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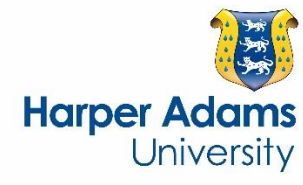

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A B S T R A C T

A 8-wk feeding experiment was conducted to investigate the effect of dietary supplementation with Arg on growth performance, nutrient digestibility, metabolizable energy, and intestinal morphology of growing turkeys. A total of one hundred and eighty 56-d-old male grower turkeys were weighed individually and randomly assigned to 1 of 3 dietary treatments with 6 replicate pens and 10 turkeys per pen in a completely randomized design. Dietary treatments consisted of basal diets supplemented with 0, 0.5, and 1.0 g Arg/kg. Growth response was measured during the grower (d 56 to 84) and finisher (d 84 to 112) phases, while nutrient digestibility, metabolizable energy, and intestinal morphology were measured at d 84 and 112. Arginine supplementation had no effect on growth response during the grower phase. During the finisher phase, feed conversion ratio decreased initially as Arg supplementation increased from 0 to 0.5 g/kg, but it increased with the 1.0 g Arg/kg (quadratic, $P = 0.028$). At d 84, grower turkeys fed diets supplemented with 1.0 g Arg/kg had greater (linear, $P < 0.001$) apparent dry matter, crude protein, and ether extract digestibility. At d 84, greatest apparent metabolizable energy, nitrogen corrected apparent metabolizable energy, and true metabolizable energy values were obtained with grower turkeys fed diet supplemented with 0.5 g Arg/kg (quadratic, $P < 0.001$). At d 84, duodenum, and ileum villus height in grower turkeys increased linearly, and quadratically ($P < 0.001$) with increasing Arg supplementation. Dietary supplementation with Arg reduced the apical widths in duodenum (linear, $P = 0.003$; quadratic, $P < 0.001$), jejunum (linear and quadratic, $P < 0.001$), and ileum (linear, $P = 0.010$; quadratic, $P = 0.004$) of grower turkeys. At d 112, jejunum villus height (quadratic, P = 0.042), and ileum villus height (linear, $P = 0.022$; quadratic, $P = 0.042$) of finisher turkeys increased, while duodenum apical widths reduced (quadratic, $P = 0.033$) with increasing Arg supplementation. In conclusion, Arg supplementation showed a linear improvement in nutrient digestibility of grower turkeys at d 84, increased nutrient absorption

in grower, and finisher turkeys as indicated by increased intestinal villus height at d 84, and 112. Furthermore, dietary supplementation with 0.5 g Arg/kg promoted a quadratic improvement in feed conversion ratio of finisher turkeys, and metabolizable energy values of grower turkeys at d 84.

Keywords: Growing turkeys, Gut morphology, Arginine, Metabolizable energy

1. Introduction

Arginine is known as one of the most versatile amino acids in body cells and plays a vital role as a substrate for protein synthesis, it acts as an intermediate in the hepatic urea cycle, as well as precursor for the synthesis of various important metabolic molecules, including nitric oxide (NO), polyamines, and creatinine (Kim et al., 2007; Wu and Morris, 1998). Arginine increased the release of growth hormone and insulin-like growth factor (IGF-I) in the blood (Newsholme et al., 2005), improved muscle performance, facilitated glucose uptake into the muscle cells (Stevens et al., 2000; Tan et al., 2009), regulated expression of fat-metabolic genes (Tan et al., 2011), improved the jejunal activities for carbohydrate, and protein digestion (Uni and Ferket, 2003).

Arginine increased protein synthesis, improved growth of poultry birds (Kidd et al., 2001), and attenuated whole body growth in growing pigs fed mold-contaminated diet (Yin et al., 2014). Arginine supplementation also improved daily weight gain of milk-fed piglets (Kim and Wu, 2004). Dietary supplementation with Arg activated intestinal innate immunity of mice (Ren et al., 2014a) and ameliorated intestinal abnormalities in growing pigs (Yin et al., 2014). Increased final body weight gain of broilers (Munir et al., 2009) and piglets (Yao et al., 2011) have been reported following dietary supplementation with Arg. Kidd et al. (2001) also reported that increasing dietary Arg from 100 to 120% of NRC (1994)

recommendation resulted in increased body weight gain of broilers. Ren et al. (2014b) suggested that Arg supplementation could be a potential therapy for intestinal inflammatory disease.

Mammals are able to synthesize their own Arg in order to meet their nutritional requirements. However, birds appear unable to synthesize Arg via the urea cycle due to lack of carbamoyl phosphate synthetase I in mitochondria (Lewis, 1996). Therefore, chickens depend completely on exogenous arginine to meet their needs for protein synthesis and other functions (Tamir and Ratner, 1963). In poultry birds fed practical corn-soybean meal based diets, Arg was regarded as the fifth limiting amino acid, after Met, Lys, Thr, and Val (Vieira and Berres 2007). Hence, adequate dietary levels of these amino acids are needed to support optimum growth and carcass yield of fast-growing commercial birds like turkeys.

Genetic selection of modern-day poultry with a view to improve growth, body weight gain, feed efficiency, and breast muscle weight within a short period (Burt, 2002) had resulted in increased susceptibility of poultry to various stressors (Lin et al., 2006). Stress removal has become one of the most important challenges in poultry production, especially in tropical, and subtropical areas. Mujahid (2007) reported that alleviating stressors through dietary manipulations are considered practical solution in enhancing poultry performance reared under tropical condition. Dietary supplementation with Arg has been reported to alleviate stressors in birds (Attia et al., 2011). Previous studies showed that chickens required more Arg than NRC (1994) recommendations under stress conditions (Brake et al., 1998). With the goal of modern-day turkey production which, seeks to attain highest weight gain and meat yield over a short period, it will be worthwhile to investigate the effect of supplemental Arg in turkeys raised under tropical condition. The current study, therefore, investigated the effect of diet supplemented with Arg on growth performance, nutrient digestibility, metabolizable energy, and intestinal morphology of growing turkeys.

2. Materials and Methods

2.1. Management of turkeys

This research work was conducted at the turkey unit of the Teaching and Research Farms, University of Agriculture, Abeokuta, Nigeria during the late dry season. Experimental procedures were in accordance with the guidelines of the Animal Care Committee of the Federal University of Agriculture, Abeokuta Nigeria. A total of 200 one-day-old, male turkey poults obtained from a commercial hatchery (British United Turkeys; Obasanjo Farms Ltd, Ibadan, Nigeria) were reared together under a deep litter housing system for a 56-d pre-experimental period. Dried wood shavings were used as litter material. The pre-experimental period lasted for the pre-starter (d 0 to 28) and starter (d 28 to 56) phases of the turkeys. Brooding of turkeys was done for 0 to 28 d of age, while normal ambient temperature prevailed after the brooding period. Turkeys were fed with commercial maize-soybean meal based pre-starter (metabolizable energy (ME) = 11.79 MJ/kg, crude protein (CP) = 278 g/kg, Met = 5.1 g/kg, and Lys = 16 g/kg) and starter diets (ME = 12.13 MJ/kg, CP = 259 g/kg, Met = 4.6 g/kg, and Lys = 15 g/kg), which met the NRC (1994) nutritional requirements of the various age groups. During the pre-experimental period, feed and clean water were supplied ad libitum, while no mortality occurred. After the 56-d pre-experimental period, the feeding study was initiated, which lasted for 8 wk.

2.2. Dietary treatments

At d 56, 180 male turkeys of similar weights were selected, weighed individually, and allotted to 1 of 3 treatments with 6 pens (dimension, 2.5 × 1.8 m) per treatment, and 10 turkeys per pen in a completely randomized design. A total of 18 similar floor pens were used in this study. The pens were furnished with wood shavings as beddings. A maize-soybean meal diet (basal diet), which met the NRC (1994) nutritional requirement was

formulated for grower (d 56 to 84), and finisher (d 84 to 112) phases of turkeys (Table 1). Two additional experimental diets were subsequently formulated for the grower and finisher phases by supplementing the basal diet with 0.5 and 1 g Arg/kg (Shanghai TECH Chemical Industry, Shanghai, China). Turkeys had ad libitum access to feed and water.

2.3. Growth performance

The bodyweight of the birds per pen was measured on a weekly basis, while the gain in weight was computed. Daily feed intake was also measured as the difference between the feed offered and leftovers, while feed conversion ratio was also computed. A record of mortality was kept as it occurred.

2.4. Nutrient digestibility and metabolizable energy

Metabolism trial was conducted at d 84 and 112 of the study. Briefly, a turkey per replicate was randomly selected and housed separately in appropriate metabolism cages fitted with individual feed troughs and facility for separate excreta collection. The turkeys were acclimatized for 2 d prior to the commencement of 4 d collection period. Excreta collected per turkey per day was oven dried (60^{o}C) and used for analysis. Proximate composition of feed and dried excreta samples were analyzed for dry matter (Method 934.01), crude fibre (Method 978.01), ether extract (Method 920.39), ash (Method 942.05), and crude protein (N × 6.25; Method 990.03) using standard methods of AOAC (2000). Amino acids contents of the diets were determined (Harper Adams University Laboratory, Newport, UK) using HPLC (SSNIFF Spezialdiäten GmbH, Soest, Germany) and following standard methods (European Commission, 1998).

At the expiration of metabolic trial, turkeys were starved of diets, given unrestricted access to clean water for 24 h during which the excreta voided were discarded. After the expiration of 24 h starvation, each turkey was dosed with 50 mL of warm glucose solution to

148 reduce stress and deprived of feed for another 24 h making a total of 48 h starvation period.
149 Total excreta collection per turkey during the last (24 h) phase of feed starvation was used for
150 the estimation of endogenous losses. Gross energy of excreta samples (from fed and starved
151 turkeys) was estimated using the adiabatic bomb calorimeter (Model 1261; Parr Instrument
152 Co., Moline, IL, US). The apparent metabolizable energy (AME), nitrogen corrected AME
153 (AMEn), true metabolizable energy (TME), and nitrogen corrected TME (TMEn) were
154 computed using the equations as described by Sibbald (1989).

155 *2.5. Intestinal morphology*

156 At d 84 and 112, a turkey per replicate was randomly selected, slaughtered, carcass
157 opened, and the entire gastrointestinal tract excised. Samples were taken from the mid-region
158 of the intestinal segments; duodenum (from gizzard outlet to the end of the pancreatic loop),
159 jejunum (from the pancreatic loop to Meckel's diverticulum), and ileum (from Meckel's
160 diverticulum to the cecal junction). The gut samples were washed with 0.1 M phosphate
161 buffered saline (pH 7.4), fixed in Bouin's solution for 6 h, and dehydrated in a graded ethanol
162 (xylene) series. Each segment was embedded in paraffin wax using standard technique.
163 Intestinal histology was measured according to Hampson (1986). Villus height and crypt
164 depth was determined by a Nikon Phase Contrast Microscope Integrated Digital Imaging
165 Analyses (Nikon Tec, Shinagawa, Tokyo, Japan). The villi length was measured from the tip
166 to the villi base, and the crypt depth was measured from the base of the villi to the base of the
167 crypt. The villus widths were measured at the basal and apical parts to obtain the basal, and
168 apical width, respectively.

169 *2.6. Statistical Analysis*

170 Data obtained from this study was subjected to one-way analysis of variance in a
171 completely randomized design. The pen was used as the experimental units for statistical

172 analysis. The data were statistically analyzed using the ANOVA procedure of SAS (1999).
173 Orthogonal polynomials were used to assess the linear and quadratic effects of varying
174 supplemental levels of Arg.

175

176 **3. Results**

177 *3.1. Growth performance*

178 The growth performance of growing turkeys fed the diets supplemented with Arg is as
179 shown in Table 2. At the grower phase, Arg supplementation had no effect on all growth
180 parameters measured. During the finisher phase, feed intake initially reduced as Arg
181 supplementation increased from 0 to 0.5 g/kg, but it increased with the 1.0 g Arg/kg (linear, P
182 = 0.009; quadratic, $P < 0.001$). In a similar manner, feed conversion ratio of finisher turkeys
183 decreased as Arg supplementation increased from 0 to 0.5 g/kg, but increased with the 1.0 g
184 Arg/kg (quadratic, $P = 0.028$).

185 Effect of Arg supplementation on overall performance of turkeys measured at d 56 to
186 112 is shown in Table 2. Body weight of turkeys reduced quadratically as Arg
187 supplementation increased from 0 to 0.5 g/kg, but showed a quadratic increase with the 1.0 g
188 Arg/kg ($P = 0.039$). Feed intake initially reduced as Arg supplementation increased from 0 to
189 0.5 g/kg, but increased with the 1.0 g Arg/kg (linear, $P = 0.022$; quadratic, $P = 0.017$). Feed
190 conversion ratio of turkeys measured at d 56 to 112 reduced as Arg supplementation
191 increased from 0 to 0.5 g/kg, but increased with the 1.0 g Arg/kg (linear, $P = 0.015$).

192 *3.2 Nutrient digestibility*

193 Table 3 shows the dry matter and nutrient digestibility values of growing turkeys fed
194 the diets supplemented with Arg. At d 84, grower turkeys fed diets supplemented with 1.0 g

Arg/kg had a greater (linear, $P < 0.001$) dry matter, crude protein and ether extract, crude fibre, and ash digestibility values. Dry matter, crude protein, ether extract, and crude fibre digestibility of grower turkeys at d 84 increased linearly ($P < 0.001$) with increasing Arg supplementation.

In finisher turkeys measured at d 112, dry matter digestibility reduced (linear, $P = 0.014$; quadratic, $P = 0.030$), while ash digestibility increased (linearly and quadratic, $P < 0.001$) with increasing Arg supplementation. Dietary supplementation with Arg had no effect on crude protein, ether extract, and crude fibre digestibility of finisher turkeys at d 112.

3.3 Metabolizable energy values

The metabolizable energy values of growing turkeys fed the diets supplemented with Arg is shown in Table 4. At d 84, AME, AMEn, and TME of grower turkeys increased quadratically as Arg supplementation increased from 0 to 0.5 g/kg, but reduced with the 1.0 g Arg/kg ($P < 0.001$). In a similar manner, TMEn increase as Arg supplementation increased from 0 to 0.5 g/kg, but reduced with the 1.0 g Arg/kg (quadratic, $P = 0.021$). At d 112, Arg supplementation had no effect on AME, AMEn, TME, and TMEn values of finisher turkeys in this study.

3.4 Intestinal morphology

Table 5 shows the effect of Arg supplementation on intestinal morphology of grower turkeys at d 84. The villus height increase (linear and quadratic, $P < 0.001$), while apical width reduced (linear, $P = 0.003$; quadratic, $P < 0.001$) with increasing Arg supplementation in the duodenum of grower turkeys at d 84. Basal width (quadratic, $P = 0.047$) and crypt depth (linear, $P = 0.043$; quadratic, $P < 0.001$) reduced as Arg supplementation increased from 0 to 0.5 g/kg, but increase with the 1.0 g Arg/kg.

In the jejunum of grower turkeys at d 84, villus height, and crypt depth increase as Arg supplementation increased from 0 to 0.5 g/kg, but reduced with the 1.0 g Arg/kg (quadratic, $P < 0.001$). Apical width reduced linearly and quadratically ($P < 0.001$) with increasing Arg supplementation. Arginine supplementation had no effect on the jejunum basal width in grower turkeys at d 84.

In the ileum of grower turkeys at d 84, villus height increase linearly, and quadratically ($P < 0.001$) with increasing Arg supplementation. Dietary supplementation with Arg showed a linear and quadratic reduction (linear, $P = 0.010$; quadratic, $P = 0.004$) in apical widths of grower turkeys at d 84. The basal width (linear, $P = 0.004$; quadratic, $P = 0.021$) and crypt depth (linear and quadratic, $P < 0.001$) in the ileum also reduced with increasing Arg supplementation.

The effect of Arg supplementation on intestinal morphology of finisher turkeys at d 112 is also shown in Table 6. The villus height, basal width, and crypt depth of the duodenum were not affected with Arg supplementation. However, apical width of the duodenum reduced quadratically ($P = 0.033$) with increasing Arg supplementation. In the jejunum of finisher turkeys at d 112, villus height increase quadratically ($P = 0.042$) with increasing Arg supplementation. In the ileum of finisher turkeys at d 112, villus height increase linearly and quadratically (linear, $P = 0.022$; quadratic, $P = 0.042$) with increasing Arg supplementation. Apical width, basal width, and crypt depth in the jejunum and ileum of finisher turkeys at d 112 were not affected by Arg supplementation.

4. Discussion

4.1 Growth performance

The non significant effect of Arg on the growth response of grower turkeys obtained

242 in this study agreed with previous literature. Veldkamp et al. (2000) reported that increasing
243 dietary Arg supplementation had no effect on growth performance of 28 to 140 d male
244 turkeys. Costa et al. (2001) investigated the effect of varying Arg/Lys ratios in diets of 22 to 42
245 d, male Ross broilers and reported no effect of Arg level on growth performance. Contrary
246 opinion following dietary supplementation with Arg has been reported (Kwak et al., 1999).
247 The absence of significant effect recorded in this study with respect to the growth
248 performance of grower turkeys with increasing dietary Arg supplementation could be
249 attributed to the similar Arg/Lys ratios of the experimental diets and the dosage of Arg
250 supplemented. Increased supplemental levels of Arg above the concentration used in the
251 current study (Labadan Jr et al., 2001) and increased Arg/Lys ratios (Mendes et al., 1997)
252 were reported to improve feed conversion and production performance in broiler chickens.
253 The differences between the findings obtained at the grower phase of the current study and
254 previous literature could also be attributed to sex and species of birds used.
255 Improved feed conversion ratio obtained for finisher turkeys fed diet supplemented
256 with 0.5 g Arg/kg when compared to turkeys fed diet supplemented with 1 g Arg/kg
257 suggested a better utilization of dietary protein at the 0.50 g Arg/kg. Takahashi et al. (1999)
258 reported that dietary supplementation with Arg improved feed efficiency in male broiler
259 chickens. Mendes et al. (1997) and Brake et al. (1998) also reported improved feed
260 conversion ratio with the addition of Arg to broilers' diet. Arginine was reported to exhibit a
261 secretagogue activity by which, it induces the release of pituitary and pancreatic hormones,
262 which in turn improve feed intake, feed conversion ratio, and indirectly protein synthesis
263 (Davila et al., 1987). Arginine is a primary component of proteins, which are only derived
264 from the diet. Hence, a dietary deficiency of Arg will adversely affect protein synthesis and
265 growth (Khajali et al., 2011). The result of the present study corroborated the findings of

Labadan Jr et al. (2001) who reported that supplemental Arg are needed for improved feed conversion rather than for live weight gain in broilers.

4.2 Apparent nutrient digestibility

A linear increase in dry matter, crude protein, ether extract, and crude fibre digestibility values of grower turkeys obtained in the current study with increasing Arg supplementation agreed with Uni and Ferket, (2003) who reported that Arg improved the normal functioning of the digestive system in both mammals, and birds, thereby enhancing improved nutrient utilization. Zhan et al. (2008) also reported that dietary Arg supplementation enhanced gut development and increased intestinal growth, which in turn resulted in positive influence on nutrient absorption and digestion. Improved nutrient digestibility obtained with grower turkeys fed the diets supplemented with Arg could also be related to the important function of Arg in improving the gut morphology of animals. The production of nitric oxide following Arg supplementation in poultry has been reported to support the development of the intestine, growth of mucosa microvasculature, mucosal barrier, and subsequently resulted in increased nutrient absorption (Yao et al., 2011).

4.3 Metabolizable energy

Greater AME values obtained with grower turkeys fed the diets supplemented with Arg when compared with the control group implied improved metabolizable energy values of the diets supplemented with Arg. This could be due to improved physiological functions of digestive system following arg supplementation (Uni and Ferket, 2003). Zhan et al. (2008) earlier reported that dietary Arg supplementation enhanced gut development, which resulted

in improved intestinal growth with positive effect on nutrient absorption. Greater AME, AMEn, and TME values obtained for grower turkeys as Arg supplementation increased from 0 to 0.5 g Arg/kg when compared with other dietary treatments suggested better dietary energy utilization at 0.50 g Arg/kg. However, Arg supplementation had no effect on AME, AMEn, TME, and TME values of finisher turkeys in this study.

The differences in response of grower and finisher turkeys in terms of metabolizable energy values following dietary Arg supplementation might be as a result of age differences. Sulistiyanto et al. (1999) reported that utilization of energy-yielding feedstuffs in poultry birds was age dependent. Batal and Parsons (2002) also reported that younger birds showed increased nutrient utilization than older birds. Ruth and Field (2013) reported that during critical periods of development such as growing phase, dietary Arg concentration and availability is of significant importance to the structure, and functioning of the intestine than at maturity.

4.4. Intestinal morphology

The linear and quadratic reduction in duodenal and jejunal apical widths of grower turkeys, and quadratic reduction in duodenal apical width of finisher turkeys obtained with increasing Arg supplementation in the present study suggested increased mature enterocytes, signifying increased enzyme activity in the villus brush border (Chen et al., 2011). A linear and quadratic increase in duodenal and ileum villus heights of grower turkeys, ileum villus heights of finisher turkeys, and quadratic increase in the jejunal villus heights of finisher turkeys recorded with increasing Arg supplementation in the present study suggested that Arg promoted increased villus height and consequently increased nutrient absorption. The size and height of villi are important for intestinal function (Yamauchi et al., 1993) as increased

313 villi height have been suggested to lead to increase in the intestinal surface area and
314 consequently increased nutrient absorption (Soltan, 2009).

315 Arginine is involved in the synthesis of polyamines, which in turn are associated
316 with cell division, protein synthesis, intestine development, and tissue growth (Pegg and
317 McCann 1982; Tan et al., 2010). Arginine needs to be hydrolyzed into urea and ornithine by
318 kidney arginase during the synthesis of polyamines (Wu and Morris 1998). Reduction or
319 absence of polyamines has been reported by Ruemmele et al. (1999) to inhibit the
320 proliferation, migration, and apoptosis of intestine cells. As a precursor of polyamines, Arg
321 may be considered a trophic agent in the stimulation of the development of intestinal
322 mucosa, accelerating the mitotic process in the villus-crypt region with a resultant increase
323 in the number, and size of villus cells resulting in increased nutrient uptake (Ruemmele et
324 al., 1999). Liu et al. (2012) also reported that dietary Arg facilitated the uptake of more
325 nutrients from the maternal to the fetus tissue for fetal development. The positive effect of
326 Arg on gut morphology noticed in this study agreed with findings of Zhan et al. (2008) who
327 reported that dietary supplementation with Arg had a positive effect on villus height in the
328 small intestine of early weaned pigs. Foye et al. (2007) reported that Arg when administered
329 in ovo resulted in enhanced intestinal uptake in turkeys. Intestinal villi conformation have
330 been reported to be linked with growth as longer villi were associated with increased body
331 weight gain (Maneewan and Yamauchi, 2004). Higher values of villi heights were observed
332 in chickens that showed increased body weight (Solis De Los Santos et al., 2007).
333

334 5. Conclusion

335 Dietary supplementation with Arg from the present study showed a linear
336 improvement in dry matter, crude protein, and ether extract digestibility of grower turkeys.
337 Arginine supplementation improved intestinal morphology as indicated by increased villus

height in grower and finisher turkeys. Furthermore, dietary supplementation with 0.5 g Arg/kg improved the feed conversion ratio of finisher turkeys and promoted a quadratic improvement in metabolizable energy values of grower turkeys.

Conflict of interest statement

There is no conflict of interest with any individual or organization regarding the materials discussed in the manuscript.

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503 **Table 1**

504 Composition of basal diet for grower (d 56 to 84), and finisher (d 84 to 112) turkeys[a]

Item	Grower	Finisher
Ingredient (g/kg)		
Maize	575	622
Fish meal (720 g/kg)	89	46
Soybean meal	264	240
Soybean oil	-	2
Wheat offal	47	65
Bone meal	6	6
Limestone	8	8
Vitamin/mineral premix	5	5
L-Lys	1	1
DL-Met	2	2
Salt	3	3
Total	1,000	1,000
Calculated composition		
Ca (g/kg)	10.5	9.5
P (g/kg)	6.5	5.4
Metabolizable energy (kcal/kg)	3,196	3,275
Determined composition (g/kg DM basis)		
Crude protein	230.3	195.5
Crude fibre	33.2	39.0
Ether extract	32.1	30.7
Indispensable amino acids		
Arg	16.3	14.3
His	6.6	5.9
Ile	11.0	9.3
Leu	21.6	20.0
Lys	14.3	11.3
Met	5.5	4.6
Phe	11.7	10.5
Thr	11.5	8.1
Val	12.4	10.3
Dispensable amino acids		
Asp	24.8	21.4
Cys	36.0	33.0
Glu	43.4	39.9
Gly	11.2	9.4
Ala	13.7	11.9
Pro	14.8	14.0
Ser	11.5	10.3
Tyr	5.2	4.8

505 [a]Provided vitamin-mineral premix per kilogram of diet: 1,200 IU vitamin A; 300 IU
506 vitamin D_3; 4.2 mg vitamin E; 0.2 mg vitamin K_3; 0.2 mg vitamin B_1; 0.66 mg vitamin B_3;
507 0.5 mg vitamin B_6; 2 μg vitamin B_{12}; 0.1 mg folic acid; 0.02 mg biotin; 1.5 mg Ca

pantothenate, 0.07 g choline chloride; 12 mg antioxidant (butylhydroxytoluene); 0.23 g Ca; 0.5 mg Cu; 5.1 mg Zn; 6 mg Fe; 7.1 mg Mn; 0.06 mg I; and 0.02 mg Se.

Table 2

The growth performance of grower (d 56 to 84), and finisher (d 84 to 112) turkeys fed diet supplemented with Arg[a]

Item	Arg (g/kg)			Pooled	*P*-value	
	0	0.5	1.0	SEM	Linear	Quadratic
Body weight (g/turkey)						
d 56	2,627	2,572	2,743	8	0.113	0.164
d 84	5,893	5,730	6,025	11	0.419	0.115
d 112	9,030	8,772	9,500	201	0.184	0.039
Average daily feed intake (g/turkey)						
d 56 to 84	292	292	299	4	0.661	0.803
d 84 to 112	457	412	617	55	0.009	<0.001
d 56 to 112	375	352	458	36	0.022	0.017
Average daily weight gain (g/turkey)						
d 56 to 84	117	113	117	6	0.654	0.688
d 84 to 112	112	109	124	8	0.304	0.385
d 56 to 112	114	111	121	5	0.099	0.075
Feed conversion ratio						
d 56 to 84	2.51	2.59	2.55	0.02	0.628	0.744
d 84 to 112	4.08	3.79	4.97	0.23	0.062	0.028
d 56 to 112	3.28	3.18	3.79	0.90	0.015	0.075

[a]Based on 6 pens/treatment, and SEM = standard error of the mean.

516 **Table 3**

517 Dry matter and nutrient digestibility (%) of grower (at d 84), and finisher (at d 112) fed diet
518 supplemented with Arg[a]

Item	Arg (g/kg)			Pooled	*P*-value	
	0	0.5	1.0	SEM	Linear	Quadratic
d 84						
Dry matter	78.37	83.55	86.81	4.05	<0.001	0.507
Crude protein	59.28	69.30	70.66	2.66	<0.001	0.929
Ether extract	72.78	74.86	75.17	2.39	<0.001	0.697
Crude fibre	56.26	62.19	69.23	2.26	<0.001	0.716
Ash	52.04	51.40	64.99	2.60	<0.001	0.391
d 112						
Dry matter	88.24	87.63	84.09	2.72	0.014	0.030
Crude protein	69.65	71.37	70.34	0.96	0.255	0.275
Ether extract	61.57	59.57	61.96	1.44	0.730	0.069
Crude fibre	61.01	63.97	68.56	0.65	0.059	0.173
Ash	62.12	69.76	78.25	1.98	<0.001	<0.001

519 [a]Based on 6 pens/treatment, and SEM = standard error of the mean.

520

521 **Table 4**

522 Metabolizable energy values (MJ/Kg) of grower (at d 84), and finisher (at d 112) turkeys fed
523 diet supplemented with Arg[a]

	Arg (g/kg)			Pooled SEM	*P* – value	
Item	0	0.5	1.0		Linear	Quadratic
d 84						
AME	13.74	14.91	14.25	1.69	0.054	<0.001
AMEn	13.47	14.17	13.14	2.01	0.139	<0.001
TME	15.95	16.68	15.75	2.72	0.417	<0.001
TMEn	12.57	13.08	12.14	2.50	0.201	0.021
d 112						
AME	14.75	14.51	14.45	0.08	0.124	0.278
AMEn	13.75	13.45	13.54	0.07	0.216	0.182
TME	14.71	14.31	14.51	0.08	0.337	0.134
TMEn	14.87	14.69	14.76	0.12	0.589	0.475

524 [a]Based on 6 pens/treatment, SEM = standard error of the mean, AME = apparent
525 metabolizable energy, AMEn = apparent metabolizable energy corrected for nitrogen, TME =
526 true metabolizable energy, and TMEn = true metabolizable energy corrected for nitrogen.

527

528 **Table 5**

529 Effect of Arg supplementation on intestinal morphology (μm) of grower (at d 84) turkeys[a]

Item	Arg (g/kg)			Pooled	*P*-value	
	0	0.5	1.0	SEM	Linear	Quadratic
Duodenum						
Villus height	1,070	1,350	1,463	115	<0.001	<0.001
Apical width	92.7	57.7	54.0	8.5	0.003	<0.001
Basal width	170	130	150	23	0.286	0.047
Crypt depth	475.0	437.7	587.7	29.9	0.043	<0.001
Jejunum						
Villus height	1,675	2,055	1,418	124	0.193	<0.001
Apical width	119.0	52.7	47.7	11.6	<0.001	<0.001
Basal width	238	248	180	21	0.095	0.087
Crypt depth	468	495	385	28	0.055	<0.001
Ileum						
Villus height	370	475	1,013	109	<0.001	<0.001
Apical width	98	80	80	9	0.010	0.004
Basal width	165	140	118	16	0.004	0.021
Crypt depth	1,575	1,475	775	108	<0.001	<0.001

530 [a]Based on 6 pens/treatment, and SEM = standard error of the mean.

531

532 **Table 6**

533 Effect of Arg supplementation on intestinal morphology (μm) of finisher (at d 112) turkeys[a]

Item	Arg (g/kg)			Pooled SEM	*P*-value	
	0	0.5	1.0		Linear	Quadratic
Duodenum						
Villus height	1,530	1,550	1,540	32	0.075	0.099
Apical width	152.4	125.5	120.5	21.2	0.062	0.033
Basal width	255	253	250	6	0.189	0.077
Crypt depth	505	502	501	11	0.095	0.175
Jejunum						
Villus height	1,850	2,001	2,200	196	0.065	0.042
Apical width	149.2	152.4	150.5	8.3	0.099	0.078
Basal width	286	289	290	9	0.095	0.087
Crypt depth	527	531	523	21	0.094	0.095
Ileum						
Villus height	450.6	496.6	500.8	99.2	0.022	0.042
Apical width	122.2	125.1	120.5	6.2	0.115	0.155
Basal width	220	216	222	9	0.099	0.091
Crypt depth	1,599	1,599	1,598	27	0.074	0.065

534 [a]Based on 6 pens/treatment, and SEM = standard error of the mean.