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Effect of organic acid blend on the growth performance, apparent nutrient digestibility and blood indices of growing turkeys

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Abstract

Organic acid is a viable alternative to antibiotics used to control the spread of infection and manage disease outbreak in poultry production since antibiotics was banned due to its hazardous residual effect in human health. Organic acid blend introduced in the diets of turkey and the effect on the growth performance, apparent nutrient digestibility and blood indices were investigated. The organic acid blend (Fysal-MP, Selko brand, Netherlands) used in this study comprise of a blend of sorbic, formic, acetic, lactic, propionic, citric, silicic acid and ammonium formate. Eighty (80) 4-week old turkeys weighing 1.04 ± 0.01 kg were assigned on weight equalization basis to four dietary treatments comprising of basal diet (control), diets supplemented with 2, 3, and 4 g/kg organic acid blend. Each treatment were replicated four times with five turkeys per replicate. Data obtained were subjected to Analysis of Variance in a Completely Randomized Design. In overall, dietary supplementation with 4 g/kg organic acid resulted in increased ($p<0.05$) final liveweight, weight gain, feed intake and improved ($p<0.05$) feed conversion ratio. Grower turkeys fed diet supplemented with organic acid irrespective of the inclusion levels recorded increased ($p<0.05$) apparent dry matter, ether extract, crude fibre and ash digestibility. Highest ($p<0.05$) total serum protein, globulin, glucose and the least ($p<0.05$) total serum cholesterol and triglyceride were recorded with starter turkeys fed diet supplemented with 4 g/kg organic acid blend. Dietary supplementation with 4 g/kg organic acid at the grower phase resulted in the least ($p<0.05$) low-density lipoprotein. Dietary supplementation of diets with 3g/kg organic acid blend improved the final live weight, weight gain, feed conversion ratio, dry matter, fat digestibility and suggested immune stimulatory effects in starting turkeys. However at the grower phase, dietary supplementation with 4 g/kg organic acid blend showed improved growth performance, apparent nutrient digestibility and serum chemistry.

Keywords: Organic acid blends, turkeys, growth performance, apparent nutrient digestibility, haematological indices, serum biochemistry

Running title: Organic acid blend effect on growing turkeys

Effet du mélange d'acides organiques sur les performances de croissance, la digestibilité apparente des nutriments et les indices sanguins de la dinde en croissance

Résumé

L'acide organique est une alternative viable aux antibiotiques utilisés pour contrôler la propagation des infections et gérer les épidémies dans la production avicole, puisque les antibiotiques ont été interdits en raison de leurs effets résiduels dangereux sur la santé humaine. Un mélange d'acides organiques introduit dans l'alimentation des dindes et leur effet sur les performances de croissance, la digestibilité apparente des nutriments et les indices sanguins ont été étudiés. Le mélange d'acides organiques (Fysal-MP, marque Selko, Pays-Bas) utilisé dans cette étude comprend un mélange d'acide sorbique, formique, acétique, lactique, propionique, citrique, silicique et de formiate d'ammonium. Quatre-vingt (80) dindes âgées de 4 semaines pesant 1,04 ± 0,01 kg ont été assignées, sur la base d'une égalisation du poids, à quatre traitements alimentaires comprenant un régime de base (témoin), des régimes complétés avec 2, 3 et 4 g/kg de mélange d'acides organiques. Chaque traitement a été répété quatre fois avec cinq dindes par répétition. Les données obtenues ont été soumises à une analyse de variance dans une conception complètement randomisée. Dans l'ensemble, une supplémentation alimentaire avec 4 g/kg d'acide organique a entraîné une augmentation ($p < 0,05$) du poids vif final, un gain de poids, une consommation alimentaire et une amélioration ($p < 0,05$) du taux de conversion alimentaire. Les dindes d'élevage nourries avec un régime enrichi en acide organique, quels que soient les niveaux d'inclusion, ont enregistré une augmentation ($p < 0,05$) de la matière sèche apparente, de l'extrait d'éther, des fibres brutes et de la digestibilité des cendres. Les protéines sériques totales, les globulines, le glucose les plus élevées ($p < 0,05$) et les taux de cholestérol et de triglycérides sériques totaux les plus faibles ($p < 0,05$) ont été enregistrés chez des dindes de démarrage nourries avec un régime enrichi de 4 g/kg de mélange d'acides organiques. Une supplémentation alimentaire avec 4 g/kg d'acide organique au cours de la phase de croissance a entraîné la production du moins ($p < 0,05$) de lipoprotéines de basse densité. La supplémentation alimentaire des régimes avec un mélange d'acides organiques de 3 g/kg a amélioré le poids vif final, le gain de poids, le taux de conversion alimentaire, la matière sèche, la digestibilité des graisses et a suggéré des effets immunostimulants chez les dindes en démarrage. Cependant, au stade de croissance, une supplémentation alimentaire avec un mélange d'acides organiques de 4 g/kg a montré une amélioration des performances de croissance, de la digestibilité apparente des nutriments et de la chimie du sérum.

Mots-clés: Mélanges d'acides organiques, dindes, performances de croissance, digestibilité apparente des nutriments, indices hématologiques, biochimie sérique

Introduction

Turkey (*Meleagris gallopavo*) is a meat-type species of poultry selected mainly for rapid growth, efficient feed conversion, and high meat yield of valuable carcass parts than chicken (Oso *et al.,* 2008). While the production of other poultry species has rapidly increased over the years (Okoruwa *et al.,* 2006), little successes have been recorded in commercial turkey production in developing countries (Perez-Lara *et al*., 2013), due to the problem of disease management (Agbonika and Folorunsho, 2020).

In order to combat the spread of infection and manage disease outbreak in poultry production most especially in tropical countries, antibiotics have been used over the years. However, the use of antibiotic growth promoters (AGP) was banned in European countries due to the problem of antibiotic resistance (Forgetta *et al*., 2012), presence of antibiotic residues in meat products (Gonzalez and Angeles, 2017) and its hazardous residual effect in human health. Ever since, viable alternatives that could be used as feed additives in animal production have been explored (Ragaa *et al.,* 2016).

One of such alternatives is the use of organic acids (OA) in animal nutrition. Organic acids (OA) are conservation agents used to protect feed from microbial and fungal proliferation (Kum *et al*., 2010). They are regarded as safe and have been approved for use as feed additives in animal production (Baaboua *et al.,* 2018). It has also been discovered that organic acids are capable of improving growth performance (Galli *et al.,* 2021), increasing the immune and antioxidant properties of livestock (Abudabos *et al.,* 2017), improving imtestinal function (Xu *et al.,* 2020; Stamilla *et al.,* 2020), and regulating the intestinal microbiota (Ma *et al.,* 2021) of broiler chickens. However, limited information are available on the use of organic acid in the nutrition of turkeys. Thus, the objective of this study was to investigate the effect of organic acids blend on the growth performance, apparent nutrient digestibility and blood indices of growing turkeys to evaluate another aspect of poultry aside broiler chickens.

Materials and methods

The experiment was carried out according to the regulations of the animal welfare committee of the Federal University of Agriculture, Abeokuta, Nigeria.

Test Ingredients

A commercial blend of organic acids (Fysal-MP; Selko brand, Netherlands) containing 1, 2 propanediol, sorbic acid, formic acid, acetic acid, lactic acid, propionic acid, ammonium formate, citric and silicic acid was used for this experiment.

Experimental birds and dietary treatments: A total of 80 unsexed day-old British United turkey poults were used in this study. The experimental pen was partitioned (using wire mesh) into 16 pens. Each pen was an open-sided unit which had a disinfected concrete floor littered with wood-shavings. Each pen was equipped with two conical feeders and two drinkers. The pre-experimental period commenced from day old to 27 days. During the pre-experimental period, poults were fed with maize-soybean meal-based pre-starter diet (metabolizable energy (ME) = 11.79 MJ/kg, crude protein (CP) = 278 g/kg, Methionine = 5.1 g/kg, and Lysine = 16 g/kg). At day 28, turkeys were weighed individually and distributed on weight equalization basis into four dietary treatments with each treatment replicated four times (n=4) and each replicate housed five turkeys. Appropriate medication and management practices were followed. A maize-soybean meal diets (basal diets), which met the NRC (1994) nutritional requirement for starter (28-56 days) and grower (57–84 days) turkeys were formulated and used as basal diets as shown in Table 1.Four experimental diets were formulated for each of the phase by supplementing the basal diet with 0, 2, 3 and 4g/kg of organic acid blend. Turkeys were fed *ad libitum* with the experimental diets and drinking water were offered *ad libitum*.

Table 1: percentage composition of experimental turkey starter and grower fed organic acid blend diets

Ingredients	Starter period (4-8 weeks)	Grower period (8-12 weeks)
Maize	50.00	57.00
Soybean meal	36.00	26.50
Wheat offal	0.00	4.90
Fishmeal (72% CP)	8.90	8.60
Limestone	1.00	0.80
Lysine	0.20	0.20
Methionine	0.50	0.20
Bone meal	3.00	0.50
Salt (NaCl)	0.25	0.30
Vitamin/trace mineral premix*	0.15	0.50
Palm oil	0.00	0.50
Total	**100.00**	**100.00**
Determined nutrients		
Energy(kcal/kg)	2,813.10	2928.78
Crude protein (%)	26.53	23.76
Fat (%)	4.33	4.82
Fiber (%)	3.93	3.94
Calculated nutrients		
Phosphorus (%)	0.95	0.55
Calcium (%)	1.69	0.72
Lysine (%)	1.70	1.48
Methionine (%)	0.95	0.62

**Turkey poults Premix provided the following: Vitamin A 40,000,000 I U; Vitamin D_3 4,000 I.U;Vitamin E 40mg;Vitamin K_3 8mg;Vitamin B_1 2.5,mg; Vitamin B_2 8mg; Vitamin B_6 5mg Pantholelic acid 20mg;Vitamin B_{12} 0.025mg; Niacin 75mg; Folic acid 2.5mg ;Biotin 0.5mg;Selenium 0.2mg;Iodine 0.15mg; Iron 80mg; Manganese 120mg;Copper 15mg;Zinc 120mg;Choline 3.0mg; Cobalt 0.05mg.*

Turkey grower Premix provided the following: Vitamin A 12,500,000 I U; Vitamin D_3 2,500 I.U;Vitamin E 40mg;Vitamin K_3 2mg;Folic acid 1,mg;Niacin 55mg;Pantholelic acid 11.5mg;Vitamin B_{12} 0.025mg;Selenium 0.12mg;Iodine 1.5mg; Iron 100mg; Manganese 120mg;Copper 8.5mg,Zinc 80mg;Choline 2.5mg.

Data collection

Growth performance: A known quantity of feed was given to turkeys in each replicate group at the beginning of each week and the left over at the end of the seventh day was measured and subtracted from the feed offered at the beginning of the week, then divided by the number of turkeys in each replicate to obtain the average feed intake/turkey/week.

$$Average\ feed\ intake\ per\ bird\ (kg/bird) = \frac{feed\ offered\ (kg)\ -\ Leftover\ feed\ (kg)}{No.\ of\ birds}$$

Turkeys were weighed at the beginning of the 8-week experimental period and weekly thereafter. The average weight gain was obtained by weighing each bird in each replicate on a weekly basis and the initial live weight was subtracted from the final live weight, then divided by the total number of birds in each replicate.

$$Average\ weight\ gain\ (kg/bird) = \frac{final\ live\ weight\ (kg)\ -\ Initial\ live\ weight\ (kg)}{No.\ of\ birds}$$

Feed conversion ratio was expressed as a ratio of the average feed intake to average weight gain and it was calculated as:

$$Feed\ conversion\ ration = \frac{Average\ feed\ intake\ (kg)}{Average\ weight\ gain\ (kg)}$$

Metabolic trial: A metabolic trial was carried out when the birds were 56 and 84 days old. A turkey per replicate was randomly selected and housed separately in appropriate metabolic cages fitted with appropriate feed troughs, drinkers and facility for separate excreta collection. The turkeys were acclimatized for three days followed by a collection period of 4 days. A known amount of feed was given to turkeys during the 4 days collection period and the left over was subtracted from the feed offered to obtain the feed intake during the metabolic trial period while water was supplied *ad libitum*. Turkeys were acclimatized for 3 days prior the commencement of a 4-day metabolic trial. The total droppings voided per bird was collected separately in a labeled aluminum foil daily, weighed wet and oven dried at 60°C to constant weight. The oven dried droppings from the same replicate was pooled and ground. The ground samples were analyzed for dry matter, crude protein, crude fiber, ether extract, and ash contents according to standard procedures of AOAC (2000)

Blood collection: At day 56 and 84, blood samples (6 mL each) were collected from the jugular vein of one turkey per replicate. 3 mL of the blood was collected into vials containing ethylene diamine tetra-acetate (EDTA) for the determination of haematological indices while the remaining 3ml were collected into plain bottles (without EDTA), centrifuged (2500 x g) for 15 minutes and used for serum chemistry analysis.

Haematological indices: Haemoglobin concentration (Hb) was estimated using the cyanmethaemoglobin method (Canan, 1958). Packed cell volume (PCV), red blood cell (RBC), and white blood cell counts (WBC) were determined using Wintrobe haematocrit tube according to the method of Schalm *et al.* (1975).

Serum Chemistry: Total serum protein, serum albumin, serum globulin (Varley *et al.,* 1980) and serum uric acid concentration (Wootton, 1964) and serum creatinine (Bousnes and Taussky, 1945) were measured according to standard procedures. Serum enzymes such as alanine aminotransferase (ALT) and aspartate aminotransferase (AST) were determined by standard methods using Randox test kits (Randox Laboratories, Antrim, UK).

Statistical analysis: Data obtained from the experiment were subjected to one-way Analysis of Variance (ANOVA) in a Completely Randomized Design using General Linear Model procedure of IBM Corp. Released 2011. IBM SPSS Statistics for windows version 20.0.Means of significant results were compared using Tukeys Test. Polynomial contrast was used for the linear and quadratic effect.

Results

Effect of dietary organic acid blend supplementation on growth performance characteristics of turkeys

The effect of organic acid blend supplementation on the performance characteristics turkeys is as shown in Table 2. Dietary supplementation with organic acid blend at the starter phase affected (P <0.05) all the growth indices measured with the exception of feed intake (AFI). Average final liveweight (AFLW) (*P =0.003*) and average weight gain (AWG) (*P =0.002*) of starter turkeys showed a linear increase while the feed conversion ratio (FCR) improved (Linear. *P =0.000*; Quadratic. *P =0.030*) with 3 g/kg organic acid supplementation. At the grower phase, AFLW improved linearly (*P =0.000*), AWG (L. *P =0.004*; Q. *P =0.021*) and AFI (*P =0.000*) increased linearly and quadratically with increasing organic acid blend inclusion levels from 0 g/kg to 4 g/kg. In overall performance, AFLW (L. *P =0.000*) and AWG (L. *P =0.000*; Q. *P =0.045*) of turkeys increased as organic acid blend supplementation increased from 0 g/kg to 4 g/kg. The best overall FCR (L. *P = 0.046*; Q. *P =0.018*) was obtained with turkeys fed diet supplemented with 4 g/kg organic acid blend.

Table 2: Effect of dietary organic acid blend supplementation on growth performance characteristics of turkeys

	Organic acid levels						
Treatments	0g/kg diet	2g/kg diet	3g/kg diet	4g/kg diet	SEM	P-*value*	
Parameters						*L*	*Q*
Starter(4-8 weeks)							
AIW (kg/bird)	1.04	1.05	1.05	1.04	0.003	0.918	0.175
AFLW (kg/bird)	3.82^{c}	3.99^{bc}	4.40^{a}	4.24^{ab}	0.072	0.003	0.118
AWG (kg/bird)	2.78^{c}	2.94^{bc}	3.35^{a}	3.07^{ab}	0.072	0.002	0.132
AFI (kg/bird)	5.65	5.49	5.51	5.53	0.029	0.209	0.142
FCR	2.03^{a}	1.87^{ab}	1.65^{c}	1.73^{bc}	0.044	0.000	0.030
Grower (8-12 weeks)							
AIW (kg/bird)	3.82^{c}	3.99^{bc}	4.40^{a}	4.24^{ab}	0.073	0.003	0.118
AFLW (kg/bird)	7.68^{c}	7.89^{bc}	8.25^{b}	9.06^{a}	0.150	0.000	0.057
AWG (kg/bird)	3.86^{b}	3.9^{b}	3.84^{b}	4.83^{a}	0.133	0.004	0.021
AFI (kg/bird)	10.21^{c}	11.74^{b}	11.78^{b}	12.68^{a}	0.230	0.000	0.000
FCR	2.66	3.01	3.11	2.63	0.081	0.980	0.08
Overall performance (4-12 weeks)							
AIW (kg/bird)	1.04	1.05	1.05	1.04	0.003	0.918	0.175
AFLW (kg/bird)	7.68^{c}	7.89^{bc}	8.25^{b}	9.06^{a}	0.151	0.000	0.057
AWG (kg/bird)	6.64^{c}	6.84^{bc}	7.19^{b}	8.02^{a}	0.150	0.000	0.045
AFI (kg/bird)	15.86^{c}	17.23^{b}	17.29^{b}	18.20^{a}	0.217	0.000	0.000
FCR	2.40^{ab}	2.52^{a}	2.41^{ab}	2.27^{b}	0.032	0.046	0.018

^{abc}Mean on the same row having different superscripts are significantly different (P<0.05). AIW= Average initial weight AFLW= Average final live weight, AWG=Average weight gain, AFI= Average feed intake, FCR= Feed conversion ratio, SEM= Standard error of means, L= Linear, Q= Quadratic

Effect of dietary organic acid blend supplementation on the apparent nutrient digestibility of turkeys

Effects of blends of organic acid supplementation on the apparent nutrient digestibility of turkeys shown in Table 3 revealed a significant effect ($P<0.05$) on all digestibility parameters measured. Dry matter digestibility increased linearly and quadratically ($P=0.000$) in starter turkeys as organic acid blend inclusion increased from 0 g/kg to 3 g/kg. Beyond 2 g/kg supplementation of organic acid blend, CP digestibility reduced linearly and quadratically ($P=0.000$) as organic acid supplementation increased. Ether extract digestibility showed a similar value at 2 g/kg and 3 g/kg organic acid blend inclusion when compared with the control. Beyond 3 g/kg organic acid supplementation, EE digestibility decreased linearly and quadratically ($P=0.000$).

Grower turkeys fed diet supplemented with organic acid blend irrespective of inclusion levels showed improved apparent dry matter, ether extract, crude fibre and ash digestibility when compared with control group. Crude protein digestibility values of grower turkeys fed diet containing 2 g/kg and 3 g/kg organic acid blend improved quadratically ($P=0.000$) when compared with control.

Table 3: Effect of dietary organic acid blend supplementation on apparent nutrient d igestibility of turkeys

	Organic acid levels						
Treatments Parameters	0g/kg diet	2g/kg diet	3g/kg diet	4g/kg diet	SEM	P-*value* *L*	*Q*
Starter (8 weeks)							
Dry matter (%)	80.04^{c}	81.84^{b}	83.98^{a}	82.25^{b}	0.385	0.000	0.000
Crude protein (%)	79.46^{ab}	80.49^{a}	78.65^{b}	73.19^{c}	0.747	0.000	0.000
Ether extract (%)	86.73^{b}	87.15^{a}	87.15^{a}	86.28^{c}	0.096	0.000	0.000
Crude fibre (%)	51.21^{b}	53.00^{b}	56.84^{a}	55.36^{a}	0.650	0.000	0.050
Ash (%)	74.70	72.27	76.46	73.81	0.433	0.424	0.803
Grower (12 weeks)							
Dry matter (%)	80.67^{b}	88.51^{a}	88.40^{a}	87.49^{a}	0.883	0.000	0.000
Crude protein (%)	75.85^{c}	85.07^{a}	83.04^{a}	79.77^{b}	1.015	0.059	0.000
Ether extract (%)	85.55^{b}	86.90^{a}	86.73^{a}	86.38^{a}	0.156	0.011	0.000
Crude fibre (%)	54.14^{b}	72.62^{a}	69.04^{a}	66.05^{a}	2.354	0.057	0.008
Ash (%)	65.14^{b}	77.69^{a}	77.71^{a}	76.08^{a}	1.465	0.000	0.000

^{abc}Mean on the same row having different superscripts are significantly different (P<0.05). SEM= Standard error of means, L= Linear, Q= Quadratic

Effect of dietary organic acid blend supplementation on haematological indices of turkeys

The effect of dietary supplementation levels of organic acid blend on haematological indices of turkeys is shown in Table 4. Pack cell volume of starter turkeys increased linearly (*P =0.000*) with increasing levels of organic acid blend inclusion, while haemoglobin (Hb) increased linearly (*P =0.000*) and quadratically (*P =0.021*) with increasing organic acid blend inclusion from 0 g/kg to 4 g/kg. Red blood cell count of starter turkeys showed a linear increase (*P =0.007*) as organic acid blend inclusion level increased from 0 g/kg to 4 g/kg. Highest (*P =0.000*) white blood cell counts and eosinophil were recorded with starter turkeys fed diet supplemented with 3 g/kg organic acid blend while highest lymphocyte count was obtained with turkeys fed diet supplemented with 4 g/kg organic acid blend. At the grower phase, organic acid blend showed no effect on all haematological indices measured.

Table 4: Effect of dietary organic acid blend supplementation on the haem atological indices of turkeys

	Organic acid levels						
Treatments Parameter	0g/kg diet	2g/kg diet	3g/kg diet	4g/kg diet	SEM	P-*value* *L*	*Q*
Starter (8 weeks)							
PCV (%)	39.00[c]	40.00[c]	45.00[b]	52.00[a]	1.472	0.000	0.055
Hb (g/dL)	13.10[c]	13.20[c]	15.10[b]	17.40[a]	0.488	0.000	0.021
RBC ($\times10^{12}$/L)	3.30[b]	3.30[b]	3.80[ab]	4.30[a]	0.152	0.007	0.319
WBC ($\times10^{9}$/L)	13.00[b]	12.50[b]	16.40[a]	11.20[c]	0.527	0.416	0.000
Heterophils (%)	36.00[a]	24.00[b]	32.00[a]	25.00[b]	1.468	0.004	0.143
Lymphocytes (%)	64.00[c]	73.00[ab]	66.00[ab]	75.00[a]	1.586	0.029	1.000
Eosinophils (%)	0.00[c]	1.00[b]	2.00[a]	0.00[c]	0.218	0.031	0.000
Basophils (%)	0.00	0.00	0.00	0.00	0.00	.-	-
Monocytes (%)	0.00	2.00	0.00	0.00	0.223	-	-
Grower (12 weeks)							
PCV (%)	36.00	37.00	35.00	36.00	0.658	0.757	1.000
Hb (g/dL)	12.30	12.30	11.70	12.10	0.120	0.262	0.398
RBC ($\times10^{12}$/L)	3.10	3.10	2.90	3.10	0.055	0.696	0.398
WBC ($\times10^{9}$/L)	10.80	9.80	11.10	10.40	0.155	0.931	0.470
Heterophils (%)	31.00	33.00	35.00	33.00	0.606	0.124	0.089
Lymphocytes (%)	63.00	63.00	62.00	66.00	0.730	0.221	0.174
Eosinophils (%)	2.00	2.00	0.00	1.00	0.214	-	-
Basophils (%)	1.00	1.00	2.00	0.00	0.183	-	-
Monocytes (%)	3.00	1.00	1.00	0.00	0.281	-	-

[abc]Mean on the same row having different superscripts are significantly different (P<0.05). PCV= Packed cell volume, Hb = haemoglobin, RBC = Red blood cell, WBC = White blood cell, MCH = Mean Corpuscular Haemoglobin, MCHC = Mean Corpuscular Haemoglobin Concentration, SEM = Standard error of means, L= Linear, Q= Quadratic

Effect of organic acid blend supplementation on serum biochemistry of turkeys

Effect of organic acid blend supplementation on the serum biochemistry of turkeys is shown in Table 5. Starter turkeys fed diet supplemented with 4 g/kg organic acid blend had the highest (*P =0.000*) total serum protein, globulin, glucose concentration and the least serum total cholesterol, triglyceride, very low density lipoprotein (VLDL) and high density lipoprotein (HDL). Alkaline phosphatase (ALP) reduced (*P =0.000*) linearly and quadratically with increasing organic acid blend inclusion from 0 g/kg to 4 g/kg. The least serum creatinine (*P =0.000*) and aspartate amino transferase (AST) (L. *P =0.000*; Q. *P =0.038*) was recorded with starter turkeys fed diet supplemented with 3 g/kg organic acid blend. Serum bicarbonate levels in starter turkey decreased linearly (*P =0.000*) with increasing organic acid blend inclusion from 0 g/kg to 4 g/kg.

At the grower phase, highest concentration of total serum protein (*P =0.010*), globulin (*P =0.000*) and AST level (*P =0.000*) were obtained with turkeys fed diet supplemented with 3 g/kg organic acid blend. The highest serum creatinine (*P =0.000*) and alanine amino transferase (ALT) (*P =0.002*) concentration were recorded with grower turkeys fed diet supplemented with 3 and 4 g/kg organic acid blend, while the least creatinine (*P =0.000*), uric acid (L.*P =0.003*; Q.*P =0.000*) and serum chloride (*P =0.000*) levels were recorded with the control group. The least serum ALP (L.*P =0.002*; Q.*P =0.004*) was recorded with grower turkeys fed diet containing 3 g/kg organic acid blend. The least (L. *P =0.002*) low density lipoprotein was recorded with turkeys fed diet supplemented with 4 g/kg organic acid blend.

Table 5: Effect of dietary organic acid blend supplementation on serum biochemistry of turkeys

¤	Organic acid levels						
treatments Parameters	0g/kg diet	2g/kg diet	3g/kg diet	4g/kg diet	SEM	P-*value* *L*	*Q*
Starter (8weeks)							
Total Serum Protein (g/dL)	5.65^{b}	5.10^{c}	5.30^{c}	6.18^{a}	0.111	0.000	0.000
Serum Albumin (g/dL)	3.30^{a}	2.68^{c}	2.90^{b}	3.20^{a}	0.067	0.729	0.000
Serum Globulin (g/dL)	2.50^{b}	2.40^{bc}	2.35^{c}	2.98^{a}	0.066	0.000	0.000
Glucose (mg/dL)	148.75^{d}	160.00^{c}	167.75^{b}	231.50^{a}	8.315	0.000	0.000
Creatinine (mg/dL)	0.50^{c}	0.80^{a}	0.00^{d}	0.70^{b}	0.080	0.000	0.000
AST (U/L)	88.00^{b}	93.00^{a}	68.75^{d}	72.00^{c}	2.660	0.000	0.038
ALT (U/L)	18.00^{b}	19.75^{a}	18.75^{ab}	20.00^{a}	0.272	0.015	0.539
Uric acid (mg/dL)	13.60^{a}	7.61^{c}	8.90^{b}	5.13^{d}	0.806	0.000	0.003
ALP (U/L)	37.00^{a}	28.88^{b}	22.50^{c}	20.13^{d}	1.702	0.000	0.000
Ca (mg/dL)	10.63^{d}	14.04^{b}	15.99^{a}	12.53^{c}	0.540	0.001	0.000
K (mEq/L)	5.10^{a}	3.90^{c}	3.68^{c}	4.65^{b}	0.160	0.030	0.000
Na (mEq/L)	120.62	119.58	121.20	120.60	0.314	0.577	0.727
Cl (mEq/L)	106.75^{b}	136.50^{a}	103.50^{c}	134.50^{a}	3.950	0.000	0.392
CO_3 (mg/dL)	17.80^{a}	15.70^{b}	13.70^{c}	12.13^{d}	0.571	0.000	0.511
T Chol (mg/dL)	109.40^{c}	118.65^{a}	111.43^{b}	98.35^{d}	1.883	0.000	0.000
TRIG (mg/dL)	107.00^{a}	61.30^{c}	64.30^{b}	50.10^{d}	5.590	0.000	0.000
HDL (mg/dL)	56.40^{c}	71.80^{a}	62.50^{b}	50.60^{d}	2.057	0.000	0.000
VLDL (mg/dL)	21.38^{a}	12.35^{b}	12.90^{b}	10.00^{c}	1.117	0.000	0.000
LDL (mg/dL)	32.10^{d}	34.20^{c}	36.00^{b}	37.70^{a}	0.580	0.000	0.687
Grower (12 weeks)							
Total Protein (g/dL)	5.10^{c}	5.40^{bc}	6.30^{a}	5.90^{b}	0.160	0.010	0.170
Albumin (g/dL)	3.18	3.80	3.20	3.30	0.086	0.694	0.057
Globulin (g/dL)	1.90^{c}	1.60^{c}	3.20^{a}	2.60^{b}	0.175	0.000	0.353
Glucose (mg/dL)	155.00	124.00	180.00	155.00	5.486	0.163	0.618
Creatinine (mg/dL)	0.45^{c}	1.69^{b}	1.93^{a}	1.92^{a}	0.161	0.000	0.000
AST (U/L)	66.00^{c}	53.00^{d}	82.00^{a}	76.00^{b}	2.963	0.000	0.093
ALT (U/L)	17.00^{b}	21.00^{ab}	24.00^{a}	25.00^{a}	1.063	0.002	0.354
Uric acid (mg/dL)	20.00^{c}	33.40^{a}	31.60^{ab}	28.60^{b}	1.482	0.003	0.000
ALP (U/L)	27.00^{a}	26.00^{a}	15.00^{b}	23.00^{a}	1.346	0.002	0.004
Ca (mg/dL)	15.80	16.20	17.00	15.50	0.341	0.975	0.193
K (mEq/L)	6.80^{a}	6.50^{ab}	5.00^{c}	6.10^{b}	0.199	0.002	0.006
Na (mEq/L)	131.90^{a}	134.33^{a}	113.70^{c}	125.30^{b}	2.195	0.000	0.018
Cl (mEq/L)	87.20^{d}	105.05^{c}	123.30^{b}	169.40^{a}	7.972	0.000	0.000
CO_3 (mg/dL)	14.70^{b}	14.72^{ab}	14.17^{b}	15.95^{a}	0.279	0.038	0.206
T Chol (mg/dL)	92.00^{b}	90.00^{bc}	85.00^{c}	102.00^{a}	1.852	0.021	0.001
TRIG (mg/dL)	61.30^{c}	91.70^{a}	83.60^{b}	90.80^{a}	3.221	0.000	0.000
HDL (mg/dL)	51.00^{b}	44.40^{c}	41.80^{c}	60.60^{a}	2.028	0.005	0.000
VLDL (mg/dL)	12.30^{b}	18.30^{a}	16.70^{a}	18.20^{a}	0.716	0.001	0.012
LDL (mg/dL)	28.70^{a}	27.50^{a}	26.50^{a}	23.20^{b}	0.691	0.002	0.312

[abcd]Mean on the same row having different superscripts are significantly different (P<0.05).

AST = Aspartate amino transferase, ALT = Alanine amino transferase, ALP = Alkaline phosphatase, Ca = Calcium, K = Potassium, Na = Sodium, Cl = Chlorine, CO_3 Carbonate, T Chol = Total cholesterol, TRIG = Triglycerides, HDL = High density lipoprotein, VLDL = Very low-density lipoprotein, LDL = Low density lipoprotein, SEM= Standard error of means, L= Linear, Q= Quadratic

Discussion

The linear improvement in final live weight, weight gain and feed conversion ratio of starting turkeys observed in the current study as organic acid inclusion increased from 0 g/kg to 3 g/kg agreed with the findings of Kemal *et al.* (2003) who reported that the addition of organic acid to starter turkeys ration improved weight gain. Celik *et al.* (2003) also recorded improved feed conversion ratio in turkey poults fed diet supplemented with organic acid blend (containing propionic acid, formic acid, acetic acid) when compared with unsupplemented group. The positive effect of organic acid blend on growth performance observed in the current study with young turkeys could be attributed to a decrease in gut pH initiated by the various organic acids which could lead to increased proteolytic enzyme activity, protein digestibility, as well as bacteriostatic and bactericidal action against pathogenic bacteria (Papatisiros *et al.,* 2013).

The improvement in weight gain and feed intake following dietary supplementation with organic acid blend at the grower phase in this present study agreed with earlier studies with broilers that organic acid inclusion improves the body weight (Chen *et al.,* 2013). Saddeiy (2013) also observed a significant improvement in feed consumption of broilers fed diet supplemented with different levels of organic acid. The overall growth performance (4-12 weeks) showed improved final live weight, weight gain, feed intake and feed conversion ratio when turkeys are fed diet supplemented with 4 g/kg organic acid blend. This study corroborated the findings of Ragaa *et al.* (2016), who reported that feeding diet supplemented with formic acid at 5 g/kg significantly increased the body weight gain and improve feed conversion ratio. Propionic acid increases feed intake by improving palatability of feed and may increase permeability of mucosal cell of the intestine which increases the rate of utilization of nutrients and results in better feed conversion, but higher level also reduces feed intake (Cave, 1984). Series of studies with poultry bird indicated that organic acids in their undissociated forms are able to pass through the cell membrane of bacteria and once inside the cell, the acid dissociates to produce H^+ ions which lowers the pH of the cell causing the organism to use its energy in restoring normal balance (Papatisiros *et al.,* 2013). This result is in line with the findings of Milbradt *et al.* (2017) who reported a non-significant effect on the feed conversion ratio of growing turkeys fed diet .supplemented with organic acid.

The improved dry matter and fat digestibility obtained for starter turkeys fed with 3 g/kg organic acid was similar with the trend recorded for growth performance indices at 3 g/kg supplemental level. Ao *et al.* (2009) reported that dietary supplementation of broiler diet with 2% citric acid increased the retention of dry matter. The ability of organic acid to improve dry matter digestibility could be linked to improvement in the fibre digestibility as poor fibre utilization has been reported to cause watery faeces in broilers (Oluyemi and Robert 2000; Choct, 2009). According to Van Der sluis (2002), the positive effect of organic acid on digestion was related to slower passage of feed in the intestinal tract, better absorption of the necessary nutrients and less wet droppings. Organic acid inclusion improved the apparent dry matter, crude fiber, ether extract and ash digestibility notwithstanding the level of inclusion at the grower phase. Organic acids are known to alter pancreatic secretion and acidify intestinal digesta leading to a reduction in the gut pH (Leeson *et al.,* 2005). Organic acid raises gastric proteolysis and therefore improve the digestibility of protein and

amino acid because it lowers the pH of the chyme and thus enhances the digestibility of protein (Samanta *et al.,* 2010).
Results of haematological indices at the starter phase showed that feeding of diets supplemented with organic acid affected influenced the red blood cells, packed cell volume, haemoglobin, white blood cells, lymphocytes and eosinophil. Improvement in packed cell volume and red blood cell following organic acid inclusion implied that organic acid inclusion improved a better transportation of oxygen and absorbed nutrients. Packed cell volume (PCV) which is defined as the percentage of red blood cells in blood (Purves *et al.,* 2003) is largely involved in the transport of oxygen and absorbed nutrients This is in disagreement with Ndelekwute *et al.* (2016) who recorded that haematological parameter were not affected by feeding organic acid treated diets to broiler chicken.

Significant increase in white blood cell and lymphocytes concentration observed for starting turkeys following dietary supplementation with 3 g/kg organic acid inclusion suggested immune stimulatory effects following organic acid inclusion. Ali *et al.* (2017) also reported a significant increase in the lymphocyte and white blood cell count of broiler chickens fed diet supplemented with organic acids which was attributed to improved immune system. The elevated lymphocytes as organic acid inclusion level increase could be a physiological adjustment against negative antigenic effects associated with the diet.

The current study revealed increase in total serum protein and globulin with increasing dietary supplementation levels of organic acid. This suggested that organic acid inclusion improved utilisation of dietary protein. This corroborated the result of Ghazalah *et al.* (2011) who reported that addition of formic acid resulted in increased total serum protein and globulin content when compared with control group. Glucose level in starter turkeys increased while alkaline phosphatase (ALP) decreased as the dietary inclusion with organic acid increased. Reduction in liver enzymes such as ALP concentration suggested improved liver functioning and the absence of liver damage. Hatice *et al.* (2013) reported an increased glucose level in laying hens fed diet supplemented with organic acid mixture which supported the trend noticed in the present study. Fushimi *et al.* (2001) reported that rats fed diet supplemented with acetic acids at different levels had significantly higher serum glucose concentrations. Dietary acidification might stimulate glycogenesis by increasing the influx of glucose 6-phosphate (G-6-P) into the glycogen synthesis pathway through the inhibition of glycolysis caused by an increase in citrate levels (Fushimi *et al.,* 2001).

Increase in serum calcium concentration observed with organic acid supplementation in starter turkeys could be attributed to a decreased pH in the gastrointestinal tract caused by feeding organic acid, which might increase the absorption of calcium from the gut into the bloodstream. Brenes *et al.* (2003) reported that addition of 20 g/kg citric acid into broiler diets also increased blood calcium and phosphorus and their retention by 3.3 while Swiatkiewicz and Arczewska-wlosek (2012) stated that several studies with rat have shown that reducing the gut pH increases the activity of digestive enzymes and the solubility of minerals. Therefore, organic acid may have a positive effect on mineral absorption, primarily calcium. Serum uric acid in this study at the starter phase fell within the normal range (3-17 mg/dL) as recorded by Bounous *et al.* (2000)**.** This result could be implicative of effective utilization of protein and amino acid with improvement in their digestibility. Contrary to the result obtained at the starter phase, grower turkeys fed diet supplemented with organic acid recorded a higher serum uric acid beyond the normal range (3-17 mg/dL) as recorded by Bounous *et al.* (2000) and this may be as a result of difference in the breed of turkeys used or higher protein digestibility. The reduction in blood cholesterol observed at the starter phase could be attributed to the organic mixture added to the diet which produce lactic acid and conjugated bile acids. The differences between the present study and those of other studies may be due to differences in the type or level of organic acid used and to the types of animals been studied.

In conclusion, supplementation with organic acid blend in the present study significantly improve the overall growth performance, dry matter, crude protein, crude fiber and ether extract digestibility. Dietary supplementation with 3g/kg organic acid blend improve the final live weight, weight gain, feed conversion ratio, dry matter, fat digestibility and suggested immune stimulatory effects in starting turkeys. Meanwhile at the grower phase, dietary supplementation with 4 g/kg organic acid blend showed improved growth performance, apparent nutrient digestibility and serum chemistry.

Authors contribution: In the present manuscript, Orbugh Adebukola Taiwo was responsible for the provision, integration, and writing of the article, Oso Abimbola Oladele, was responsible for experimental conception, layout, design and overall project supervision, Lala Adebukunola O, co-supervised the research work and corrected the manuscript, Sogunle O. M, co-supervised the work, Ogunleye Johnson Bukola and Emmanuel Adeyeye assisted in data collection and manuscript editing while Durojaiye Olufemi James assisted in data analysis. All authors read and approved the final version of this article.

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