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Supplementation of organic acid blends in water improves growth, meat yield, dressing parameters and bone development of broilers

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Abstract

The present study was conducted in order to examine the effects of supplementing two liquid organic acid blends on growth performance, meat yield, dressing parameters, organ weights and bone development of broilers. A total of 120 broiler chicks were assigned to five dietary treatments in four replications with six birds per replication over a period of 5 weeks, following a completely randomized design. Dietary groups included; Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration. Results indicated that supplementation of organic acids improved (P<0.05) growth performance of broilers compared to the control. Among the supplemented groups, highest (P<0.05) body weight and body weight gain were in the AW-C group, followed by the N-C, AW-P, and N-P groups. Feed intake was higher (P<0.05) in the AW-C and N-C groups compared to the N-P and control groups. Feed conversion ratio was improved (P<0.05) in the organic acid groups, and the AW-C group showed the best value. Dressing yield as well as thigh and drumstick meat relative weights were higher (P<0.05) in the organic acid groups compared to control, whereas breast meat increased (P<0.05) in the AW-C group compared to the AW-P and control groups. Increased (P<0.05) relative weights of head and neck were observed in the AW-C group as well as that of gizzard in the N-C group compared to the other groups. On the other hand, abdominal fat content decreased (P<0.05) in the organic acid groups. Whole leg and wing bone relative weights increased (P<0.05) in the AW-C, AW-P, and N-C groups compared to the other groups. Further, longer (P<0.05) shank in the organic acid groups as well as longer drumstick bone length in the AW-C group were observed compared to the other groups. It was concluded based on the study results that supplementation of both organic acid blends improves growth performance, increases meat yield, organ development, dressing parameters and influences bone development of broilers. Therefore, as continuous addition of Activate showed better results compared to Nutrilac in terms of some tested parameters, it could be applied to broiler water to exert beneficial effects.

Key words: Organic acids, Growth performance, Meat yield, Bone development, Broiler

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Introduction

Considering the health hazards associated with antibiotic growth promoters and their addition to poultry diets, it is of great interest to investigate potential alternatives capable of maintaining growth performance and beneficial intestinal microbial populations. Among the candidate replacements for antibiotics are organic acids, both individual acids and blends of several acids (Gunal et al., 2006). Unlike antibiotics, the antimicrobial activity of organic acids is pH-dependent (Ozduven et al., 2009). Probable modes of action of organic acids include reduction of the digesta pH value in the gastrointestinal tract (Ravindran and Kornegay, 1993), regulation of the microbial population balance in the gut, stimulation of digestive enzyme secretion (Harada et al., 1988; Thaela et al., 1998), and promotion of growth and recovery of the intestinal morphology (Galfi and Bokori, 1990; Walsh et al., 2007). Organic acids have clear and significant benefits in weanling piglets (Li et al. 2008) and have been observed to benefit poultry performance (Haque et al., 2010; Chowdhury et al., 2009). Several studies have suggested that

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the addition of organic acids to broiler rations improved weight gain (Afsharmanesh and Pourreza, 2005; Haque et al., 2010), increase feed consumption (Moghadam et al., 2006), improve feed efficiency (Abdel-Fattah et al., 2008), and influence immune responses (Rahmani and Speer, 2005; Abdel-Fattah et al., 2008). In addition, organic acid supplementation increases retention of phosphorus (Brenes et al., 2003; Liem et al., 2008), tibia ash (Rafacz-Livingston et al., 2005; Martinez-Amezcua et al., 2006) and toe ash (Atapattu and Nelligaswatta, 2005) in broiler chicks.

Water quality management is very important for guaranteeing broiler performance. Contaminated drinking water is the most prominent risk factor for the spread of bacterial infection, such as *Campylobacter*, in broiler flocks (Chaveerach et al., 2004). Therefore, acidified drinking water could play a crucial role in terms of biosecurity in preventing the spread of pathogenic organisms via drinking water among broiler flocks (Kapperud et al., 1993; Pearson et al., 1993; Gibbens et al., 2001). In the broiler industry, different organic acids have been added to drinking water. For example, formic acid, acetic acid, and propionic acid have very high solubilities in water (Freitag, 2007). Desai et al. (2007) indicated that inclusion of a combination of formic acid and propionic acid in drinking water increases weight gain of broilers and improves the feed conversion ratio (FCR). In addition, Samanta et al. (2010) reported that organic acids improve gastric proteolysis as well as the digestibility of proteins and amino acids. Further, organic acids have antimicrobial effects due to their diffusion through the bacterial cell membrane and subsequent dissociation into anions and protons, which disturbs the electron balance inside the cell (Philipsen, 2006). Several studies have also reported that both dietary formic acid and propionic acid reduce the small intestinal, cecal, and fecal populations of *Salmonella* and *E. coli* in chickens (Izat et al., 1990; Al-Tarazi and Alshawabkeh, 2003). However, addition of acetic acid to drinking water has no effect on the performance or ileal microbial counts of chickens (Akbari et al., 2004.). In addition, Runho et al. (1997) indicated that dietary addition of fumaric acid does not affect body weight gain of broilers, although it does improve the FCR. Other studies have shown that supplementation of lactic acid or butyric acid to water or feed significantly reduces *Salmonella* colonization in crops or the intestine (Byrd et al., 2001; Cox et al., 1994). Laboratory trials have proven that formic acid, both individually and in combination with other organic acids, has greater bactericidal effects on *E. coli* and *Salmonella* (Liem, 2007; Stonerock, 2007). Recent studies (Haque et al., 2010; Chowdhury et al., 2009) reported that supplementation of dietary organic acids such as citric acid enhances growth performance of broiler chicks, increases bone ash deposition, and produces healthy broilers possessing a stronger immune response against enteric pathogens and infectious diseases.

Organic acids have been used for decades to preserve and protect feeds from microbial and fungal destruction or to increase the preservation of fermented feeds (Canibe, 2001; Giesen, 2005; Freitag, 2007). Acidification of drinking water is another implementation method commonly used in the broiler industry, but studies on its efficacy in broilers are limited. Based on previous observations, in our study, we applied two liquid organic acid blends to drinking water of broilers. The objectives were to determine the effects of organic acid supplementation to drinking water on growth performance, meat yield, dressing parameters, internal organ weights, and bone development of broilers.

Materials and Methods

Experimental designs, birds and diet

A total of 120 broiler chicks (Cobb 500) were assigned to five dietary treatments in four replications with six birds per replication over a period of 5 weeks, following a completely randomized design. Dietary groups included; Control = Without organic acids; AW-C = Activate-continuous: 1 mL/3L for one part of the day during the whole period; AW-P = Activate-periodic: 1 mL/3L during only the 2^{nd} and 4^{th} weeks; N-C = Nutrilac-continuous: 1.5 mL/1L for one part of the day during the whole period; N-P = Nutrilac-periodic: 1.5 mL/1L during only the 2^{nd} and 4^{th} weeks. Activate {liquid organic acid blend of Novus International Inc., St. Charles, MO; composed of propionic acid, formic acid, and 2-

hydroxy-4-methylthio-butanoic acid} and Nutrilac {liquid organic acid blend of Novartis (Bangladesh) Limited, Dhaka, Bangladesh; composed of lactic acid and formic acid} were collected from a local market. The dosage was selected according to the manufacturer's instructions. All birds received a starter diet from 0-3 weeks and a finisher diet from 4-5 weeks. All diets were formulated to meet the nutrient requirements of broiler chickens (NRC, 1994). Composition of ingredients and estimated nutrient contents of diets are shown in Table 1.

Broiler management

The bird shed and necessary equipments were properly cleaned, washed, dried, disinfected and subsequently left empty for 1week before the arrival of chicks. Fresh, cool and clean drinking water supplemented with water additive was supplied to experimental birds once every morning during the entire experimental period or during the 2nd and 4th weeks. Fresh, clean and dried rice husk was used as litter material at a depth of about 3 cm. The litter and housing area were disinfected with a safe and suitable disinfectant every other day. Care was taken to ensure proper ventilation as birds advanced in age and they were vaccinated against Gumboro and Newcastle diseases. Brooding temperature was maintained at 32°C at the beginning and then reduced gradually at a rate of 2.5°C per week until the birds had adjusted to the environmental temperature. Broilers were exposed daily to 23 hours of continuous light followed by a 1 hourdark period throughout the experimental period. Floor space given to each broiler was 960cm^2.Chicks were handled carefully to avoid any pain or injury. Birds were fed *ad libitum* and had free access to water throughout the whole study.

Table 1. Ingredients and chemical composition of diets

Item	Starter (0-3 weeks)	Finisher (4-5weeks)
Ingredients (%, as feed basis)		
Yellow corn	57.37	59.44
oybean meal	26.50	25.40
Rice polish	5.00	4.70
Soybean oil	2.00	2.20
Protein concentrate	5.50	5.00
Salt	0.25	0.25
Dicalcium phosphate	1.64	1.50
Limestone	0.92	0.88
Vit-Min. premix[1]	0.30	0.30
Choline chloride	0.08	0.07
L-lysine	0.24	0.16
Methionine	0.20	0.10
Total	100	100
Calculated chemical composition (% dry matter)		
Crude protein	22.50	21.00
Crude fat	4.00	4.50
Crude fiber	6.00	6.00
Methionine	0.79	0.70
Calcium	0.90	0.85
Available phosphorus	0.54	0.52
ME (kcal/kg)	3100	3150

Provided the following nutrients per kg of diet: vitamin A, 6000IU; vitamin D3, 800IU; vitamin E, 20IU; vitamin K3, 2mg; thiamin, 2mg; riboflavin, 4mg; vitamin B6, 2mg; vitamin B12, 1mg; pantothenic acid, 11mg; niacin, 10mg; biotin, 0.02mg; Cu, 21mg; Fe, 100mg; Zn, 60mg; Mn, 90mg; I, 1.0mg; Co, 0.3mg and Se, 0.3mg.

Growth performance measurement

To calculate body weight gain, body weights of broilers were measured every week from the initial day to the final day of the study. Feed intake of broilers was determined by offering a known quantity of feed and then weighing residues on a weekly basis. Feed conversion ratio (FCR) was calculated based on the ratio of the amount of feed consumed to body weight gain of broilers.

Measurement of dressing parameters, meat yield and bone development

At the end of the experimental period, two broilers with average pen weights from each replication were selected, slaughtered and dissected. Meat of dissected broiler was separated from carcasses following the procedure of Jones (1984). After complete bleeding, heads, legs, feathers, viscera and skin were removed in order to determine carcass weights. Meat (breast, thigh, drumstick and wing) and bone (whole leg, drumstick, thigh and wing) relative weights were determined by calculating the weight of each meat or bone with respect to body weight. Bone length of neck, shank, drumstick, thigh and wing were measured in centimeters (cm). Relative weights of dressing parameters (head, neck, blood, feather, skin and abdominal fat) and internal organ (liver, heart and gizzard) were also determined by calculating the weight of each parameter or organ with respect to body weight.

Statistical analysis

Data were analyzed by using the general linear models of SAS (2003) to estimate variance components with a completely randomized design. Duncan's multiple comparison tests were used to examine significant differences among the treatment means. The level of significance was set at P<0.05.

Results and Discussion

Growth performance

Supplementation of organic acids affected growth performance of broilers. Figure 1 showed that body weight increased (P<0.05) in the AW-C, N-C, and N-P groups by the 2nd week compared with the control group. Higher (P<0.05) body weight was observed in the AW-C group by the 3rd week as well as the AW-C and N-C groups by the 4th week compared to others. Final body weight was higher in the supplemented groups compared to the control group and the AW-C group showed the highest value (P<0.05). Body weight gain was higher (P<0.05) in the supplemented groups after 2 weeks. Throughout the total experimental period, the AW-C group showed the highest body weight gain compared to the control group, followed by those of the N-C, AW-P, and N-P groups (P<0.05). After 2 weeks, feed intake significantly increased among the treatment groups. Specifically, the AW-C and N-C groups consumed higher (P<0.05) amounts of feed compared to the control and N-P groups throughout the total experimental period. Additionally, the FCR was higher in the supplemented groups by the 4th and 5th weeks as well as throughout the total experimental period compared to the control group and the AW-C group showed the best value (P<0.05).

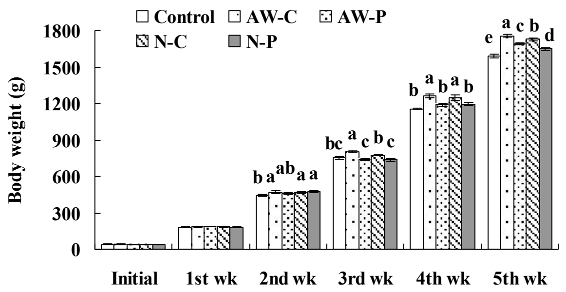

Figure 1. Effects of organic acids on body weight of broilers. Data are presented as the mean ± SE. Bars within a time class not sharing a common letter are significantly different (P<0.05). Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration

Meat yield

Meat yields of the different treatment groups are represented in Figure 2. Supplemented groups showed higher (P<0.05) thigh and drumstick meat yields compared to the control group. Breast meat yield was also higher (P<0.05) in the AW-C group compared to the control and AW-P groups, whereas, wing meat was not significantly (P>0.05) different among the groups.

Dressing parameters

Data concerning dressing parameters are presented in Table 3. Dressing yield was higher

(P<0.05) in the supplemented groups compared to the control group. Head and neck relative weights increased in the organic acid groups and the AW-C group exhibited the highest value (P<0.05). Abdominal fat content decreased in the treated groups, with the N-C group showing the lowest value. Heavier gizzard weight was also observed in the N-C group (P<0.05). Other parameters were not affected (P>0.05) among the groups.

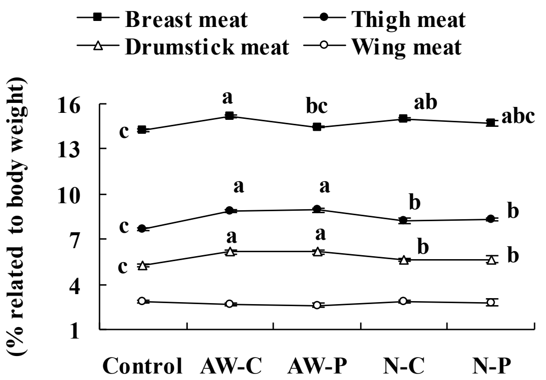

Figure 2. Effects of organic acids on meat yield of broilers (% related to body weight). Data are presented as the mean ± SE. Mean values of individual meat yields within treatments not sharing a common letter are significantly different (P<0.05). Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration.

Bone development

Bone development results of broilers among the different treatments are shown in Figure 3 and Table 4. Whole leg bone relative weight were higher (P<0.05) in the supplemented groups compared to the control group. Thigh bone relative weight increased (P<0.05) in the AW-C, AW-P and N-C groups compared to the control group. Shank and drumstick lengths were also higher (P<0.05) in the supplemented group compared to the control group, and the AW-C group showed the longest drumstick bone. Drumstick and wing bone relative weight as well as neck, thigh and wing bone length were not significantly different among the groups (*P*>0.05).

Discussion

In poultry production, water should be as clean as possible in order to avoid contamination by microorganisms. High quality water is very important to maintain good digestion and a healthy gut flora, which increase the absorption of all essential nutrients (Sureshkumar, 2011). Therefore, acidified drinking water could play a crucial role in ensuring the biosecurity of broiler flocks.

In this study, organic acid supplementation increased body weight and feed intake of broiler as well as improved the FCR. Improvements in growth performance are frequently attributed to the composition and activity of the gut microflora, which regulate nutrient utilization (Yang et al., 2009). Supplementation of organic acids in drinking water helps to reduce the level of pathogens in water, crops and the proventriculus, regulate the gut microflora, increase feed digestion and improve growth performance of birds (Philipsen, 2006). Desai et al. (2007) demonstrated that inclusion of a combination of formic acid and propionic acid in drinking water increases body weight gain of broiler and improves the FCR, thereby increasing nitrogen retention. Moreover, Samanta et al. (2010) reported that organic acid supplementation improves gastric proteolysis while improving the digestibility of proteins and amino acids in broiler. It has been reported that dietary organic acids such as citric acid increase body weight (Afsharmanesh and Pourers 2005; Abdel-Fattah et al. 2008; Chowdhury et al., 2009), feed consumption (Moghadam et al. 2006; Atapattu and Nelligaswatta, 2005) and feed efficiency (Afsharmanesh and Pourreza 2005; Haque et al., 2010) of broilers. However, other studies reported that supplementation of butyric acid, lactic acid, acetic acid or formic acid to feed or water has no effect on performance of chickens (Cox et al., 1994; Akbari et al., 2004).

Moreover, Garcíaet al., 2007) indicated that dietary supplementation of formic acid has no effect on body weight gain of broilers but improves the FCR. Among different acids and treatment groups, a continuous supply of activate exerted the greatest benefits in this study. Activate is a combination of liquid organic and inorganic acids that includes 2-hydroxy-4-methylthio-butanoic acid, a highly available source of methionine (Yi et al., 2007) that has been proven to have a strong, acidification and synergistic effect in water when combined with selected inorganic and organic acids.

Table 2. Effects of organic acids on growth performance of broilers

Parameter	Treatment					PSE
	Control	AW-C	AW-P	N-C	N-P	
Body weight gain (g/broiler)						
1st week	139.53	141.89	143.63	141.61	139.98	2.65
2nd week	258.83^{b}	284.22^{a}	277.06^{ab}	285.28^{a}	291.06^{a}	15.97
3rd week	314.11^{ab}	333.56^{a}	277.10^{b}	304.33^{ab}	263.42^{c}	21.34
4th week	401.64^{b}	461.67^{a}	449.11^{a}	474.78^{a}	457.25^{a}	27.68
5th week	430.08^{c}	493.01^{ab}	501.02^{a}	478.22^{ab}	456.33^{bc}	25.50
Total (0-5 week)	1544.2^{e}	1714.33^{a}	1647.8^{c}	1684.35^{b}	1608.03^{d}	20.02
Feed intake (g/broiler)						
1st week	235.96	234.1^{a}	233.9^{a}	232.71^{a}	231.92^{a}	5.50
2nd week	454.42^{b}	490.99^{a}	481.05^{a}	496.36^{a}	495.05^{a}	12.35
3rd week	527.56^{ab}	536.91^{a}	462.25^{c}	498.50^{b}	439.13^{c}	20.72
4th week	740.08^{b}	803.75^{ab}	783.43^{ab}	837.69^{a}	810.28^{ab}	45.68
5th week	739.91^{b}	797.85^{ab}	835.26^{a}	779.01^{ab}	759.27^{b}	40.09
Total (0-5 week)	2697.92^{c}	2863.6^{a}	2795.89^{ab}	2844.28^{a}	2735.66^{bc}	48.38
Feed conversion ratio (feed/gain)						
1st week	1.69	1.65	1.63	1.64	1.66	0.05
2nd week	1.76	1.74	1.75	1.74	1.7	0.10
3rd week	1.68	1.62	1.69	1.64	1.67	0.11
4th week	1.84^{a}	1.74^{c}	1.75^{bc}	1.76^{bc}	1.77^{b}	0.02
5th week	1.72^{a}	1.62^{d}	1.67^{b}	1.63^{cd}	1.66^{bc}	0.02
Total (0-5 week)	1.75^{a}	1.67^{c}	1.70^{b}	1.69^{bc}	1.70^{b}	0.01

$^{a-e}$Values with different superscripts in the same row differ significantly (P<0.05). PSE = Pooled standard error. Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration

The nutritional effects of Activateare due to its abundance of methionine, which is known to promote detoxification and stimulation of the hepatic system. Activate further plays an important role in the destruction of harmful microorganisms that affect animal performance and food safety. In a study on pigs, a dry organic acid blend of Activate was found to enhance the growth performance of weaning pigs as well as modulate the intestinal microbial population and pH level of early-weaned pigs (Li et al., 2008). In another study by Cole et al. (1968), supplementation of organic acids to drinking water not only was shown to improve growth performance but also reduce the number of *E. coli* in the gut of post-weaning pigs. Partnanen and Morz (1999) and Piva et al. (2002) reported that inclusion of organic acids in the diet could enhance growth performance and modulate intestinal microbiota in pigs. Dibner and Butin(2002) suggested that organic acids improve protein and energy digestibility by reducing microbial competition with the host for nutrients, decreasing endogenous nitrogen loss, lowering the incidence of sub-clinical infections and secretion of immune mediators, and reducing production of ammonia and other growth-depressing microbial metabolites. Any of these could be mechanisms through which butyrate improves feed utilization, leading to better performance of broilers. In this study, supplementation of organic acids increased carcass, breast, thigh and drumstick meat yields. The result coincides with the findings of Aksu et al. (2007), who reported that carcass, thigh, and breast weights of broiler scan be improved by organic acid supplementation at 4g/kg of feed. In a study by Atapattu and Nelligaswatta (2005), addition of citric acid to a rice byproduct-based diet was shown to linearly increase carcass weight of broilers. Further, dietary supplementation of 0.5% citric acid and 0.5% acetic acid has been found to linearly improve dressing yield by 3.31% over control (Islam et al., 2008). In addition, Chowdhury et al. (2009) and Denli et al. (2003) observed higher carcass weight in broilers receiving organic acids with antibiotics. However, previous studies have shown that carcass, breast and thigh yields are not affected by dietary butyric acid (Mahdavi and

Table 3. Effects of organic acids on dressing parameters and internal organ weights of broilers (% related to body weight)

Items	Treatment					PSE
	Control	AW-C	AW-P	N-C	N-P	
Carcass yield	58.94^{b}	64.41^{a}	63.20^{a}	63.06^{a}	62.24^{a}	1.13
Head	2.18^{d}	2.46^{a}	2.34^{c}	2.40^{b}	2.40^{b}	0.03
Neck	1.52^{c}	1.75^{a}	1.70^{b}	1.69^{b}	1.72^{b}	0.02
Blood	3.39	3.50	3.66	3.70	3.84	0.58
Feather	6.92	6.90	7.06	7.40	7.28	0.69
Skin	8.25	9.36	8.02	8.74	9.03	0.78
Liver	2.06	2.02	2.01	1.95	2.12	0.18
Heart	0.43	0.44	0.48	0.48	0.44	0.05
Gizzard	1.41^{bc}	1.62^{ab}	1.36^{c}	1.66^{a}	1.40^{bc}	0.12
Abdominal fat	1.51^{a}	1.28^{bc}	1.31^{b}	1.24^{c}	1.28^{bc}	0.03

$^{a-d}$ Values with different superscripts in the same row differ significantly (P<0.05). PSE = Pooled standard error. Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration.

Torki, 2009), citric acid (Haque et al., 2010), formic acid (García et al., 2007) and propionic acid (Khosravi et al., 2012) supplementation. Similar to our study, Brzóska and Stecka, (2007) reported that inclusion of fumaric acid with probiotics and prebiotics in water increases dressing percentage compared to addition with feed or antibiotics. In a comparison of bacitracin methylene disalicylate or 0.1/0.2% butyric acid, Leeson et al. (2005) noted increased carcass weight and breast meat yield in birds fed 0.2% butyric acid. In a recent study, Saki et al. (2012) reported an increase in breast and thigh meat yields at 21 days, whereas the effect could not be observed at 42 days. Increased dressing yield upon organic acid supplementation could be attributed to higher live weight. This result is partially supported by Sapra and Mehta (1990), who observed increased edible meat yield at a higher body weight. The positive effect of organic acid supplementation on digestion is related to the slower passage of feed in the intestinal tract, better absorption of necessary nutrients, and less wet droppings (Van Der Sluis, 2002). Another explanation is that organic acids improve gastric proteolysis as well as the digestibility of proteins and amino acids (Samanta et al., 2010), thereby increasing the musculature of broilers.

In our study, organic acid supplementation increased head, neck, and gizzard relative weights. In agreement with our result, Aksu et al. (2007) has noted that neck and internal edible organ weights can be improved by organic acid supplementation at 4g/kg of feed. However, Islam et al. (2008) found no differences in head, skin, giblet, and visceral relative weights in broilers fed acetic acid or citric acid. Saki et al. (2012) observed higher relative liver and heart weights as well as lower gizzard weight at 21 days, whereas the effect was not seen at 42 days. In this study, reduction of abdominal fat content was observed in the organic acid groups. This result is generally in line with those of Panda et al. (2009), who reported that abdominal fat content can be significantly reduced by butyric acid treatment compared to control or antibiotic treatment, and Lessard et al. (1993), who observed that pyruvic acid or citric acid supplementation reduces abdominal fat content.

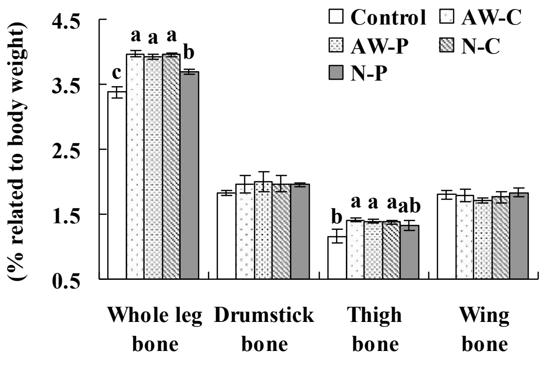

Figure 3. Effects of organic acids on bone development of broilers (% related to body weight). Data are presented as the mean ± SE. Bars within individual bones not sharing a common letter are significantly different (P<0.05). Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration

Table 4. Effects of organic acids on bone length (cm) of broilers

Item	Treatment					PSE
	Control	AW-C	AW-P	N-C	N-P	
Neck	7.75	8.20	8.25	8.25	7.75	0.61
Shank	7.25[b]	8.25[a]	8.01[a]	8.25[a]	7.75[a]	0.39
Drumstick	8.50[c]	9.75[a]	9.25[b]	9.03[b]	9.01[b]	0.23
Thigh	6.25	6.40	6.50	6.50	6.10	0.47
Wing	11.00	11.50	11.75	11.00	11.25	0.69

[a-c] Values with different superscripts in the same row differ significantly (P<0.05). PSE = Pooled standard error. Control = Without organic acids; AW-C = Activate continuous administration; AW-P = Activate periodic administration; N-C = Nutrilac continuous administration; N-P = Nutrilac periodic administration

Likewise, Ibrahim et al. (1997) has shown that organic acid supplementation reduces visible fat (14.2%) and skin fat (36.9 and 40.2% of high and low energy controls, respectively) percentages in ducks. However, Brzóska and Stecka, (2007) reported that inclusion of fumaric acid with probiotics and prebiotics in water has no effect on gizzard, liver, or abdominal fat pad weight of broilers. In a report by Denli et al. (2003), dietary supplementation of organic acids was shown to have no effect on abdominal fat pad or liver weight compared with control. Similar results have been observed upon dietary supplementation of fumaric acid (Skinner et al.1991) and butyric acid (Mahdavi and Torki, 2009).These results indicate that the organic acids used in this study had significant effects on fat metabolism.

Organic acids have been evaluated numerous times for their efficacy in improving growth performance. However, there has been very little work investigating the efficacy of citric acid in mineral utilization by broiler chicks. In this study, organic acids appeared to increase whole leg and thigh bone relative weights, as well as shank and drumstick lengths. These results are in agreement with a study by Liem et al. (2008), who reported that the addition of citric acid, malic acid, and fumaric acid increases the percentage of tibia ash. Several organic acids have been reported to improve mineral absorption and phytate-P utilization when supplemented ton on-ruminant diets (Boling et al., 2000). Citric acid treatment has been shown to significantly increase the tibia ash content, thereby improving utilization of phosphorus (Chowdhury et al., 2009; Haque et al., 2010).

Similarly, use of citric acid found to increase retention of phosphorus (Brenes et al., 2003), tibia ash (Rafacz-Livingston et al., 2005; Martinez-Amezcua et al., 2006; Moghadam et al.2006), and toe ash (Atapattu and Nelligaswatta, 2005) in broiler chicks. In a recent study, Świątkiewicz and Arczewska-Wlosek (2012) reported that organic acids have no effects on tibial parameters; however, short chain fatty acids (SCFA; formic acid, propionic acid, and acetic acid)alone or in combination with medium chain fatty acids (caproic acid and capric acid) have been shown to increase the yielding load and stiffness of femurs. In another study, dietary supplementation of SCFA was found to significantly increase relative retention of calcium (45.0 vs. 41.1%).

It was concluded that SCFA can improve bone quality and calcium balance in broiler chickens fed either a diet with standard levels of calcium and phosphorus or a diet with reduced levels of these macro minerals. Deepa et al. (2011) noted previously that supplementation of citric acid, both individually and in combination with phytase, can significantly improve phosphorus retention in broilers. In detail, calcium and nitrogen retention were significantly higher in broiler groups that received phytase plus citric acid. Organic acids such as citric acid improve phosphorus and calcium retention by combining with dietary calcium, which reduces the formation of highly indigestible calcium phytate complexes. Moreover, low intestinal pH (created by organic acids) increases the solubility and absorption of phosphorus and calcium in the small intestine (Overland et al., 2002), thereby improving retention of phosphorus and calcium.

Conclusion

Supplementation of organic acids to water improved growth performance, meat yield, dressing parameters and bone development of broiler in this study. Results also indicated that continuous addition exerted beneficial effects compared to periodic addition. Further, Activate showed better results compared to nutrilac in terms of some tested parameters. It is also suggested, due to the natural buffering capacity of water and interactions with minerals, that producer monitor the pH level of drinking water when using acidifiers at the manufacturer's recommended levels.

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