ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF POULTRY SCIENCE

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308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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International Journal of Poultry Science 14 (11): 589-594, 2015
ISSN 1682-8356
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A Study on Efficacy of Fumaric Acid Supplementation in Diet of Broiler Chicken

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Abstract: The aim of the present study was to determine the effect of dietary supplementation of fumaric acid on the performance, carcass characteristics and pH of different segments of gastro-intestinal tract (GIT) in broiler chicken. One hundred eighty, one week old broiler chicks were utilized for the study and distributed into four treatment groups, each having three replicates of 15 chicks each. Birds in the control (T1) group were fed the basal diet whereas in other treatment groups basal diet was supplemented with 0.5% (T2), 1% (T3) and 1.5% (T4) fumaric acid. Broiler chicken fed diets supplemented with fumaric acid showed a significantly ($p<0.05$) linear improvement in the body weight gains compared to control. Highest body weight gain of 1270.64±22.37 was observed in the group fed 1.5% fumaric acid in the diet (T4). There was a non-significant ($p>0.05$) effect on cumulative feed consumption in the birds among different treatment groups with lowest consumption in the control. Feed conversion ratio (FCR) improved in all the treatment groups fed fumaric acid in the diet with best FCR of 1.63±0.03 in T4. No significant ($p<0.05$) effect was observed in the carcass characteristics between various treatment groups including control. The pH of crop, proventriculus and gizzard decreased non-significantly ($p>0.05$), however no effect in the pH of different segments of small intestine was noticed. It may be concluded that fumaric acid proved to be a good substitute to antibiotic growth promoters in improving the performance of broiler chicken.

Key words: Broiler chicken, carcass, fumaric acid, performance, pH

INTRODUCTION

The use of antibiotics as growth promoters in poultry feed has been practiced worldwide during the last 50 years (Yegani and Korver, 2008) and their use is still in practice (Aziz Mousavi *et al.*, 2012; Khan *et al.*, 2012; Shamlo *et al.*, 2014) despite of the growing concern over the transmission and proliferation of resistant bacteria via the food chain. This led the European Union (EU) in 2006 to ban antibiotic growth promoters to be used as additives in animal nutrition. The nutritionists and researchers thus attempted to explore other potential alternatives, claiming to boost the production and growth performance of poultry birds (Khan *et al.*, 2014). The alternative which has showed some potential in this regard are organic acids.

Organic acids and their salts are generally regarded as safe (GRAS) and have been approved by most member states of EU to be used as the feed additives in animal production (Cakir *et al.*, 2008). A wide range of organic acids with variable physical and chemical properties are available for poultry, of which many are used in the drinking water or mixed with the feed (Huyghebaert *et al.*, 2011; Menconi *et al.*, 2014). Organic acids can be defined as carboxylic acids including fatty acids, which have the chemical structure of R-COOH with acidic properties. However, not all organic acids have been used as feed additives in poultry diets (Kim *et al.*, 2015). Short chain fatty acids such as formic (C1), acetic (C2), propionic (C3), and butyric acid (C4), and other carboxylic acids such as lactic, malic, tartaric, fumaric, and citric acid have been most commonly used in the poultry industry because their chemical and physical properties are applicable to poultry diets (Dibner and Buttin, 2002). Fumaric acid ($C_4H_4O_4$) is a weak organic acid with a fruit-like taste (Kim *et al.*, 2015).

The use of organic acids has been reported to protect the young chicks by competitive exclusion (La Ragione and Woodward, 2003), enhancement of nutrient utilization and growth and feed conversion efficiency (Denli *et al.*, 2003). Organic acids, such as lactic, acetic, tannic, fumaric, propionic, caprylic acids, etc. have been shown to exhibit beneficial effects on the intestinal health and performance of birds (Adil *et al.*, 2010; Saki *et al.*, 2012; Menconi *et al.*, 2014). The organic acids in nondissociated (nonionized, more lipophilic) form can penetrate the bacteria cell wall and disrupt the normal physiology of certain types of bacteria (Dhawale, 2005). Apart from the antimicrobial activity, they reduce the pH of digesta, increase the pancreatic secretion, and have trophic effects on the mucosa of gastro-intestinal tract (Dibner and Buttin, 2002). The potential of organic acids in lowering chyme pH is another property of this

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compound to support the growth, as this feature may increase protein digestion (Gauthier, 2002). Organic acids have made a great contribution to the profitability in the poultry production and also provided people with the healthy and nutritious poultry products (Ricke, 2003; Moharrery and Mahzonieh, 2005). Acidification with various organic acids has been reported to reduce the production of toxic components by the bacteria and colonization of pathogens on the intestinal wall, thus preventing the damage to epithelial cells (Langhout, 2000), also improve the digestibility of proteins, calcium, phosphorus, magnesium, and zinc, and serve as substrates in the intermediary metabolism (Kirchgessner and Roth, 1988).

Although supplementation of organic acids has been evidenced to support the health and performance of birds, the use of organic acids must be administrated in low dosage, as excessive dosage may result in growth depression in intestinal villus height and width, as well as crypt depth (Smulikowska *et al*., 2010). The present study was thus conducted with the objectives to evaluate the effect of dietary supplementation of fumaric acid at different levels on the performance, carcass characteristics and pH of different GIT segments of broiler chicken.

MATERIALS AND METHODS

Methodology: A total number of 180 Cobb straight run commercial broiler chicks were utilized in this study. On arrival chicks were provided with 8% sugar solution and ground maize for first 12 hours. To avoid stress, water soluble vitamins and electrolytes were added to the drinking water for first 3 days. At 7 days of age, birds were individually weighed and randomly assigned into four treatment groups, each having three replicates of 15 chicks each. The birds were placed in battery cages and temperature was gradually reduced from 32 to 20°C on day 42. The chicks were maintained on a 24 hours consistent lighting schedule. Proper ventilation was ensured throughout the experimental period which lasted 42 days. Birds were vaccinated against New castle and Gumboro's diseases. Fresh feed and water were provided daily ad libitum. The feeding programme consisted of a starter diet until 21 days and a finisher diet until 42 days of age. All diets for each period were prepared with the same batch of ingredients and all diets within a period had the same composition. The diets were formulated to meet the recommendations of the Bureau of Indian Standards (BIS, 1992). The ingredients and nutrient composition on dry matter (DM) basis of the control diet is shown in Table 1. Birds in the control (T1) group were fed the basal diet whereas in other treatment groups basal diet was supplemented with 0.5% (T2), 1% (T3) and 1.5% (T4) fumaric acid. The fumaric acid in powder form was mixed thoroughly in aforesaid quantities to a small amount of feed (1 kg) in a premixer. The resultant mixture was then mixed with the rest of the feed in a mechanical blender until a thorough and consistent mixture was obtained.

Table 1: Ingredient and nutrient composition of basal diet

Ingredients	Starter (1-3 weeks)	Finisher (4-6 weeks)
Yellow maize	52.0	60.0
Soybean bean	30.0	23.0
Fish meal	10.0	10.0
Rice bran	5.5	4.5
Trace mineral and vitamin mixture	2.5	2.5
Total	100.0	100.0
Nutrient composition (Calculated values)		
Metabolizable energy (Kcal/kg diet)	2835	2889
Crude protein (%)	22.42	20.56
Crude fibre (%)	3.18	3.20
Total ash (%)	10.13	9.61
Calcium (%)	1.64	1.63
Available phosphorus (%)	0.76	0.69

Parameters recorded: The body weight of birds per replicate was recorded on individual basis at weekly intervals. Cumulative feed consumption per replicate was also recorded on weekly basis. Feed conversion ratio per replicate was worked out at weekly intervals by taking into consideration weekly body weight gain and feed consumption of respective replicate.

At the end of the feeding trial (42 days), six birds per treatment were selected at random and utilized for the carcass evaluation study. Each bird was weighed immediately before severing the jugular vein at the atlantooccipital joint and then allowed to bleed. The shanks were cut off at the hock joint, and carcass was subjected to the scalding process at 60°C for 30 seconds. The feathers were removed completely by hand picking leaving the skin intact. Thereafter, the abdominal cavity was opened to expose the visceral organs, and the carcass characteristics were evaluated. Length of intestines was measured by means of a measuring tape.

The pH of the gut contents was determined by using the method of Al-Natour and Alshawabkeh (2005). Ten grams each from crop and caeca were collected aseptically in 90 ml sterilized physiological saline (1:10 dilution) and pH was determined.

Statistical analysis: The data obtained were statistically expressed as means ± standard error and assessed by General Linear Model procedure of SPSS (20.0) software considering replicates as experimental units. Duncan's multiple range test (Duncan, 1955) was used to test the significance of difference between means. Differences were considered significant at $p<0.05$.

RESULTS AND DISCUSSION

The body weight gains were significantly ($p<0.05$) improved by dietary supplementation of fumaric acid when compared with the control group (Table 2). A linear

Table 2: Effect of fumaric acid on the performance of broiler chicken

Parameter	Control (T1)	0.5% Fumaric acid (T2)	1% Fumaric acid (T3)	1.5% Fumaric acid (T4)
Initial body weight (g)	342.09±3.45	352.20±4.59	352.98±7.23	352.0±8.54
Final body weight (g)	1464.24±5.49[a]	1512.15±32.26[a]	1619.09±24.99[b]	1623.84±16.26[b]
Body weight gain (g)	1122.15±8.49[a]	1159.95±30.65[a]	1266.11±26.55[b]	1270.64±22.37[b]
Feed consumption (g)	2052.49±23.22[a]	2103.71±16.31[b]	2111.36±7.23[b]	2076.49±6.29[ab]
FCR	1.83±0.01[a]	1.82±0.06[a]	1.67±0.03[b]	1.63±0.03[b]

Means within the same row with different superscripts are significantly different ($p<0.05$)

increase in the body weights of broiler chicken was observed with increase in the level of fumaric acid in the diet, with highest weight gain of 1270.64±22.37 in the birds fed 1.5% fumaric acid (T4). The results of the present study coincide with the results of other researchers (Islam *et al*., 2008; Ao *et al*., 2009; Mohamed and Bahnas, 2009; Nuh Ocak *et al*., 2009; Adil *et al*., 2011) who reported that the supplementation of organic acid improves the body weight gain compared to the unsupplemented group in poultry. However, Hernandez *et al*., 2006; Houshmand *et al*., 2012 did not find any positive effects of organic acids on growth performance of broiler chickens. The acid type and concentration, composition of diet and environment of the experiment have been considered as responsible factors for inconsistency in results (Dibner and Buttin, 2002). The improved body weight gain is probably due to the beneficial effect of organic acids on the gut flora. Ricke, 2003 reported that the organic acids may affect the integrity of microbial cell membrane or cell macromolecules or interfere with the nutrient transport and energy metabolism causing the bactericidal effect. Use of organic acid mixture decreases the total bacterial and gram negative bacterial counts significantly in the broiler chicken (Gunal *et al*., 2006). Samanta *et al*. (2010) also reported that organic acids reduce *E. coli* and other harmful bacteria which may enhance poultry growth. Besides, the butyric acid has been reported to reduce the virulent gene expression and invasiveness in *Salmonella enteritidis*, leading to its decreased colonization in the caeca of broiler chicken (Porter and Curtiss, 1997; Lawhon *et al*., 2002; Van Immerseel, 2004). Furthermore, organic acids supplementation has pH reducing property, although non-significant, in various gastrointestinal segments of the broiler chicken (Abdel-Fattah *et al*., 2008). The reduced pH is conducive for the growth of favourable bacteria simultaneously hampering the growth of pathogenic bacteria which grow at a relatively higher pH. The microbiological and pH decreasing abilities of organic acids might have resulted in the inhibition of intestinal bacteria leading to the increased availability of nutrients to the host, thus improving the performance of birds.

The feed consumption varied non-significantly ($p>0.05$) among the treatment groups when compared to the control, with lowest consumption in the control group (Table 2). These results are in agreement with the results of Denli *et al*. (2003) and Yakhkeshi *et al*. (2014) who also reported increased feed consumption with the supplementation of organic acids in the diet. However, Hernandez *et al*. (2006) found no difference in the cumulative feed consumption between the groups fed organic acids and the control group. Chicks fed diets supplemented with fumaric acid showed a significant ($p<0.05$) improvement in the FCR as against the chicks fed the control diet (Table 2). The improvement in the FCR could be possibly due to better utilization of nutrients resulting in increased body weight gain in the birds fed fumaric acid. These results are in concordance with other researchers (Vogt *et al*., 1981; Runho *et al*., 1997; Adil *et al*., 2010) who reported that supplementation of organic acids improved the feed conversion ratio in broiler chicken. Similar observations were also recorded by Sultan *et al*. (2014) with the supplementation of citric acid in poultry.

The carcass characteristics of broiler chicken fed diets supplemented with fumaric acid showed no significant differences ($p>0.05$) between various treatment groups (Table 3). However, a significant improvement in carcass parameters of broilers fed diets supplemented with citric, propionic or fumaric acids have been reported by Snow *et al*. (2004); Abd El-Hakim *et al*. (2009) but no such effect was observed in the present study. Denli *et al*. (2003) also reported that organic acids resulted in remarkable increase in the intestinal weight and length of broiler chicken. These changes have been attributed to the fact that organic acids have direct stimulatory effect on the gastro-intestinal cell proliferation as was reported by other workers with short chain fatty acids. The short chain fatty acids are believed to increase plasma glucagon-like peptide 2 (GLP-2) and ileal pro-glucagon mRNA, glucose transporter (GLUT2) expression and protein expression, which are all signals which can potentially mediate gut epithelial cell proliferation Tappenden and McBurney (1998). The short chain fatty acids can accelerate gut epithelial cell proliferation, thereby increase intestinal tissue weight (Le Blay *et al*., 2000; Fukunaga *et al*., 2003) but no such effect was observed in the present study which might be due to the difference in type and concentration of organic acid used in various studies.

The results of pH of various GIT segments in broiler chicken fed supplemental fumaric acid in the diet are presented in Table 4. The pH of crop, proventriculus and

Table 3: Carcass characteristics of broiler chicken fed fumaric acid in the diet

Parameter	Control (T1)	0.5% Fumaric acid (T2)	1% Fumaric acid (T3)	1.5% Fumaric acid (T4)
Ready to Cook Yield (%)	74.20±0.64	73.70±0.59	72.30±0.55	72.48±0.63
Giblet (%)	5.68±0.19	5.54±0.14	5.78±0.51	5.58±0.24
Length of intestines (cm/100g live wt.)	11.26±0.21	11.19±0.12	11.18±0.16	11.28±0.09

Table 4: Effect of fumaric acid on the pH of various GIT segments of broiler chicken

Parameter	Control (T1)	0.5% Fumaric acid (T2)	1% Fumaric acid (T3)	1.5% Fumaric acid (T4)
Crop	5.05±0.03	4.96±0.06	4.92±0.04	4.87±0.05
Proventriculus	3.15±0.04	3.09±0.07	3.10±0.02	3.06±0.01
Gizzard	3.21±0.02	3.19±0.08	3.13±0.06	3.15±0.04
Duodenum	5.85±0.11	5.92±0.09	5.84±0.04	5.88±0.07
Jejunum	6.25±0.08	6.25±0.03	6.23±0.01	6.27±0.03
Ileum	7.51±0.14	7.47±0.04	7.56±0.08	7.54±0.13

gizzard reduced non-significantly ($p>0.05$), however no effect in the pH of different segments of small intestine was noticed, thus agreeing with the results of Waldroup *et al.* (1995). Moreover, Yakhkeshi *et al.* (2014) reported a significant decrease in the pH of all the GIT segments with the inclusion of organic acids in the broiler chicken which may be due to the use of different acid type and concentration. The results of the present study are supported by the fact that the effects of organic acids down the digestive tract gets diminished because of reduction in the concentration of acids as a result of absorption and metabolism (Bolton and Dewar, 1964). Organic acids provide an appropriate pH in the gut which improves the microflora, reduce gut harmful bacteria, increase utilization of nutrients, and improve performance of chickens (Roser, 2006), thus further supporting the results of improved performance of broiler chicken found in the present study.

Conclusion: It could be concluded that under the condition of the present study, fumaric acid proved to be a good substitute to antibiotic growth promoters in improving the performance of broiler chicken. Further studies regarding type, combination and dosage of organic acids are warranted in order to utilize them optimally as feed additive in improving the performance and gut health of broiler chicken.

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