Pakistan J. Zool., vol. 49(6), pp 2161-2171, 2017. DOI: http://dx.doi.org/10.17582/journal.pjz/2017.49.6.2161.2171

Effect of Adding Different Levels of Dietary Electrolyte in Broiler Rations using Sodium Bicarbonate as a Source of Electrolyte

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Article Information
Received 11 April 2017
Revised 30 May 2017
Accepted 03 July 2017
Available online 16 November 2017

Authors' Contribution
The current papers is MSc research work of TBY. NAT finalized the research. Both the authors wrote the manuscript.

Key words
Broiler, Dietary electrolyte balance, NaHCO3.

ABSTRACT

The study was designed to investigate the effect of feeding different levels of dietary electrolyte by adding sodium bicarbonate ($NaHCO_3$) on the performance of broilers. Experiment was conducted in two phases. In first phase (0-4 weeks), six broiler starter rations were formulated; a ration without $NaHCO_3$ was served as control whereas other five rations had 0.15-0.73% $NaHCO_3$ in the rations. In this way six dietary treatments resulted in dietary electrolyte balance (DEB) and sodium levels of 245, 262, 279, 297, 314, 331 meq/kg and 0.166, 0.206, 0.246, 0.286, 0.326, 0.336%, respectively. Protein and energy values in all broiler starter rations were kept at 20% and 2800 kcal/kg, respectively. In second phase, six finisher rations (5-6 weeks) were formulated viz., control ration and five other rations having 0.10-0.74% levels of $NaHCO_3$. The resulting dietary treatments were having DEB and sodium levels of 222, 240, 256, 273, 290, and 307 meq/kg and sodium levels of 0.203, 0.243, 0.283, 0.323 and 0.363%, respectively. The protein and energy level were 18% and 2800 kcal/kg, respectively. One eighty day-old broiler chicks were distributed in 18 units having 10 chicks each according to completely randomized design. Feed consumption, weight gain and feed conversion ratio (FCR) were significantly ($P<0.05$) improved in broilers fed all the experimental diets as compared to control during starter and finisher phases. A quadratic response was also observed on the performance of broilers during starter phase. However, a linear effect was seen for feed consumption during finisher phase while quadratic effect was observed for weight gain and FCR in boilers fed different levels of DEB and sodium. At 28 day of age percent thigh meat yield, breast meat yield and abdominal fat yield were significantly better in broilers fed experimental rations as compared to those fed control ration however non-significant ($P>0.05$) differences were observed in dressing percentage. But at 42 day age dressing percentage, percent thigh meat yield, breast meat yield and abdominal fat yield did not show any treatment effect. The electrolyte contents (Na^+, K^+, and Cl^-) of thigh and breast meat were also significantly higher in broilers fed experimental rations as compared to control. Similarly, significantly better Na^+, K^+, and Cl^- contents of thigh and breast meat were observed ($P<0.05$) among all the treatments. The results of present study depict that to support optimal performance of broilers, DEB levels between 250-300 and sodium levels of 0.28% is required.

INTRODUCTION

Dietary electrolyte balance (DEB) is a principal factor in the acid-base regulation, which determines blood pH for better enzymatic efficiency and thus, influences bird growth and performance (Murakami *et al*., 2001; Ahmad and Sarwar, 2006; Hassan *et al*., 2011). It has been reported that an electrolyte balance of 150 to 350 meq/kg in commercial broiler diets (1 to 21-day) guaranteed a maximum growth rate and optimum bird performance (Borges *et al*., 2003; Ahmad *et al*., 2005). Sodium and chloride are minerals with imperative physiological functions and a wide range of suggested requirements (Hassan *et al*., 2011). Both are low cost nutrients and their manipulation in diet has little influence on the diet cost.

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0030-9923/2017/0006-2161 $ 9.00/0

The effect of acid base balances on different metabolic processes of animals and hence on performance is currently a global issue (Borges *et al*., 2004; Gaddam *et al*., 2009; El-Sheikh and Salama, 2010). According to Mongin (1981), DEB refers to the difference between positive and negative ions present in the diet ($Na^+ + K^+ - Cl^-$) and is commonly expressed as meq kg^{-1} dry matter (DM). Besides the minimum required level of each element, proportions among them must be considered and maintained. The established value that expresses the quantity and relation among them is called Mongin number (MN; Silva *et al*., 1993):

$$MN = meq\ Na^+ + meq\ K^+ - meq\ Cl^-$$

To determine optimum dietary electrolyte balance it is important to keep the balance between the Na^+ and Cl^-. NRC (1994) recommended a minimum requirement of 0.15%, Na^+ and Cl^- for young broiler chickens. Frame *et* *al*. (2001) concluded that a diet containing 0.10 to 0.12% Na and 0.38 to 0.40% Cl, significantly improved turkey poults livability by reducing spontaneous cardiomyopathy mortality without adverse effects on poults weight or feed conversion ratio.

To obtain the best body weight gain (BWG) the level of Na^+ at 0.20% of the diet and the Cl^- requirement should be about 0.20% (Britton, 1991, 1992). NRC (1994) has established requirements of 0.20% each for Na^+ and Cl^- for chicks from 0 to 3 weeks. Butolo *et al*. (1995) verified the influence of NaCl levels on feed conversion ratio (FCR) and suggested a requirement of 0.55% NaCl or 0.22% Na^+. With this aim, to verify broiler nutritional requirements from 1 to 21 days, Murakami *et al*. (1997b) estimated the best BWG with 0.25% of Na^+. In another experiment evaluating two sources and levels of Na^+, Murakami *et al*. (1997a) estimated a requirement of 0.20% of Na^+ for 21 days. These authors verified that there were no productive differences between sodium bicarbonate ($NaHCO_3$) and NaCl as Na^+ sources. Barros *et al*. (1998) estimated a nutritional requirement of 0.25% of Na^+ for male and female broiler chickens from 1 to 21 days. Maiorka *et al*. (1998) determined a nutritional requirement of 0.30% Na^+ for maximum performance from 1 to 21 days of age. The best DEB varies according to manipulation of electrolytes (Borges *et al*., 2003). When Na^+ and $C1^-$ were manipulated, best weight gain was found with 199 meq/kg DEB. Rondon *et al*. (2000) found optimal DEB of 250 meq/kg when Na^+ levels varied and 319 meq/kg when the manipulated ion was K^+.

Table I.- Chemical composition of the experimental rations.

	Starter diets (0-28 d) (Na+K-Cl, meq/kg)						Finisher diets (21-49 d) (Na+K-Cl, meq/kg)					
Ingredients	**245[1]**	**262**	**279**	**297**	**314**	**331**	**222[1]**	**240**	**256**	**273**	**290**	**307**
Corn (maize), %	30.00	30.00	30.00	30.00	30.00	30.00	32.00	32.00	32.00	32.00	32.00	32.00
Soybean meal, %	24.00	24.00	24.00	24.00	24.00	24.00	18.40	18.40	18.40	18.40	18.40	18.40
Canola meal, %	7.50	7.50	7.50	7.50	7.50	7.50	7.00	7.00	7.00	7.00	7.00	7.00
Sunflower meal, %	1.21	1.21	1.21	1.21	1.21	1.21	3.54	3.54	3.54	3.54	3.54	3.54
Rice tips, %	19.51	19.51	19.37	19.22	19.10	19.07	21.52	21.52	21.00	21.52	21.38	21.37
Vegetable oil, %	1.03	1.03	1.03	1.03	1.03	1.05	1.00	1.00	1.00	1.00	1.00	1.00
Rice polishing, %	8.00	7.85	7.85	7.85	7.85	7.63	8.00	7.85	7.71	7.56	7.55	7.37
Corn gluten meal 60%, %	1.89	1.89	1.89	1.89	1.89	1.92	1.00	1.00	1.00	1.00	1.00	1.02
Molasses, %	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00	3.00
Bone meal, %	—	—	—	—	—	—	1.93	1.93	1.93	1.93	1.93	1.93
Dicalcium phosphate, %	1.77	1.77	1.77	1.77	1.77	1.77	0.83	0.83	0.83	0.83	0.83	0.83
Calcitic limestone, %	1.27	1.27	1.27	1.27	1.27	1.27	0.99	0.99	0.99	0.99	0.99	1.24
L-lysine.Hcl, %	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15	0.15
D L -Methionine, %	0.16	0.16	0.16	0.16	0.16	0.16	0.14	0.14	0.14	0.14	0.14	0.14
NaHCO3, %	—	0.15	0.29	0.44	0.59	0.73	—	0.05	0.27	1.46	1.99	
Premix,[2] %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total, %	100.0	100.0	100.0	100.0	100.0		100.0	100.0	100.0	100.0	100.0	100.0
Chemical composition of the rations												
ME, kcal/kg	2800	2796	2791	2786	2781	2778	2800	2795	2791	2787	2782	2778
Crude protein, %	20.00	19.98	19.97	19.96	19.94	19.94	17.97	17.95	17.93	17.91	17.90	17.88
Calcium, %	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Available phosphorus, %	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
Methionine, %	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lysine, %	1.14	1.14	1.14	1.14	1.14	1.14	1.00	1.00	1.00	1.00	1.00	1.00
Sodium, %	0.166	0.206	0.246	0.286	0.326	0.366	0.163	0.203	0.243	0.283	0.323	0.363
Chloride, %	0.200	0.200	0.200	0.200	0.200	0.200	0.199	0.199	0.199	0.199	0.199	0.199
Potassium, %	0.89	0.89	0.89	0.89	0.89	0.89	0.80	0.80	0.80	0.80	0.80	0.80

[1], control treatment, no addition of $NaHCO_3$-carbonate. [2] Vitamin Mineral Premxi contribution of per Kg diet: VIT. A, 7500 (IU); VIT. D3, 2500 (IU); VIT. B1, 1.0 (mg); VIT.B2, 5.5 (mg); VIT.B6, 2.2 (mg); VIT. B12, 0.02 (mg); VIT. E, 8 (IU); VIT. K3, 2 (mg); Folic acid, 0.50 (mg); Pantothenic acid, 13 (mg); Niacin, 37 (mg); Choline chloride, 500 (mg); Biotin, 0.10 (mg); Manganese, 66 (mg); Zinc, 55 (mg); Copper, 6 (mg); Iodine, 1.2 (mg); Iron, 27.5 (mg).

Since the previous literature on sodium requirements indicates that 0.20% level of dietary Na^+ are scarce for the best performance of broilers, the objective of present study was to investigate the effect of different levels of sodium and dietary electrolyte balance on body weight gain, feed conversion ratio, feed intake, dressing percentage, and breast muscle yield and to determine the optimum level of sodium and DEB in broiler rations.

MATERIALS AND METHODS

One hundred and eighty day-old Hubbard broiler chicks of mixed sex were purchased from commercial hatchery and randomly distributed into 18 experimental pens of 10 chicks each. Chicks were reared under standard hygienic conditions. One pen was allotted to each replicate at random. Each ration was fed to three experimental units selected at random. Each pen was equipped with a feeder and waterer for round the clock free access to feed and water. Electric bulbs and fans were used to comfort birds and for 24 h of light. A thin layer (5-10cm) of saw dust was used as bedding material. The birds were vaccinated against Newcastle disease and infectious bursal disease. The nutrient profile of the basal diet is presented in the Table I. The chicks received a starter ration from 0-4 weeks and finisher ration from 5-6 weeks.

To segregate the effect of electrolytes, six experimental feeds were formulated to have almost the similar percentages of feed ingredients. The desired target "Mongin number" or DEB was obtained by adding $NaHCO_3$ alone to the feed; amount of K^+ and Cl^- were fixed. Feed ingredients, diets and water samples were analyzed for Na, K and Cl. Na and K levels in feed ingredients and diets were determined by flame spectrophotometry (AOAC, 1990), whereas Cl^- was determined by $AgNO_3$ titration (Lacroix *et al*., 1970).

Phase-I: This phase consisted of 1-4 weeks of age of birds. Six broiler starter rations were formulated; one without addition of $NaHCO_3$ served as control ration whereas other five rations were having 0.15-0.73% levels of $NaHCO_3$ (Table I). In this way six dietary treatments resulted in DEB and sodium levels of 245, 262, 279, 297, 314, 331 meq/kg and 0.166, 0.206, 0.246, 0.286, 0.326, 0.336%, respectively. The rations were formulated by using computer software UFFDA (Pesti *et al*., 1992). Prior to formulation each ingredient was analyzed in triplicate for proximate composition by standard procedures (AOAC, 1990). The diets were isonitrogenous and isocaloric including levels of 0.89% K+ and 0.20% Cl-. The dietary protein and energy value in broiler starter rations were kept at or near 20% and 2800 kcal/kg, respectively.

Phase-II: In second phase of experiment (5-6 weeks) six finisher rations were formulated; one control ration without addition of $NaHCO_3$ and five other rations 0.10-0.74% levels of $NaHCO_3$ (Table I). The resulting dietary treatments were having DEB and sodium levels of 222, 240, 256, 273, 290, and 307 meq/ kg and sodium levels of 0.203, 0.243, 0.283, 0.323 and 0.363%, respectively. In finisher rations the dietary protein and energy level were kept at 18% and 2800 Kcal/kg, respectively.

Data on weekly weight gain and feed consumption per replicate was collected during the trial and was used to calculate respective feed conversion ratios. Mortality and any other untoward ailments were also recorded. At the end of 28th day and 42nd day, all the birds were weighed and 10% of the housed birds (1 bird/replicate) were selected randomly; slaughtered, and after four minute bleeding time the feathers were removed and carcass manually eviscerated to determine dressing percentage and parts yield. Data on dressing percentage (excluding heart, liver, lungs, gizzard and spleen), thigh, and breast meat yield (as percent of carcass weight) and abdominal fat percentage (comprised the fat surrounding the bursa of fabricius, cloaca, and abdominal muscles) was recorded. Muscle sample (5-10 g) breast and thigh region was taken for the analysis of electrolyte contents.

The data thus collected was analysed according to completely randomized design and significant means were compared by Duncan's Multiple Range Test to draw a valid conclusion (Steel *et al*., 1997).

Table II.- Performance of broilers fed diets with different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) from 0 to 28 d of age.

Mongin No/ DEB (meq/kg)	Weight gain/ bird (g)	Feed intake/ bird (g)	FCR (Feed/ Gain)	Mortality %
245	445.2^{b}	1417^{b}	3.18^{a}	0.00^{c}
262	775.4^{a}	1623^{a}	2.11^{ab}	1.00^{b}
279	818.5^{a}	1527^{ab}	1.92^{b}	1.67^{b}
297	788.8^{a}	1518^{ab}	1.97^{b}	1.67^{b}
314	876.9^{a}	1656^{a}	2.04^{b}	2.67^{b}
331	827.3^{a}	1583^{ab}	2.03^{ab}	3.00^{a}

$^{a-c,}$ Means within a column and having superscripts but lacking a common superscript differ (P <0.05).

RESULTS

Starter phase (0-28 d)

During starter phase mean values for weight gain, feed consumed and FCR are given in Table II. Maximum weight per bird (820.5 g) was observed in birds fed diet E having DEB 314 meq/kg (0.366% sodium level) while the minimum (445.16 g) was observed in birds fed control diet (245 meq/kg, Na level 0.166%). There were significant differences ($p<0.05$) of weight gain in birds fed all the experimental diets as compared to those fed control. While the results of weight gain were similar statistically in birds fed all the experimental diets. The body weight gain was maxim at sodium level of 0.28% and DEB levels of 370-300 meq/kg. Quadratic responses of weight gain and FCR were obtained during the starter phase (Fig. 1). Brenes *et al*. (1988) and Teeter *et al*. (1985) found increase in weight gain at 9% with 0.5% $NaHCO_3$ addition and attributed this beneficial effect due to HCO_3- ions. The value of DEB (314 meq/kg) used in this study is higher than the value considered as ideal (250 meq/kg) by Mongin (1981), but this is within the range of 250-350 meq/kg suggested by Johnson and Karunajeewa (1985). Murakami *et al*. (2000) suggested better performance of broilers from 1-21 days of age with diets containing DEB between 246 and 315 meq/kg.

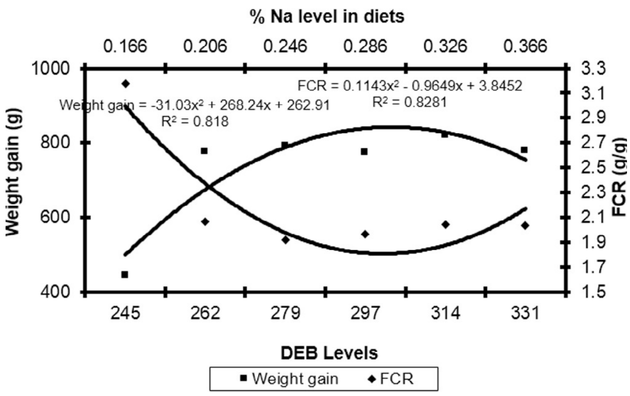

Fig. 1. Performance of broilers fed diets with different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) from 0 to 28 d of age.

During starter phase maximum feed (1632.42 g) was consumed by the birds fed diet having DEB level of 314 meq/kg of the diet (Na^+= 0.326%, K^+=0.89%; Cl^- =0.20%) while minimum (1417.36g) feed intake was observed in the birds fed control diet (DEB level 245 meq/kg, 0.166% Na). Maximum feed intake was observed in birds fed higher DEB and sodium levels. Balnave and Gorman (1993) observed improved feed consumption with $NaHCO_3$ supplementation. It is obvious that addition of $NaHCO_3$ in the starter diet proved beneficial at each level of supplementation. The results have also supported the findings of Rondon *et al*. (2000) who reported that sodium levels had quadratic effect on feed intake during starter phase. The feed intake and BWG were maximized at DEB level of 297 meq/kg (0.286% Na). These values are similar to the requirement of 0.28% sodium for starter phase, estimated by Maiorka *et al*. (1998) and higher than those reported by Britton (1992), NRC (1994) and Murakami *et al*. (1997a). All of them estimated a Na^+ requirement of 0.20% which is higher than those reported by Barros *et al*. (1998) and Murakami *et al*. (1997b) who estimated Na requirement of 0.25% during the starter phase.

FCR values also revealed significant differences ($p<0.05$) among treatment means. During starter phase birds fed DEB level of 279 meq/kg had the best FCR (1.92) followed by those given ration having DEB of 297 meq/kg (1.97) while the lowest (3.18) in the birds fed control diet. Improved FCR was observed in birds receiving diet (DEB level of 297 meq/kg, 0.286% Na). However, Vieira *et al*. (2003) found that performance of birds given 0.12% sodium in feed was impaired when compared with those fed the diets having high sodium levels (0.24%).

A linear effect ($p<0.01$) on mortality was observed in birds fed all the experimental diets as compared to control (Fig. 2). Increasing Na levels with increasing DEB levels caused increased mortality and it was maximizing in birds receiving DEB level of 331 meq/kg (0.386% Na). Higher DEB levels might have accounted for increased mortality due to the ascites in present study.

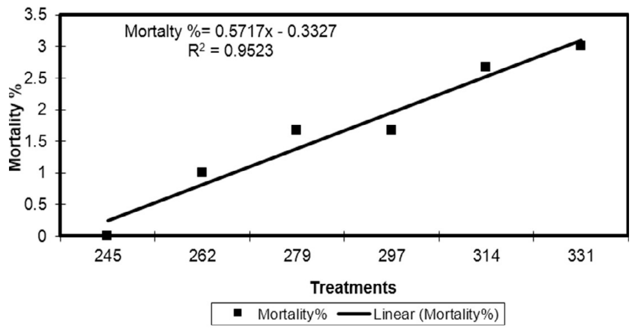

Fig. 2. Effect of different levels of sodium and dietary electrolyte balance on mortality of birds during starter phase.

Carcass measurements (28th day carcass responses)

Perhaps the most important criterion in evaluating performance is the carcass data. The carcass data at 28th day is shown in Table III. Increasing dietary sodium with $NaHCO_3$ showed an improvement in carcass yield, to a limit and improved water intake of the carcass (Fig. 3, Table III).

Dressing percentage

The mean values for dressed weight on different experiment treatments are shown in Table III. Although the statistical analysis of dressing percentage revealed non-significant difference (p<0.05) among all treatment means yet maximum carcass weight (58.58%) was yielded by the birds fed control diet having DEB level of 297 meq/kg (0.286% Na). The minimum carcass weight (47.29%) was observed in the birds fed diet having DEB levels of 331 meq/kg (0.366% Na). Current study have supported the findings of previous work by Champaign (1994) who reported that in his study electrolytes failed to affect dressing percentage of broilers.

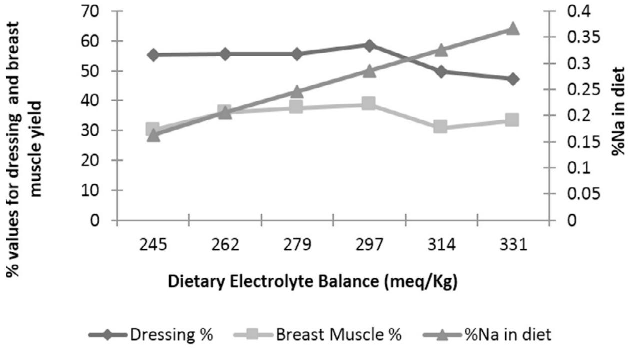

Fig. 3. Effect of different levels of sodium and dietary electrolyte balance on dressing % and breast muscle % during starter phase.

Table III.- Effect of adding different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) on dressing %, breast muscle %, thigh muscle % and abdominal fat % on 28th day.

Mongin No/ DEB (meq/kg)	Dressing (%)	Thigh muscle (%)	Breast muscle (%)	Abdominal fat (%)
245	55.23^{a}	41.67^{a}	30.33^{b}	4.94^{a}
262	55.58^{a}	43.19^{a}	36.03^{ab}	1.96^{b}
279	55.37^{a}	43.96^{a}	37.59^{ab}	1.39^{b}
297	58.58^{a}	42.70^{a}	38.56^{ab}	2.22^{b}
314	49.71^{a}	43.44^{a}	30.77^{b}	1.90^{b}
331	47.29^{a}	43.59^{a}	33.21^{ab}	1.95^{b}

$^{a-c}$ Means within a column and having superscripts but lacking a common superscript differ (*P* <0.05) by DMR.

Breast muscle yield

Maximum BMY (38.56%) was obtained from the birds fed diet having 297 meq/kg of DEB level (0.286% Na) while the minimum yield (30.33%) was observed in birds fed control diet (Table III). NRC (1994) reported that out of essential amino acids lysine is mainly responsible for breast meat yield. Wallis (1999) reported that methionine in the presence of adequate lysine is mainly responsible for breast meat yield and other carcass responses. It seems that high dietary Cl^- and high dietary K^+ might have caused problem in lysine and methionine absorption that lead to fewer breast meat yield in the birds fed diet containing higher DEB levels *i.e.* 314 and 331 meq/kg. In the present study the protein levels were low as compared to NRC (1994) recommendations but the diets were balanced for Essential Amino Acids according to NRC (1994) recommendations. However, Jianlin *et al*. (2001) reported that breast meat yield was unaffected by dietary lysine levels. Similarly, Zarate *et al*. (2003) observed that reducing CP levels as compared to NRC standards reduced BMY significantly in summer reared broilers and even, the EAA supplementation in 10% excess of the industry standards had not any detectable influence on BMY. Significant differences observed in present study may be the result of diets formulated with Na and varying levels of dietary electrolyte balance. The improvements in breast meat yield may be due to increased tissue water content.

Thigh muscle yield

The maximum thigh meat (43.96%) was yielded by the birds fed diet having DEB level of 279 meq/kg (Na+=0.246%; K+=0.89%; Cl^-=0.2%) while the minimum thigh meat (41.67%) was yielded by the birds fed control diet while an intermediate yield in birds receiving diet having DEB level of 297 meq/kg (0.286% Na). However, the statistical analysis revealed non-significant differences among all the treatment means for thigh meat yield.

Abdominal fat

The mean values for abdominal fat on different experimental treatments revealed significant difference (p<0.05) among the treatments. The birds fed diet having DEB level of 279 meq/kg (0.246% Na) had the minimum abdominal fat (1.39%) while the maximum abdominal fat (4.94 %) was observed by the birds fed control diet (Table III).

DISCUSSION

Finisher phase (21 to 42 d) and overall (0 to 42 d) performance

Statistical analysis of feed intake, weight gain, and FCR during finisher phase and overall trial period revealed significant differences (p<0.05) among all treatments (Tables IV, V). A quadratic effect for weight gain and FCR was observed during finisher phase and for overall period (Figs. 3, 4). Although non-significant results were obtained for dietary treatments of $NaHCO_3$ addition yet maximum weight per bird (973.6 g) was gained by the group fed diet having DEB level of 273 meq/kg (0.283% Na) while minimum weight gain per bird (507.92 g) was observed in birds fed control diet. Assessing the overall performance for 0-42 days; maximum weight gain was also observed in group having DEB level of 273 meq/kg (0.283% Na) (Table V).

Table IV.- Performance of broilers fed diets with different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) from 29 to 42 d of age.

Mongin No/ DEB (meq/kg)	Weight gain/ bird (g)	Feed intake/ bird (g)	FCR (Feed/ Gain)	Mortality %
222	507.9^{b}	1718.7^{a}	3.41^{a}	0.00^{c}
240	931.6^{a}	1994.6^{c}	2.11^{bc}	1.00^{b}
256	926.5^{a}	2062.4^{bc}	2.08^{bc}	1.67^{b}
273	973.6^{a}	2065.2^{bc}	1.92^{c}	1.67^{b}
290	808.0^{a}	2023.9^{bc}	2.49^{b}	2.67^{a}
307	850.6^{a}	2187.7^{b}	2.47^{b}	3.00^{a}

$^{a-c,}$ Means within a column and having superscripts but lacking a common superscript differ *(P* <0.05) by DMR.

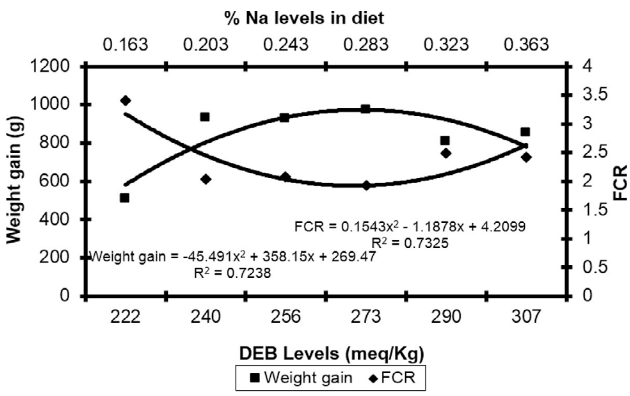

Fig. 4. Effect of different levels of dietary electrolyte balance and sodium ion on weight gain (0-42 days).

Maximum body weight gain was recorded in the birds receiving sodium level of 0.286% Na and DEB level of 297 meq/kg in accordance with NRC (1994) recommendations of 0.20% Na. Vieira *et al*. (2003) found increased body weight gain when the Na^{+} level was increased up to 0.24%. Body weight gain was significantly better in birds fed supplemented rations (treatments) as compared to those fed control ration but non-significant results were recorded within the sodium and DEB supplemental treatments as it was previously observed by Borgatti *et al*. (2004) in their studies. However, the results do not support the findings of Britton (1992), NRC (1994), Murakami *et al*. (1997b) in respect of Na^{+} requirements. They reported Na^{+} requirements of 0.20% but the estimated requirement of Na (0.20%) was far less than observed as optimum level of Na (0.286%) for weight gain and FCR during the finisher phase in the present study. The DEB and Na level of 297 meq/kg and 0.286% was optimal in overall evaluation of performance data.

The results of feed consumption of birds fed control diet and diet having DEB level of 314 meq/kg have significantly better results with respect to all other treatments. During finisher phase maximum feed (2102 g) was consumed by the birds fed diet having DEB level of 307 meq/kg (0.363% Na) while the minimum (1718.70 g) was observed by the birds fed control diet. However, average amount of feed (1850g) was consumed by the broilers receiving diet with DEB levels of 297meq/kg (0.286% Na). Increased feed intake was observed at higher sodium and DEB levels. Also, during 0-42 days (Table V) maximum amount of feed (3685 g) was consumed by the birds fed diet having DEB level of 307 meq/kg (0.363% Na) while the minimum (1718.70 g) was observed by the birds fed control diet.

Table V.- Performance of broilers fed diets with different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) from 0 to 42 d of age.

Mongin No/ DEB (meq/kg)	Weight gain/ bird (g)	Feed intake/ bird (g)	FCR (Feed/ Gain)	Mortality %
222	953^{b}	3136^{c}	3.30^{a}	0.00^{d}
240	1760^{a}	3522^{ab}	2.00^{bc}	1.00^{c}
256	1720^{a}	3432^{b}	2.00^{bc}	2.67^{b}
273	1798^{a}	3368^{b}	1.88^{c}	2.67^{b}
290	1629^{a}	3660^{a}	2.26^{b}	4.33^{a}
307	1630^{a}	3685^{a}	2.26^{b}	4.67^{a}

$^{a-d,}$ Means within a column and having superscripts but lacking a common superscript differ *(P* <0.05) by DMR.

Feed consumption in the finisher phase increased significantly with addition of supplemental sodium in the diet. Rondon *et al*. (2000) observed feed intake reduction in response to dietary increase of Mongin number obtained by the addition of chloride. In the present study the chloride was fixed according to NRC (1994) recommendations (0.2%) so the higher weight gain observed in higher sodium and DEB level supplementation. It might be due to increased sodium ion in the diet. Increased Na caused increased water intake and ultimately feed intake was increased because feed intake is positively correlated to water intake. The results of the present study have supported the findings of the Karunajeewa and Barr (1985), who observed significantly better feed consumption during finisher stage when birds were fed. They further justified that the birds at finisher stage were more tolerant to potassium than starter phase combined with higher Mongin number. The probable explanation may be that feed consumption is dependent on sodium level in the ration and higher sodium might have enhanced feed intake. Similar results were reported by Damron *et al*. (1986) who observed improvement in the feed intake as the level of $NaHCO_3$ in the diet was increased.

A quadratic response of dietary sodium chloride on FCR in birds fed all the experimental diets was observed (Tables IV, V). Improved FCR was observed by the addition of $NaHCO_3$ in the experimental diets. During finisher phase birds fed diet having DEB of 273 meq/kg (Na^+=0.283%; K^+=0.80%; Cl^-=0.20%) was responsible for improved FCR (1.92) while the worse FCR (3.41) was observed by the birds fed control diet. During 0-42 day period, the overall FCR (1.88) was observed in birds receiving DEB level of 273 meq/kg.

It was demonstrated earlier by Hooge *et al*. (1999) that supplemented sodium chloride improved feed conversion efficiency. Murakami *et al*. (2001) out lined the sodium requirement (0.20%) for the maximum growth less than suggested on the basis of present study.

Control diet had significantly lower mortality of the birds as compared to those fed other dietary treatments. A linear effect was found for the mortality during the finishing phase and for overall performance period. However, the highest mortality was observed in the birds fed the diet having DEB level of 307 meq/kg (0.363% Na).

Mortality due to ascites in the birds fed high sodium with increasing dietary electrolyte balance might have occurred in present study. The results of the current study have supported the findings of Xiang *et al*. (2004) who also observed the incidence of ascites (PHS) in the broilers given water having highest level of sodium chloride. Similar results were also obtained by other researchers (Wideman and Bottje, 1993).

In contrast, results of present study do not support the work conducted by the findings of Hullan *et al*. (1978) and Borges *et al*. (2000) who observed no treatment effect on mortality in any of evaluated starter or finisher phase performance. The overall results of the experiment showed significant differences in the incidence of mortality in birds fed the higher levels of sodium chloride (0.5%). Moreover, Borges *et al*. (2003), (2004) and Borgatti *et al*. (2004) also found no differences in mortality between treatments with different dietary electrolyte balance.

42nd carcass responses

Dressing percentage (%)

Maximum dressed weight (*i.e.,* 58.0%) was yielded by the birds fed diet having DEB level of 256 meq/kg (0.243% Na) while poor dressing percentage (53.56%) was yielded by those fed dietary treatment of DEB 307 meq/kg (0.363% Na). However, dressing percentage values revealed non-significant difference (P>0.05) among all the treatments (Table III). Results of the present study have supported the findings of Champaign (1994) who reported similar observation in his research study.

Thigh and breast meat yield

The maximum thigh meat (*i.e.,* 44%) was yielded by the birds fed control diet while the minimum thigh meat (*i.e.,* 39.18%) was yielded by the birds fed on diet F (307 meq/kg). Similarly, The maximum breast meat (*i.e.,* 38.83%) was obtained from the birds fed on diet having DEB level of 256 meq/kg (0.236% Na) of diet; while the minimum breast meat yield (*i.e.,* 36.00%) was observed in the birds fed the diet DEB of 240 meq/kg (0. 203% Na). However, the results did not show any treatment effect statistically (Table VI). The results of the present study have supported the findings of Whiting *et al*. (1991) and Dewar and Whitehead (1973) who reported non-significant differences in breast and thigh meat percentage due to dietary inclusion of salts in broiler rations. Borges *et al*. (2003) also demonstrated the similar results.

Abdominal Fat

Fat surrounding abdominal organs was isolated and calculated as the percentage of carcass weight. The birds fed diet having DEB of 273 meq/kg (0.283% Na) had the minimum abdominal fat (*i.e.,* 2.32%) while the maximum abdominal fat (*i.e.,* 3.14) was observed by the birds fed diet having DEB level of 240 meq/kg (0.203% Na; Table VI). However, the differences among treatment means did not depict any significant effect. Darden and Marks (1985) found that there was no direct effect of salt on abdominal fat. However, Wojcik *et al*. (1983) found increased abdominal fat with the addition of sodium chloride in the diet of broilers.

Sodium, potassium and chloride contents of thigh and breast muscles

Minimum Na^+ contents (82.35 meq/100g) of thai meat at 28th day and 123.9 meq/100g at 42nd day were observed by the birds fed control diet while maximum Na^+ contents *i.e.,* 143.6 meq/100g at 28th day and 288.0 meq/100g at 42nd day were observed by the birds fed diet having DEB levels of 273 meq/kg 0.283% Na (Tables VII, VIII). The minimum Na^+ contents *i.e.,* 60.97 meq/100g at 28th day and 101.5 meq/100g at 42nd day were observed by the birds fed control diet while maximum Na^+ contents *i.e.,* 141.7 meq/100g at 28th day and 142.7 meq/100g at

42[nd] day were observed by the birds fed diet having DEB levels of 262 meq/100g (0.206% Na: Tables VII, VIII). Minimum K^+ contents *i.e.,* 120.9 meq/100g at 28[th] day and 119.3 meq/100g at 42[nd] day was observed by the birds fed control diet while maximum K^+ contents *i.e.,* 312.0 meq/100g at 28[th] day and 313.0 meq/100g at 42[nd] day were observed by the birds fed diets having DEB levels of 331 meq/100g and 290 meq/kg, respectively. The minimum K^+ contents *i.e.,* 121.85 meq/100g at 28[th] day and 121.9 meq/100g at 42[nd] day was observed by the birds fed control diet while maximum K^+ contents *i.e.,* 295.0 meq/100g at 28[th] day and 292 meq/100g at 42[nd] day were observed by the birds fed having DEB levels of 331 meq/100g and 290 meq/kg, respectively.

The minimum Cl^- contents *i.e.,* 69.43 meq/100g at 28[th] day and 114.4 meq/100g at 42[nd] day was observed by the birds fed control diet having Na and DEB levels of 0.366% and DEB level of 331 meq/kg while maximum Cl^- contents *i.e.,* 82.50 meq/100g at 28[th] day and 124.5 meq/100g at 42[nd] day was observed by the birds fed control diet.

Table VI.- Effect of different levels of sodium bi-carbonate on slaughter parameters in chicks.

Parameters	Treatments					
	A	B	C	D	E	F
Dressing (%) 28[th] day	55.23	55.58	55.37	58.58	49.71	47.29
Thigh meat (%) 28[th] day	41.67	43.19	43.96	42.70	43.44	43.59
Breast meat (%) 28[th] day	30.33^b	36.03^{ab}	37.59^{ab}	38.56^a	30.77^b	33.21^{ab}
Abdominal fat (%) 28[th] day	4.95^a	1.96^b	1.39^b	2.22^b	1.90^b	1.95^b
Dressing (%) 42[nd] day	57.23	56.30	58.0	56.10	51.0	53.56
Thigh meat (%)42[nd] day	44.00	41.51	41.61	41.83	42.10	39.18
Breast meat (%)42[nd] day	36.20^{ab}	36.0^{ab}	38.83^a	36.30^{ab}	37.63^{ab}	38.01^a
Abdominal fat (%)42[nd] day	2.79	3.46	2.92	2.45	2.54	2.77

Table VII.- Effect of adding different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) on sodium, potassium and chloride contents of breast and thigh muscles at 28[th] day.

Parameters	Treatments (Na+K-Cl, meq/kg)					
	245	**262**	**279**	**297**	**314**	**331**
Na^+ (meq/100g) thigh 28[th] day	82.35^a	141.7^c	120.0^d	118.5^c	118.1^c	118.7^c
K^+ (meq/100g) thigh 28[th] day	120.90^d	255.0^c	284.3^b	285.6^b	281.0^b	312.0^a
Cl^- (meq/100g) thigh 28[th] day	82.50^a	80.26^b	77.95^c	74.47^d	71.42^e	69.43^f
Na^+ (meq/100g) breast 28[th] day	60.97^a	141.7^a	141.7^a	143.6^a	125.41^b	125.41^b
K^+ (meq/100g) Breast 28[th] day	121.85^c	288.3^a	292.3^a	270.0^b	285.0^a	285.0^a
Cl^- (meq/100g) Breast 28[th] day	81.46^a	80.34^{ab}	78.85^b	76.10^c	74.07^d	72.00^e

[a–d,] Means within a column and having superscripts but lacking a common superscript differ *(P* <0.05) by DMR.

Table VIII.- Effect of adding different dietary electrolyte balances (DEB; Na + K - Cl, meq/kg) on sodium, potassium and chloride contents of breast and thigh muscles at 42[nd] day.

Parameters	Treatments (Na+K-Cl, meq/kg)					
	222	**240**	**256**	**273**	**290**	**307**
Na^+ (meq/100g) thigh 42[nd] day	123.9^d	141.8^c	141.9^c	288.0^a	284.6^b	141.1^c
K^+ (meq/100g) thigh 42[nd] day	119.32^d	271.7^c	288.7^b	295.3^b	313.0a	286.7^{bc}
Cl^- (meq/100g) thigh 42[nd] day	124.49^a	122.6^b	120.3^c	118.2^d	115.8^e	144.4^f
Na^+ (meq/100g) breast 42[nd] day	101.5^b	141.6^a	142.4^a	142.2^a	142.7^a	142.7^a
K^+ (meq/100g) breast 42[nd] day	120.75^c	274.0^b	271.7^b	288.3^a	292.0^a	272.3^a
Cl^- (meq/100g) breast 42[nd] day	122.14^a	121.5^a	120.4^b	118.5^c	118.1^c	117.8^c

[a–d,] Means within a column and having superscripts but lacking a common superscript differ *(P* <0.05) by DMR.

The minimum Cl^- contents *i.e.,* 72 meq/100g at 28th day and 117.8 meq/100g at 42nd day were observed by the birds fed diet having DEB levels of 331 meq/kg (0.366% Na). Maximum Cl^- contents *i.e.,* 122.2 meq/100g at 28th day and 81.46 meq/100g at 42nd day was observed by the birds fed control diet. Statistical analysis of sodium, potassium and chlorine contents of thigh and breast meat revealed significant difference ($p<0.05$) both at 28th and 42nd days.

The results of the present study demonstrate that dietary $NaHCO_3$ could significantly affect sodium, potassium, and chloride contents of thigh and breast meat at 28th and 42nd day. Breast meat's Na^+ contents were lower than that of thigh meat at all stages while K^+ contents of breast meat were higher than thigh meat at all stages. However, at 42nd day thigh meat's K^+ contents increased than that of breast meat. Sharma and Gangwar (1987) reported that breast muscle had significantly lower Na^+ and higher K^+ concentrations than thigh muscle in 4-8 week broilers in heat stress conditions (32 ºC). However, this parameter requires further investigations.

CONCLUSION

Performance of birds in weight gain, feed consumption and FCR was improved with respect to control at each level of Na-Bicarb addition. However, A quadratic effect was recorded for FCR, weight gain and feed consumption during the starter phase. Mortality was significantly different in groups receiving different sodium and DEB levels however, birds receiving higher sodium and DEB levels had maximum mortality. Overall performance data showed that adding different levels of dietary electrolyte in broiler rations using sodium bicarbonate as a source of electrolyte could improve performance of birds but its higher levels may be avoided to obviate high mortality.

Statement of conflict of interest

Authors have declared no conflict of interest.

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