



## Determination of the Effect of Feeding Different Sodium Chloride Regimes on Growth Performance, Viscera Organ Weights and Meat Quality Parameters of Broilers from Hatch to 35 Days of Age

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**ABSTRACT** This study intended to investigate the growth performance and meat quality traits in broilers fed different regimens of NaCl over a period of 35 days. Seven hundred and fifty 1-day-old chicks (Cobb 500) were randomly assigned to five NaCl feeding regimens to obtain three replicates for each regimen. Broilers in CON group were provided with concentrations of 0.35% NaCl for the duration of the experimental period. The other groups were provided with two concentrations of NaCl (0.45% and 0.55%) under two durations, namely: 1) 1~28 d: 0.45% or 0.55% NaCl for 28 days then CON; and 2) 1~35 d: 0.45% or 0.55% NaCl for 35 days. Broilers fed 0.55% NaCl for 1~35 d showed improved ( $P<0.05$ ) growth performance compared with broilers fed the CON regimen. Moreover, higher water holding capacity of breast meat was shown by the broilers fed 0.55% NaCl for 1~28 d when compared with that in broilers fed the CON diet ( $P<0.05$ ). Broilers fed 0.45% NaCl showed an increase ( $P<0.05$ ) in the lightness of the meat over CON diet and the 0.55% NaCl diet. In addition, broilers offered CON had the highest redness value and highest crude ash content in the breast meat ( $P<0.05$ ). Feeding 0.45% NaCl for 1~35 d and 0.55% NaCl for 1~28 d resulted in a higher ( $P<0.05$ ) protein content in breast meat. In conclusion, broilers fed diets with 0.55% NaCl for 1~35 d showed improved growth performance as well as water holding capacity and protein content of the breast meat.

(Key words: broilers, growth performance, protein, sodium chloride, water holding capacity)

## INTRODUCTION

The high temperature in the summer poses extensive challenges to the poultry industry, for instance, less feed intake and subsequent lower weight gain incorporated mortality which plays an adverse effect on total poultry production (Teeter and Belay, 1996). High environment temperature ( $> 26^{\circ}\text{C}$ ) induces the loss of ions from plasma with sweat and urine that reduce the level of plasma  $\text{K}^{+}$  and  $\text{Na}^{+}$  which resulted lower dietary electrolyte balance (DEB) in broilers (Borges et al., 2004). The DEB value is determined by the ratios of  $\text{Na}^{+}$ ,  $\text{Cl}^{-}$  and  $\text{K}^{+}$  levels in the plasma that

responsible in regulating the acid-base balance and pH, which are the factors help to maintain optimum enzymatic efficiency in broilers (Hooge, 2003). Moreover, DEB has a crucial role in broiler growth performance including proper bone development and litter quality (Borges et al., 2004).

It has been known that, addition of cation like  $\text{Na}^{+}$  and  $\text{K}^{+}$  along with  $\text{Cl}^{-}$  could be used to enhance the growth performance of broilers (Mushtaq et al., 2005). Dietary sodium chloride (NaCl) is an inexpensive ion source that can be used to enhance the DEB in broilers (Murakami et al., 2001). Sodium is also responsible for amino acids and sugar absorption in the small intestine (Leeson and Summers,

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2001). Importantly,  $\text{Cl}^-$  level in the diets should be maintained because, excess level of  $\text{Cl}^-$  can be a reason for the leg and articulation outbreaks in broilers (Murakami et al., 2001). It has been stated that increasing  $\text{Na}^+$  levels from 0.10% to 0.46% in the diet, improved the growth performance of broilers in the pre-starter phase (Maiorka et al., 2004). Interestingly, incorporating NaCl as the primary source of  $\text{Na}^+$  to the diets has ability to improve the growth performance of broilers compared to the use of sodium bicarbonate (Murakami et al., 2000). However, previous studies emphasised that maintaining proper DEB value (200~300 meq/kg) also important to obtain optimum performance from broilers fed elevated levels of NaCl (Murakami et al., 2000). Additionally, it is important to consider that broilers were more sensitive to the levels of electrolytes at early stages than later stages which allow to reduce the  $\text{Na}^+$  and  $\text{Cl}^-$  incorporation into broiler diets (Mushtaq et al., 2013). Therefore, it is unnecessary to supply higher level of NaCl into diets at later stage of broilers.

Results of the previous studies revealed that supplementation of elevated levels of dietary NaCl under preferable DEB value to broilers have been inconsistent. Further, fewer studies investigated the effect of NaCl on meat quality and carcass parameters of broilers. Therefore, this study was designed to test the hypothesis of broilers fed elevated level of NaCl improved growth performance in hot and humid (32°C and 90% respectively) environmental condition while maintaining the carcass and meat quality parameters for 35 d.

## MATERIAL AND METHODS

### 1. Experiment Design and Management

A total of 750 one-day-old Cobb 500 male broiler chicks were randomly distributed into one of five feeding regimens to give three replicates per each (50 birds/replicate). Broilers were allotted into the CON group provided 0.35% level of NaCl for 35 d. Broilers in other four groups provided two elevated levels of NaCl (0.45% and 0.55%) under two feeding regimens consisted of broilers were in other four groups provided two levels of NaCl (0.45% and 0.55%) under two durations which is known as 1) 1~28 d: feeding

0.45% and 0.55% level of NaCl for 28 d then provide CON diet for 28 d to 35 d, 2) 1~35d: feeding 0.45% and 0.55% level of NaCl for 35d.

All the management practices were followed the Cobb broiler management guide (2012). Birds were in the deep litter cages under normal environment conditions. The average temperature and humidity were recorded as 32°C and 90%, respectively during the experimental period. Broilers were permitted to *ad-libitum* access to experimental diets and water.

### 2. Experimental Diets

Experimental diets were formulated to fulfil or exceed the Cobb 500 broiler nutrition requirement (Cobb500-vantress, 2012). Maize-broken rice and soybean meal were used to produce basal diets. All the diets were free from added antibiotics and any other antimicrobial growth promoters. Feeding program was divided into three phases as following starter (day 1~14), grower (day 15~28) and finisher (day 29~35) during the experimental period (Table 1). Starter and grower diets were produced as crumble form whereas finisher feed was made in pellet form. Sodium chloride was added into the experimental diets in expenses of maize and soybean meal via dietary salt.

### 3. Measurements

Initial body weights of the broiler chicks were measured and recorded on a pen basis on arrival. Thereafter, final body weights (pen basis) were measured to determine the average daily weight gain of broilers on day 35. Feed intake was measured based on the feed disappearance rate in each cage and calculated the daily average feed intake for the experimental period. Finally, the mortality corrected feed conversion ratio was measured per each cage.

At the end of the experiment, two birds near to the median weight from each cage were selected (n=6) and euthanized by cervical dislocation. Abdominal incisions were made to remove the internal organs such as the liver, gizzard, small intestine, and heart. Thereafter, absolute weights of the abovementioned organs were taken after removing fat and other adherent materials then recorded as relative weights to the body weights.

**Table 1.** Composition (% as-fed basis) of the basal diet (CON)

Item	Starter (d 0~14)			Grower (d 15~28)			Finisher (d 29~35)		
	CON <sup>1</sup>	0.45(%)	0.55(%)	CON	0.45(%)	0.55(%)	CON	0.45(%)	0.55(%)
Maize	35.60	35.56	35.50	34.07	34.06	33.97	41.21	41.12	41.02
Soybean meal	24.00	23.60	23.00	24.00	24.00	24.00	22.30	22.25	22.25
Broken rice	19.00	19.31	19.82	24.00	24.00	24.00	17.00	17.00	17.00
Rice polish	4.03	4.03	4.03	3.07	3.07	3.07	3.12	3.15	3.15
Meat and bone meal	4.97	4.97	4.97	4.93	4.93	4.93	3.88	3.85	3.85
Vegetable oil	2.00	2.00	2.00	2.97	2.97	2.97	3.98	4.00	4.00
DDGS <sup>2</sup>	3.12	3.12	3.12	3.03	3.03	3.03	3.00	3.00	3.00
CGM <sup>3</sup>	4.88	4.88	4.88	2.00	2.00	2.00	3.00	3.00	3.00
Lysine-HCl	0.40	0.42	0.44	0.45	0.45	0.45	0.48	0.49	0.49
DL-Methionine	0.27	0.27	0.29	0.31	0.31	0.31	0.33	0.35	0.35
L-Threonine	0.12	0.13	0.14	0.13	0.13	0.13	0.16	0.17	0.17
Salt	0.20	0.30	0.40	0.20	0.30	0.30	0.20	0.30	0.40
Vitamin/mineral premix*	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Limestone	0.50	0.50	0.50	0.53	0.53	0.53	0.30	0.30	0.30
Dicalcium phosphate	0.60	0.60	0.60	0.63	0.63	0.63	0.71	0.71	0.71
Phytase**	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Calculated nutrition composition									
Energy	2,950	2,950	2,950	3,050	3,050	3,050	3,150	3,150	3,150
Crude protein	22.00 (22.35)***	22.00 (22.23)	22.00 (22.38)	21.00 (21.11)	21.00 (21.01)	21.00 (21.06)	19.50 (19.88)	19.50 (19.75)	19.50 (19.67)
Crude ash	4.65	4.65	4.65	4.80	4.80	4.80	5.10	5.10	5.10
NaCl	0.35 (0.34)	0.45 (0.48)	0.55 (0.57)	0.35 (0.38)	0.45 (0.49)	0.55 (0.57)	0.35 (0.35)	0.45 (0.46)	0.55 (0.57)
Calcium	0.95	0.95	0.95	1.01	1.01	1.01	1.08	1.08	1.08
Phosphorous (total)	0.64	0.64	0.64	0.68	0.68	0.68	0.71	0.71	0.71
DEB (mEq/kg)	207.74	204.48	200.18	207.87	207.88	207.81	191.88	190.77	190.68

<sup>1</sup> Control diet.<sup>2</sup> Distillers dried grains solute.<sup>3</sup> Corn gluten meal.\* Supplied per kilogram of total diets: Fe (FeSO<sub>4</sub> · H<sub>2</sub>O), 80 mg; Zn (ZnSO<sub>4</sub> · H<sub>2</sub>O), 80 mg; Mn (MnSO<sub>4</sub> · H<sub>2</sub>O), 80 mg; Co (CoSO<sub>4</sub> · H<sub>2</sub>O), 0.5 mg; Cu (CuSO<sub>4</sub> · H<sub>2</sub>O), 10 mg; Se (Na<sub>2</sub>SeO<sub>3</sub>), 0.2 mg; I, (Ca(IO<sub>3</sub>) · 2H<sub>2</sub>O) 0.9 mg; vitamin A, 24,000 IU; vitamin D<sub>3</sub>, 6,000 IU; vitamin E, 30 IU; vitamin K, 4 mg; thiamin, 4 mg; riboflavin, 12 mg; pyridoxine, 4 mg; folacine, 2 mg; biotin, 0.03 mg; vitamin B<sub>8</sub>, 0.06 mg; niacin, 90 mg; pantothenic acid, 30 mg.\*\* Natuphos<sup>®</sup> E, BSAF, Germany.

\*\*\* Calculated values.

#### 4. Sample Collection and Laboratory Analyses

Breast meat was separated from the carcass and samples were packed in the vacuumed sample bags and stored in the iceboxes until transport to the laboratory. Hereafter, laboratory analyses for the meat quality parameters and proximate composition were performed within one-week post-mortem.

#### 5. Meat Quality Analysis

Water holding capacity, pH value, cooking loss and meat colour of the broiler breast meat were measured using the methods described by the Jayasena et al. (2013) and Nuwan et al. (2016). Proximate compositions (crude protein, crude fat, NaCl, crude ash, Ca and P) were measured in the breast meat samples as the methods described in AOAC (1995) and Lakshani et al. (2016).

#### 6. Statistical Analysis

Data were analysed by the General Linear Model (GLM) procedure of one-way ANOVA of SPSS software (version

24, Armonk, NY: IBM Corp.). Each replicate of the treatments was considered as the experimental unit for the growth performance whereas the birds which selected to near to the medium body weight of each replicate were considered as experimental units for the meat quality parameters. Tukey's multiple range test was performed when the significance was found at  $P < 0.05$ .

## RESULTS

The results of broilers fed different NaCl regimens on growth performance of broilers presented in Table 2. Broilers fed diet with 0.55% level of NaCl for 1~35d improved ( $P < 0.01$ ) ADG, ADFI and FCR compared broilers fed CON diet on day 35. Broilers fed a diet with 0.45% level of NaCl for 1~28 d reduced ( $P < 0.01$ ) the feed intake compared to broilers fed CON diet on day 35.

The effect of broilers fed different NaCl regimens on viscera organ weights presented in Table 3. Broilers fed elevated levels of NaCl did not alter ( $P < 0.05$ ) the relative

**Table 2.** Growth performance of broilers fed diet with different NaCl regimens for 35 days

Item	CON <sup>1</sup>	1~35 d		1~28 d <sup>2</sup>		SEM	P-value
		0.45 (%)	0.55 (%)	0.45 (%)	0.55 (%)		
ADG (g)	51.86 <sup>ab</sup>	51.70 <sup>b</sup>	57.19 <sup>c</sup>	49.88 <sup>a</sup>	52.30 <sup>b</sup>	0.149	0.001
ADFI (g)	85.12 <sup>b</sup>	86.05 <sup>c</sup>	92.52 <sup>d</sup>	84.51 <sup>a</sup>	86.21 <sup>c</sup>	0.038	0.001
FCR (g)	1.67 <sup>bc</sup>	1.67 <sup>bc</sup>	1.62 <sup>a</sup>	1.69 <sup>c</sup>	1.65 <sup>ab</sup>	0.004	0.003

<sup>1</sup> Control diet with 0.35% level of NaCl.

<sup>2</sup> Feeding a specific diet for 28 days and then feeding a CON diet from day 29 to day 35.

SEM, standard error of mean; ADG, average daily gain; ADFI, average daily feed intake; FCR, feed conversion ratio.

**Table 3.** Viscera organ weights of broilers fed diet with different NaCl regimens for 35 days

Item	CON <sup>1</sup>	1~35 d		1~28 d <sup>2</sup>		SEM	P-value
		0.45 (%)	0.55 (%)	0.45 (%)	0.55 (%)		
Gizzard (%)	1.38	1.27	1.24	1.28	1.26	1.210	0.803
Heart (%)	0.46	0.42	0.46	0.40	0.41	0.014	0.467
Small intestine (%)	5.53 <sup>b</sup>	5.50 <sup>b</sup>	3.92 <sup>a</sup>	5.43 <sup>b</sup>	4.62 <sup>ab</sup>	0.186	0.040

<sup>1</sup> Control diet with 0.35% level of NaCl.

<sup>2</sup> Feeding a specific diet for 28 days and then feeding a CON diet from day 29 to day 35.

SEM, standard error of mean.

weights of gizzard and heart compared to broilers fed CON. Interestingly, broilers supplemented 0.55% level of NaCl for 1~35 d has reduced ( $P<0.05$ ) the relative weight of small intestine compared to broilers fed CON on day 35.

Meat quality parameters of broiler breast meat from the broilers fed different NaCl regimens presented in Table 4. Broilers fed a diet with 0.55% NaCl for 1~28 d showed higher ( $P<0.01$ ) WHC compared to those fed CON on day 35. The lightness of the surface of breast meat has been increased ( $P<0.01$ ) by the 0.45% NaCl supplementation to the broilers regardless of the feeding duration that compared to broilers fed CON diet on day 35. In the aspect of breast meat redness, broilers fed a diet with 0.45% and 0.55% NaCl

level for 1~28 d obtain lower value ( $P<0.05$ ) compared to broilers fed CON diet on day 35.

The effect of different regimens of NaCl supplementation on the proximate nutrition composition of broiler breast meat is presented in Table 5. Broilers fed a diet with 0.45% for the 1~35 d had amplified ( $P<0.01$ ) the breast meat protein content by 4% compared to broilers fed CON on day 35. Interestingly, broilers fed CON and 0.55% level of NaCl for 1~35 d increased ( $P<0.01$ ) the crude ash of the broiler breast meat compared to broilers fed other diets. Moreover, broilers fed 0.55% level of NaCl increased ( $P<0.05$ ) the Ca amount in the breast meat by 75% compared to those fed CON diet.

**Table 4.** Meat quality parameters of broilers fed diet with different NaCl regimens for 35 days

Item	CON <sup>1</sup>	1~35 d		1~28 d <sup>2</sup>		SEM	P-value
		0.45 (%)	0.55 (%)	0.45 (%)	0.55 (%)		
WHC (%)	78.83 <sup>ab</sup>	81.22 <sup>bc</sup>	78.22 <sup>a</sup>	78.49 <sup>a</sup>	82.21 <sup>C</sup>	0.257	0.002
CL (%)	27.08	27.55	26.82	27.12	30.48	0.459	0.145
pH	5.86	5.84	5.89	5.92	6.04	0.039	0.537
L*	62.57 <sup>a</sup>	67.74 <sup>b</sup>	62.51 <sup>a</sup>	66.49 <sup>b</sup>	66.93 <sup>B</sup>	0.305	0.001
a*	15.00 <sup>b</sup>	12.03 <sup>ab</sup>	12.22 <sup>ab</sup>	11.26 <sup>a</sup>	11.83 <sup>A</sup>	0.658	0.019
b*	14.02	15.09	16.80	15.10	15.93	0.520	0.581

<sup>1</sup> Control diet with 0.35% level of NaCl.

<sup>2</sup> Feeding a specific diet for 28 days and then feeding a CON diet from day 29 to day 35.

SEM, standard error of mean; WHC, water holding capacity; CL, cooking loss; L\*, lightness of the meat; a\*, redness; b\*, yellowness.

**Table 5.** Proximate chemical composition in breast meat of broilers treated different NaCl regimens for 35 days

Item	CON <sup>1</sup>	1~35 d		1~28 d <sup>2</sup>		SEM <sup>3</sup>	P-value treatment
		0.45 (%)	0.55 (%)	0.45 (%)	0.55 (%)		
Protein (%)	22.63 <sup>ab</sup>	23.46 <sup>c</sup>	23.40 <sup>bc</sup>	22.27 <sup>a</sup>	23.48 <sup>c</sup>	0.082	0.001
Crude ash (%)	1.52 <sup>b</sup>	1.23 <sup>a</sup>	1.51 <sup>b</sup>	1.15 <sup>a</sup>	1.12 <sup>a</sup>	0.020	0.001
Calcium (%)	0.033 <sup>a</sup>	0.048 <sup>ab</sup>	0.035 <sup>a</sup>	0.048 <sup>ab</sup>	0.058 <sup>c</sup>	0.041	0.001
Phosphorous (%)	0.22	0.21	0.23	0.22	0.23	0.006	0.716
Salt (%)	0.070	0.070	0.065	0.073	0.075	0.066	0.563
Ether extract (%)	4.71	4.31	4.23	4.53	4.42	0.060	0.160

<sup>1</sup> Control diet with 0.35% level of NaCl.

<sup>2</sup> Feeding a specific diet for 28 days and then feeding a CON diet from day 29 to day 35.

SEM, standard error of mean.

## DISCUSSION

There is a strong concern that exists regarding the acidbase balance for the conservation of performance and survivability of broilers under higher environmental temperature conditions (Ahmad and Sarwar, 2005). Increased mineral excretion was observed in broilers that reared in hot areas where the temperature is higher than 24°C (Belay et al., 1992). In this light, acid-base balance in the plasma gets altered in broilers (Ahmad and Sarwar, 2005). Therefore, broiler diets supplemented with sodium (Na), potassium (K) and, chloride (Cl) were documented as important gears for maintaining the acid-base balance of broilers (Hooge, 2003). However, there were considerable studies investigated the elevated levels of Na<sup>+</sup> and Cl<sup>-</sup> effect on broiler growth performance while fewer studies focus on the meat quality parameters.

Previous studies were concluded that incorporation of Na<sup>+</sup>, K<sup>+</sup>, and Cl<sup>-</sup> to broiler diets to attain the range of dietary electrolyte balance (DEB) between 155 mEq/kg to 300 mEq/kg, has been sustained the growth performance of broilers (Ahmad and Sarwar, 2005). Interestingly, all the diets under each treatment in the current study maintained similar DEB value inside the above-mentioned limits, thus, it is clear that the results obtained in the current study were independent of the DEB value of the diets.

The NaCl requirement for broilers ranged between 0.30~0.40% in thermos-neutral conditions (NRC, 1994). On the other hand, the NaCl requirement of broilers was estimated between 0.33~0.58% in Cobb 500 nutrition guide, (2015). Mushtaq et al. (2007) concluded that broilers required 0.50~0.53% NaCl level for obtained optimum growth performance in hot environmental conditions. Furthermore, leaner effect between Na<sup>+</sup> amount in the diet and the weight gain of broilers regardless of Cl<sup>-</sup> amount has been found by the Mushtaq et al. (2005). In agreement, the current study obtained improved weight gain and FCR from the broilers fed diet with 0.22% level of Na<sup>+</sup> than those fed diets with 0.18% and 0.12% Na<sup>+</sup> for 35d. It is cleared that Na<sup>+</sup> content in dietary salt plays a key role rather than Cl<sup>-</sup> content to obtain higher growth performance in broilers.

There was a lack of recent studies described the effect of NaCl on viscera organ weights of broilers. However, Castro

et al. (2009) stated that the dietary Na level did not affect the viscera organ weights of broilers. It is hypothesized that increased size of digestive organs led to improve broiler capacity to ingest and digest the feed. However, current study observed lower growth performance for broilers fed lower level of NaCl while obtaining higher small intestinal weights compared to broilers fed 0.55% level of NaCl. Interestingly, Bedford et al. (1991) explained that dietary salt would reduce the viscosity of small intestine which may affect the small intestinal development of broilers.

It has been described that lower pH value resulted lower WHC in the poultry meat (Woelfel et al., 2002). Further, it could be identified as an indicator of a meat defect called pale, soft, and exudative (PSE) meat. In contrast, we did not find any significant treatment effect on pH value of the meat. Interestingly, NaCl has able to increase WHC in meat through moisture absorption (Allen et al., 1998). Similarly, results of this study also obtained higher WHC from the broilers fed 0.55% level of NaCl. In the aspect of meat lightness (L\* value), Allen et al. (1998) found that there was a negative relationship between WHC and meat lightness. However, these findings did not line with the current study which revealed that reduced lightness of the meat could cause by an unknown factor. On the other hand, less WHC could be reduced the protein level of the meat as a result of the removal of water-soluble protein due to the external pressures after or while slaughtering process. In agreement, higher meat crude protein level which obtained from broilers fed 0.55% of NaCl for 1~28 d may be resulted due to their high meat WHC. Broilers fed 0.55% level of salt for 1~35 d has increased the crude ash content in the meat while lowering the calcium level. Consequently, it is evident that calcium deposition of breast meat gets reduced while increasing the total mineral content in broiler breast meat by an elevated level of dietary NaCl in diets.

In conclusion, broilers fed 0.55% of NaCl for 1~35 d improved growth performance along with increased water holding capacity and protein content of the breast meat.

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## REFERENCES

- Ahmad T, Sarwar M 2005 Influence of varying sources of dietary electrolytes on the performance of broilers reared in a high temperature environment. *Anim Feed Sci Tech* 120(3-4): 277-298.
- Allen CD, Fletcher DL, Northcutt JK, Russell SM 1998 The relationship of broiler breast color to meat quality and shelf-life. *Poult Sci* 77(2):361-366.
- Association of Official Analytical Chemists 1995 *Official Methods of Analysis*. 16th ed. Association of Official Analytical Chemists, Washington, DC, USA.
- Bedford MR, Classen HL, Campbell GL 1991 The effect of pelleting, salt, and pentosanase on the viscosity of intestinal contents and the performance of broilers fed rye. *Poult Sci* 70(7):1571-1577.
- Belay T, Wiernusz CJ, Teeter RG 1992 Mineral balance and urinary and fecal mineral excretion profile of broilers housed in thermoneutral and heat-distressed environments. *Poult Sci* 71(6):1043-1047.
- Borges SA, Fischer da Silva AV, Majorca A, Hooge DM, Cummings KR 2004 Physiological responses of broiler chickens to heat stress and dietary electrolyte balance (sodium plus potassium minus chloride, milliequivalents per kilogram). *Poult Sci* 83(9):1551-1558.
- Castro EEC, Penz Júnior AM, Ribeiro AML, Sbrissia AF 2009 Effect of water restriction and sodium levels in the drinking water on broiler performance during the first week of life. *Revista Brasileira de Zootecnia* 38(11): 2167-2173.
- Hooge DM 2003 Practicalities of using dietary sodium and potassium supplements to improve poultry performance. In *Proceedings of Arkansas Nutrition Conference* (Vol. 19).
- Jayasena DD, Jung S, Kim HJ, Bae YS, Yong HI, Lee JH, Kim JG, Jo CR 2013 Comparison of quality traits of meat from Korean native chickens and broilers used in two different traditional Korean cuisines. *Asian-Australas J Anim Sci* 26:1038-1046.
- Lakshani P, Jayasena DD, Jo C 2016 Comparison of quality traits of breast meat from commercial broilers and spent hens in Sri Lanka. *Korean J Poult Sci* 43(2):55-61.
- Leeson S, Summers JD, Caston LJ 2001 Response of layers to low nutrient density diets. *J Appl Poult Res* 10(1): 46-52.
- Maiorka A, Magro N, Bartels HADS, Kessler ADM, Penz Jr AM 2004 Different sodium levels and electrolyte balances in pre-starter diets for broilers. *Brazilian J Poult Sci* 6(3): 143-146.
- Murakami AE, Oviedo-Rondon EO, Martins EN, Pereira MS, Scapinello C 2001 Sodium and chloride requirements of growing broiler chickens (twenty-one to forty-two days of age) fed corn-soybean diets. *Poult Sci* 80(3):289-294.
- Murakami AE, Saleh EA, Watkins SE, Waldroup PW 2000 Sodium source and level in broiler diets with and without high levels of animal protein. *J Appl Poult Res* 9(1): 53-61.
- Mushtaq T, Sarwar M, Nawaz H, Mirza A, Ahmad T 2005 Effect and interactions of dietary sodium and chloride on broiler starter performance (hatching to twenty-eight days of age) under subtropical summer conditions. *Poult Sci* 84(11):1716-1722.
- Mushtaq T, Mirza MA, Athar M, Hooge DM, Ahmad T, Ahmad G, Mushtaq MMH, Noreen U 2007 Dietary

- sodium and chloride for twenty-nine-to forty-two-day-old broiler chickens at constant electrolyte balance under subtropical summer conditions. *J Appl Poult Res* 16(2):161-170.
- Mushtaq MMH, Pasha TN, Mushtaq T, Parvin R 2013 Electrolytes, dietary electrolyte balance and salts in broilers: an updated review on growth performance, water intake and litter quality. *World's Poult Sci J* 69(4):789-802.
- Nuwan KAS, Wickramasuriya SS, Jayasena DD, Himali Tharangani RM, Song Z, Yi YJ, Heo JM 2016 Evaluation of growth performance, meat quality and sensory attributes of the broiler fed a diet supplemented with curry leaves (*Murraya koenigii*). *Korean J Poult Sci* 43(3): 169-176.
- Teeter RG, Belay T 1996 Broiler management during acute heat stress. *Anim Feed Sci Technol* 58(1-2):127-142.
- Woelfel RL, Owens CM, Hirschler EM, Martinez-Dawson R, Sams AR 2002 The characterization and incidence of pale, soft, and exudative broiler meat in a commercial processing plant. *Poult Sci* 81:579-584.
- Vantress C 2012 Cobb Broiler Management Guide. Cobb-Vantress, Siloam Springs, AR, USA.
- Vantress C 2015 Broiler Performance and Nutrition Supplement. Cobb500, Arkansas, USA.

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