



Dietary effects of different organic acids on growth and nutrient digestibility of broiler

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Abstract

An experiment was conducted to determine the effect of organic acids (acetic, butyric, citric and formic acids) on growth and nutrient digestibility of broilers. One hundred fifty (150) day old Hubbard chicks were used. There were five dietary treatments such viz Diet 1 as control contained no organic acid, diets 2, 3, 4, and 5 contained 0.25% acetic, butyric, citric and formic acids, respectively. Each treatment was replicated three times having 10 birds arranged in completely randomized design (CRD). Feed and water were given *ad libitum*. Feeding of organic acid diets lasted for 7 weeks starting from the second week. At the starter phase, formic acid improved live weight. Feed and water intakes were significantly ($P < 0.05$) reduced by butyric acid. Feed: gain ratio was improved by formic acid. At the finisher phase, live weight was significantly ($P < 0.05$) improved by the acids except butyric acid. Feed intake, daily gain and feed: gain ratio were not significant ($P > 0.05$). Crude protein and ether extracts digestibility were improved by all the organic acids ($P < 0.05$). It is therefore concluded that 0.25% formic acid could be added to broiler diets.

Key words: broilers, growth, nutrient digestibility, organic acids

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Bang. J. Anim. Sci. 2016. 45 (2): 10-17

Introduction

Recent concerns about antibiotics resistance in livestock industry indicate the need for alternative strategies to improve animal performance and health without the use of antibiotics. To this end some dietary products have been used to replace antibiotics in poultry diets. The products include; probiotics like yeast culture, prebiotic, essential oils, spices and organic acids (Cave, 1978; Chudhury, 2002; Patterson and Burkholder, 2003; Lesson *et al.*, 2005; Windisch *et al.*, 2008; Gao *et al.*, 2008). Organic acids have been used for decades in feed preservation, protecting feed from bacterial and fungal destruction (Canibe *et al.*, 2008). Evidence of the potentials of organic acids to support growth of broilers abounds (Waldroup *et al.*, 1995; Ndelekwute *et al.*, 2015). Growth promoting effect of organic acids is due to their antibacterial and antifungal effect and stimulation of villi growth (Lesson *et al.*, 2005). In Nigeria and other developing countries, poultry production is improving and the demand for its meat and eggs is ever increasing.

Increasing demand for poultry meat has been attributed in part to meat consumers' desire to eat meat with lesser level of cholesterol in preference to red meat such as beef which contains higher cholesterol than poultry meat (Ndelekwute *et al.*, 2008). With the increasing demand not only in Nigeria, but world over, animal nutritionists are faced with the task of producing feeds that could give heavier broiler chickens in good time. To this end, certain nutritional strategies have been adopted to achieve this, such as addition of feed additives to the feed to promote growth of monogastric animals (Partenen and Mroz, 1999). Such feed additives also regarded as growth promoters or enhancers are antibiotics (Dibner, 2004) and hormones (Maynard *et al.*, 1981). Treatment feeds and feedstuffs against microbial entity is necessary because it had been reported that feeds and feedstuffs were contaminated by bacteria and fungi (Gathumbi *et al.*, 1996).

Organic acids comprise of any organic carboxylic acid with the general formula R-COOH such as acetic acid, butyric acid, citric acid, propionic acid, lactic acid and formic acid butyric, citric and formic acids) to improve growth and nutrient

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digestibility of broilers (Dibner,2004). The objective of this study was to evaluate the efficacy of four organic acids (acetic, (acetic, butyric, citric and formic acids) to improve growth and nutrient digestibility of broilers.

Materials and Methods

Site of the experiment

The experiment was conducted at the Teaching and Research Farm of the Department of Nutrition and Forage Science of the Michael Okpara University of Agriculture Umudike, Abia State, Nigeria. The average relative humidity during the experiment was over 72% and average ambient temperature of 28°C.

Experimental design

Completely randomized design (CRD) was followed for the experiment. One hundred fifty (150) day old chicks of Hubbard strains were used. These were divided into five treatments and replicated three times. Each replicate had 10 birds. T1 received no organic acid in the diet, T2 = acetic acid, T3 = butyric acid, T4 = citric acid, and T5 = formic acid. Each organic acid was added at 0.25% of the diets (Tables 1 and 2). The birds were stabilized in the brooding room for one week during which the control diet was feed to all the birds. At the end of the first week, the birds were allotted to the five treatment groups and fed organic acid diets for three weeks for starter phase and four weeks for the finisher phase.

Table 1.Ingredients and nutrients composition of starter diets

Ingredients (%)	Control	Acetic acid	Butyric acid	Citric acid	Formic acid
Maize	55.0	55.0	55.0	55.0	55.0
Soybean mael	28.0	28.0	28.0	28.0	28.0
Fish meal	3.00	3.00	3.00	3.00	3.00
Palm kernel cake	10.3	10.05	10.05	10.05	10.05
Bone meal	3.0	3.0	3.0	3.0	3.0
Organic acid	-	0.25	0.25	0.25	0.25
Salt (NaCl)	0.25	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10	0.10
*Premix	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated nutrients (%)					
Crude protein	21.41	21.40	21.40	21.40	21.40
Energy (MJME/kg)	11.85	11.84	11.84	11.84	11.84
Ether extract	3.62	3.62	3.62	3.62	3.62
Crude fibre	4.38	4.36	4.36	4.36	4.36
Ash	6.54	6.54	6.54	6.54	6.54
Calcium	1.11	1.11	1.11	1.11	1.11
Phosphorous	0.86	0.84	0.84	0.84	0.84
Lysine	1.12	1.11	1.11	1.11	1.11
Methionine	0.55	0.54	0.54	0.54	0.54

* premix supplied per kg starter diet: vitamin A 15,000 I.U, vitamin D₃ 13000 iu, thiamin 2mg, Riboflavin 6mg, pyridoxine 4mg, Niacin 40mg, cobalamine 0.05g, Biotin 0.08mg, chooline chloride 0.05g, Manganese 0.096g, Zinc 0.06g, Iron 0.024g, Copper 0.006g, Iodine 0.014g, Selenium 0.24mg, Cobalt 0.024mg and Antioxidant 0.125g.

Management of birds

The birds were kept for one week in the brooding room. Heat was supplied by kerosene stove placed under a hover. At the end of the one week stabilization period the birds were transferred to

a deep litter rearing house having wood shavings as bedding materials. A portion of the house where the birds were placed was covered with water proof material. They were randomly separated into the five treatment groups and weighed. Brooding continued to the third week of

age. Feeding of acidified diets started at the second week. The birds were vaccinated against Newcastle disease and infectious bursal

(Gumboro) disease. Feed and water were supplied *ad libitum*.

Table: 2. Ingredients and nutrients composition of finisher diets

Ingredients (%)	Control	Acetic acid	Butyric acid	Citric acid	Formic acid
Maize	55.00	55.00	55.00	55.00	55.00
Soya bean meal	25.00	25.00	25.00	25.00	25.00
Fish meal	2.00	2.00	2.00	2.00	2.00
Palm kernel cake	14.30	14.05	14.05	14.05	14.05
Bone meal	3.00	3.00	3.00	3.00	3.00
Organic acid	-	0.25	0.25	0.25	0.25
Salt (NaCl)	0.25	0.25	0.25	0.25	0.25
Lysine	0.10	0.10	0.10	0.10	0.10
Methionine	0.10	0.10	0.10	0.10	0.10
*Premix	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Calculated (%)					
Crude protein	19.85	19.84	19.84	19.84	19.84
Energy (MJME/kg)	12.05	12.00	12.00	12.00	12.00
Ether extract	5.40	5.42	5.42	5.42	5.42
Crude fibre	5.60	5.58	5.58	5.58	5.58
Ash	6.30	6.31	6.31	6.31	6.31
Calcium	1.09	1.10	1.10	1.10	1.10
Phosphorous	0.80	0.72	0.72	0.72	0.72
Lysine	1.02	1.00	1.00	1.00	1.00
Methionine	0.45	0.44	0.44	0.44	0.44

*premix supplied per kg finisher diet: vitamin 10, 0001.u., vitamin D₃ 12,0001.u. Vitamin E 201.U., Vitamin K2.5mg, thiamine 2.0mg, Riboflavin 3.0mg, pyridoxine 4.0mg, Niacin 20mg, cobalamin 0.05mg, panthemic acid 5.0mg, Folic acid 0.5mg, Biotin 0.08mg, choline chloride 0.2mg, Manganese 0.006g, Zinc 0.03g, Copper 0.006g, Iodine 0.0014g, Selenium 0.24g, cobalt 0.25g and antioxidant 0.125g

Data collection and digestibility trial

Data were collected on feed intake, water intake and body weight. Feed intake and live body weight were used to calculate the feed: gain ratio. The total collection method was used to conduct the digestibility trial in metabolism cages. The metabolism room and cages were thoroughly washed and disinfected. At the end of the feeding experiment, one bird from each of the three replicates of a dietary group giving a total of 15 birds were randomly assigned to a metabolism cage. The weight of each bird used was similar to forestall the effect of weight on digestibility. The birds were acclimatized with *ad libitum* feeding for four days before fecal collection was carried out. At the end of the acclimatization period, a known quantity of feed was given daily to each bird. To minimize feed wastages, feeding was done in the morning by 8.00hrs; in the afternoon by 1.00hrs and in the evening by 6.00hrs making sure the birds did not

lack feed at any point in time. Each morning before feeding commenced, leftover feed was recorded and feed intake noted.

Feces were collected and weighed for five days. Collected feces were immediately taken to the laboratory where they were oven dried at 60°C to a constant weight. Dry fecal samples were ground to pass through 1mm sieve. The five days fecal collection was pooled and thoroughly mixed together. A portion was taken, stored in a refrigerator from which proximate analysis was carried out according to AOAC (1990). Results of the proximate analysis were used to calculate the apparent nutrient digestibility was calculated as thus; Nutrient digestibility (%) =

$$\frac{\text{Nutrient in feed} - \text{nutrient in feces}}{\text{Nutrient in feed}} \times 100$$

Statistical analysis

At the end of the experiment, data collected were subjected to analysis of variance (ANOVA). Significant means were separated using Duncan New Multiple Range Test (DNMRT) according to (Steel and Torrie, 1980).

Results

Growth Performance

Table 3 shows the effect of organic acids on performance of starter broilers. Initial body weight (weight after one week of stabilization in the brooding room) was not significant ($P>0.05$) During the starter phase, organic acid treated diets significantly ($P<0.05$) influenced the live weight. Formic acid diet produced the heaviest live weight compared to other diets except citric acid diet. Butyric acid treated diet produced the least live weight. Formic acid diet posted significantly ($P<0.05$) better daily gain than the control and butyric acid, but similar to those of

citric and acetic acids. Butyric acid group significantly ($P<0.05$) posted the least daily gain.

Daily feed intake was significantly better in birds fed the control diet and other organic acids compared to butyric acid. Birds that consumed formic acid diet significantly ($P<0.05$) produced the best feed: gain ratio. Broilers on other organic acids produced feed: gain ratios that were similar ($P>0.05$) to the control. Protein intake was significantly influenced ($P<0.05$). Protein intake of butyric acid fed-birds was significantly less than those on citric and formic acids but similar ($P>0.05$) to those on control and acetic acid diets. The result of the effect of organic acids on water intake indicated that the impact was significant ($P<0.05$). Birds fed citric acid diet consumed more water than any other group followed by formic acid. There was no significant difference between the water intake of acetic acid group and that of the control. Butyric acid reduced ($P<0.05$) water intake.

Table 3. Effects of organic acids on starter broiler chicks

Ingredients (%)	Control	Acetic acid	Butyric acid	Citric acid	Formic acid	SEM
Parameters						
Initial live weight (g)	72.00	76.00	77.00	74.00	74.67	1.11
Final live weight (g)	560.00 ^b	580.00 ^b	500.00 ^c	598.33 ^{ab}	637.00 ^a	12.11
Daily weight gain (g)	23.23 ^b	24.00 ^{ab}	20.14 ^c	24.97 ^{ab}	26.78 ^a	2.11
Daily feed intake (g)	53.90 ^a	55.25 ^a	48.70 ^b	58.49 ^a	56.11 ^a	3.53
Feed: gain ratio	2.32 ^a	2.30 ^a	2.42 ^a	2.34 ^a	2.10 ^b	0.01
Daily protein intake (g)	11.54 ^{ab}	11.83 ^{ab}	10.43 ^b	12.52 ^a	12.01 ^a	1.22
Protein efficiency ratio	2.01 ^b	2.03 ^b	1.93 ^b	1.99 ^b	2.23 ^a	0.10
Daily water intake (ml)	71.97 ^b	75.60 ^b	65.27 ^c	85.87 ^a	80.54 ^a	4.77
Water: feed ratio	1.34 ^c	1.37 ^b	1.34 ^c	1.47 ^a	1.44 ^{ab}	0.09

*Superscripts a, b, c, d mean along the same row with different superscripts are significantly ($p < 0.05$) different. SEM, Standard error means.

Table 4 shows the growth performance of broiler finisher chickens as affected by diets. Response of the birds to diets with organic acids was significantly different ($P<0.05$) in some of the parameters measured except daily gain, feed: gain ratio, protein intake and protein efficiency ratio were similar ($P>0.05$). All the birds on organic acid diets except butyric acid posted better final live weight compared to control. The final live weight of formic acid dietary group was similar to those of citric and acetic acids. The result also indicated clearly that citric and acetic acid dietary groups showed improvement over

the control in terms of final live weight judging from the result of the starter phase. There was no significant difference in the same parameter at the starter phase between acetic acid, citric acid and the control. However, at the end of the finisher phase both acetic and citric acids were significantly ($P<0.05$) superior. Weight gain of broilers fed butyric acid diets was improved over the control diet. This is because judging from the result of the starter phase, weight gain of butyric acid was significantly inferior to that of the control, but was no longer inferior at the finisher phase.

Table 4. Effects of organic acids on finisher broiler chicken

Organic acids	Control	Acetic acid	Butyric acid	Citric acid	Formic acid	SEM
Parameters						
Initial live weight (g)	560.00 ^b	580.00 ^b	500.00 ^c	598.33 ^{ab}	637.00 ^a	12.11
Final live weight (g)	1705.33 ^b	1775.00 ^a	1589.67 ^c	1789.00 ^a	1831.33 ^a	27.80
Daily weight gain (g)	40.90	42.68	38.92	42.81	42.83	3.45
Daily feed intake (g)	109.15 ^{ab}	115.17 ^{ab}	106.17 ^b	118.62 ^a	116.71 ^a	10.26
Feed: gain ratio	2.67	2.70	2.73	2.77	2.72	0.15
Daily protein intake(g)	21.67	22.86	21.07	23.55	23.17	1.66
Protein efficiency ratio	1.89	1.87	1.85	1.82	1.85	0.08
Daily water intake(ml)	163.90 ^b	192.88 ^{ab}	168.86 ^b	200.36 ^a	208.19 ^a	13.74
Water: feed ratio	1.50 ^b	1.67 ^a	1.59 ^b	1.69 ^a	1.78 ^a	0.06

*Superscripts a, b, c, d mean along the same row with different superscripts are significantly ($p < 0.05$) different. SEM, Standard error means.

Daily gain was the same ($P > 0.05$). However, formic, citric and acetic acid groups marginally showed some level of superiority over the control and butyric acid. Citric and formic acid diets significantly ($P < 0.05$) produced higher daily feed intake than butyric acid diet. Daily feed intake of the control was similar to all the organic acids. It was observed that feed consumption of broilers fed butyric acid diet was improved at this phase. Citric and formic acid diets significantly ($P < 0.05$) improved daily water consumption over control and butyric acid diets. However, daily water intake for acetic acid was similar to control, butyric, citric and formic acids. The quantity of water consumed per gram of feed (water: feed ratio) was higher in birds fed formic, citric and acetic acid diets compared to control and butyric acid diets. It was the same in control and butyric acid.

Nutrient digestibility

Table 5 shows the apparent nutrient digestibility of broilers as affected by diets. Nutrient digestibility were significantly ($P < 0.05$) influenced. Except for the dry matter, organic acids significantly improved digestibility of all the nutrients considered. In comparison to the control, protein was better digested by citric and formic acids; fibre by butyric and formic acids; ether extract by all the acids; ash by butyric, citric, and formic acids. Digestibility of nitrogen free extract was better in citric and formic acids. Energy utilization was significantly higher in all the organic acid groups.

Discussion

The improved growth of birds fed acetic acid, citric acid, formic acid, over those on control diet could be attributable to reported inhibitory and lethal effect of organic acids on pathogenic microflora and their contributions to digestion and absorption of nutrients in the gut. Many authors have reported antimicrobial actions of organic acids (Alshawabkeh *et al.*, 2002; Sun, 2004; Paul *et al.*, 2007), their ability to reduce the gut pH (Dibner, 2004) and inducement of endogeneous secretions such as bile and pancreatic enzymes (Thaela, 1998). These are key indicators for adequate nutrient digestion and utilization. Early feeding of organic acids in bird's life improves protein digestion, reduces colonization of the gut by *E. coli*, *Salmonella*, and *Campylobacter* which could cause thickening of the intestinal wall, reduction of villi height, number of villi, increase in crypt depth and promotion of fermentation in the foregut which hampers nutrient utilization (Debevere, 1987; Waldroup *et al.*, 1995; Dibner, 2004; Canibe *et al.*, 2008; Windisch *et al.*, 2008). Therefore, any strategy which could increase the amount of acid in the *proventriculus* would improve protein digestion as the results on digestibility had shown. Improvement of growth performance of acetic, butyric and citric acids over the control at the finisher phase showed crossover (carryover) effect of the organic acids. It implies that feeding of such organic acids for a long period could improve their performance.

Table 5. Effects of organic acids on nutrient digestibility of broiler chicken

Parameters (%)	Control	Acetic acid	Butyric acid	Citric acid	Formic acid	SEM
Dry matter	66.44	64.46	68.56	68.34	68.34	1.01
Crude protein	62.87 ^c	63.21 ^c	66.04 ^{bc}	68.96 ^{ab}	70.98 ^a	3.21
Crude fibre	31.82 ^b	36.60 ^{ab}	39.33 ^a	37.14 ^{ab}	39.84 ^a	2.12
Ether extract	60.76 ^b	72.12 ^a	75.92 ^a	75.96 ^a	77.98 ^a	5.41
Crude ash	54.81 ^b	54.82 ^b	59.80 ^a	59.32 ^a	59.85 ^a	2.8
Nitrogen free extract	65.00 ^b	66.46 ^b	66.61 ^b	71.56 ^a	69.99 ^a	2.32
Energy utilization	62.00 ^b	68.86 ^a	67.40 ^a	69.10 ^a	68.25 ^a	3.9

*Superscripts a, b, c, d mean along the same row with different superscripts are significantly ($p < 0.05$) different. SEM, Standard error means.

Hence prolonged feeding of organic acids could be advocated. Reduced feed intake induced by butyric acid could be due to its foul odour (the butyric acid treated feed smelled like liquid of fermented cassava). This could have been repulsive to adversely affect feed intake and consequently other performance indices. It has been stated that the required daily feed intake of birds must be met before optimum growth could be achieved (Oluyemi and Roberts, 2000). Feed intake below daily requirement could lead to shortfall in the daily requirement of nutrients and such birds perform poorly (Obioha, 1995)).

The feed and gain ratio of butyric acid that was similar to the control and other organic acids except formic acid, is an indication that its live weight may not be due to metabolic or physiological impairment but due to reduced feed intake. The ability of formic acid-fed birds to gain more weight per unit protein consumed, further shows the superiority of the acid as a growth promoter. Also better protein efficiency ratio of butyric acid compare to control, acetic and citric acids further explains that it may not have impaired the metabolic processes to produce the least body weight, but rather its daily feed intake may not have supplied the required quantity of nutrients for growth. This work corroborates earlier report (Skinner *et al.*, 1991). In contrast, Paul *et al.* (2007) did not observe significant improvement. The disagreement of Paul *et al.* (2007) could be due to the fact that they conducted their experiment in cages. Organic acids are more effective in more contaminated environment as in deep litter house (Paul *et al.*,

2007) under which this experiment was conducted.

The relationship between water and feed intake was in consonant with the fact that quantity of water taken by birds has a direct relationship with the feed intake (Oluyemi and Roberts, 2000). This was clearly observed in water: feed ratio where citric and formic acids which consumed higher quantity of feed had the highest water: feed ratios.

Apparent nutrient digestibility

The current observations on digestibility of protein and ether extract could be attributed to earlier report (Dibner, 2004) that organic acids induced endogenous secretions such as protease and bile which are essential for nutrient utilization. The ability of the organic acids to reduce bacteria population in the gut has been reported (Canibe *et al.*, 2008) and could have led to the better nutrient digestibility. In this regard, production of gases (such as ammonia, amines through fermentation caused by gram negative pathogenic bacteria), gut colonization and thickening of the intestinal wall which would have reduced digestibility and absorption of nutrients could have been inhibited (McHan, 1992; Thaela, 1998)). This result could be linked to the better performance in live weight observed of birds fed organic acid diets (except butyric acid). This result is in agreement with Kemme (1998) except in dry matter where he reported improved dry matter digestibility contrary to what was obtained in the present study. However, Hernandez *et al.* (2006) did not observe any significant differences

Conclusion

Addition of organic acids especially formic acid in diets for broilers showed improvement in live weight at both the starter and finisher phases. Digestibility of nutrients was also improved. Therefore, addition of formic acid to broiler diets could be recommended.

Acknowledgement

The authors are grateful to the University of Uyo, Nigeria and the Tertiary Education Trust Fund (TETFUND), Nigeria for sponsoring this research. We are also grateful to Nekel Livestock Consultants, a Division of Nekel Agriculture Services, Uli, Anambra State, Nigeria for their technical support.

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