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Impact of Diets Containing Varying Levels of Sodium Chloride as a Source of Electrolyte in Broiler Chickens

Research Article

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ABSTRACT

The impact of diets containing varying levels of sodium chloride as a source of electrolyte on growth performance, organ traits, gastrointestinal impact, tibia mineralization, and water intake of broiler chickens were investigated. A total of 300 mixed sexed of day-old chicks at two weeks of age were allotted to 6 dietary treatments in a completely randomized experimental design with 5 replicates of 10 birds each. The dietary treatments during the starter phase, from 14 to 28 days old, were supplemented by varying NaCl levels including T1= 0 g/kg (control), T2= 1.30 g/kg, T3= 2.00 g/kg, T4= 2.30 g/kg, T5= 3.30 g/kg and T6= 4.00 g/kg. The dietary treatments during finisher phase, from 28 days to 56 days old, included: T1=0 g/kg (control), T2= 2.30 g/kg, T3=3.30 g/kg, T4= 4.30 g/kg, T5= 5.30 g/kg and T6= 6.30 g/kg. Result of the study showed that birds in T3 and T4 that were fed diet with moderate inclusion levels of sodium chloride had the highest ($P<0.05$) feed intake and body weight gain with an improved feed conversion ratio. Generally, treatment groups T2 to T9 had the highest ($P<0.05$) weight of gizzard, liver, heart, kidney, intestines and caeca. Also, intestine lengths, caecal length, excreta moisture, water intake, ileal and pH of caecal digesta were highest in treatment groups. However, result of the tibia mineralization analysis showed that ash content in T1 (control) was the highest ($P<0.05$). It is concluded that T3 and T4 in broilers diet can improve growth performance.

KEY WORDS broiler chicken, gastrointestinal, organ traits, performance, tibia mineralization, water intake.

INTRODUCTION

Poultry sector is the greatest sector, with the highest growth reflected in the increased demand for food globally (Neves *et al.* 2014). According to Sleman *et al.* (2015) one of the fastest means of producing quantity and premium animal protein for human consumption is via broiler production, because of its little fat content, elevated protein, and amino acid balance. Broiler chicken is the most low-cost source of farm animal protein, contributing enormously to the growing request for animal food products worldwide (Farrell, 2013). Broiler production despite its contribution in the mitigation of poverty and hunger for animal food products is still faced with increasing ecological challenges. One of these outstanding ecological challenges is heat stress which is caused by high environmental temperatures. Heat stress causes respiratory alkalosis leading to an excess of blood bicarbonate, which is eliminated via urine, pulling other electrolytes such as Ca^+, Na^+, and K^+ (Molero, 2007). The disturbance of blood acid-base balance through hyperventilation results in respiratory alkalosis and thus, suppresses growth of broiler chickens (Lin *et al.* 2005). High environment temperature greater than 26 ˚C induces ions loss such as Na^+ and thus, resulting to low electrolyte balance in birds (Borges *et al.* 2004). The effect of acid-base balances on diverse metabolic processes in animals and hence on performance is presently a worldwide matter (El-Sheikh and Salama, 2010).

However, in the acid-base equilibrium, nutritional electrolyte is a prime factor that regulates blood pH for improved enzymatic efficacy and thereby, influencing birds growth and performance (Hassan *et al.* 2011). Farm animal must regulate the input and output of ions to maintain acid–base homeostasis. Failure to maintain the correct electrolyte balance within the cell will affect metabolic pathways and make them unable to function efficiently and thus, resources are diverted to achieve homeostasis at the expense of growth. According to the definition given by Mongin (1981) ration acid-base balance is the difference between negative and positive ions contained in the ration (Na^{+}+K^{+}–Cl^{-}) and is ordinarily expressed as meq kg^{-1} dry matter. The dietary electrolyte balance value is determined by the ratios of Na^{+}, Cl^{-}, and K^{+} levels in the plasma that are responsible for regulating the acid-base balance and pH. They help in maintaining optimum enzymatic efficiency in broilers (Hooge, 2003). Electrolyte balance in ration has an essential role in broiler growth performance that includes, proper bone development and quality of litter (Borges *et al.* 2004).

One of the dietary protocols that can be used to bring balance between acid and base in the farm animal is sodium chloride (common salt). It is a low-cost nutrient and its utilization/manipulation in ration has a small effect on the ration price. It is well documented that, cations like Na^{+} and Cl^{-} can be used as a dietary protocol to improve broiler growth performance (Mushtaq *et al.* 2005). According to Murakami *et al.* (2001) sodium chloride is a low-cost ion source that can be utilized to improve the acid balance in broilers.

Leeson *et al.* (2001) stated that sodium is responsible for sugar and amino acids absorption in the small intestine. Meanwhile, Hassan *et al.* (2011) revealed that sodium and chloride are minerals with crucial physiological functions and a wide range of suggested requirements. In intensively raised fast-growing chickens, an adequate intake of dietary sodium has a beneficial influence on feed consumption and growth rate of birds (Borges *et al.* 2004). Adedokun and Applegate (2014) stated that sodium chloride in ration affects feed consumption. Sodium chloride also affects the digestibility of amino acids in the ration (Chrystal *et al.* 2020). It has been observed that elevated inclusion of sodium chloride in ration decreases voluntary feed intake (Ferket and Gernat, 2006). The growth performance of birds was enhanced when the sodium content of the ration was raised to 2-3 g/kg feed (Mushtaq *et al.* 2007), which is above the commendations of NCR (1994). An increase in sodium content of ration to 3 g/kg was also observed to enhance breast muscle yield, and decrease abdominal fat deposition (Mushtaq *et al.* 2005). Sodium plays a crucial role in several physiological processes, and it is known to positively affect enzyme activities and tissue protein synthesis (Olanrewaju *et al.* 2007). According to a few researchers, sodium and other electrolytes contribute to the growth and mineralization of bone tissues. In a study by Murakami *et al.* (1997), the ash content of bones decreased along with an increase in the sodium content of chicken ration. Another experiment by (Murakami *et al.* 2000) showed that sodium intake of 1.5 g/kg ration is required for adequate mineralization of tibia in broilers. It has been established that minerals such as sodium and chloride, and potassium are crucial for nutrient absorption in the intestine (Boron and Boulpaep, 2016). Any discrepancy in acid/base balance can negatively affect the digestive process due to resulting changes in the digester's pH. Since the maintenance of bird's acid-base balance is vital for improving performance under high environmental temperature (Brake *et al.* 1994), this present study was designed to investigate the impact of ration containing varying levels of sodium chloride as a source of electrolytes on growth performance, organ traits, gastrointestinal impact, tibia mineralization and water intake of broiler chickens.

MATERIALS AND METHODS

Ethical consideration

This experiment was conducted according to the provisions of the Ethical Committee (MUC271SOYE01) on the use of animals and humans for biomedical research at the University of Nigeria, Nsukka, Enugu, Nigeria.

Study site

The study was carried out at the Poultry Section of the Department of Animal Science Teaching and Experimental Farms, University of Nigeria, Nsukka Enugu State. Nsukka lies within longitude 6˚ 45′E and 7˚ E and latitude 7˚ 12.5 ′N and at the altitude 447 m above sea level. The climate of the study environment is naturally tropical, with relative humidity ranging from 65 to 80% and 26.8 ˚C mean daily temperature (Okonkwo and Akubuo, 2007). The yearly rainfall ranges from 1567.05 mm-1846.98 mm (Metrological Center, Crop Science Department, University of Nigeria, Nsukka Enugu State). The study lasted for 6 weeks.

Characteristics of sodium chloride

The tested sodium chloride, was purchased from Peace Ugwu's food ventures located at Ogige Market Nsukka Enugu State, Nigeria. Sodium chloride commonly known as common salt is an ionic compound with the chemical formula NaCl, representing 1:1 ratio of sodium and chloride ions and with molar masses of 22.99 and 35.45 g/mol respectively.

Experimental birds and management

A total of 300 heads of mixed sexed day-old chicks of broiler chickens at two weeks of age were allotted to 6 dietary treatments in a completely randomized experimental design with 5 replicates of 10 birds each. The birds were housed in a deep litter system with fresh wood shavings as litter. Birds in each treatment and replicates were finished and they started without randomization at the finisher feeding phase. Prior to the arrival of the birds from the hatchery, the brooding house was cleaned with detergent and disinfected with strong disinfectant after which wood shavings were spread. The brooding house was pre-heated with a charcoal pot a few hours before the arrival of the birds. Drinkers and feeding troughs were acquired, disinfected and strategically positioned. Clean drinking water and feed were made ready before the arrival of the birds. Overall flock prophylactic administration and routine vaccination were given as follows; day one: New castle disease vaccine-intraocular), week two: Gumboro disease vaccine, week three: Lasota (New castle disease vaccine), week four: Gumboro disease vaccine, week five: fowl pox vaccine, week 6-8. A stress pack was given to the birds in drinking water at 100 g/50 liters to increase appetite and energy supply. Clean water and treatments were provided *ad libitum* throughout the six weeks of the study. Monitoring of the room temperature was done with the help of a thermometer, and lighting was provided using a 200v watt bulb.

Experimental diets

The feeding strategy lasted for 6 weeks. Basal diets for starter and finisher diets presented in (Tables 1 and 2) were formulated to meet the birds' dietary nutritional requirements (NRC, 1994). The proximate compositions of the experimental diets were analyzed according to the association of official agricultural chemists (AOAC, 1990) methods.

Growth performance parameters

At the beginning of the experiment, the birds were weighed to obtain their initial body weight. Subsequently, their average live-weights were measured on weekly basis by weighing all the birds in each replicate using a 10.1 kg aptitude precision weighing balance (models A and D Weighing GK-10K industrial balance) produced in China. The live weights gain was used to compute the average daily weight gain (ADWG) per bird in each replicate. Feed intake was taken from first day of the study to the end. Feed intake was measured by first weighing the feed before being given to the birds.

Then, the difference between the feed provided the preceding day and left over feed in the feeding trough the next morning was divided with the number of birds in each replicate in order to get daily feed intake per bird for each replicate.

Feed conversion ratio (FCR) was calculated by dividing the feed intake of birds with body weight gain of birds. Average daily feed intake (ADFI) was obtained by dividing the daily feed intake of birds with the number of days the feeding trial lasted. Average daily weight gain (ADWG) was obtained by dividing weight gained by birds with the number of days the feeding trial lasted.

Organ parameters

At the end of the feeding trial (42 days), three birds were randomly selected from each replicate for the determination of organ weights and sizes according to the Provisions of the Ethical Committee (MUC271SOYE01) on the use of animals and humans for biomedical research of the University of Nigeria, Nsukka, Enugu, Nigeria.

Immediately after slaughtering the birds, the slaughtered birds were properly dissected after removing their feathers and their visceral organs weights and sizes (weights of liver, heart, gizzard, kidney, caeca, intestines) were determined.

Excreta moisture determination

At the end of the feeding trial, excreta samples were collected from each replicate and taking to the lab to determine their moisture content using the following formula:

Moisture (%)= weight of dried sample / fresh weight used (2 g) × 100

Gastrointestinal parameters

Samples of ileal and caecal digester were collected from the eviscerated chickens. pH of ileal and caecal digester were measured using a microelectrode and a pH/ION meter.

Tibia mineralization

Tibia mineralization was done by determining the ash, calcium and phosphorus contents in the tibia of the selected birds.

Ash determination

The residue remaining after the destruction of the organic matter of feed is referred to as ash.

% percentage of ash= (weight after ignition–weight of the crucible/weight of the sample taken) × 100

Table 1 Ingredients (%) and chemical composition (g/kg DM) of experimental diets for broiler starter

Ingredients (%)	**Diets**					
	T1	T2	T3	T4	T5	T6
Maize	42.00	42.00	42.00	42.00	42.00	42.00
Wheat offal	7.00	7.00	7.00	7.00	7.00	7.00
Soybean meal	14.00	14.00	14.00	14.00	14.00	14.00
Groundnut cake	20.00	20.00	20.00	20.00	20.00	20.00
Palm kernel cake	10.00	10.00	10.00	10.00	10.00	10.00
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	4.25	4.25	4.25	4.25	4.25	4.25
Vitamin premix	025	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100
Sodium chloride (g/kg ration)	0.00	1.30	2.00	2.30	3.30	4.00
Calculated compositions (%)						
Crude protein (%)	22.57	22.57	22.57	22.57	22.57	22.57
Metabolizable energy (Mcal/kgME)	2800	2800	2800	2800	2800	2800
Crude fibre (%)	4.80	4.80	4.80	4.80	4.80	4.80
Crude fat (%)	3.90	3.90	3.90	3.90	3.90	3.90
Chemical composition (%)						
Crude matter	90	89.90	90.10	90.05	90.01	90.40
Crude fibre	4.80	4.81	4.80	4.81	4.80	4.82
Crude protein	22.56	22.57	22.59	22.59	22.56	22.55
Crude fat	3.90	3.89	3.91	3.90	3.90	3.89
Crude ash	7.80	7.89	8.00	8.05	8.54	8.67
Carbohydrate	56.87	56.89	56.91	56.90	56.90	56.80
Nitrogen free extract	50.94	50.74	50.71	50.70	50.21	50.47

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
* Each 2 kg of vitamin premix contains: vitamin A: 1000000 IU; vitamin D_3: 2200.000 mg; vitamin B_1: 1500 mg; vitamin B_2: 5000 mg; vitamin K_3: 2000 mg; vitamin B_{12}: 10 mg; vitamin B_6: 1500 mg; vitamin E: 10000 mg; Biotin: 20 mg; Niacin: 15000 mg; Folic acid: 500 mg and Calpan: 5000 mg.

Table 2 Ingredients (%) and chemical composition (g/kg DM) of experimental diets for broiler finisher

Ingredients (%)	Diets					
	T1	T2	T3	T4	T5	T6
Maize	38.00	38.00	38.00	38.00	38.00	38.00
Wheat offal	13.00	13.00	13.00	13.00	13.00	13.00
Soybean meal	8.00	8.00	8.00	8.00	8.00	8.00
Groundnut cake	14.00	14.00	14.00	14.00	14.00	14.00
Palm kernel cake	20.00	20.00	20.00	20.00	20.00	20.00
Fish meal	2.00	2.00	2.00	2.00	2.00	2.00
Bone meal	4.25	4.25	4.25	4.25	4.25	4.25
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25	0.25
Lysine	0.25	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100	100
Sodium chloride (g/kg ration)	0	2.30	3.30	4.30	5.30	6.30
Calculated composition (%)						
Crude protein (%)	20.00	20.00	20.00	20.00	20.00	20.00
Metabolizable energy (Mcal/kgME)	3000	3000	3000	3000	3000	3000
Crude fibre (%)	5.85	5.85	5.85	5.85	5.85	5.85
Crude fat (%)	4.20	4.20	4.20	4.20	4.20	4.20
Chemical composition (%)						
Crude matter	90.20	91.05	90.11	90.33	91.00	89.99
Crude fibre	5.85	5.65	5.65	5.81	5.80	5.75
Crude protein	20.10	20.09	20.08	20.00	20.11	20.03
Crude fat	4.21	4.11	4.23	4.24	4.18	4.22
Crude ash	5.85	5.79	5.65	5.89	5.85	5.95
Carbohydrate	62.21	62.21	62.21	62.21	62.21	62.21
Nitrogen free extract	54.19	55.41	54.50	54.39	55.06	54.04

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
* Each 2 kg of vitamin premix contains: vitamin A: 1000000 IU; vitamin D_3: 2200.000 mg; vitamin B_1: 1500 mg; vitamin B_2: 5000 mg; vitamin K_3: 2000 mg; vitamin B_{12}: 10 mg; vitamin B_6: 1500 mg; vitamin E: 10000 mg; Biotin: 20 mg; Niacin: 15000 mg; Folic acid: 500 mg and Calpan: 5000 mg.

Phosphorus determination

Calculated with Molybdate Method:

Phosphorus (mg/100 g)= An / As × C / W

Where:
An: absorbance of the test sample.
As: absorbance of the standard solution.
C: concentration of standard solution.
W: weight of the sample used.

Calcium determination

(Ca/L) / PPM ca= T × M × E × 1000

Where:
T: titre value.
M: molarity of EDTA.
E: equivalent weight of calcium.

Water intake

Water intake was taking using a measuring cylinder in each treatment from the beginning of the feeding trial to the end (42days).

Statistical design and analysis

Data generated were subjected to the analysis of variance (ANOVA) in CRD using statistical package (SPSS, 2003) Windows version 8.0. Mean differences were separated using Duncan's New Multiple Range Test (Duncan, 1955) as outlined by Obi (2002).

The statistical model used to test the effects of treatments on general growth performance, visceral organs, gastrointestinal parameters, water intake and tibia mineralization parameters was:

$X_{ij} = \mu + T_i + E_{ij}$

Where:
X_{ij}: individual observation.
μ: population mean.
T_i: treatment effect.
E_{ij}: experimental error.

RESULTS AND DISCUSSION

The results of the impact of ration containing varying levels of sodium chloride as source of electrolyte on growth performance of broiler chickens from 3-8weeks of age is shown in Table 3, Figure 1 and 2.The inclusion of sodium chloride in the ration of broiler chickens in this experiment had significant effect (P<0.05) on the values for body weight gain, average daily weight gain, feed intake, feed conversion ratio and average daily feed intake among the treatment. Body weight gain of T4 groups birds were the highest (P<0.05) followed by T3, T5, T6, T2 and T1. Average daily feed intake and average daily weight gain values among the treatments followed the same trend as observed for body weight gain. Feed intake values of T3 and T4 were the highest among the treatments, followed by T5, T6, T2 and T1 groups. Feed conversion ratio values of treatment T1 birds (control) were the highest (P<0.05) among the treatments followed by T2, T6, T5 and T3 and T4 that were the same.

Table 4 and Figure 3 shows the results of the impact of ration containing varying levels of sodium chloride as source of electrolyte on organ traits of broiler chickens from 3-8 weeks of age. Inclusion of sodium chloride had significant effect (P<0.05) on liver, gizzard, heart and kidney values. Liver weight value of treatment T5, T4, and T3 were the same (P>0.05), but significantly lower than the values of 22.85 and 21.75 observed for treatment 1 and 2 that were also the same and value of 37.75recorded in T2. Gizzard weight value of T2, T3, T4 and T6 birds were the same (P>0.05), but significantly lower than value of 59.45 observed for T5 birds and higher than the value of 33.85 observed for T1 birds. Kidney weight value among the treatments followed the same trend as observed for gizzard weights. Heart weight values of T4 and T5 were the same (P>0.05), but significantly higher than the values of 9.85and 9.65observed for T6 and T2 which were also the same and values 10.55and 8.05 observed for T3 and T1 respectively.

Table 5 and Figure 4 shows the results of the gastrointestinal effect of broiler chickens fed varying levels of sodium chloride as a source of dietary electrolyte from 3-8 weeks of ages. Small intestine weight value of T5 birds were the highest (P<0.05) among the treatments, while T3, T4 and T6 were the same (P>0.05), but lower than the value of 88.75 and 77.45 observed for T2 and T1 respectively. Large intestine weight of T4 birds were the highest (P<0.05), followed by T5 and T3 that were the same (P>0.05), T6 and T2 that were also the same statistically and T1. Small intestine length of T4 birds were the highest among the treatments (P<0.05) followed by T6, T5 and T3 that were the same, T2 and T1. Large intestine length value of T3 were the highest (P<0.05) followed by T2, T4 and T5 that were statistically the same (P>0.05), T6 and T1. Caecal weight value of T4 birds were the highest (P<0.05) among the treatments followed by T1, T2 and T6 that were the same statistically, T3, and T4 that also the same (P>0.05). Caecal length value of T6 birds were the highest followed by T2, T3 and T5 that were the same statistically, T4 and T1.

Table 3 The results of the impact of ration containing varying levels of sodium chloride as source electrolyte on growth performance of broiler chickens from 3-8 weeks of age

Parameters	Treatments						SEM
	T1	T2	T3	T4	T5	T6	
Initial body weight (g/bird)	500.00	500.00	497.00	499.00	493.00	495.00	4.43
Body weight gain (g/bird)	1680.00^{f}	1901.00^{e}	2410^{b}	2460.88^{a}	2250.00^{c}	2009.70^{d}	23.98
Average daily weight gain (g/bird)	40.00^{f}	45.26^{e}	57.38^{b}	58.59^{a}	53.57^{c}	47.85^{d}	0.50
Feed intake (g/bird)	5010.00^{e}	5200.00^{d}	5923.00^{a}	5980.00^{a}	5720.00^{b}	5390.00^{c}	24.97
Feed conversion ratio (g/g)	2.98.00^{a}	2.74.^{b}	2.46^{e}	2.43^{e}	2.54^{d}	2.68^{c}	0.02
Average daily feed intake (g/bird)	119.28^{f}	123.80^{e}	141.02^{b}	142.38^{a}	136.19^{c}	128.33^{d}	0.52

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

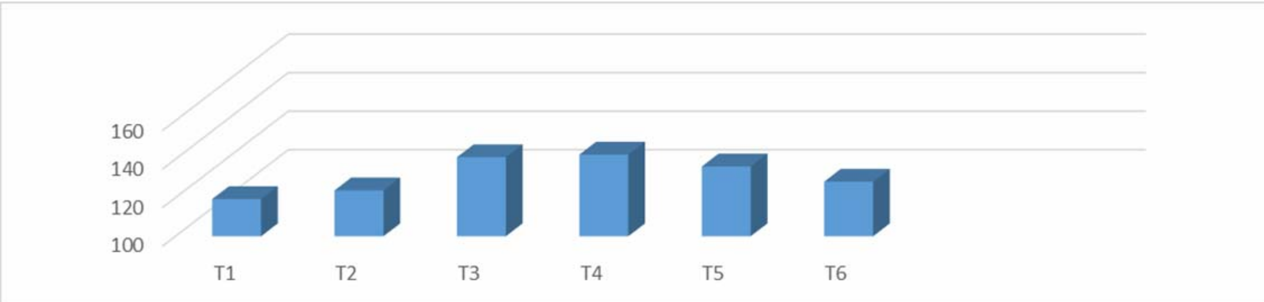

Figure 1 Average daily feed intake of broiler chickens fed ration containing varying levels of sodium chloride as source of from 3-8 weeks of age

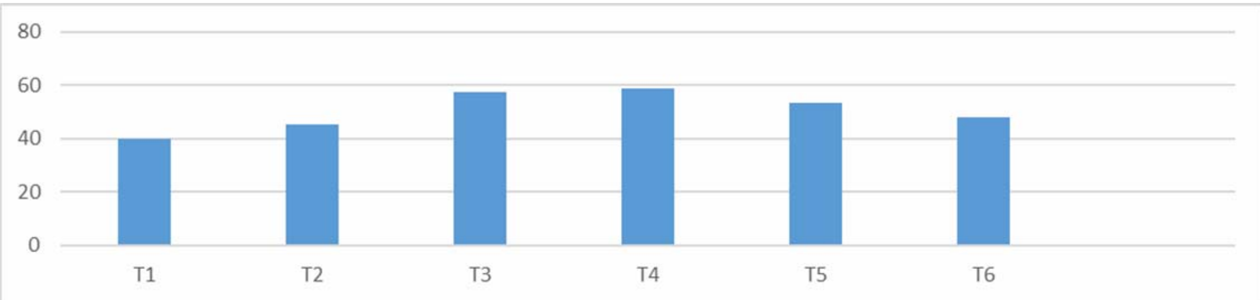

Figure 2 Average daily weight gain of broiler chickens fed ration containing varying levels of sodium chloride as source of from 3-8 weeks of age

Table 4 The results of the impact of ration containing varying levels of sodium chloride as source of electrolyte on organ traits of broiler chickens from 3-8 weeks of age

Parameters	Treatments						SEM
	T1	T2	T3	T4	T5	T6	
Liver weight (g)	22.85^{c}	37.75^{b}	41.85^{a}	41.35^{a}	42.05^{a}	21.75^{c}	1.30
Gizzard weight (g)	33.85^{c}	42.05^{b}	46.45^{b}	50.65^{b}	59.45^{a}	41.60^{b}	3.17
Heart weight (g)	8.05^{d}	9.65^{c}	10.55^{b}	11.05^{a}	11.45^{a}	9.85^{c}	0.3
Kidney weight (g)	10.75^{c}	11.05^{b}	11.25^{b}	11.29^{b}	12.75^{a}	10.85^{b}	0.31

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

Figure 3 The results of the impact of ration containing varying levels of sodium chloride as source of electrolyte on organ traits of broiler chickens from 3-8 weeks of age

Table 5 Gastrointestinal impact of broiler chickens fed ration containing varying levels of sodium chloride as source of electrolyte from 3-8 weeks of age

Parameters	Treatments						SEM
	T1	T2	T3	T4	T5	T6	
Small intestine weight (g)	77.45^{e}	88.75^{d}	104.95^{b}	105.87^{b}	108.45^{a}	103.99^{b}	1.20
Large intestine weight (g)	4.99^{d}	8.65^{c}	9.63^{b}	10.81^{a}	9.86^{b}	8.96^{c}	0.21
Small intestine length (cm)	148.00^{d}	192.00^{c}	197.00^{b}	200.90^{a}	195.00^{b}	197.00^{b}	1.89
Large intestine length (cm)	11.12^{d}	12.98^{b}	13.32^{a}	12.99^{b}	12.78^{b}	12.68^{c}	0.12
Caecal weight (cm)	3.95^{c}	3.45^{c}	5.15^{b}	6.05^{a}	5.20^{b}	3.35^{c}	0.32
Caecal length (cm)	16.55^{e}	22.05^{b}	20.55^{c}	18.55^{d}	20.05^{c}	25.55^{a}	0.85
pH of ileal and caecal digester	9.83^{e}	10.83^{b}	11.03^{a}	10.50^{c}	10.40^{d}	10.40^{d}	0.11
Excreta moisture (%)	65.05^{f}	77.05^{e}	81.16^{d}	85.05^{c}	88.95^{b}	91.23^{a}	1.22

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/kg ration.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

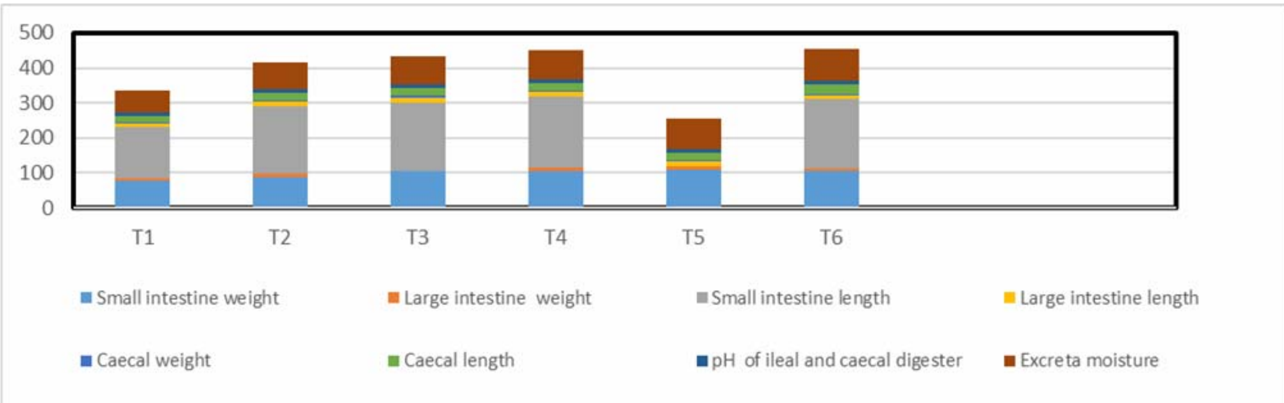

Figure 4 Gastrointestinal impact of broiler chickens fed ration containing varying levels of sodium chloride as a source of electrolyte from 3-8 weeks of age

pH of ileal and caecal digester value of T3 were the highest among the treatments, followed by T2, T4, T5 and T6 that were the same and T1. Excreta moisture T6 were the highest followed by T5, T4, T3 T2 and T1.

The results of the mineralization effect of broiler chickens fed ration containing varying levels sodium chloride as source of electrolyte from 3weeks-8weeks of age showed on Table 6 and Figure 5.

Ash value of T3 birds were the highest (P<0.05), followed by T4 and T5 that were the same, T2 and T1 that were the same also and T6. Calcium value of T4 birds were the highest, followed by T3, T6 and T5 that were the same, T2 and T1.

Phosphorous value of T6 birds were the highest, followed by T5, T4 and T3 that were the same and T2 and T1 that were also the same.

Table 6 Tibia mineralization impact of broiler chickens fed ration with varying levels of sodium chloride as a source of electrolyte from 3-8 weeks of age

Parameters	Treatments						SEM
	T1	T2	T3	T4	T5	T6	
Ash (%)	13.09[c]	14.34[c]	20.55[a]	16.55[b]	16.95[b]	11.55[d]	0.83
Calcium (ppm)	2.48[e]	3.92[d]	7.04[b]	9.60[a]	5.60[c]	5.68[c]	O.90
Phosphorous (mg/100 g)	9.00[d]	9.06[d]	10.58[c]	10.58[c]	12.09[b]	13.60[a]	0.49

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

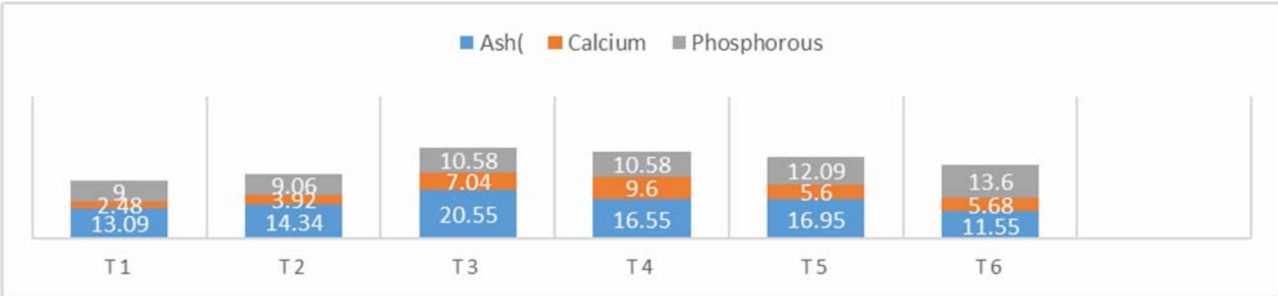

Figure 5 Tibia mineralization impact of broiler chickens fed diets containing varying levels of sodium chloride as a source of dietary electrolyte from 3-8 weeks of age

The results of the water intake of broiler chickens fed ration containing varying levels of sodium chloride as source of electrolyte from 3-8weeks of age are shown on Table 7 and Figure 6. Treatment 5 had the highest water intake value, followed by T4, T3, T2, T6 and T1 respectively.

Feed intake and weight gain were significantly improved (P<0.05) in favor of birds on sodium diets. The relative increase in feed intake in favor of birds on sodium diets compared to control birds can be attributed to tastiness of feed which sodium chloride contributes and this agrees with the work of Adedokun and Applegate (2014) who stated that sodium chloride in ration affect feed consumption positively.

Previously, McDonald *et al.* (2010) confirmed that increased salt such as sodium chloride in ration increased appetite in birds and thus, increasing feed intake. In intensively raised fast-growing birds, a sufficient intake of dietary sodium has a favorable impact on feed intake and rate of growth in birds (Borges *et al.* 2004). Also, it may be reliable to state that the improved weight gains in favor of birds on sodium chloride compared to control birds (T1) observed in this study could be as a result of increased feed intake, digestion, and absorption of digested nutrients across the intestinal walls.

This assertion was confirmed by various researchers such as Chrystal *et al.* (2020) who stated that sodium chloride affects digestibility of amino acids in ration.

McDonald *et al.* (2010) also confirmed that sodium plays a key role in the transmission of nerve impulses, absorption of sugars and amino acids from the digestive tract. According to Hassan *et al.* (2011) sodium and chloride are minerals with crucial physiological functions.

Olanwewaju *et al.* (2007) observed that sodium has a positive effect on enzyme activities and tissue protein synthesis. Earlier studies by Murakami *et al.* (2000) emphasized that maintaining suitable dietary electrolyte balance value is important to obtain optimum performance in broilers when fed higher levels of sodium chloride. According to the findings of Mushtaq *et al.* (2007) growth performance of birds was enhanced when the sodium content of ration was raised to 2-3 g/kg and T3 birds group that was observed to be one of the group with best performance in terms of weight gain in this present study got sodium chloride inclusion up to the level used by (Mushtaq *et al.* 2007). Other studies that investigated the effects of sodium on gastrointestinal roles revealed that an increased dietary sodium consumption from 0.5 to 3.2 g/kg enhanced the activity of intestinal ATPases that involves in nutrient transport in the small intestine (Gal-Garber *et al* . 2003).

Minerals such as sodium and chloride are crucial for nutrient absorption in the intestine (Boron and Boulpaep, 2016).

Table 7 Results of the water intake of broiler chickens fed ration containing varying levels of sodium chloride as a source of electrolyte from 3-8 weeks of age

Parameters (mL)	Treatments						SEM
	T1	T2	T3	T4	T5	T6	
Water intake per bird	2868[f]	3345[d]	3486[c]	4184[b]	5226[a]	3133[e]	54.67

Stater) T1: 0 g NaCl/kg ration (control); T2: 1.30 g NaCl/kg ration; T3: 2.00 g NaCl/kg ration; T4: 2.30 g NaCl/kg ration; T5: 3.30 g NaCl /kg ration and T6: 4.00 g NaCl kg ration.
Finisher) T1: 0 g NaCl/kg ration (control); T2: 2.30 g NaCl/kg ration; T3: 3.30 g NaCl/kg ration; T4: 4.30 g NaCl/kg ration; T5: 5.30 g NaCl /kg ration and T6: 6.30 g NaCl/ kg ration.
The means within the same row with at least one common letter, do not have significant difference (P>0.05).
SEM: standard error of the means.

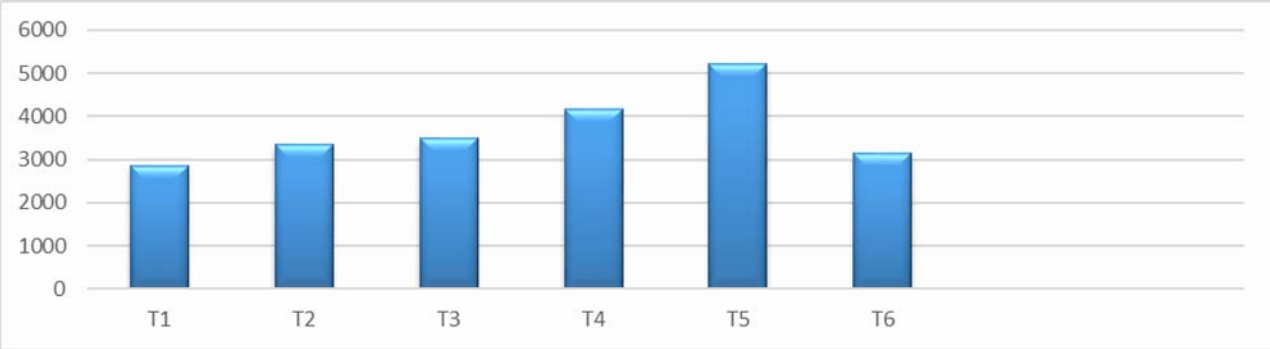

Figure 6 Results of the water intake of broiler chickens fed ration containing varying levels of sodium chloride as a source of electrolyte from 3-8 weeks of age

Therefore, pertinent to say that if the products of digestion such as glucose is well absorbed, much energy will be made available during cellular metabolism for animal's utilization for growth, development and other physiological activities and this may have led to the enhanced performance recorded in favor of the treatment groups in this present study. The improved weight gains recorded in this present study in favor of the treatment group is in tandem with the work of Jankowski *et al.* (2011a), Jankowski *et al.* (2011b) and Vieira *et al.* (2003) who recorded improved growth performance with increased sodium chloride inclusion above convectional requirement in broiler ration.

However, it was also observed that the treatment 5 and 6 birds with the highest sodium inclusion (4 g/kg and 6.30 g/kg of sodium chloride at starter and finisher stage respectively) had the lowest growth performance. This agrees with the experiment conducted by Jankowski *et al.* (2011a), Jankowski *et al.* (2011b) who observed that excessive sodium chloride in ration did not increase body weight gain, final body weight, gain, and improve feed conversion ratio in birds. Also, reduced performance observed in T5 and T6 group was confirmed by Ferket and Gernat (2006) who observed that elevated inclusion of sodium chloride in ration decreased voluntary feed intake in birds. It could be that excessive inclusion of sodium chloride in the ration makes it unpalatable and thereby, reducing feed intake. Furthermore, reduced growth performance recorded in T1 (0 g NaCl/kg ration) compared to those on sodium ration corresponds with the work of McDonald *et al.* (2010) who observed that symptoms of sodium deficiency include poor growth, reduced utilization of digested proteins and energy. This may be as a result of the reduced enzyme function caused by absence of sodium chloride in the feed and it is well documented that sodium plays a very crucial role in enzyme function that controls feed digestion and nutrient metabolism and protein synthesis Olanrewaju *et al.* (2007). Feed conversion ratio of birds on small (T2), moderate (T3, T4) and high (T5, T6) sodium chloride inclusion were lower than the control birds. The is in tandem with results of numerous studies which indicates that an increase in sodium content of the ration is followed by an improvement in the growth performance of broilers and feed conversion efficiency (Vieira *et al.* 2003). When feed digestion, nutrient absorption and metabolism are efficient, more feed will be converted to the desired products (weight gain). It was also observed that very high sodium inclusion negatively affected feed conversion ratio because among the treatment groups, feed conversion ratio of T5 and 6 birds on ration with highest sodium chloride inclusion were higher (P<0.05) when compared to treatment 3 and 4 with moderate increase in sodium inclusion (T3 and T4).

There are deficiency of newest studies that unfolds the impact of sodium chloride on viscera organ weights of broilers (Table 4 and Figure 2). However, the result of this study showed that dietary treatments, significantly (P<0.05) improved the visceral organs of birds. Sodium chloride significantly (P<0.05) increased the relative weight of gizzard, heart, kidney and liver. However, weight of an animal is positively correlated with the body organs. Normal increase in size of digestive organs leads to improvement in broiler capacity to ingest and digest feed and this could be the reason why birds on sodium chloride ration made the highest organ weights. A well-developed heart will function to provide oxygen needed for digestion and other physiological activities in the body. A large, well-developed gizzard improves gut motility and may increase cholecystokinin release, which in turn stimulates the secretion of pancreatic enzymes (Rui *et al.* 2020). The decreased gizzard weight recorded in control birds could be elucidated in part by the diminution in microbial populace of the upper parts of the guts (Dehghani-Tafti and Jahanian, 2016). The improved kidney observed in the study maybe due to the ability of the sodium chloride to stabilize the pH of the intestine and this helps in the proliferation of positive bacteria that reduces the pressure of kidney in the removal of waste. Furthermore, among treatment groups, treatment 6 birds with the highest sodium chloride inclusion (6.30 g/kg) showed retarded values of these internal organ measured in this study and had similar values for liver and heart weights with the control birds. For the control birds, this result was probably due the facts that animals enjoy feed with moderate sodium chloride inclusion in ration which increases feed intake and thus, leading to high body weight gain and adequate organ development and control had zero sodium chloride inclusion. For T6 group birds, it could be attributed to fact that feed intake was depressed due to excessive salt inclusion Ferket and Gernat (2006) and according to the findings of Jankowski *et al.* (2011a) and Jankowski *et al.* (2011b) high sodium chloride in ration did not increase the final body weight, support body weight gains and improve feed conversion ratio birds and thus leading to reduced organ development.

Birds on sodium diets made higher intestinal weights and lengths compared to control groups, while among the treatment groups, birds fed ration with the lowest sodium (T2) content had the lowest intestinal weights and length values compared with those fed ration with medium (T3, T4) and the highest (T5, T6) sodium chloride concentrations (Table 5 and Figure 3). Intestine weights and lengths increased with moderately increasing level of sodium chloride. This is probably due to increased body weight gain, water intake and feed intake. The small intestine is the site for absorption and the improved weight and length indicates better absorption and utilization of nutrients. The observed decrease in relative length of the small and large intestine in T1 group birds could probably cause by a decrease in the thickness of the contents of the small intestine and a reduction in the crypt cell multiplication rate (Oyeagu *et al.* 2019). Some authors upheld that the decrease in the length of the gut may be associated with a reduction in the viscosity of the gut contents and the concentration of volatile fatty acids in the ceca as well as rapid passage rate of the digester and its greater dilution with water (Oyeagu *et al.* 2019). The cited authors like Mushtaq *et al.* (2007) observed that increase in intestinal weights would result from increased water intake. One of the few studies that investigated the impact of sodium on gastrointestinal function revealed that an increase in dietary sodium intake from 0.5-3.2 g/kg ration improved the activity of intestinal ATPases that involves in nutrient conveyance in the small intestine (Gal-Garber *et al.* 2003). The cited authors observed also that an increase in intestinal weight can result from elevated water intake. This could be the major reason why excreta moisture of the treatment groups was higher compared to the control group. Increase in water intake in birds due to high salt intake bring about watery droppings. Increase in sodium chloride in this study increased the pH of small intestinal and caecal digester compared with control groups. In comparison with the sodiumdeficient group, increased sodium in the rationincreased the caecal weight and length.

The tibia mineralization impact of broiler chickens fed ration containing varying levels of sodium chloride as a source of electrolyte from 3 weeks-8 weeks of age (Table 6 and Figure 4). The lowest crude ash content of tibia dry matter was observed both in chickens fed a ration without sodium chloride and with the highest addition of sodium chloride. Experiment by (Murakami *et al.* 2000) showed that dietary sodium intake is essential for sufficient tibia mineralization in broilers, but surplus of it could decrease the ash content of bone as observed in this study and is in agreement with the study of Murakami *et al.* (1997) who observed that ash content of bones decreased along with an increase in the sodium content of chicken ration. In this study, sodium chloride lacking ration caused a substantial diminution in the calcium and phosphorus content of tibia dry matterand this could make bonevulnerable to breaking more easily.

The results of the water intake of broiler chickens fed ration containing varying levels of sodium chloride as a source electrolyte from3weeks-8weeks of age (Table 7 and Figure 5). Water intake increased as sodium chloride in the ration increased. This could be due to the fact that too much salt causes extreme thirst (McDonald *et al.* 2010). Increased levels of sodium chloride in the ration leads to an increase in water consumption and moisture content of excreta (Kidd *et al.* 2003). Mushtaq *et al.* (2007) confirms that negative consequences of an increased dietary intake of sodium include higher water consumption levels and a higher moisture content of litter and these observations were all in consonance with the significant increase in excreta moisture and water consumption observed in treatment groups in this study. Gal-Garber *et al.* (2003) observed an increase in intestinal weight, which could result from increased water intake and result of this study agrees with it.

CONCLUSION

Sodium chloride improved performance and growth of immune organs weights in broilers. Dietary inclusion of sodium chloride in broiler chickens from 3.30-4.30 g/kg feed had the highest performance and therefore recommended for use by broiler producers at this level. The highest sodium inclusion (Treatment 5 and 6) made least performance among the treatment groups.

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