed samples or diet.

To ensure diets were as precise as possible, corn and soybean meal samples were taken from different bags and mixed to create a representative sample. Next, they were scanned at Mississippi State University (Starkville, MS) 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) prior to diet formulation at each phase (Table 2). Diets were formulated on a digestible AA basis and all AA were provided at ratios based off the goal dLys content; these ratios were maintained across all experimental diets. Common grower and finisher diets were formulated to 1.05% dLys + 3086.47 kcal/kg AME, and 0.95% dLys + 3170.25 kcal/kg AME, respectively (Tables 3 and 4).

Batching. Basal diets were individually manufactured at the Poultry Research Unit, Mississippi State University. Ingredients with inclusion <0.5% of the total diet, such as trace minerals, vitamins, and crystalline AA, were weighed and mixed to create a premix. A vertical screw mixer with 0.907-tonne capacity (MFP Vertical Mixer, Easy Automation Inc., Welcome, MN) was used to mix the macro ingredients (i.e., corn and soybean meal) and the appropriate premix of each diet for 5 min. Next, soybean oil was added to each basal diet and mixed for an additional 10 min to create a homogenous diet.

Feed Manufacture. All diets were transported and pelleted at the Poultry Research Unit, United States Department of Agriculture (Starkville, MS). The steam conditioned temperature was maintained at 81°C (10 s) and the incoming steam pressure was 262 kPa. The pelleting order for experimental diets occurred in order of increasing levels of AME at each AAD, with diets formulated to MAA being pelleted first, followed by HAA. Flushing of whole corn grain was conducted between AAD to avoid cross contamination. Throughout each run, feed samples were collected from the cooler discharge and analyzed by a commercial laboratory (AOAC International, 2006; The University of Missouri Agricultural Experiment Station Chemical Laboratories). Starter feed was provided to the birds as a crumble from day 0 to 14, while common grower and finisher diets were provided as pellets from day 14 until the end of the study.

Measured Variables

Live Performance. Performance data were obtained by measuring the weight of the remaining feed and individual birds at day 14, 28, 35, and 41 to calculate the average BW, BW gain (**BWG**), average feed intake/bird (**FI**), and FCR corrected and uncorrected for mortality (**uFCR**). Total Lys intake/bird (g) and gross energy (**GE**) intake/bird (kcal) were calculated utilizing the analyzed total Lys and GE of the diet (Table 2) fed during the first 14 d of age and multiplying it by day 0 to 14 FI. Animal

Table 5. Effect of varying AAD and AME levels on day 0 to 14 Cobb MV × Cobb 500 male performance.[1]

Starter AAD	Starter AME	Day 14 Avg[2] BW (kg)	Day 0–14 BWG[3] (kg)	Day 0–14 Avg FI[4]/ bird (kg)	Day 0–14 Total Lys intake/ bird[5] (g)	Day 0–14 GE intake/ bird[6] (kcal)	Day 0–14 FCR[7]	Day 0–14 uFCR[8]	Day 0–14 percent mortality[9] (%)
MAA	VLE	0.469	0.424	0.534	7.21[c]	2,111	1.262	1.269	1.3
	LE	0.479	0.434	0.531	7.40[b,c]	2,149	1.243	1.254	1.8
	ME	0.482	0.436	0.529	7.29[c]	2,172	1.209	1.214	1.8
	HE	0.482	0.435	0.524	7.10[c]	2,183	1.202	1.206	1.2
HAA	VLE	0.477	0.433	0.534	8.08[a]	2,140	1.232	1.237	2.4
	LE	0.495	0.449	0.535	7.68[a,b]	2,175	1.195	1.205	3.0
	ME	0.488	0.444	0.522	7.42[b,c]	2,167	1.175	1.176	2.4
	HE	0.487	0.442	0.522	7.51[b,c]	2,193	1.160	1.168	1.8
SEM[10]		0.0087	0.0087	0.0097	0.138	37	0.0106	0.0118	1.64
Marginal means—starter AAD									
MAA		0.478	0.433	0.529	7.23	2,155	1.226[a]	1.233[a]	1.5
HAA		0.487	0.442	0.528	7.71	2,167	1.192[b]	1.197[b]	2.4
SEM		0.0025	0.0025	0.0028	0.067	18	0.0053	0.0060	0.83
Marginal means—starter AME level									
VLE		0.473	0.429	0.533	7.71	2,126	1.245[a]	1.251[a]	1.8
LE		0.488	0.442	0.533	7.52	2,163	1.219[b]	1.228[b]	2.4
ME		0.485	0.440	0.526	7.38	2,169	1.193[c]	1.197[c]	2.1
HE		0.484	0.438	0.522	7.23	2,188	1.182[c]	1.187[c]	1.5
SEM		0.0035	0.0035	0.0040	0.093	25	0.0071	0.0080	1.11
P-values									
AAD[11]		0.2700	0.2700	0.6015	0.0006	0.8315	<0.0001	<0.0001	0.3637
AME[12]		0.1139	0.1139	0.2279	0.0031	0.2302	<0.0001	<0.0001	0.6250
AAD × AME[13]		0.9336	0.9336	0.8792	0.0018	0.9342	0.5509	0.8101	0.9952

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

Abbreviations: AAD, amino acid density; dLys, digestible Lys; FCR, feed conversion ratio; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME.

[2]Average.

[3]BW gain (kg).

[4]Feed intake/bird (kg).

[5]Total Lys intake/bird on day 0 to 14 (g), which was calculated using day 0 to 14 feed intake/bird and analyzed Lys/diet.

[6]Gross energy intake/bird on day 0 to 14 (kcal), which was calculated using day 0 to 14 feed intake/bird and analyzed GE/diet.

[7]FCR (feed:gain) was adjusted with mortality weight.

[8]FCR (feed:gain) was not adjusted with mortality weight.

[9]Percent mortality is based on a beginning pen number of 14 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 AAD 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 AAD × AME interaction; alpha set at $P \leq 0.05$.

handling and all procedures conducted in this study followed guidelines from the Mississippi State University Institutional Animal Care and Use Committee, in accordance with the Guide for the Care and Use of Agricultural Animals Research and Teaching (Federation of Animal Science Societies, 1999).

Processing Measurements. One day prior to processing at the Mississippi State University Poultry Processing Plant, 3 birds per pen (±100 g of average BW/pen; total of 288 males) were selected, weighed, and tagged. Feed removal was conducted 10 h prior to processing. On the day of processing, the tagged birds were

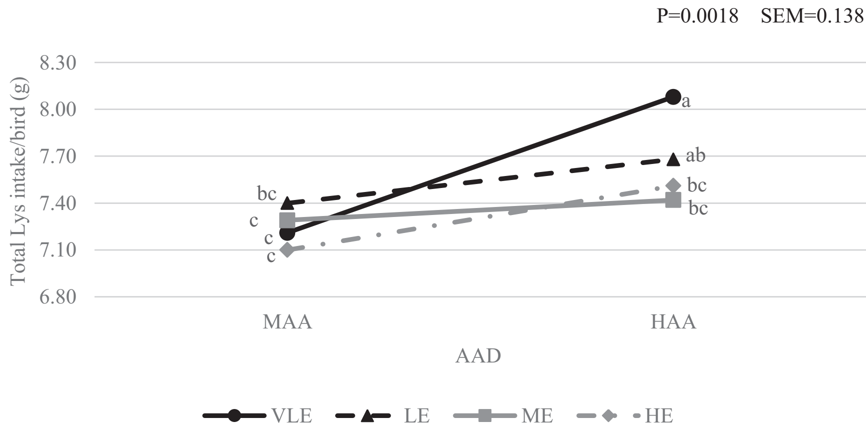

Figure 1. AAD × AME interaction for day 0 to 14 total Lys intake/bird (g). Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME. [a–c]Means within a column not sharing a common superscript differ ($P < 0.05$). Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

hung by their feet on an automatic processing line and electrically stunned, exsanguinated, and then submerged in hot water (52°C–66°C) to facilitate the removal of feathers, which was performed by an automated plucking machine with rubber fingers. Subsequently, chicken feet were cut at the hock joint, and carcasses were manually rehung on a second automated line. Each carcass had its head, neck, and viscera mechanically removed. The abdominal fat pad was manually removed and weighed. Hot carcasses were weighed and chilled in an ice bath for 3 h (≤4°C), prior to deboning. Deboning was conducted on a stationary line, where each carcass was deboned by 1 of 3 trained people. The weights of carcasses, boneless skinless breasts (pectoralis major), tenders (pectoralis minor), thighs, drumsticks, and wings were recorded to calculate processing yield (relative to live day 41 BW and day 42 carcass weight).

Statistical Analysis

A 2 (AAD) × 4 (AME) factorial arrangement of treatments within a randomized complete block design was utilized, in which the day 0 BW was considered a covariate. The floor pens with 14 males each were considered experimental units, and each dietary treatment had 12 replicated floor pens. To analyze the data, the GLM procedure (2-way ANOVA) of SAS (version 9.4; SAS Institute Inc., 2014, Cary, NC) was performed, with significance level set at a P-value ≤ 0.05; treatment mean differences were further explored with Tukey's range test. In addition, PROC CORR was utilized for correlation analyses between total Lys intake/bird (g) and BWG, as well as FCR; correlation analyses between GE intake/bird (kcal) and BWG and FCR were also conducted.

RESULTS AND DISCUSSION

Feed Analysis

Feed samples were analyzed for total AA profile, CP, and GE to confirm the calculated nutrient levels. The analyzed values from each diet are displayed in Tables 1–4, and they demonstrate treatment differences at expected ranges.

Broiler Performance

No AAD × AME interactions or differences for the main effects were observed for BW, BWG, FI, and percent mortality throughout the study, as well as day 0 to 41 FCR and uFCR ($P > 0.05$; Tables 5–7). Similar to these results, varying dietary levels of AAD and AME did not affect percent mortality throughout the rearing period (Zhai et al., 2014). In contrast, when evaluating the effects of AAD and AME on performance and processing yield of mixed-sex Cobb

Table 6. Carryover effect of feeding starter (day 0–14) diets varying in AAD and AME levels on day 0 to 28 Cobb MV × Cobb 500 male broiler performance.[1]

Starter AAD	Starter AME	Day 28 Avg[2] BW (kg)	Day 0–28 BWG[3] (kg)	Day 0–28 Avg FI[4]/ bird (kg)	Day 0–28 FCR[5]	Day 0–28 uFCR[6]	Day 0–28 percent mortality[7] (%)
MAA	VLE	1.58	1.53	2.17	1.417	1.437[a]	1.3
	LE	1.60	1.56	2.17	1.399	1.401[b]	1.8
	ME	1.60	1.55	2.18	1.402	1.390[b]	2.4
	HE	1.63	1.58	2.20	1.392	1.355[c]	1.8
HAA	VLE	1.61	1.56	2.18	1.405	1.427[a]	3.0
	LE	1.61	1.56	2.19	1.400	1.387[b]	3.6
	ME	1.62	1.57	2.17	1.381	1.434[a]	3.0
	HE	1.60	1.56	2.17	1.386	1.397[b]	3.0
SEM[8]		0.025	0.025	0.033	0.0083	0.0083	1.72
Marginal means—starter AAD							
MAA		1.60	1.56	2.18	1.402	1.405	1.8
HAA		1.60	1.56	2.17	1.394	1.399	3.1
SEM		0.013	0.013	0.016	0.0041	0.0041	0.86
Marginal means—starter AME level							
VLE		1.59	1.55	2.18	1.411[a]	1.412	2.2
LE		1.60	1.56	2.18	1.399[a,b]	1.402	2.7
ME		1.60	1.56	2.17	1.393[b]	1.401	2.7
HE		1.61	1.57	2.18	1.390[b]	1.393	2.4
SEM		0.017	0.017	0.022	0.0056	0.0056	1.17
P-values							
Starter AAD[9]		0.8462	0.8462	0.7806	0.2173	0.0376	0.1156
Starter AME[10]		0.7502	0.7502	0.9988	$<$0.0001	0.0002	0.8398
Starter AAD × AME[11]		0.4037	0.4037	0.9421	0.1047	0.0275	0.9391

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

Abbreviations: AAD, amino acid density; dLys, digestible Lys; FCR, feed conversion ratio; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Common diets were fed to all birds from day 14 to 41; therefore, day 0 to 28 includes a carryover effect of feeding diets varying in AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME.

[2]Average.

[3]BW gain (kg).

[4]Feed intake/bird (kg).

[5]FCR (feed:gain) was adjusted with mortality weight.

[6]FCR (feed:gain) was not adjusted with mortality weight.

[7]Percent mortality is based on a beginning pen number of 14 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 AAD 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 AAD × AME interaction; alpha set at $P \leq 0.05$.

MV × Cobb 700 broilers, Johnson et al. (2020) observed a significant AAD × AME interaction for BW at day 26. Birds fed low AAD + HE diets (day 0–12: 1.18% dLys + 3,003 kcal/kg AME; and day 12–26: 0.99% dLys + 3,172 kcal/kg AME) had the lowest BW when compared to those fed the other dietary treatments (Johnson et al., 2020). In addition, a previous study evaluating the response of Cobb MX × Cobb 700 straight-run broilers to different levels of AAD and AME found a significant AAD × AME interaction for FI and BW at day 28, 35, 42, and 54 (Zhai et al., 2014). In that study, feeding HAA and LE (day 0–14: 1.25% dLys + 2,987 kcal/kg AME; day 14–28: 1.14% dLys + 3,085 kcal/kg AME; day 28–35: 0.98% dLys + 3,130 kcal/kg AME;

Table 7. Carryover effect of feeding grower (day 0–14) diets varying in AAD and AME levels on day 0 to 41 Cobb MV × Cobb 500 male broiler performance.[1]

Starter AAD	Starter AME	Day 41 Avg[2] BW (kg)	Day 0–41 BWG[3] (kg)	Day 0–41 Avg FI[4]/ bird (kg)	Day 0–41 FCR[5]	Day 0–41 uFCR[6]	Day 0–41 percent mortality[7] (%)
MAA	VLE	2.57	2.53	4.09	1.62	1.62	1
	LE	2.60	2.55	4.26	1.61	1.67	7
	ME	2.59	2.54	4.19	1.62	1.66	5
	HE	2.69	2.64	4.27	1.60	1.63	4
HAA	VLE	2.62	2.57	4.23	1.63	1.65	5
	LE	2.60	2.56	4.20	1.63	1.66	6
	ME	2.51	2.47	4.11	1.59	1.61	5
	HE	2.57	2.53	4.07	1.62	1.64	4
SEM[8]		0.084	0.084	0.103	0.020	0.028	2.4
Marginal means—starter AAD							
MAA		2.61	2.57	4.21	1.61	1.64	4
HAA		2.58	2.53	4.16	1.62	1.64	5
SEM		0.042	0.042	0.051	0.010	0.014	1.2
Marginal means—starter AME level							
VLE		2.59	2.55	4.16	1.62	1.64	3
LE		2.60	2.55	4.23	1.62	1.67	6
ME		2.55	2.51	4.15	1.61	1.63	5
HE		2.63	2.59	4.18	1.61	1.63	4
SEM		0.057	0.057	0.069	0.014	0.019	1.6
P-values							
Starter AAD		0.8841	0.8841	0.9658	0.6715	0.6790	0.7666
Starter AME		0.9291	0.9291	0.7606	0.5723	0.2508	0.2950
Starter AAD × AME		0.6583	0.6583	0.1288	0.5014	0.2598	0.5392

There were no significant differences observed at P</= 0.05.

Abbreviations: AAD, amino acid density; dLys, digestible Lys; FCR, feed conversion ratio; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Common diets were fed to all birds from day 14 to 41; therefore, day 0 to 41 includes a carryover effect of feeding diets varying in AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME.

[2]Average.

[3]BW gain (kg).

[4]Feed intake/bird (kg).

[5]FCR (feed:gain) was adjusted with mortality weight.

[6]FCR (feed:gain) was not adjusted with mortality weight.

[7]Percent mortality is based on a beginning pen number of 14 birds.

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

and day 35–54: 0.90% dLys + 3,130 kcal/kg AME) diets resulted in lower FI and BW. However, when Cobb MX × Cobb 700 broilers were fed diets with HAA and AME (day 0–14: 1.25% dLys + 3,042 kcal/kg AME; day 14–28: 1.14% dLys + 3,140 kcal/kg AME; day 28–35: 0.98% dLys + 3,185 kcal/kg AME; and day 35–54: 0.90% dLys + 3,185 kcal/kg AME), similar FI and BW were obtained (Zhai et al., 2014). Based on the current study, no significant difference for the main effect of AAD was found for day 0 to 28 FCR ($P > 0.05$; Table 6). Contrary to these results, literature has previously reported improvements in day 28 FCR of Cobb MX × Cobb 700 (Zhai et al., 2013) when feeding higher AAD in the diets. These conflicting data are likely due to differences in body conformation, growth rate, and feed intake between these 2 strains.

Table 8. Correlations between total Lys intake/bird and BWG, as well as FCR; GE intake/bird and BWG, as well as FCR (day 0–14).[1]

Day 0–14 Total Lys intake/ bird[2]	Day 0–14 BWG[3]	Day 0–14 FCR[4]
R	0.55	0.018
P-values	<0.0001	0.8699
Day 0–14 GE intake/bird[5]		
R	0.80	−0.21
P-values	<0.0001	0.0544

Abbreviations: FCR, feed conversion ratio; GE, gross energy.

[1]Total Lys intake/bird (g) and GE intake/bird (kcal) were calculated utilizing the analyzed total Lys and GE of the diet (Table 2) fed from day 0 to 14 and multiplying it by the intake during this feeding period on a per bird basis.

[2]Total Lys intake/bird on day 0 to 14 (g), which was calculated using day 0 to 14 feed intake/bird and analyzed Lys/diet.

[3]BW gain (kg).

[4]FCR (corrected for mortality).

[5]GE intake/bird on day 0 to 14 (kcal), which was calculated using day 0 to 14 feed intake/bird and analyzed GE/diet.

FCR (Day 0–14). Significant differences were observed for the main effect of AAD and AME for day 0 to 14 FCR and uFCR ($P < 0.0001$; Table 5), in which feeding starter diets formulated to HAA improved FCR as well as uFCR. Additionally, birds receiving starter ME and HE diets had the lowest FCR and uFCR, with those fed starter diets formulated to LE showing intermediate results. Feeding a starter VLE diet resulted in the highest day 0 to 14 FCR and uFCR. These results are inconsistent with a previous study in which feeding higher AME (3,042 vs. 2,987 kcal/kg) to Cobb MX × Cobb 700 broilers increased day 14 FCR (Zhai et al., 2014).

Total Lys and GE Intake/Bird (Day 0–14). A significant AAD × AME interaction was observed for day 0 to 14 total Lys intake/bird ($P = 0.0018$; Table 5; Figure 1), in which there was a decrease in total Lys intake/bird when birds were fed increasing starter AME levels for the diets formulated to starter HAA. Birds fed HAA + VLE had the highest total Lys intake/bird as compared to those fed diets formulated to starter MAA, as well as HAA with ME or HE, with birds fed HAA + VLE showing similar results. Birds fed MAA + LE and diets formulated to HAA with ME or HE had similar total Lys intake/bird in comparison to those fed diets formulated to MAA with VLE, ME, and HE. A slight plateau was observed for total Lys intake/bird when increasing AME levels from LE to HE for diets formulated to HAA, in which birds fed MAA + LE demonstrated similar total Lys intake/bird. Additionally, another plateau was observed for day 0 to 14 total Lys intake/

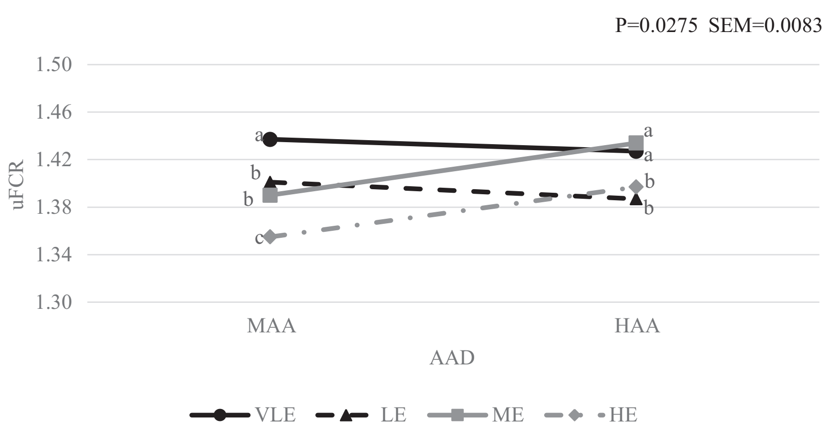

Figure 2. AAD × AME interaction for day 0 to 28 uFCR. Common diets were fed to all birds from day 14 to 41; therefore, day 0 to 28 includes a carryover effect of feeding diets varying in AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME. [a–c]Means within a column not sharing a common superscript differ ($P < 0.05$). Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; uFCR, feed conversion ratio uncorrected for mortality; VLE, very low AME.

Table 9. Effect of varying AAD and AME levels from day 0 to 14 on day 42 processing characteristics reported as average yield relative to day 41 live weight.[1]

			Yield relative to day 41 live weight (%)[3]						
Starter AAD	Starter AME	Day 41 Avg[2] BW (kg)	Carcass	Breast[4]	Tender[5]	Drumstick	Thigh	Wing	Fat pad
MAA	VLE	2.55	72.4	18.5	3.96	10.23	12.9	8.01	1.24
	LE	2.59	72.8	18.7	3.89	10.08	12.8	8.10	1.25
	ME	2.58	72.6	18.7	3.83	9.93	12.8	7.98	1.17
	HE	2.68	72.1	18.9	3.86	10.26	12.8	7.98	1.21
HAA	VLE	2.63	72.4	18.9	3.75	9.97	12.8	8.06	1.14
	LE	2.60	72.8	18.8	3.87	10.18	12.9	8.12	1.23
	ME	2.56	72.5	18.7	3.90	9.88	12.6	8.05	1.30
	HE	2.57	72.5	18.5	3.89	10.09	12.8	8.19	1.13
SEM[6]		0.051	0.24	0.27	0.062	0.111	0.21	0.091	0.046
Marginal means—starter AAD									
MAA		2.60	72.5	18.7	3.89	10.12	12.8	8.02	1.22
HAA		2.58	72.5	18.7	3.85	10.05	12.8	8.11	1.20
SEM		0.025	0.12	0.13	0.031	0.055	0.10	0.045	0.023
Marginal means—starter AME level									
VLE		2.59	72.4	18.7	3.86	10.10	12.8	8.04	1.19
LE		2.60	72.8	18.8	3.88	10.13	12.9	8.11	1.24
ME		2.55	72.6	18.7	3.86	9.93	12.7	8.01	1.24
HE		2.63	72.3	18.7	3.87	10.18	12.8	8.09	1.17
SEM		0.036	0.17	0.19	0.044	0.078	0.15	0.064	0.032
P-values									
Starter AAD		0.7686	0.7901	0.9943	0.4425	0.2355	0.7338	0.1851	0.6111
Starter AME		0.7370	0.2203	0.9711	0.9786	0.0859	0.7460	0.6886	0.3298
Starter AAD × AME		0.2949	0.8248	0.5562	0.1051	0.4056	0.8936	0.6989	0.0927

There were no significant differences observed at P</= 0.05.

Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Common diets were fed to all birds from day 14 to 41; therefore, processing characteristics at day 42 (reported as average yield relative to day 41 live weight) are a carryover effect of feeding diets varying in AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME.

[2]Average.

[3]Yield relative to day 41 live 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.

bird when increasing AME levels from VLE to ME for diets formulated to MAA. Birds fed MAA with AME levels of VLE, ME, or HE had the lowest total Lys intake/bird, with those fed MAA + LE as well as HAA with ME or HE performing similarly. However, no AAD × AME interaction or differences for the main effects were observed for day 0 to 14 GE intake/bird ($P > 0.05$; Table 5).

Correlation Analysis (Day 0–14). Significant correlations were observed for total Lys intake/bird and BWG at day 0 to 14 ($P < 0.0001$; R = 0.55), as well as day 0 to 14 GE intake/bird and BWG ($P < 0.0001$; R = 0.80; Table 8). No correlations ($P > 0.05$; Table 8) were observed for total Lys intake/bird and FCR, or for total GE intake/bird and FCR at day 0 to 14.

FCR (Day 0–28). A significant AAD × AME interaction was observed for day 0 to 28 uFCR ($P = 0.0275$; Table 6; Figure 2), in which there was a decrease in uFCR when birds were fed increasing starter AME levels for diets formulated to starter MAA. Also, feeding MAA + HE during the starter phase yielded the lowest day 0 to 28

Table 10. Effect of varying AAD and AME levels from day 0 to 14 on day 42 processing characteristics reported as average yield relative to day 42 carcass weight.[1]

			Yield relative to day 42 carcass weight[3] (%)					
Starter AAD	Starter AME level	Carcass weight[2] (kg)	Breast[4]	Tender[5]	Drumstick	Thigh	Wing	Fat pad
MAA	VLE	1.85	25.6	5.48	14.09	17.8	11.08	1.68
	LE	1.88	25.7	5.35	13.81	17.7	11.11	1.72
	ME	1.87	25.8	5.29	13.67	17.6	10.99	1.62
	HE	1.93	26.1	5.35	14.19	17.7	11.06	1.68
HAA	VLE	1.91	26.1	5.17	13.78	17.7	11.13	1.58
	LE	1.89	25.9	5.32	14.00	17.8	11.16	1.69
	ME	1.86	25.6	5.37	13.64	17.1	11.12	1.81
	HE	1.86	25.5	5.38	13.95	17.6	11.31	1.56
SEM[6]		0.036	0.35	0.084	0.150	0.28	0.121	0.063
Marginal means—starter AAD								
MAA		1.88	25.8	5.37	13.95	17.7	11.06	1.67
HAA		1.88	25.8	5.30	13.86	17.6	11.18	1.66
SEM		0.018	0.17	0.042	0.075	0.14	0.060	0.032
Marginal means—starter AME level								
VLE		1.88	25.9	5.33	13.93	17.7	11.11	1.63
LE		1.89	25.8	5.33	13.92	17.7	11.13	1.71
ME		1.86	25.7	5.32	13.69	17.4	11.05	1.72
HE		1.90	25.8	5.36	14.07	17.7	11.18	1.62
SEM		0.026	0.25	0.059	0.106	0.20	0.085	0.045
P-values								
Starter AAD		0.8932	0.8450	0.3392	0.3503	0.5067	0.1655	0.7831
Starter AME		0.8453	0.9759	0.9697	0.0609	0.4864	0.7566	0.3051
Starter AAD × AME		0.3709	0.3940	0.0945	0.3446	0.7777	0.8386	0.0636

There were no significant differences observed at P</= 0.05.

Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Common diets were fed to all birds from day 14 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 AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 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.

uFCR. A similar result was not found for birds fed starter diets formulated to HAA with increased AME level. Overall, increasing AAD in starter diets formulated to ME and HE resulted in an increase in day 0 to 28 uFCR, while no change in uFCR was observed in birds fed starter diets formulated to VLE and LE. However, this interaction was lost by the end of the study ($P > 0.05$; Table 7). Although previous data did not observe a significant AAD × AME interaction for day 28 FCR, a significant interaction for FCR at day 42 was determined where there was an improvement in FCR when feeding high levels of AAD and AME to Cobb MX × Cobb 700 straight-run broilers (Zhai et al., 2014). In addition, a significant difference in the current study was observed for the main effect of AME for day 0 to 28 FCR, where feeding starter ME and HE improved FCR as compared to those fed starter diets formulated to VLE. Birds receiving LE during the starter phase had a similar and intermediate performance ($P < 0.0001$; Table 6).

Table 11. Effect of varying AAD and AME levels from day 0 to 14 on day 42 processing characteristics reported as average weight.[1]

Starter AAD	Starter AME	Avg[2] weight (kg) Breast[3]	Tender[4]	Drumstick	Thigh	Wing	Fat pad
MAA	VLE	0.474	0.101	0.260	0.328	0.204	0.032
	LE	0.488	0.101	0.259	0.332	0.210	0.033
	ME	0.484	0.099	0.255	0.327	0.205	0.031
	HE	0.506	0.104	0.273	0.342	0.214	0.032
HAA	VLE	0.500	0.098	0.262	0.336	0.212	0.030
	LE	0.492	0.101	0.264	0.335	0.211	0.032
	ME	0.488	0.101	0.257	0.325	0.209	0.033
	HE	0.475	0.100	0.259	0.327	0.210	0.029
SEM[5]		0.0126	0.0026	0.0047	0.0076	0.0038	0.0014
Marginal means—starter AAD							
MAA		0.488	0.101	0.262	0.332	0.208	0.032
HAA		0.488	0.100	0.260	0.331	0.210	0.031
SEM		0.0063	0.0013	0.0023	0.0038	0.0019	0.0010
Marginal means—starter AME level							
VLE		0.487	0.100	0.261	0.332	0.208	0.031
LE		0.490	0.101	0.262	0.333	0.210	0.323
ME		0.486	0.100	0.256	0.326	0.207	0.032
HE		0.491	0.101	0.266	0.335	0.212	0.031
SEM		0.0089	0.0018	0.0033	0.0054	0.0027	0.0010
P-values							
Starter AAD		0.9643	0.5974	0.5588	0.7760	0.4229	0.3271
Starter AME		0.9791	0.8902	0.2275	0.6914	0.6483	0.6260
Starter AAD × AME		0.1654	0.6345	0.1597	0.4487	0.4739	0.3346

There were no significant differences observed at P</= 0.05.

Abbreviations: AAD, amino acid density; dLys, digestible Lys; HAA, high amino acid density; HE, high AME; LE, low AME; MAA, medium amino acid density; ME, medium AME; VLE, very low AME.

[1]Common diets were fed to all birds from day 14 to 41; therefore, processing characteristics at day 42 (reported as average weight) are a carryover effect of feeding diets varying in AAD and AME levels from day 0 to 14. Dietary treatments were formulated to 2 AAD: MAA = 1.18% dLys and HAA = 1.28% dLys; and 4 AME levels: VLE = 2,890 kcal/kg AME, LE = 2,980 kcal/kg AME, ME = 3,070 kcal/kg AME, and HE = 3,160 kcal/kg AME.

[2]Average carcass weight (kg).

[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.

Processing (Day 42)

Processing data demonstrated no significant AAD × AME interactions, or significance for the main effects for any measured variable ($P > 0.05$; Tables 9–11). This performance may have resulted due to feeding in the experimental period for a short time (i.e., day 0–14). Maynard et al. (2019) fed varying levels of AA and AME to Cobb MV × Cobb 700 broilers during short periods of time (i.e., finisher [day 29–36] and withdrawal [day 37–46] phases) and found no differences for the processing parameters. However, expected performance given a similar treatment structure has been conflicting. Previous literature (Vieira and Angel, 2012) has suggested that high-yielding broilers need a higher Lys level in the final phase due to the increase in their pectoralis major size in proportion to their total body volume. In contrast, previous research studying the impact of varying AAD and AME throughout grow out reported an interaction of AAD and AME at day 55, where Cobb MX × Cobb 700 straight-run broilers fed HAA and LE diets had the lowest carcass, breast, wing, front half, and back half weights when compared to those fed diets formulated to low AAD + LE, low AAD + HE, and HAA + HE (Zhai et al., 2014). In addition, they also found significance for the main effects of AAD and AME on other processing parameters, in which feeding a higher AAD decreased drumstick, thigh, and fat pad weights, as well as decreased fat pad yield (relative to BW) and increased wing yield (relative to BW); feeding a higher AME diet had an opposite effect (Zhai et al., 2014).

SUMMARY AND FUTURE DIRECTION

This study highlights the importance of evaluating the response of a relatively new commercial broiler cross, the Cobb MV × Cobb 500, to varying AAD and AME levels during the starter phase and their carryover effects on day 42 growth performance and yield. Results for the main effect of AAD demonstrated that birds fed HAA had the lowest day 0 to 14 FCR and uFCR (a reduction of approx. 3 points). Feeding ME and HE diets during the starter phase resulted in the lowest day 0 to 14 FCR and uFCR (4–5 points, respectively). A significant AAD × AME interaction was observed for day 0 to 28 uFCR. Regardless of the starter AAD, there was an improvement in day 0 to 28 uFCR when increasing starter AME levels from VLE to LE. However, no significant differences were found at the end of this study. This may be due to the starter AAD and AME levels tested, the common grower and finisher AAD and AME levels fed, or because the starter phase was not long enough to induce a carryover effect on performance supplied via enhancing AA and AME of the diet. Further research should investigate formulation strategies during the grower and finisher feeding phases, as well as evaluate the impact of varying AAD and AME levels on female Cobb MV × Cobb 500 broilers during all feeding phases.

CONCLUSIONS AND APPLICATIONS

1. Cobb MV × Cobb 500 male broilers fed HAA (1.28% dLys) during the starter phase had the lowest day 0 to 14 FCR and uFCR. Additionally, feeding starter diets formulated to ≤ME (3,070 kcal/kg AME) improved day 0 to 14 FCR, while feeding diets formulated to ≤ LE (2,980 kcal/kg AME) improved day 0 to 28 FCR.
2. A significant AAD × AME interaction was observed for day 0 to 14 total Lys intake/bird, where there was a decrease in total Lys intake/bird when birds were fed increasing starter AME levels for the diets formulated to starter HAA; birds fed HAA + VLE (2,890 kcal/kg AME) had the highest total Lys intake/bird as compared to those fed diets formulated to starter MAA (1.18% dLys), as well as HAA with AME levels of ME or HE (3,160 kcal/kg AME), with birds fed HAA + VLE showing similar results, although no AAD × AME interaction or differences for the main effects were found for day 0 to 14 GE intake/bird.
3. A significant AAD × AME interaction was observed in day 0 to 28 uFCR, where a decrease in uFCR was observed when increasing starter AME levels in the diets formulated to starter AAD. Broilers fed starter diets formulated to MAA + HE had the lowest uFCR. However, this interaction was lost by the end of the grow-out period, likely due to diet formulation strategies only provided in the starter phase.
4. Overall growth performance and processing data were not affected by AAD and/or AME; however, the current study's results may be different if other formulation metrics are utilized in the grower and finisher phases.

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DISCLOSURES

Cobb Vantress assisted in study design, but did not have a role in data analysis, interpretation, or writing of the report.

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