Apparent nutrient digestibility, gut pH and digesta viscosity of broiler chickens fed acidified water

Abstract

A six week study was carried out to investigate the effect of different organic acids fed through drinking water on nutrient digestibility, faecal moisture, gut pH and digesta viscosity of broiler chickens. The organic acids were acetic acid, butyric acid, citric acid and formic acid. One hundred and fifty (150) day old Anak chicks were used. There were five treatments. Treatment 1 which served as control consumed water with no organic acid, while treatments 2, 3, 4 and 5 were offered drinking water treated with 0.25% acetic acid, butyric acid, citric acid and formic acid respectively. Each treatment was replicated three times with ten birds per replicate. The experiment was arranged in completely randomized design (CRD). Feed and water were offered ad libitum. Results showed that faecal moisture, dry matter and nitrogen free extracts digestibility, gut pH and duodenum digesta viscosity were significantly (P<0.05) reduced by organic acids. Protein, ether extract and fibre digestibility coefficients were significantly (P<0.05) improved by organic acids. In conclusion, the organic acids could be used through the drinking water to improve digestibility, reduce faecal moisture, gut pH, digesta viscosity of broilers and invariably their productivity.

Keywords: digesta viscosity, drinking water, pH, nutrient digestibility, organic acids

Introduction

Provision of both quality and adequate feed to broiler chickens is essential for optimum performance. Quality feed is one which supplies all the nutrients required for productivity while adequate feeding means provision of the daily feed requirement free choice.1 Earlier reports indicated that access to quality feed and attainment of daily requirement has been suggested to be better ways to achieve faster growth in broiler chickens.2,3 But the quality and quantity of feed cannot guarantee optimum productivity if the feed so supplied is not well utilized by the animal.4 The breakdown of each macro nutrient (starch, protein, fats and oils) of the feed into their respective micro forms (glucose, amino acids and fatty acids absorbable by the chicken is important. This process is known as digestion which is measured as digestibility.

Maynard et al.,5 defined digestibility as the amount of the feed fed that disappeared from the digestive system expressed as the percentage of the quantity fed. Digestibility is affected among other factors by certain endogenous secretions such as enzymes, hydrochloric acid and bile. Even after feed is fully digested it must be absorbed for effective utilization. Level of absorption depends among other factors on the number of villi, height of villi and crypt depth.6 The gut according to Patterson & Burkholder7 and Paul et al.,8 could be modulated to achieve enhanced performance of chickens. To this end, feeding strategies to improve digestibility have been employed. Feed grade enzymes, probiotics, prebiotics, yeast, spices and essential oils, have been reported to increase digestibility in monogastric animals.9–11

Recently, Ndelekwute et al.,12 and Mohammed13 reported that organic acids enhanced growth performance of broiler chicks. Earlier, Waldroup et al.,14 Patten & Waldroup15 and Dibner16 had emphasized the essentials of organic acids in nutrient utilization by broilers. Nutrient utilization could be affected by the pH of the feed, intestinal pH and movement of digesta (transit time) in the gastrointestinal tract. The movement of digesta in the gut depends largely on the viscosity which could affect nutrient absorption. The conventional way of feeding organic acids has been through the feed. The quality of the drinking water also need to be considered according to Oviedo.17 Hence it has been suggested that drinking water for birds could be sanitized with organic acids for better performance.18 Better performance here include the faecal moisture which could be a reflection of digested nutrient conditions in the gut.

Therefore, the objective of this research was to determine the effect of drinking water acidified by organic acids (acetic, butyric, citric and formic acids) on nutrient digestibility, faecal moisture, digesta pH and viscosity at final stage of broiler chickens.

Materials and methods

Site of experiment

The experiment was conducted at the Teaching and Research Farm of Department of Animal Science and Forage Science, Michael Okpara University of Agriculture, Umudike, Nigeria.

Experimental design

Completely randomized design (CRD) was used. One hundred and fifty (150) day old Anak chicks were used. There were divided into five treatments replicated three times with 10 birds per replicate. Each treatment group received acetic acid, butyric acid, citric acid or formic acid at 0.25% level of the drinking water, while the control group received neither of the organic acids. Birds were fed ad libitum with starter and finisher diets formulated according to nutrient requirements of broilers as shown in Table 1. Management of birds

At day old, the chicks were weighed, after which they were transferred into the brooding room. Glucose was added to their feed...
drinking water the first day for faster energy intake. From the second day, vitamins and minerals were added to their drinking water for seven days. They were stabilized for one week in the brooding room. Heat was supplied by a kerosene stove placed under a cover. At the end of the one week stabilization period the birds were randomly allotted to treatment groups in a rearing house, covered with water proof material. Heat supply continued to the third week of age. Feeding of organic acids through the drinking water started from second week. Starter and finisher feeds and the acidified water were supplied free choice. The birds were vaccinated against Newcastle and Gumboro diseases.

### Table 1 Experimental diets

| Ingredients                  | Starter | Finisher |
|------------------------------|---------|----------|
| Maize                        | 55.00   | 55.00    |
| Soya bean meal               | 28.00   | 26.00    |
| Palm kernel cake             | 10.30   | 13.30    |
| Fish meal                    | 3.00    | 2.00     |
| Bone meal                    | 3.00    | 3.00     |
| Salt (NaCl)                  | 0.25    | 0.25     |
| Lysine                       | 0.10    | 0.10     |
| Methionine                   | 0.10    | 0.10     |
| Premix*                      | 0.25    | 0.25     |
| Total                        | 100.00  | 100.00   |

**Calculated composition (%)**

- Crude protein: 22.10 20.65
- Energy (MJ ME/kg): 11.99 12.03
- Ether extract: 3.92 6.16
- Crude fibre: 5.01 6.00
- Ash: 7.04 6.80
- Calcium: 1.2 1.11
- Phosphorus: 1.01 0.88
- Lysine: 1.12 1.05
- Methionine: 0.55 0.50

*Starterm Premix supplied per kg diet vitamin A 15,000 I.U, vitamin D3 13000 IU, thiamin 2mg, Riboflavin 6mg, pyridoxine 4mg, Niacin 40mg, cobalamin 0.05g, Biotin 0.08mg, choline 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. CON: control; AA: acetic acid; BA: butyric acid; CA: citric acid; FA: formic acid.

**Finisher Premix supplied per kg diet vitamin 10, 000 IU, vitamin D3 12,000 IU, vitamin E 200 IU, Vitamin K 2.5mg, thiamine 2.0mg, Riboflavin 3.0mg, pyridoxine 4.0mg, Niacin 20mg, cobalamin 0.05mg, Pantethenic 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.

### Digestibility study

Total collection method was used. Before the birds were introduced, both 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 each, in a metabolism room. Male birds were used and weights of the birds used were similar to reduce possible effect of sex and weight on digestibility. The birds were both fed and watered ad libitum. They were acclimated for four days. 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.

Faeces was collected and weighed for four days. Collected faeces were immediately taken to the laboratory where they were oven dried at 60°C to constant weight. Dry faecal samples were ground to pass 1mm sieve. The four days faecal collection was pooled and thoroughly mixed together. A portion was taken from each treatment, stored in a refrigerator from which proximate analysis was carried out according to AOAC.19 Faecal moisture and apparent nutrient digestibility were calculated as shown below:

Faecal moisture = \( \frac{\text{Weight of wet faeces} - \text{Weight of dry faeces}}{\text{Weight of wet faeces}} \times 100 \)

Apparent nutrient digestibility = \( \frac{\text{Nutrient in feed} - \text{Nutrient in faeces}}{\text{Nutrient in feed}} \times 100 \)

### Determination of viscosity and pH of Digesta

5g of digesta obtained from the duodenum, ileum and caecum was used to measure the viscosity using cone/plate geometry according to Lee et al.,20 with cone angle 1° and diameter 40mm at 37°C. The digesta was suspended in 5mls distilled water and mechanically stirred for two hours at room temperature (28°C). Immediately, the viscosity was measured using a Viscometer (Bohlin CS 50 Rheometer, manufactured by Bohlin Reologi, Muhlacker, Germany).

A pH meter was used to determine the pH. 1g of the digesta was taken and mixed with 10mls of distilled deionized water and the pH immediately measured according to Nisbet et al.21

All the data were subjected to analysis of variance (ANOVA). Significant means were separated using Duncan New Multiple Range Test (DNMRT) according to Steel & Torrie.22

### Results

Table 2 shows the effect of acid treated drinking water on faecal moisture and nutrient digestibility. The Organic acids significantly (P<0.05) reduced faecal moisture. The digestibility of protein, fibre and ether extract were significantly (P<0.05) improved by the organic acids. Addition of the organic acids did not improve dry matter and nitrogen free extract digestibility, rather the digestibility of dry matter and nitrogen extract were significantly (P>0.05) reduced by addition of the acids. There was no significant (P>0.05) effect of the organic acids on digestibility of ash and energy utilization.

Effect of organic acid treated drinking water on the pH of different segments of the gastro intestinal tract (Table 3) is indicating that the pH was significantly (P<0.05) reduced by the organic acids in all the segments except in the duodenum. In the duodenum, only butyric acid produced similar pH as compared to the control.

### Table 1

| Ingredients                  | Starter | Finisher |
|------------------------------|---------|----------|
| Maize                        | 55.00   | 55.00    |
| Soya bean meal               | 28.00   | 26.00    |
| Palm kernel cake             | 10.30   | 13.30    |
| Fish meal                    | 3.00    | 2.00     |
| Bone meal                    | 3.00    | 3.00     |
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### Conclusion
The influence of the organic acids on digesta viscosity is indicated in Table 3. There were no significant (P>0.05) differences in viscosity at the caecum compared to the control. At the duodenum, acetic and citric acids significantly (P<0.05) reduced digesta viscosity. At the ileum only citric acid significantly reduced the viscosity (P<0.05) in comparison to the control.

**Table 2 Effect of organic acid treated drinking water on digestibility coefficient and fecal moisture of the broilers**

| Parameters (%) | T1 (CON) | T2 (AA) | T3 (BA) | T4 (CA) | T5 (FA) | SEM |
|----------------|----------|---------|---------|---------|---------|-----|
| Faecal moisture | 67.50<sup>a</sup> | 57.53<sup>c</sup> | 53.50<sup>b</sup> | 57.75<sup>c</sup> | 59.65<sup>a</sup> | 3.88 |
| Dry matter | 75.23<sup>a</sup> | 66.51<sup>b</sup> | 66.26<sup>c</sup> | 67.67<sup>c</sup> | 68.38<sup>b</sup> | 4.76 |
| Crude protein | 63.68<sup>a</sup> | 68.28<sup>c</sup> | 69.73<sup>b</sup> | 75.43<sup>c</sup> | 74.37<sup>c</sup> | 4.08 |
| Crude fibre | 32.20<sup>a</sup> | 37.78<sup>c</sup> | 40.32<sup>b</sup> | 38.26<sup>a</sup> | 39.67<sup>a</sup> | 2.77 |
| Ether extract | 62.88<sup>a</sup> | 75.01<sup>a</sup> | 83.13<sup>a</sup> | 77.45<sup>c</sup> | 80.21<sup>a</sup> | 5.02 |
| Crude ash | 57.18<sup>a</sup> | 58.24<sup>a</sup> | 61.8<sup>a</sup> | 60.48<sup>b</sup> | 62.69<sup>b</sup> | 2.07 |
| NFE | 71.87<sup>a</sup> | 63.74<sup>a</sup> | 64.38<sup>a</sup> | 67.19<sup>a</sup> | 64.90<sup>a</sup> | 3.01 |
| Energy | 68.45<sup>a</sup> | 66.85<sup>a</sup> | 69.2<sup>a</sup> | 67<sup>a</sup> | 65.98<sup>a</sup> | 2.78 |

abc, means along the same row with different superscripts are significantly (p<0.05) different. CON, control; AA, acetic acid; BA, butyric acid; CA, citric acid; FA, formic acid

**Table 3 Effect of organic acid treated drinking water on pH and viscosity of digesta of the broilers**

| Parameters | T1 (CON) | T2 (AA) | T3 (BA) | T4 (CA) | T5 (FA) | SEM |
|------------|----------|---------|---------|---------|---------|-----|
| pH (−Log H<sup>+</sup>) | | | | | | |
| Crop | 5.37<sup>a</sup> | 4.45<sup>a</sup> | 4.99<sup>a</sup> | 4.37<sup>a</sup> | 4.67<sup>a</sup> | 0.56 |
| Gizzard | 3.87<sup>a</sup> | 3.17<sup>a</sup> | 3.21<sup>a</sup> | 3.14<sup>a</sup> | 3.27<sup>a</sup> | 0.67 |
| Duodenum | 6.53<sup>a</sup> | 6.14<sup>a</sup> | 6.32<sup>a</sup> | 6.01<sup>a</sup> | 6.17<sup>a</sup> | 0.24 |
| Ileum | 6.79<sup>a</sup> | 6.61<sup>a</sup> | 6.64<sup>a</sup> | 6.60<sup>a</sup> | 6.5<sup>a</sup> | 0.54 |
| Caecum | 5.95<sup>a</sup> | 5.59<sup>a</sup> | 5.47<sup>a</sup> | 5.39<sup>a</sup> | 5.50<sup>a</sup> | 0.56 |
| Viscosity (Pa/s) | | | | | | |
| Duodenum | 1.36<sup>a</sup> | 1.27<sup>a</sup> | 1.37<sup>a</sup> | 1.27<sup>a</sup> | 1.32<sup>a</sup> | 0.02 |
| Ileum | 1.84<sup>a</sup> | 1.79<sup>a</sup> | 1.84<sup>a</sup> | 1.74<sup>a</sup> | 1.76<sup>a</sup> | 0.05 |
| Caecum | 1.99<sup>a</sup> | 1.96<sup>a</sup> | 1.93<sup>a</sup> | 1.91<sup>a</sup> | 1.89<sup>a</sup> | 0.02 |

abc, means along the same row with different superscripts are significantly (p<0.05) different. CON, control; AA, acetic acid; BA, butyric acid; CA, citric acid; FA, formic acid

**Discussion**

The ability of the organic acids to reduce faecal moisture could be due to the improved fibre digestibility. Poor digestibility of fibre has been reported to cause watery faeces in broiler chickens. Organic acids such as acetic acid, butyric and formic acids (acetic, butyric, citric and formic acids) reduced faecal moisture, gut pH and digesta viscosity. At the ileum only citric acid significantly reduced the viscosity (P<0.05) in comparison to the control.

**Conclusion**

The present report indicates that the test organic acids (acetic, butyric, citric and formic acids) reduced faecal moisture, gut pH and apparent nutrient digestibility. Acetic and citric acids reduced digesta viscosity in the duodenum. Therefore, these organic acids could be added to broiler chickens drinking water to improve their productivity.
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Conflict of interest

The author declares no conflict of interest.

References

1. Ndelekwute EK, Okereke CO, Essien EB, et al. Effect of lime (Citrus aurantifolia) juice on meat yield and profitability of broilers. *Nig J of Agric Food and Environ.* 2015;11(2):53–58.

2. Obioha FC. *A guide to poultry production in the tropics.* 1st ed. Enugu, Nigeria: Ecena Pub; 1992:88–95.

3. Oluyemi JA, Roberts FA. *Poultry production in warm wet climate.* 2nd ed. Ibadan, Nigeria: Spectrum Books Ltd; 2000:210.

4. Ndelekwute EK, Assam ED, Assam EM, et al. Effect of organic acid treated drinking water on growth of broiler chickens. *Nig J Anim Prod.* 2014;41(2):116–123.

5. Maynard LA, Loosli JK, Hintz HF, et al. *Animal Nutrition.* 7th ed. New Delhi, India: Tata McGraw Hill Pub; 1981:122–134.

6. Chot C. Managing gut health through nutrition. *Brit Poult Sci.* 2009;50(1):9–15.

7. Patterson JA, Burkholder KM. Application of prebiotics and probiotics in poultry production. *Poult Sci.* 2003;82(4):627–631.

8. Paul SK, Samanta G, Halder G, et al. Effect of combination of organic acid salts as antibiotic replacer on the performance and gut health of broiler chickens. *Livestock Res Rural Dev.* 2007;19(11):52–61.

9. Chudhury SR. Effect of dietary garlic on cholesterol metabolism in laying hens. *Poult Sci.* 2002;81(12):1856–1862.

10. Raju MVIN, Reddy VR, Rama Rao SV, et al. Yeast: A multifunctional feed supplement for poultry. *Poult Int.* 2006;45(7):16–21.

11. Windsich W, Schedle K, Pfitzner C, et al. Use of phytoecogenic products as feed additives for swine and poultry. *J Anim Sci.* 2008;86(14 Suppl):E140–E148.

12. Ndelekwute EK, Enyenih GE, Unah UL, et al. Dietary effects of different organic acids on growth and nutrient digestibility of broiler. *Bang J Anim Sci.* 2016a;45(2):10–17.

13. Mohammed HA. Effect of utilization organic acid supplement on broiler (ROS-308) feeding at pre-starter and starter period breeding on basic performance parameters. *Int J Adv Res Biol Sci.* 2016;3(6):76–81.

14. Waldroup A, Kaniawati S, Maumomoustakos A. Performance characteristics and microbiological aspects of broilers fed diets supplemented with organic acids. *J Food Protect.* 1995;58(5):482–489.

15. Patten JD, Waldroup PW. Use of organic acids in broiler diets. *Poult Sci.* 1998;77(8):1178–1182.

16. Dibner J. Organic acids: Can they replace antibiotic growth promoters. *Feed Int.* 2004;25(12):14–16.

17. Oviedo EO. Important factors in water quality to improve broiler performance. *USA: Coop Ext Serv Bulletin North Carolina;* 2006:15–19.

18. Marco Q. Water quality and broiler performance. Broiler Supervisor’s Short Course. Bulletin, New Carolina, USA. 2008;11–13.

19. AOAC. *Official Methods of Analysis.* 15th ed. Washington DC, USA. 2000.

20. Lee KW, Everts H, Kappert HJ, et al. Growth performance, intestinal viscosity, fat digestibility and plasma cholesterol in broiler chickens fed a rye-containing diet without or with essential oil components. *Int J Poult Sci.* 2004;3(9):613–618.

21. Nishet DI, Corrier DE, Deloach JR. Effect of mixed cecal microflora maintained in continuous culture and of dietary lactose on Salmonella typhimurium colonization in broiler chicks. *Avian Dis.* 1993;37(2):528–535.

22. Steel RGD, Torrie JH. Principles and Procedures of statistics. Sydney: McGraw Hill Int. books Co; 1980.

23. Ndelekwute EK, Ebenso IE, Okereke CO, et al. Serum biochemistry, haematology and gut ecosystem of broiler chickens fed diet treated with organic acids. *Nig J Agric Food and Environ.* 2016b;12(1):32–36.

24. Leeson S, Namkung H, Ankongiovanni H, et al. Effect of butyric acid on the performance and carcass yield of broiler chickens. *Poult Sci.* 2005;84(9):1418–1422.

25. MacDonald P, Edwards RA, Greenhalgh JFD. *Animal Nutrition.* 5th ed. London: Longman; 2000:56–60.

26. Makkink C. Acid binding capacity in feedstuffs: Lowering the B-value especially for young animals. *Feed Int.* 2001;22(10):24–27.

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