Journal of Animal and Veterinary Advances 11 (7): 983-987, 2012
ISSN: 1680-5593

The Effects of Drinking Water Carbonation on Performance and Blood Gases and pH in Heat-Stressed Male Broilers

H. Bayraktar and C. Seremet
Department of Animal Science, Faculty of Agriculture, Ege University,
3500 Bornova, Izmir, Turkey

Abstract: The present study was conducted to examine the effects of drinking water carbonation on performance and pH value, pCO_2 and pO_2 of blood in male broilers exposed to heat stress. A total of 312, day old male broiler chicks were allocated to two groups with three replicates. During the 42 days experimental period while first group (control) received normal drinking water (pH 7.4) second group consumed carbonated drinking water (pH 5.7). No significant differences were observed between male broilers given normal and carbonated drinking water in terms of body weight, feed intake, feed conversion ratio and mortality. Birds treated carbonated drinking water has significantly lower blood pH and pO_2 and higher blood pCO_2 compared to the control group. The results indicated that carbonated water might ameliorate blood acid-base imbalance caused by heat stress.

Key words: Broiler performance, carbonated drinking water, heat stress, acid-base balance, Turkey

INTRODUCTION

Fast growing broilers are more susceptible to heat stress. Ambient temperatures exceeding the thermal comfort zone rise birds' heat load, resulting in a decrease in feed consumption, feed efficiency body weight gain and livability (Borges *et al*., 2003; Daghir, 2008). In addition, meat quality, intestinal microflora and immune system were adversely affected by high ambient temperatures (Borges *et al*., 2007).

In poultry which lacks sweat glands, one of the visible responses to cool the body is the elevation of respiration rate (Okela *et al*., 2003). Panting behavior increases carbon dioxide (CO_2) loss from lungs and partial pressure of CO_2 (pCO_2) in blood was reduced causing a decrease in HCO_3 concentrations due to the increase in HCO_3 excretion with a reduction of H^+ excretion by the kidneys to maintain the acid-base balance in the bird. Lowered H^+ concentration raises the level of blood plasma pH, a leading to respiratory alkalosis (Borges *et al*., 2007). Teeter *et al*. (1985) introduced that the maintenance of carbon dioxide and/or blood pH is critical to growth rate. Carbonation of drinking water is an advised practice to improve blood acid-base balance for hot regions (Daghir, 2008).

According to some researchers, carbonated drinking water significantly decreased body temperature and respiration rate of broilers under natural Summer conditions (Soutyrine *et al*., 1998) and improved blood acid-base balance of cockerels during acute heat stress (Bottje and Harrison, 1985a). In previous studies, Bottje *et al*. (1983) and Bottje and Harrison (1985b) observed better daily weight gain and feed efficiency in heat-stressed cockerels by using carbonated drinking water. Similary, Soutyrine *et al*. (1998) found that carbonated water significantly increased body weight and improved feed conversion without effecting feed consumption of broilers at 7 weeks of age. In addition, these researchers reported that broilers receiving carbonated water had better thermoregulation as indicated by lower body temperatures and respiration rate. In the studies carried out by Kreider *et al*. (1990) and Koelkebeck *et al*. (1993), carbonated drinking water improved tibia bone breaking strength of cockerels and older laying hens during heat stress. On the other hand, Smith and Teeter (1993) achieved contradictory results about weight gain and feed efficiency of broilers receiving carbonated water.

Also, Okela *et al*. (2003) who examined the effects of ambient-temperature and chilled carbonated water on growth performance of two commercial broilers flocks reported that live weight did not alter significantly in both flocks but feed/gain ratio and mortality significantly decreased only in one flock.

In the present study, researchers have examined the changes in growth performance, mortality, blood pH, pCO_2 and pO_2 in heat-stressed male broilers consumed carbonated drinking water.

Corresponding Author: H. Bayraktar, Department of Animal Science, Faculty of Agriculture, Ege University, 3500 Bornova, Izmir, Turkey

MATERIALS AND METHODS

Experimental design: This experiment was maintained in an open-sided house. A total of 312 Ross-308 male broiler chicks were used. Total 1 day old chicks were individually weighed, wing banded and randomly distributed into two main groups with three replicates of 52 chicks each. The birds of the two experimental groups were given the same starter (0-21 days) and grower (22-42 days) diets (Table 1). The 1st group (control) received normal drinking water (pH 7.4) and the second group consumed carbonated drinking water (pH 5.7).

All of the chambers were covered with nipple water lines. Also an inner supplemental gas line, made of 5 mm diameter silicone with holes pipe was established longitudinally into the nipple line of the treatment group. The CO_2 gas was given through the inner line to carbonization by using a tube and a regulator settled at a pressure of 2-4 psi continuously (Fig. 1).

The drinking water samples were collected in prewashed polyethylene bottles (with detergent and doubly de-ionized distilled water, respectively). The pH level of water samples was measured with a portable digital pH meter (Hanna Instruments HI 8314) while collecting the samples. Each water sample was taken three times at different sampling periods. The determinations of the physical and chemical properties of the water samples were performed on the same day of sampling by the laboratory analysis (TS 5677 EN 25814, 1996; TS 4182 EN ISO 9963-2, 1998). The average levels of pH, HCO_3 (mmol L^{-1}), dissolved O_2 (mg L^{-1}) of the drinking water of control and carbonated water were measured as 7.4, 464.21, 5.1 and 5.7, 483.67 and 3.8, respectively.

Table 1: Ingredient composition and nutrient content of the experimental diets

Ingredients (%)	Starter diet 1-21 days	Grower diet[1] 22-42 days
Maize	42.92	55.70
Soybean meal	33.35	23.38
Full-fat soybean	13.90	11.66
Vegetable oil	5.00	5.00
Monocalcium phosphate	1.93	1.52
Limestone	1.67	1.29
DL-methionine	0.38	0.18
Liquid methionine	-	0.16
Bio-lysine	0.13	0.32
L-threonine	-	0.07
Salt	0.40	0.40
Coccidiostat[2]	0.07	0.07
Choline chloride	0.05	0.05
Vitamin/Mineral premix[3]	0.20	0.20
Analysed composition (g kg^{-1})		
Dry matter	98.54	98.01
Crude protein	24.40	21.17
Ether extract	8.40	7.44
Crude fibre	2.58	1.68
Crude ash	7.51	5.56
Total calcium	1.50	0.90
Total phosphorus	0.83	0.72
Metabolisable Energy (ME) (MJ kg^{-1})	12.47	12.64

[1]It was not supplemented with coccidiostat for the last 5 days; [2]Supplied per kg of diet: 105 ppm Lasalocid sodium (Avatec, Roche); [3]Supplied per kg of diet: retinol acetate 5.16 mg; cholecalciferol 0.05 mg; dl-alpha-tocopheryl acetate 30 mg; menadione 5 mg; thiamine 3 mg; riboflavin 8 mg; niacin 25 mg; calcium-D pantothenate 15 mg; pyridoxine 5 mg; cyanocobolamin 0.02 mg; folic acid 1 mg; D-biotin 0.05 mg; choline chloride 200 mg; manganese 80 mg; iron 60 mg zinc, 60 mg; copper 5 mg; cobalt 0.2 mg; iodine 1 mg; selenium 0.15 mg

Feed and water were continuously offered *ad libitum.* The lighting schedule was 24 h of light per day. During the experimental period, the average daily temperature and relative humidity inside the house ranged from 27-39°C and 40-70%, respectively.

Measurements and analysis: Body weights were determined individually at 21 and 42 days of age. Feed intake of each replicate was measured from 0-21, 22-42 and 0-42 days. Feed conversion ratio was calculated on the basis of unit feed consumed to unit body weight gain for each replicate separately, taking mortality into consideration.

At 42 days of age, twelve male birds were randomly selected from each group. Blood samples were obtained from a wing vein of each bird in the morning by using heparinized syringe and partial gas pressures (pO_2 and pCO_2) and pH were determined were determined with using an automated blood gas analyzer (Medica Easy Blood gas analyzer, Bedford, MA) as described by Hocking *et al*. (1994).

Experimental diets were ground through a 1 mm screening preparation for chemical analysis. Dry matter, crude protein, ether extract, crude ash, crude fiber, starch, sugar, total calcium and phosphorus were analyzed according to Verband Deutscher Landwirtschaftlicher Untersuchungsund Forschungsanstalten, VDLUFA (Naumann and Bassler, 1993). Estimates of metabolisable energy were based on protein, ether extract, starch and sugar levels determined on the experimental diets (Rose, 1997).

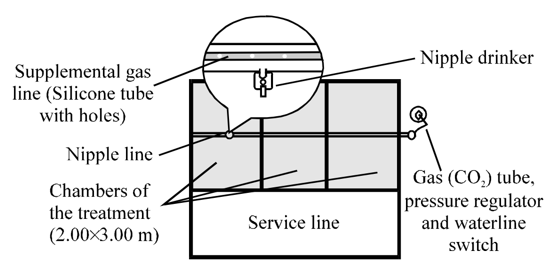

Fig. 1: The nipple line and its inner line is designed for the water treatment with CO_2 gas

Data and statistical analysis: The data were analyzed by a one-way analysis of variance using the General Linear Models (GLM) procedure of SAS Institute (1985). Further the group means were analyzed by the Duncan's multiple range test at 5% significance level ($p<0.05$).

RESULTS AND DISCUSSION

The responses of male broilers to carbonated drinking water are shown in Table 2 and 3. In Table 2, it was seen that carbonated drinking water did not significantly affect body weight, feed intake, feed conversion ratio and mortality of male broilers exposed to heat stress. The results support the observations of Okela *et al.* (2003) who reported that carbonation of ambient temperature and chilled drinking water did not produce significant benefits in live weight, feed conversion ratio and mortality after evaluating the combination of data obtained from two commercial broiler flocks. In one of experiments carried out by Smith and Teeter (1993), it was determined that carbonated water treatment significantly increased weight gain (17.2%) and feed efficiency of male broilers. These researchers did not exactly clarify the mode of action of carbonated water in weight gain enhancement and proposed that the beneficial effects of water carbonation might in part be a result of increased water consumption. In addition, Wiernusz (1998) indicated that the various drinking water supplementations may alter growth rate primarily by forcing the bird to increase its water consumption. The increase in water intake improves the efficiency of heat dissipation from the respiratory tract andto increase the intake of certain minerals to restore the concentrations of plasma electrolytes to normal levels (Benton *et al.*, 1998). On the other hand, Bottje and Harrison (1985b) found that carbonated drinking water improved average daily gain and feed efficiency in heat-stressed cockerels, suggesting that the increment in growth rate might be due to a partial compensation of the acid-base imbalance of respiratory alkalosis. According to Teeter and Smith (1986), carbonated drinking water treatment should be begun at 4 weeks of age because of the best time for electrolyte application during heat stress. Nevertheless, Soutyrine *et al.* (1998) reported that the carbonation of drinking water treatment to broilers from 4-7 weeks of age resulted in higher body weight and livability, better feed conversion and more water consumption.

Table 2: The effects of carbonated drinking water on performance of male broilers exposed heat stress

	Experimental groups			
Traits (days)	Control	Carbonated water	SEM[1]	p-value
Body weights (g)				
0	42.02	42.00	0.18	0.9705
21	752.29	747.94	4.47	0.6275
42	2257.06	2302.60	14.78	0.1247
Feed intake (g)				
0-21	781.57	779.09	11.44	0.9276
22-42	2755.04	2785.40	33.84	0.7034
0-42	3536.61	3564.46	39.34	0.7645
Feed conversion ratio (g g^{-1})				
0-21	1.12	1.10	0.02	0.8270
22-42	1.89	1.79	0.04	0.2477
0-42	1.64	1.58	0.03	0.3817
Mortality (%)				
0-42	5.13	3.21	1.13	0.3970

[1]Standard Error of Mean

Table 3: The effects of carbonated drinking water on blood gases and pH of male broilers exposed to heat stress

Experimental groups	pH	pCO_2 (mmol L^{-1})	pO_2 (mmol L^{-1})
Control	7.2900[a]	55.3200[b]	47.5600[a]
Carbonated water	7.2300[b]	62.0700[a]	37.1400[b]
SEM[1]	0.0100	1.6000	1.9900
Probability (p-value)	0.0153	0.0321	0.0255

[1]Standard Error of Mean; [a, b]LS Means within columns with no common superscript differ significantly ($p<0.05$)

As shown in Table 3, the carbonation of drinking water significantly reduced blood pH value from 7.29-7.23 and rised blood pCO_2 from 55.32-62.07 mmol L^{-1} in male broiler. In accordance with the findings, Raup and Bottje (1990) stated that birds treated carbonated water had lower arterial blood pH and higher pCO_2. At 37°C environmental temperature, Bottje and Harrison (1985a) determined that carbonated water treatment significantly decrease blood pH but not affect blood pCO_2. However, Soutyrine *et al.* (1998) indicated no blood pH and pCO_2 responses to application of carbonated drinking water during natural heat stress in broilers. Smith and Teeter (1993) noted that significant reduction in venous blood pH did not occur with carbonation of the drinking water even though the water consumed was acidic. In this study, the lower blood pH and higher blood pCO_2 might be associated with providing carbon dioxide and H^+ from carbonated water as reported by Bottje and Harrison (1985a). For this reason, the researchers implied that carbonated water treatment was apparently more effective in resisting pH change induced by heat stress than tap water treatment.

In birds exposed to high temperature, the elevation in respiratory activity increases blood pH and decreases blood pCO_2 and ultimately, blood flow patterns, body water distribution and mineral-ionic balance are disrupted. These physiological adjustments detrimentally affect nutrient utilization and meat production (Smith and Teeter, 1993). During the panting period, Teeter *et al.* (1985) reported that blood pH values in excess of 7.25 decreased growth rate and feed efficiency. As indicated by Hurwitz *et al.* (1973), maximum growth rate was obtained at 7.28 of plasma pH and depressed growth rate was observed above 7.30 or below 7.20 pH values. The pH values detected in the study are between Hurwitz *et al.* (1973)'s reported levels. Also, the growth performance findings support these statements.

The administration of carbonated drinking water significantly affected blood pO_2 of male broilers ($p<0.05$). Birds given carbonated drinking water had lower blood pO_2 (37.14 mmol L^{-1}) compared to those of the control group (47.56 mmol L^{-1}). These results of blood gases and pH showed that carbonated water administration improved blood acid-base balance under high ambient temperatures.

CONCLUSION

In the control group, the higher blood pO_2 and pH and the lower blood pCO_2 are associated with heat-induced respiratory alkalosis. The disturbances in blood acid-base balance were ameliorated by carbonation of the drinking water. However, the favorable effects did not rebound to the growth performance. Although, birds given carbonated water had higher body weight and better feed conversion ratio than the control group, these improvements were not statistically significant.

In addition, carbonation process reduced water pH from 7.4-5.7. Thus, carbonated water consumption might decrease the digestive system pH. The reduction of pH in the digestive tract might increase gastric proteolysis and improve the digestion of protein and it might also decrease the carcass contamination from the crop and intestinal contents via inhibit the development of pathogen microorganism in the intestinal tracts. In broiler production, the detrimental effects of high temperatures are more pronounced between 4 and 7 weeks of ages. In this period, the usage of carbonated water together with some natural growth promoters such as probiotics or prebiotics would be more effective in view of the improvement in acid-base balance and growth performance.

ACKNOWLEDGEMENT

Researchers wish to thank to Keskinoglu group for providing animals and feed materials.

REFERENCES

Benton, C.E., D. Balnave and J. Barake, 1998. Review: The use of dietary minerals during heat stress in broilers. Prof. Anim. Sci., 14: 193-196.

Borges, S.A., A.V.F. da Silva and A. Maiorka, 2007. Acid-base balance in broilers. World's Poult. Sci. J., 63: 73-81.

Borges, S.A., A.V.F. da Silva, J. Ariki, D.M. Hooge and K.R. Cummings, 2003. Dietary electrolyte balance for broiler chickens exposed to thermoneutral or heat-stress environments. Poult. Sci., 82: 428-435.

Bottje, W.G. and P.C. Harrison, 1985b. Effects of carbonated water on growth performance of cockerels subjected to constant and cyclic heat stress temperatures. Poult. Sci., 64: 1285-1292.

Bottje, W.G. and P.C. Harrison, 1985a. The effects of tap water, carbonated water, sodium bicarbonate and calcium chloride on blood acid-base balance in cockerels subjected to heat stress. Poult. Sci., 64: 107-113.

Bottje, W.G., P.C. Harrison, D.V. Boehm, F.E. Staten and T.W. Odom, 1983. Influence of carbonated water treatment on growth performance og heat-stressed and nonheat-stressed cockerels. Poult. Sci., 63: 1384-1384.

Daghir, N.J., 2008. Poultry Production in Hot Climates. 2nd Edn., CAB International, Wallingford, Oxfordshire, UK., Pages: 387.

Hocking, P.M., M.H. Maxwell and M.A. Mitchell, 1994. Hematology and blood composition at two temperatures in genetically fat and lean adult broiler breeder females fed ad libitum or restricted throughout life. Br. Poult. Sci., 35: 799-807.

Hurwitz, S., I. Cohen and A. Bar, 1973. Sodium and chloride requirements of chick: Relationship to acid-base balance. Poult. Sci., 52: 903-909.

Koelkebeck, K.W., P.C. Harrison and T. Madindov, 1993. Research note: Effect of carbonated drinking water on production performance and bone characteristics of laying hens exposed to high environmental temperatures. Poult. Sci., 72: 1800-1803.

Kreider, E.M., S.M. Nelson and P.C. Harrison, 1990. Influence of carbonated drinking water on tibia strength of domestic cockerels reared in hot environments. Am. J. Vet. Res., 51: 1948-1949.

Naumann, C. and R. Bassler, 1993. Methodenbuch, Band III. Die Chemische Untersuchung von Futtermitteln. VDLUFA-Verlag, Darmstadt, Germany..

Okela, P.O., L.E. Carr, P.C. Harrison, L.W. Gouglass, V.E. Byrd, C.W. Wabeck and P.D. Schreuders, 2003. Effectiveness of novel methods to reduce heat stress in broilers: Chilled and carbonated drinking water. Am. Soc. Agric. Eng., 46: 453-460.

Raup, T.J. and W.G. Bottje, 1990. Effect of carbonated water on arterial pH, PCO2 and plasma lactate in heat-stressed broilers. Br. Poult. Sci., 31: 377-384.

Rose, S.P., 1997. Principles of Poultry Science. CAB International, Wallingford, UK.

SAS Institute, 1985. SAS User's Guide: Statistics. SAS Institute Inc., Cary, NC.

Smith, M.O. and R.G. Teeter, 1993. Carbon dioxide, ammonium chloride, potassium chloride and performance of heat distressed broiler. J. Applied Poult. Res., 2: 61-66.

Soutyrine, A.G., M.O. Smith and B. Sivanadian, 1998. Feed withdrawal, potassium chloride and carbonated water effects on broiler thermotolerance. J. Applied Poult. Res., 7: 138-143.

TS 4182 EN ISO 9963-2, 1998. Water quality-determination of alkalinity-Part 2: Determination of carbonate alkalinity. Turkish Standards Institution. http://www.tse.org.tr/.

TS 5677 EN 25814, 1996. Water quality-determination of dissolved oxygen electrochenical probe method. Turkish Standards Institution. http://www.tse.org.tr/.

Teeter, R.G. and O.M. Smith, 1986. High chronic temperature stress effect on broiler acid-base and their response to supplemental NH4CL, KCL and KHCO3. Poult. Sci., 65: 1777-1781.

Teeter, R.G., M.O. Smith, F.N. Owens, S.C. Arp, S. Sangiah and J.E. Breazile, 1985. Chronic heat stress and respiratory alkalosis: Occurance and treatment in broiler chicks. Poult. Sci., 64: 1060-1064.

Wiernusz, C., 1998. Nutritional therapies to optimize poultry production during high humidty and ambient temperatures exposure. Techn. News, 6: 1-6.