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Effects of Dietary Electrolyte Balance on the Performance of Broiler Chickens Fed High Calcium Diets

[1]T.M. Shafey, [1]R.S. Aljumaah, [2]M.A.K. Abdelhalim, [2]M.M. Mady and [2]M.M. Ghannam
[1]Department of Animal Production, College of Food and Agriculture,
[2]Department of Physics, College of Sciences, King Saud University, Riyadh, Saudi Arabia

Abstract: The effects of high Calcium (Ca, 10 and 25 g kg^{-1}) and Dietary Electrolyte Balance (DEB, 250 (basal diet), 200 and 300 mEq kg^{-1} (3 diets with high Na, K and Na plus K, respectively) on the performance (Weight Gain (WG), Feed Intake (FI) and Feed Conversion Ratio (FCR)) during the starter and finisher periods (1-20 and 21-33 days of age, respectively) and plasma total Ca and electrolytes and carcass characteristics at 33 days of age of broiler chickens were investigated. DEB treatments were prepared by the addition of NH_4Cl, $NaHCO_3$, $KHCO_3$ and $NaHCO_3$ plus $KHCO_3$ to the basal diet, respectively. High Ca diet reduced WG, FI, plasma potassium, eviscerated carcass weight and increased FCR and plasma Ca. Altering DEB of 250 by ±50 mEq kg^{-1} influenced WG and FI of chickens without altering FCR, plasma total Ca and electrolytes and carcass composition. DEB 200 mEq kg^{-1} did not influence the performance of chickens. DEB 300 mEq kg^{-1} had a lower WG than DEB 200 or 250 mEq kg^{-1} during the starter period. DEB 300 mEq kg^{-1} with high Na had a higher WG than DEB 200 mEq kg^{-1} at the finisher period. DEB 300 mEq kg^{-1} with high K had lower WG and FI of chickens than other DEB treatments and eviscerated carcass weight than DEB 250 mEq kg^{-1} at 33 days of age. It was concluded that altering DEB within the range of 200-300 did not overcome the growth depression effect of high Ca. DEB manipulation influenced the performance of chickens.

Key words: Broilers, high calcium, performance, dietary electrolyte balance, blood analysis, carcass characteristics

INTRODUCTION

The relationship between dietary electrolytes is one of the main factors that influence the performance of chickens (Nesheim *et al*., 1964; Melliere and Forbes, 1966; Leach Jr. and Nesheim, 1972; Dewar and Whitehead, 1973; Hurwitz *et al*., 1973; Mongin and Sauveur, 1977; Mongin, 1981; Johnson and Karunajeewa, 1985; Halley *et al*., 1987; Hooge, 1995, 1998; Teeter, 1997; Borges *et al*., 2003a, b; Maiorka *et al*., 2004). Most of the research was associated with those elements referred to as electrolytes, sodium (Na), potassium (K) and Chloride (Cl). The amounts of these electrolytes in the diet determine Dietary Electrolyte Balance (DEB). Mongin has defined DEB as milliequivalents ((Na+K) - Cl) per kg diet and emphasized the importance of adjusting DEB to obtain optimum performance. Mongin and Sauveur (1977) considered DEB of 250 mEq kg^{-1} as an optimum level for young chick. Whilst, Teeter and Belay (1995) and Karunajeewa *et al.* (1986) reported that an Electrolyte Balance (EB) of 150-350 mEq kg^{-1} in chicken diets (1-21 days) produced an optimum performance of birds. Murakami recommended an EB between 150 and 350 mEq kg^{-1} for maximum bird performance. These monovalent ions are involved in acid-base balance of body fluids, osmotic pressure, electrical potential of cell membranes and intracellular-extracellular homeostasis (Mongin, 1981; Borges *et al*., 2003b) because they have a higher permeability and have greater absorption than divalent ions such as Ca and Mg (Borges *et al*., 2004). However, the optimum DEB is influenced by other cations and anions. Melliere and Forbes (1966) observed that the performance of chickens depended on the dietary cations: anions ratio. They selected K, Na, Calcium (Ca), Magnesium (Mg), Available Phosphorus (AP) and Cl as major ions in terms of absorption and physiological concentration and their impact on acid base balance. Mongin (1981) demonstrated that feed ingredients are alkalinizing for animals whenever the ratio of fixed cations to fixed anions is excessive (Na+K+Ca+Mg); ($Cl+PO_4+SO_4$). Johnson and Karunajeewa (1985) found that the best DEB was between 200 and 350 mEq kg^{-1} which was influenced by AP, K, Na and Cl.

Excess dietary level of Ca is known to depress growth and feed efficiency of broiler chickens (Shafey *et al*., 1990a, b; Shafey and McDonald, 1990, 1991; Shafey, 1992,

Corresponding Author: T.M. Shafey, Department of Animal Production, College of Food and Agriculture, King Saud University, P.O. Box 2460, 11451 Riyadh, Saudi Arabia

1993). Dietary electrolytes appear to play a role in mineralization of bones. Murakami *et al*. (2000) found that dietary Na requirement for adequate bone mineralization was 1.5 g kg^{-1}. Increasing dietary content of Na decreased ash content of bones in chickens (Murakami *et al*., 1997). Excess dietary Na increases urinary Ca excretion and causes loss of bone Ca (Chan and Swaminathan, 1998). High Na diet interferes with Ca metabolism. In laying hens, Na ion interferes with the supply of bicarbonate ions to the shell gland. Whilst, increasing K intake in human decreased urinary Ca excretion (Jones *et al*., 1982; Lemann Jr. *et al*., 1989). The relationship between excess dietary Ca and EB has not been fully investigated. This experiment was designed to examine the effects of DEB balance and high Ca on the performance, plasma total Ca and electrolytes and carcass characteristics of broiler chickens.

MATERIALS AND METHODS

The effects of high Ca on the performance of broiler chickens fed different DEB were investigated. A total of 300 days old male Cobb broiler chickens were individually weighed and randomly sorted into 50 replicates to minimize differences in body weight between replicates with 6 birds each. They were housed in electrically heated battery cages. Lighting was incandescent and continuous throughout the experimental period. Five replicates were randomly assigned to one of the starter diets to 20 days followed by finisher diets to 33 days of age. The experiment was a 2×5 factorial design with factors of dietary Ca (10 and 25 g kg^{-1}) and EB contents. The five DEB were 250 (basal diet), 200 (basal diet supplemented with NH_4Cl), 300 (basal diet supplemented with $NaHCO_3$ (300-Na)), 300 (basal diet supplemented with $KHCO_3$ (300-K)) and 300 (basal diet supplemented with $NaHC_3$ plus $KHCO_3$ (300 Na+K)) mEq kg^{-1}, respectively. The composition of the basal diets and minerals of DEB are shown in Table 1 and 2, respectively. The determination of DEB (Na+K - Cl), cations (Na+K+Ca+Mg) and anions (Cl+AP) mEq kg^{-1} were based on the assumption of Mongin and Sauveur (1977) and Melliere and Forbes (1966), respectively. Feed and water were available *ad libtium*.

At the completion of the experiment, blood samples were collected in heparinized evacuated blood collection tubes by cardiac puncture from 8 birds for treatment. The blood was centrifuged at 3000×g for 15 min and plasma collected. Plasma total Ca, Na and K were determined by atomic absorption spectrophotometry. Plasma Cl was determined by titration methods (Schales and Schales, 1941). Eight birds per diet were selected having average or near average treatment body weight and killed by cervical dislocation to determine processing yields and carcass quality. Measurements were made of body Weight Gain (WG), Feed Intake (FI) and Feed Conversion Ratio (FCR = FI (g)/WG (g)) from 1-20 and 21-33 days of age (starter and finisher periods, respectively), plasma total Ca and electrolytes (Na, K and Cl) and carcass characteristics. Data collected were subjected to analysis

Table 1: Composition of the basal diets (g kg^{-1})

	Starter diets (1-20 days of age)		Finisher diets (20-33 days of age)	
Ingredients	Low Ca[1]	High Ca[1]	Low Ca[1]	High Ca[1]
Wheat	200.00	109.10	163.90	131.70
Corn	395.90	400.00	467.70	439.10
Soybean meal	190.60	205.10	147.80	233.40
Cottonseed meal	100.00	100.00	100.00	22.80
Fish meal (65% protein)	30.00	40.00	30.00	30.00
Corn oil	23.80	48.90	29.70	45.00
Limestone	12.80	51.50	14.20	53.30
Dicalcium phosphate	13.00	12.00	11.00	11.30
Sodium bicarbonate	4.20	5.70	3.80	2.80
Potassium bicarbonate	2.80	2.70	4.90	3.70
Ammonium chloride	0.00	1.20	0.00	0.00
Magnesium oxide	1.30	0.10	1.40	0.40
Sodium chloride	1.10	0.00	1.40	2.10
Premix[2]	2.00	2.00	2.00	2.00
DL-Methionine	1.40	1.30	2.00	2.40
L-Lysine	1.10	0.40	0.20	0.00
Sand	20.00	20.00	20.00	20.00
Analysis				
ME (kcal g^{-1})[3]	2.93	2.93	3.00	3.00
CP (N%×6.25)[4]	22.00	22.00	20.00	20.00
Lysine (g kg^{-1})	12.00	12.00	10.00	10.00
Met + Cys (g kg^{-1})[5]	8.89	8.89	9.00	9.00
TP (g kg^{-1})[6]	7.70	7.20	6.81	6.40
Na (g kg^{-1})[7]	2.00	2.00	2.00	2.00
K (g kg^{-1})[8]	8.60	8.60	8.60	8.60
Ca (g kg^{-1})	10.00	25.00	10.00	25.00
Mg (g kg^{-1})[9]	2.97	2.97	2.97	2.97
Cl (g kg^{-1})[10]	2.00	2.00	2.00	2.00
AP (g kg^{-1})[11]	5.00	5.00	4.50	4.50
EB (mEq kg^{-1})[12]	250.00	250.00	250.00	250.00
Cations [13]	925.00	1485.00	925.00	1485.00
Anions[14]	347.00	347.00	318.00	318.00
Cations-anions	578.00	1138.00	607.00	1167.00

[1]Ca = Calcium: [2]The composition of vitamins and minerals in the premix (per ton of diet; vitamin A, 6000,000 IU; vitamin D, 1500,000 IU; vitamin E, 20,000 IU; vitamin K 1,000 mg; vitamin B_1, 1 mg; vitamin B_2, 3000 mg; vitamin B_6, 2000 mg; vitamin B_{12}, 10 mg; niacin, 20,000 mg; folic acid, 500 mg; pantothenic acid 5,000 g; biotin, 50 mg; antioxidant, 60.000 mg; cobalt, 100 ppm; copper, 5,000 ppm; iodine, 500 ppm; iron, 20.000 ppm; manganese, 40.000 ppm; selenium, 100 ppm; zinc, 30.000; [3]ME = Metabolizable Energy; [4]CP = Crude Protein; [5]Met+Cys = Methionine + Cysteine; [6]TP = Total Phosphotus; [7]Na = Sodium; [8]K = potassium; [9]Mg = Magnesium; [10]Cl = Chloride; [11]AP = Available Phosphorus was calculated on the basis of 30% availability of phosphorus in plant products; [12]EB = Dietary Electrolyte Balance (Na+K - Cl) mEq kg^{-1} based on the assumption of Mongin and Sauveur (1977); [13]Dietary cation (Ca+Na+K+Mg) mEq kg^{-1} based on the assumption of Melliere and Forbes (1966); [14]Dietary anions (Cl+aP) mEq kg^{-1} based on the assumption of Melliere and Forbes (1966)

Table 2: Treatments and calculated minerals composition of the starter and finisher diets (g kg^{-1})

	DEB (mEq kg^{-1})[1]									
	Treatments of low Calcium (Ca) diet					Treatments of high Calcium (Ca) diet				
Electrolyte salts (g kg^{-1})[2]	250	200	300	300	300	200	250	300	300	300
NH_4Cl	0.0	2.69	0.00	0.00	0.00	0.00	7.00	0.00	0.00	0.00
$NaHCO_3$	0.0	0.00	4.20	0.00	2.10	0.00	0.00	5.91	0.00	2.95
$KHCO_3$	0.0	0.00	0.00	5.00	2.50	0.00	0.00	0.00	7.00	3.00
Minerals composition in the starter diets and finisher diets (g kg^{-1})										
Ca	10.0	10.00	10.00	10.00	10.00	25.00	25.00	25.00	25.00	25.00
Na[3]	2.0	2.00	3.15	2.00	2.57	2.00	2.00	3.15	2.00	2.57
K[4]	8.6	8.60	8.60	10.55	9.57	8.60	8.60	8.60	10.55	9.57
Cl[5]	2.0	3.78	2.00	2.00	2.00	2.00	3.78	2.00	2.00	2.00
Dietary electrolytes in the starter diets (mEq kg^{-1})										
Cations[6]	925.0	925.00	975.00	975.00	975.00	1485.00	1485.00	1535.00	1535.00	1535.00
Anions[7]	347.0	397.00	347.00	347.00	347.00	347.00	397.00	347.00	347.00	347.00
Cations-anions	578.0	528.00	628.00	628.00	628.00	1138.00	1088.00	1188.00	1188.00	1188.00
Dietary electrolytes in the finisher diets (mEq kg^{-1})										
Cations[6]	925.0	925.00	975.00	975.00	975.00	1485.00	1485.00	1535.00	1535.00	1535.00
Anions[7]	318.0	368.00	318.00	318.00	318.00	318.00	368.00	318.00	318.00	318.00
Cations-anions	607.0	557.00	657.00	657.00	657.00	1167.00	1117.00	1217.00	1217.00	1217.00

[1]DEB = Dietary Electrolyte Balance (Na+K - Cl) mEq kg^{-1} based on the assumption of Mongin and Sauveur (1977); [2]Similar amounts of electrolyte salts were added to the basal starter and finisher diets at the expense of sand. Levels of Available Phosphorus (AP) and Magnesium (Mg) were 5 and 2.97 in the starter and 4.5 and 2.97 (g kg^{-1}) in the finisher diets, respectively; [3]Na = Sodium; [4]K = potassium; [5]Cl = Chloride; [6]Dietary cations (Ca+Na+K+Mg) mEq kg^{-1} based on the assumption of Melliere and Forbes (1966); [7]Dietary anions (Cl+AP) mEq kg^{-1} basedon the assumption of Melliere and Forbes (1966)

of variance using GLM procedures (SAS, 1998). Where significant variance ratios were detected, differences between treatment means were tested using the Least Significant Difference (LSD) procedures.

RESULTS AND DISCUSSION

The effects of dietary Ca and EB on the performance, plasma concentrations of total Ca, Na, K and Cl and carcass characteristics of broiler chickens are shown in Tables 3-5, respectively. Increasing dietary Ca from 10-25 g kg^{-1} diet significantly ($p<0.01$) reduced WG and FI during starter and finisher periods of chickens and increased FCR during the starter ($p<0.05$) and the entire experimental periods and plasma total Ca and decreased plasma K and eviscerated carcass weight when expressed as an absolute weight or as a proportion of live weight ($p<0.01$). These results were in agreements with Shafey *et al*. (1990a, b), Shafey and McDonald (1990, 1991) and Shafey (1992, 1993) who found that high Ca diet depressed growth, feed efficiency and increased plasma total Ca. The reduction in plasma K concentration was probably due to the interference of excess Ca to phosphorus absorption from the gut. Reduction in phosphorus absorption would lead to a deficiency in available K for the bird. This suggestion is supported by the finding of Gillis (1950) and Rinehart *et al*. (1968) who reported thata reduction in bone calcification due to K deficiency through an influence of phosphorus rather than Ca metabolism. Altering DEB content from 250-200 or 300 mEq kg^{-1} by increasing dietary content of Cl, Na, K and Na plus K (from 2-3.78, 2-3.15, 8.6-10.55 and 2 and 8.6-2.57 and 9.57 g kg^{-1}, respectively) did not influence the performance of chickens on high Ca diet. The relationship between DEB and Ca contents was investigated by Hulan *et al*. (1987) who found that the worst and the best WG of chickens were achieved when DEB were 174 and 215 mEq kg^{-1} with 1.38 and 0.95% of Ca, respectively. However, the study of Hulan *et al*. (1987) was not designed to examine the relationship between high Ca and DEB in the diet. The researchers used lower dietary content of Ca in their study.

The optimal DEB for poultry is 250 mEq kg^{-1} according to Mongin and Sauveur (1977) however, optimal growth performance has been found to occur over a range of mEq kg^{-1}. The range of DEB values used in this trial (200-300 mEq kg^{-1}) was in acceptable range which in general agreement with Johnson and Karunajeewa (1985) who reported that the best DEB value is between 250 and 300 mEq kg^{-1} which is influenced by Ap, K+, Na+ and Cl-. Similarly, little difference in the performance of chicks fed on diets in which DEB varied from 155-300 mEq kg^{-1} (Hulan *et al*., 1987). However, DEB manipulation influenced WG and FI of chickens in this trial. The addition of NH_4Cl to the diet increased Cl from 2.0-3.78 g kg^{-1} and anions by 50 mEq kg^{-1} and consequently reduced the DEB value from 250-200 mEq kg^{-1}. The DEB of 200 mEq kg^{-1} did not significantly influence chicken performance at any stage of the experiment when compared with the control (DEB

Table 3: Body Weight Gain (BWG), feed intake and Feed Conversion Ratio (FCR) of broiler chickens fed high Calcium (Ca) with different dietary levels of electrolyte balance during a 33 days experimental period

	Age (days)								
	1-20			21-33			1-33		
Dietary treatments	BWG (g)	Feed intake (g)	FCR[1]	BWG (g)	Feed intake (g)	FCR[1]	BWG (g)	Feed intake (g)	FCR[1]
Ca (g kg^{-1})									
10	802.4	1111.8	1.39	998.0	1879.5	1.88	1800.4	2991.4	1.66
25	732.7**	1067.0**	1.46**	869.7**	1685.3**	1.94	1602.4**	2752.4**	1.72**
SEM[2]	5.4	7.1	0.01	10.1	25.3	0.02	10.0	25.4	0.01
DEB (mEq kg^{-1})[3]									
250	782.1^{a}	1090.6	1.40	953.9^{ab}	1790.8^{a}	1.88	1736.0^{a}	2881.4^{a}	1.66
200-CL	783.5^{a}	1112.3	1.42	909.2^{b}	1766.7^{ab}	1.96	1692.6^{a}	2879.1^{a}	1.71
300-Na	753.2^{b}	1082.4	1.44	975.3^{a}	1845.9^{a}	1.90	1728.5^{a}	2928.3^{a}	1.69
300-K	751.6^{b}	1075.4	1.43	859.1^{c}	1657.9^{b}	1.94	1610.8^{b}	2733.3^{b}	1.70
300-Na+K	755.3^{b}	1077.7	1.43	951.1^{ab}	1816.5^{a}	1.90	1706.4^{a}	2894.2^{a}	1.70
SEM[2]	8.6	11.2	0.01	16.0	40.1	0.04	15.8	40.1	0.05
Ca x DEB	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]FCR = Feed Conversion Ratio (feed intake (g)/weight gain (g)); [2]Standard error of mean; [3]Dietary electrolyte balance (Na+K - Cl) Meq kg^{-1} based on the assumption of Mongin and Sauveur (1977); 250 (mEq kg^{-1}) = Basal diet; 200-Cl (mEq kg^{-1}) = NH_4CL was added to the basal diet; 300-Na (mEq kg^{-1}) = $NaHCO_3$ was added to the basal diet; 300-K (mEq kg^{-1}) = $KHCO_3$ was added to the basal diet; 300-Na plus K (mEq kg^{-1}) = $NaHCO_3$ and $KHCO_3$ were added to the basal diet; **Significant difference ($p<0.01$); [a, b]Means within column followed by different superscripts are significantly different ($p<0.05$)

Table 4: Plasma analysis of broiler chickens at 33 days of age fed different dietary levels of Calcium (Ca) and electrolyte balance

	Na[1]	K[1]	Cl[1]	Total Ca[1]
Dietary treatments	mmol L^{-1}			
Ca (g kg^{-1})				
10	144.6	4.94	118.7	2.29
25	141.7	4.10**	114.5	3.28**
SEM[1]	3.4	0.11	1.5	0.12
DEB (mEq kg^{-1})[2]				
250	141.2	4.43	114.8	2.75
200-Cl	141.3	4.26	122.6	2.78
300-Na	145.9	4.58	116.9	2.83
300-K	143.9	4.75	111.9	2.83
300-Na plus k	143.6	4.70	116.2	2.69
SEM[1]	5.4	0.18	2.4	0.19
Ca x EB	NS	NS	NS	NS

[1]Na = sodium, K = potassium, Cl = Chloride, Total Ca = Total Calcium; [2]Standard error of mean; [3]Dietary electrolyte balance (Na+K - Cl) Meq kg^{-1} based on the assumption of Mongin and Sauveur (1977); 250 (mEq kg^{-1}) = Basal diet; 200-Cl (mEq kg^{-1}) = NH_4CL was added to the basal diet; 300-Na (mEq kg^{-1}) = $NaHCO_3$ was added to the basal diet; 300-K (mEq kg^{-1}) = $KHCO_3$ was added to the basal diet; 300-Na plus K (mEq kg^{-1}) = $NaHCO_3$ and $KHCO_3$ were added to the basal diet; **Significant difference ($p<0.01$); [a, b]Means within column followed by different superscripts are significantly different ($p<0.05$)

Table 5: Carcass characteristics of broiler chickens at 33 days of age fed different dietary levels of Calcium (Ca) and electrolyte balance

	Body composition									
			Live body weight (g kg^{-1})			Eviscerated carcass (g kg^{-1})				
Dietary treatments	Live body weight (g)	Eviscerated carcass (g)	Abdominal fat	Neck	Eviscerated carcass	Thigh	Drums	Wings	Breast	Back
Ca (g kg^{-1})										
10	1741.7	1209.3	10.9	30.1	694.4	157.8	142.1	107.9	288.6	244.3
25	1594.2**	1133.5**	9.4	31.6	711.6**	150.7	141.5	103.4	295.8	251.2
SEM[1]	22.3	15.3	2.3	1.3	4.2	4.3	3.1	2.9	5.4	4.5
DEB (mEq kg^{-1})[2]										
250	1706.7^{a}	1191.5^{a}	12.9	29.0	699.9	156.1	142.2	109.7	287.3	244.5
200-Cl	1669.6^{ab}	1171.9^{ab}	9.3	32.8	702.1	152.4	141.0	103.2	294.8	248.5
300-Na	1709.0^{a}	1217.2^{ab}	12.0	30.8	713.8	154.8	140.8	107.4	290.4	246.4
300-K	1592.7^{b}	1118.1^{b}	7.7	32.3	702.6	152.1	141.5	104.9	294.0	250.6
300-Na plus K	1656.1^{ab}	1157.5^{ab}	9.3	29.3	698.7	155.4	143.4	103.2	294.6	248.9
SEM[1]	35.2	24.3	3.6	2.0	6.7	6.8	4.9	4.5	8.6	7.2
Ca x EB	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[1]Standard error of mean; [2]Dietary electrolyte balance (Na+K - Cl) mEq kg^{-1} based on the assumption of Mongin and Sauveur (1977); 250 (mEq kg^{-1}) = Basal diet; 200-Cl (mEq kg^{-1}) = NH_4CL was added to the basal diet; 300-Na (mEq kg^{-1}) = $NaHCO_3$ was added to the basal diet; 300-K (mEq kg^{-1}) = $KHCO_3$ was added to the basal diet; 300-Na plus K (mEq kg^{-1}) = $NaHCO_3$ and $KHCO_3$ were added to the basal diet; **Significant difference ($p<0.01$); [a, b]Means within column followed by different superscripts are significantly different ($p<0.05$)

250 mEq kg^{-1}). However, chickens fed the DEB of 200 mEq kg^{-1} had lower WG and FI, albeit non-significantly during the finisher stage when compared with the 250 mEq kg^{-1} (control diet).

The addition of $NaHCO_3$, $KHCO_3$ or $NaHCO_3$ plus $KHCO_3$ to the basal diet increased dietary cations and DEB by 50 mEq kg^{-1}. These diets had the same DEB value of 300 mEq kg^{-1} but affected the performance of chickens differently. The effects of DEB appeared to be related to the ion used and stage of growth. Chickens fed the EB of 300 mEq kg^{-1} diets had significantly ($p<0.05$) lower WG than those fed the DEB of 200 and 250 mEq kg^{-1} during the starter period. Chickens fed the DEB of 300-Na mEq kg^{-1} had significantly higher WG than those fed the DEB of 200 mEq kg^{-1} at the finisher period. Increasing dietary K from 8.6-10.55 g kg^{-1} by the addition of $KHCO_3$ without altering dietary Na content of 2 g kg^{-1} had a negative impact on the WG and FI of chickens at the finisher period when compared with those fed the other 300 mEq kg^{-1} diets. However, there was no significant difference in chicken performance among the 300 mEq kg^{-1} diets during the starter period. Chickens fed the DEB of 300-K mEq kg^{-1} had significantly ($p<0.01$) lower FI during the finisher period and eviscerated carcass than those fed the control (250 mEq kg^{-1}) and WG and FI than any other diet during the entire experimental period. These findings were in general agreement with Rondon who found a variation in the best DEB depending on the manipulated ion. These researchers reported that the best DEB was of 250 mEq kg^{-1} when Na levels varied and 319 mEq kg^{-1} when the manipulated ion was K+. Whilst, the extent of live weight reduction from feeding diets with an EB >300 meq kg^{-1} depended on the type of cation added to the diet (Na or K) and the range of the Na:K ratio for optimum growth was 0.5-1.8 (Johnson and Karunajeewa, 1985). Changes in the response of chickens to DEB-K during stages of growth (starter vs. finisher periods) are more likely related to age-change in their nutritional requirements. Different dietary levels of electrolytes are recommended at different stages of growth of chickens. NRC (1994) recommends 3, 2, 2 and 2, 3, 1.5 g kg^{-1} for for Na, K and Cl of from 0-3 and 3-6 weeks of age, respectively. This suggestion is supported by Borges who reported an EB of 251 mEq kg^{-1} in pre-starter diets. Also, Rondon found that optimum DEB varied between 250 and 319 mEq kg^{-1} for WG and FCR, respectively when evaluated the performance of broiler up to 7 days of age. Using regression analysis, Borges *et al.* (2003b) predicted that ideal DEB for WG and FCR were 186 and 197 mEq kg^{-1} from 0-21 days of age and 236 and 207 mEq kg^{-1} of feed from 0-42 days, respectively. Dietary DEB did not influence plasma total Ca and electrolytes and weight of abdominal fat or neck as a proportion of live weight and eviscerated carcass proportions of thigh, drums, wings, breast and back. The effects of DEB on plasma electrolytes were in agreement with Johnson and Karunajeewa (1985) who found that varying dietary total cation-anion balance from 327-700 and EB from 29-553 mEq kg^{-1} did not influence plasma concentrations of Ca, Na, K and Cl in chickens. Also, Borges *et al.* (2003b) reported that no difference in blood Na, K and Cl of chicken when DEB ranged from 40-340 mEq kg^{-1} diet. The effects of DEB on carcass characteristics were in agreement with Borges *et al.* (2003a) who reported that DEB of 0, 120, 240 and 360 mEq kg^{-1} diet did not influence carcass characteristics of chickens at 42 days of age.

CONCLUSION

It was concluded that altering dietary Ca (from 10-25 g kg^{-1}) and DEB (from 250 by ±50, 200-300 mEq kg^{-1}) significantly influenced the performance of chickens. Increasing dietary Ca from 10-25 g kg^{-1} diet reduced performance, eviscerated carcass weight, plasma K and increased plasma total Ca of chickens. The effects of DEB appeared to be related to the ion used and stage of growth. Chickens fed the DEB 300 mEq kg^{-1} treatments had lower WG than those fed the DEB 200 and 250 mEq kg^{-1} during the starter period. Chickens fed the DEB 300 mEq kg^{-1} with high Na had a higher WG than those fed the DEB 200 mEq kg^{-1} at the finisher period. DEB 200 mEq kg^{-1} did not influence the performance of chickens at any stage of the experiment. DEB 300 mEq kg^{-1} with high K reduced WG and FI of chickens during the entire experimental period when compared with other DEB treatments. DEB did not influence carcass characteristics and plasma total Ca and electrolytes. Dietary Ca and DEB did not influence weights of abdominal fat and carcass composition.

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REFERENCES

Borges, S.A., A.V. Fischer da Silva, A. Majorka, D.M. Hooge and K.R. Cummings, 2004. Physiological responses of broiler chickens to heat stress and dietary electrolyte balance (sodium plus potassium minus chloride, milliequivalents per kilogram). Poul. Sci., 83: 1551-1558.

Borges, S.A., A.V. Fischer da Silva, J. Ariki, D.M. Hooge and K.R. Cummings, 2003. Dietary electrolyte balance for broiler chickens under moderately high ambient temperatures and relative humidities. Poult. Sci., 82: 301-308.

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.

Chan, E.L.P. and R. Swaminathan, 1998. Calcium metabolism and bone calcium content in normal and oophorectomised rats consuming various levels of saline for 12 months. J. Nutr., 128: 633-639.

Dewar, W.A. and C.C. Whitehead, 1973. Sodium supplementation of broiler diets. Br. Poult. Sci., 14: 315-381.

Gillis, M.B., 1950. Further studies on the role of potassium in growth and bone formation. J. Nutr., 42: 45-57.

Halley, J.T., T.S. Nelson, L.K. Kirby and Z.B. Johnson, 1987. Effect of altering dietary mineral balance on growth, leg abnormalities and blood base excess in broiler chicks. Poult. Sci., 66: 1684-1692.

Hooge, D.M., 1995. Dietary electrolytes influence metabolic processes of poultry. Feedstuffs, 67: 14-21.

Hooge, D.M., 1998. Electrolyte balance in turkeysâ_™ layers examined. Feedstuffs, 70: 17-19.

Hulan, H.W., P.C.M. Simons, P.J.W. van Schagen, K.B. McRae and F.G. Proudfoot, 1987. Effect of dietary cation-anion balance and calcium content on general performance and incidence of leg abnormalities of broiler chickens. Can. J. Anim. Sci., 67: 165-177.

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

Johnson, R.J. and H. Karunajeewa, 1985. The effects of dietary minerals and electrolytes on the growth and physiology of the young chick. J. Nutr., 115: 1680-1690.

Jones, J.W., A. Sebastian, H.N. Hulter, M. Schambelan, J.M. Sutton and E.G. Biglieri, 1982. Systemic and renal acid-base effects of chronic dietary potassium depletion in humans. Kidney Int., 21: 402-410.

Karunajeewa, H., D.A. Bar and M. Fox, 1986. Effect of dietary phosphorus concentration and electrolyte balance on the growth performance of broiler chickens. Br. Poult. Sci., 27: 601-612.

Leach, Jr. R.M. and M.C. Nesheim, 1972. Further studies on tibial dyschondroplasia (cartilage abnormality) in young chicks. J. Nutr., 102: 1673-1680.

Lemann, Jr. J., R.W. Gray and J.A. Pleuss, 1989. Potassium bicarbonate, but not sodium bicarbonate, reduces urinary calcium excretion and improves calcium balance in healthy men. Kidney Int., 35: 688-695.

Maiorka, A., N. Magro, H. Bartles, A. Kessler and J. Penz, 2004. Different sodium levels and electrolyte balances in Pre-starter diets for broilers. Braz. J. Poult. Sci., 6: 143-146.

Melliere, A.L. and R.M. Forbes, 1966. Effect of altering the dietary cation-anion ratio on food consumption and growth of young chicks. J. Nutr., 90: 310-314.

Mongin, P. and B. Sauveur, 1977. Interrelationships Between Mineral Nutrition, Acid-Base Balance, Growth and Cartilage Abnormalities. In: Growth and Poultry Meat Production, Boorman, K.N. and B.J. Wilson (Eds.)., British Poultry Science, Edinburgh, United Kingdom, pp: 235-347.

Mongin, P., 1981. Recent Advances in Dietary Anion-Cation Balance in Poultry. In: Recent Advances in Animal Nutrition, Haresign, W. (Ed.)., Butterworths, London, United Kingdom, pp: 109-119.

Murakami, A.E., E.A. Saleh, J.A. England, D.A. Dickey, S.E. Watkins and P.W. Waldroup, 1997. Effect of level and source of sodium on performance of male broilers to 56 days. J. Appl. Poult. Res., 6: 128-136.

Murakami, A.E., E.A. Saleh, S.E. Watkins and P.W. Waldroup, 2000. Sodium source and level in broiler diets with and without high levels of animal protein. J. Appl. Poult. Res., 9: 53-61.

NRC, 1994. Nutrient Requirements of Poultry. 9th Edn., National Academy Press, Washington, DC. USA., ISBN-13: 978-0-309-04892-7.

Nesheim, M.C., R.M. Leach Jr., T.R. Zeigler and J.A. Serafan, 1964. Interrelationships between dietary levels of sodium, chlorine and potassium. J. Nutr., 84: 361-366.

Rinehart, K.E., W.R. Featherston and J.C. Rogler, 1968. Effects of a dietary potassium deficiency on protein synthesis in the young chick. J. Nutr., 95: 627-632.

SAS, 1998. SAS User's Guide: Statistics. Version 7.0, SAS Institute Inc., Cary, New Jersey, USA.

Schales, O. and S.A. Schales, 1941. A simple and accurate method for the determination of chloride in biological fluids. J. Biol. Chem., 140: 879-884.

Shafey, T.M. and M.W. McDonald, 1991. The effects of dietary calcium, phosphorus and protein on the performance and nutrient utilization of broiler chickens. Poult. Sci., 70: 548-553.

Shafey, T.M. and M.W. McDonald, 1990. Effects of dietary calcium and available phosphorus ratio on calcium tolerance of broiler chickens. Aust. J. Exp. Agric., 30: 483-490.

Shafey, T.M., 1992. Effects of chelating agents on the performance of growing chikens fed high calcium diets. Aust. J. Exp. Agric., 31: 765-768.

Shafey, T.M., 1993. Calcium tolerance of growing chickens: Effect of ratio of dietary calcium to nonphytate phosphorus. World's Poult. Sci. J., 49: 5-18.

Shafey, T.M., M.W. McDonald and R.A.E. Pym, 1990. The effects of dietary calcium upon growth rate, food utilization and plasma constituents in lines of chickens selected for aspects of growth or body composition. Br. Poult. Sci., 31: 587-602.

Shafey, T.M., M.W. McDonald and R.A.E. Pym, 1990. The effect of dietary calcium upon growth rate, feed efficiency and plasma constituents in lines of chickens selected for aspects of growth or body composition. Br. Poult. Sci., 31: 577-586.

Teeter, R., 1997. Balancing the electrolyte equation. Feed Mix, 5: 22-26.

Teeter, R.G. and T. Belay, 1995. Potassium's evolving role in poultry electrolyte nutrition. Feed Ingredients-IMC Agrico, Mundelein, IL.