EFFECTS OF LYSINE AND SODIUM ON THE GROWTH PERFORMANCE BONE PARAMETER, SERUM COMPOSITION AND LYSINE-ARGININE ANTAGONISM IN BROILER CHICKS

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Summary

An experiment with completely randomized design was performed to investigate the effects of lysine and supplemented sodium on growth performance, nutrients utilization, acid-base balance and lysine arginine antagonism in broiler chicks. The experiment was carried out with 3 levels of dietary lysine (0.6, 1.2 and 1.8%) and 3 levels of sodium(0.4, 0.8 and 1.2%) for an experimental period of 7 weeks.

Body weight gain of 1.2% lysine group was significantly ($p < 0.01$) higher than that of low or high lysine group. The highest feed consumption was obtained at 1.2% lysine and 0.4% sodium supplemented level (ML-1.2) and the lowest at LL-1.2. The best feed efficiency was obtained at ML-0.8 level and the worst at LL-1.2 level. Mortalities of high (1.8%) and low (0.6%) lysine groups were significantly ($p < 0.05$) higher than medium lysine (1.2%) group. Among the sodium levels, the mortality at 1.2% sodium supplemented level was significantly ($p < 0.01$) higher than that of other treatments. Serum lysine content was significantly ($p < 0.01$) different by the levels of dietary lysine. Lysine-arginine antagonism was observed in high lysine diet. Among the lysine levels, the lowest bone weight and length were shown in low lysine group. Interactions between lysine and sodium were significantly ($p < 0.05$) shown in femur weight. The levels of sodium and lysine affected significantly ($p < 0.01$) the utilization of nitrogen, ether extract, total carbohydrate and energy.

(Key Words : Broiler, Sodium, Lysine, Lysine-Arginine Antagonism)

Introduction

It has been well established the physiological role of sodium, potassium and chloride in the regulation of osmotic pressure and acid-base balance in the animal. Mongin (1980) emphasized the importance of adjusting the mineral balance and maintaining a balance of cation in the animal body. Acid-base balance affects the growth rate in chicks (Melliere and Fobes, 1966). Especially sodium exists mainly in the body as the sodium ion (Na^+) and is major cation of extracellular body fluids.

Anderson and Combs (1952) reported that significant lower weight gain was observed in growing chicks fed a high lysine diet. Thereafter, many investigators demonstrated that the depressed weight gain was due to a lysine-arginine antagonism (O'Dell et al., 1958; Jones, 1964; Boorman and Fisher, 1966; Kim et al., 1989). Sodium and potassium were particularly effective in alleviating this antagonism (Stutz et al., 1971) if supplemented in the diet conjunction with metabolizable anion such as acetate or bicarbonate. O'Dell and Savage (1966) reported that chicks fed a lysine diet responded nearly as well to supplements of dietary cations as to arginine, the limiting amino acid. Excess lysine depressed the rate of weight gain, but this was largely overcome by arginine supplementation (Savage and O'Dell, 1960; O'Dell and Savage, 1966; Dean and Scott, 1968; Austic and Nesheim, 1970; Austic and Scott, 1975). The addition of dietary sodium depressed plasma potassium, while dietary potassium did not influence blood sodium (Hurwitz et al., 1973; Cohen and Hurwitz, 1974).

Therefore, this experiment was conducted to examine the effects of electrolyte (especially sodium) and lysine interactions on growth performance, acid-base status in blood, femur bone growth, nutrients and energy utilization in broiler chicks.

Materials and Methods

In this study an experiment was conducted

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in 3 × 3 factorial arrangement with three levels of dietary lysine [0.6% (LL, low lysine), 1.2% (ML, medium lysine) and 1.8% (HL, high lysine)] and three levels of supplemented sodium (0.4, 0.8 and 1.2%). All treatments had 6 replicates with 8 birds in each replicate. At 3 days of age, experimental animals were chosen to have uniform initial body weight and fed the experimental diets for 7 weeks. A total of 288 male birds were used in the present study. Experimental diet was formulated to be low in lysine (0.6%). The basal diet for starting broiler chicks (0-3 weeks) was formulated to contain approximately 23% crude protein (N × 6.25) and 3,200 kcal of metabolizable energy per kg of diet. The composition of basal diet for starting period is shown in table 1. The basal diet for finishing broiler chicks (4-7 weeks) was formulated to contain 20% crude protein (N × 6.25) and 3,200 kcal of metabolizable energy per kg of diet as is seen in table 1. The mineral mixtures containing various levels of lysine and sodium bicarbonate replaced the variable part of the basal diet to prepare practical - type experimental diet as in presented in table 2 and 3. All chicks were raised in battery cages made of steel wire and housed in a room with 24 hours illumination and air ventilation. Feeds and water were supplied *ad libitum*. Individual body weight and feed intake on a group basis were measured at weekly intervals, and body weight gains were calculated by the differences between initial and final body weight. During the feeding trial, mortality was also recorded.

The metabolizability trial was carried out to investigate the nutrient utilization of experimental diets. The metabolizability coefficient was calculated by total fecal collection method during 7 days at the end of feeding trial period. Three chicks were selected for metabolism trial from each treatment. After four days of preliminary period for acclimatization on the new environment and management, total excreta from chicks were collected three times a day and then pooled. Thereafter collected feces were dried in an air-forced drying oven at 60℃ for 72 hours. All the excreta prepared in this way were grounded by Wiley mill to pass through 1 mm screen and analyzed for proximate composition and mineral content.

At the end of the experiment, three chicks from each replication of each treatment were selected randomly and sacrificed for bone and blood collections. The right femur was removed, soaked in boiling water for 4 minutes to facilitate scaling process of adhered muscle and tendons, and dried in an air-forced dring oven for 72 hours at 60℃. After measuring weight and length of femur, fat was extracted for 12 hours with petroleum ether in a Soxlet apparatus. The femur were then ashed individually in a muffle furnace at 550℃ for 2 hours, and the crude ash, Ca and P contents were expressed as a precent

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE BASAL DIET FOR BROILER CHICKS

	Contents (%)	
	Starter	Finisher
Ingredients :		
Corn, yellow	57.8	66.9
Soybean meal	6.7	9.5
Corn gluten meal	18.1	16.2
Feather meal	4.3	–
Wheat bran	3.5	
Tallow	3.9	1.7
Limestone	1.0	1.0
Vit.-min. mixture[1]	0.3	0.3
Salt[2]	0.2	0.2
Ca_2PO_4	1.7	1.7
Antibiotics[3]	0.1	0.1
Variables[4]	2.4	2.4
Total	100.0	100.0
Chemical composition :		
Energy (ME, kcal/kg)	3,211.00	3,214.50
Crude protein (%)	23.19	20.62
Calcium (%)	0.98	0.95
Phosphorus (%)	0.60	0.65
Lysine (%)	0.60	0.60
Sodium (%)	0.10	0.09
Potassium (%)	0.41	0.42

[1] Vitamin-mineral mixture contains the followings in 1 kg: Vitamin A, 10,000 IU; Vitamin D, 1500 IU; Vitamin E, 15 mg; Vitamin K, 5 mg; Vitamin B_2, 8 mg; Vitamin B_{12}, 8 μg; Ca-d-pantothenate, 8 mg; Niacin, 25 mg; Folic acid, 0.4 mg; Biotin, 0.2 mg; Choline, 500 mg; Pyridoxine, 1 mg; B.H.T, 125 mg; Co, 0.85 mg; I, 1.29 mg; Zn, 100 mg; Mg, 110 mg; Cu, 8.75 mg; Se, 0.15 mg; Fe, 35 mg.

[2] Refined table salt.

[3] Zinc-bacitracin was used.

[4] See table 3.

TABLE 2. FORMULA AND CHEMICAL COMPOSITION OF MINERAL MIXTURES USED FOR VARIABLE PART IN STARTING DIETS (0-3 WEEKS)

Treatment[1]	LL			ML			HL		
Items	0.4	0.8	1.2	0.4	0.8	1.2	0.4	0.8	1.2
Ingredients (%):									
Lysine		–	–	0.6	0.6	0.6	1.2	1.2	1.2
$NaHCO_3$	0.4	0.8	1.2	0.4	0.8	1.2	0.4	0.8	1.2
Sand[2]	2.0	1.6	1.2	1.4	1.0	0.6	0.8	0.4	0.0
Total	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Chemical composition (%)[3]:									
Lysine	0.6	0.6	0.6	1.2	1.2	1.2	1.8	1.8	1.8
Sodium	0.236	0.346	0.456	0.236	0.346	0.456	0.236	0.346	0.456
Potassium	0.417	0.417	0.417	0.417	0.417	0.417	0.417	0.417	0.417
Chloride	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169	0.169
E/B(mEq/kg)[4]	161.7	209.3	257.0	161.7	209.3	257.0	161.7	209.3	257.0

[1] LL, Low lysine; ML, Medium lysine; HL, High lysine
[2] Acid washed sand was used
[3] Calculated value
[4] Electrolyte balance

TABLE 3. FORMULA AND CHEMICAL COMPOSITION OF MINERAL MIXTURES USED FOR VARIABLE PART IN FINISHING DIETS (3-7 WEEKS)

Treatment[1]	LL			ML			HL		
Items	0.4	0.8	1.2	0.4	0.8	1.2	0.4	0.8	1.2
Ingredients (%):									
Lysine	–			0.6	0.6	0.6	1.2	1.2	1.2
$NaHCO_3$	0.4	0.8	1.2	0.4	0.8	1.2	0.4	0.8	1.2
Sand[2]	2.0	1.6	1.2	1.4	1.0	0.6	0.8	0.4	0.0
Total	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Chemical composition (%)[3]:									
Lysine	0.6	0.6	0.6	1.2	1.2	1.2	1.2	1.2	1.2
Sodium	0.239	0.317	0.426	0.239	0.317	0.426	0.239	0.317	0.426
Potassium	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447	0.447
Chloride	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159	0.159
E/B(mEq/kg)[4]	160.0	207.4	255.0	160.0	207.4	255.0	160.0	207.4	255.0

[1] LL, Low lysine; ML, Medium lysine; HL, High lysine
[2] Acid washed sand was used
[3] Calculated value
[4] Electrolyte balance

of moisture-free, fat-free bone. Blood samples were taken on the carotid artery at the same time as the femur samples. Blood samples were collected from the carotid artery with 23-gauge needle attached to 1 ml heparized syringe. Blood sample was centrifuged at 3,000 rpm for 15 minutes. The supernatants were seperated, sealed and preserved in the refrigerator until laboratory assays were conducted. Proximate analyses and minerals of experimental diets, excreta and bones were conducted according to the methods of AOAC (1984). Energy utilization was analyzed by Bomb Calorimeter (Adiabatic Oxygen Bomb Calorimeter-Model 1241, Parr Instrument Co., Moline, IL). In blood amino acid determinations, 1 ml serum was deprotenized with the addition of 0.2 ml 10% trichloroacetic acid solution. And the serum proteins were precipitated with a sulfosalicylic acid solution for serum amino acid analysis. Serum lysine and arginine levels were analyzed by automatic amino acid analyzer (LKB, Model 4150-alpha). An aliquot of clear supernatant obtained by centrifugation was used to determine the serum sodium, potassium and chloride. Serum sodium, potassium levels were measured by using Atomic Absorption Spectrophotometer (Shimadzu, Model AA625) and chloride levels were determined by titration method (Schales and Schales, 1941). ANOVA for the present data was carried out and means were compared by Duncan's multiple test (Duncan, 1955) using General Linear Model (GLM) Procedure of SAS (1986) package program with IBM-PC compatible computer.

Results and Discussion

1. Growth Performance

As presented in table 4, the highest body weight gain was obtained at medium lysine level (1.2%) and 0.4% Na supplemented group. Among lysine levels, body weight gain of 1.2% lysine group was significantly ($p < 0.01$) higher than that of low or high lysine. The results of this experiment agree with previous studies of Seaton

TABLE 4. BODY WEIGHT GAIN, FEED INTAKE, FEED EFFICIENCY AND MORTALITY OF BROILER CHICKS (0-7 WEEKS)

Treatment[1]	Initial body wt. (g)	Final body wt. (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency	Motality (%)
LL-0.4	57.5	1102.8^{C}	1045.3^{C}	3044.9^{C}	2.91^{ABC}	12.5
LL-0.8	57.6	1062.1^{C}	1004.5^{C}	3061.5^{C}	3.05^{ABC}	15.6
LL-1.2	57.5	995.0^{C}	937.5^{C}	3061.0^{C}	3.27^{A}	40.6
ML-0.4	57.9	2147.6^{A}	2089.7^{A}	5059.8^{AB}	2.42^{C}	9.4
ML-0.8	57.5	2077.4^{A}	2019.9^{A}	4872.0^{AB}	2.41^{C}	9.4
ML-1.2	57.2	1965.9^{AB}	1908.7^{AB}	4627.6^{AB}	2.42^{C}	9.4
HL-0.4	57.5	1494.4^{B}	1436.9^{B}	4223.6^{B}	2.94^{ABC}	15.6
HL-0.8	57.1	1706.3^{AB}	1649.2^{AB}	4446.5^{AB}	2.70^{BC}	12.5
HL-1.2	57.4	1639.6^{AB}	1582.2^{AB}	5336.8^{A}	3.37^{AB}	37.5
Among lysine levels						
LL	57.6	1053.3^{C}	995.7^{C}	3055.8^{B}	3.07^{A}	22.9^{a}
ML	57.5	2064.3^{A}	2006.8^{A}	4853.1^{A}	2.42^{B}	9.4^{b}
HL	57.5	1613.4^{B}	1555.9^{B}	4669.0^{A}	3.00^{A}	21.9^{a}
Among Na supplemented levels						
0.4	57.5	1582.2	1524.7	4109.4	2.70	12.5^{B}
0.8	57.5	1615.3	1557.8	4126.7	2.65	12.5^{B}
1.2	57.6	1533.5	1475.9	4341.8	2.94	29.2^{A}

[1] LL, ML and HL represent the levels of the lysine, and 0.4, 0.8, 1.2 represent $NaHCO_3$ supplemented levels in diets.

^{A,B,C} Mean values with different superscripts within the same column are significantly different ($p < 0.01$).

^{a,b} Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

et al. (1978) and Sibbald and Wolynetz (1986). Anderson and Combs (1952) demonstrated a significantly lower weight gain of growing chicks fed a high lysine diet as compared to those fed a basal diet containing adequate levels of lysine.

The effects of lysine and electrolyte levels on feed efficiency during the overall experimental periods are shown in table 4. In this result, the best feed efficiency was obtained at ML-0.8 group (1.2% lysine level and 0.8% sodium supplemented group) and worst at LL-1.2 group (0.6% lysine level and 1.2% sodium supplemented group). Scott and Austic (1978) reported improved growth of chicks fed high lysine diets when the diets were supplemented with electrolyte (potassium salts). Although there was no change in feed efficiency, they felt that the beneficial effect of monovalent cations could be attributed in part to restoration of normal tissue patterns of lysine and arginine, and consequently improved appetite.

Among the lysine levels, mortality of high and low lysine groups were significantly ($p < 0.05$) higher than medium lysine group. Among the electrolyte levels, mortality of 1.2% sodium group was significantly higher than other treatment groups. This result was in agreement with that of Johnson and Karunajeewa (1985). They proposed to levels of sodium greater than 0.9% caused high mortality. However, the results obtained by Nesheim et al. (1964) showed that the young chick could not tolerate high levels of sodium in terms of mortality.

2. Serum Composition

The concentrations of lysine, arginine and electrolytes in serum were affected by the levels of lysine and dietary sodium as summarized in table 5. The serum lysine and arginine levels were significantly ($p < 0.01$) affected by experimental diets. Interaction between dietary lysine and sodium were found to be singificant ($p < 0.01$)

TABLE 5. EFFECTS OF LYSINE AND DIETARY SODIUM ON THE SERUM LYSINE, ARGININE, SODIUM, POTASSIUM, CHLORIDE AND SODIUM PLUS POTASSIUM TO CHLORIDE RATIO IN BROILER CHICKS

Treatment[1]	Lysine (μg/ml)	Arginine (μg/ml)	Sodium	Potassium	Chloride	Na+K−Cl
			mEq/liter			
LL-0.4	0.81^{D}	1.59^{A}	104.1	29.2	100.5	33.3
LL-0.8	0.87^{D}	1.48^{ABC}	113.0	36.5	105.2	44.3
LL-1.2	0.97^{CD}	1.71^{A}	99.6	36.1	104.6	31.1
ML-0.4	1.29^{BCD}	1.12^{CD}	108.8	31.2	105.9	34.1
ML-0.8	1.09^{CD}	1.16^{BCD}	110.4	28.7	99.0	40.2
ML-1.2	1.21^{CD}	1.55^{AB}	107.1	28.1	114.4	20.9
HL-0.4	2.25^{A}	1.03^{D}	118.4	21.5	110.1	29.8
HL-0.8	2.01^{AB}	0.91^{D}	120.4	28.1	103.6	44.8
HL-1.2	1.68^{ABC}	1.88^{A}	136.9	34.7	132.7	38.9
Among lysine levels						
LL	0.88^{B}	1.60^{A}	105.6	34.1	103.4	36.2
ML	1.20^{B}	1.28^{B}	108.8	29.3	106.4	31.7
HL	1.98^{A}	1.27^{B}	125.2	28.1	115.5	37.8
Among Na supplemented levels						
0.4	1.45	1.25	110.4	27.5	105.5	32.4
0.8	1.33	1.19	114.6	31.1	102.6	43.1
1.2	1.29	1.71	114.5	33.0	117.2	30.2

[1] LL, ML and HL represent the levels of the lysine, and 0.4, 0.8, 1.2 represent $NaHCO_3$ supplemented levels in diets.

[A,B,C,D] Mean values with different superscripts within the same column are significantly different ($p < 0.01$).

in serum lysine and arginine concentration. The concentration of arginine in serum increased while the lysine level decreased. Jones (1984) reported that a reduction in plasma arginine occured when excess lysine was fed to chicks. Dean and Scott (1966) also suggested that a dietary excess of lysine was revealed in plasma by a large increase in plasma lysine.

Potassium and sodium are the most effective metal cations in alleviating the lysine-arginine antagonism if added to the diet in conjunction with metabolizable organic acid such as acetate or bicarbonate. Increasing dietary chloride exacerbates the lysine-arginine antagonism but has no effect on plasma lysine or arginine concentration (Calvert and Austic, 1981).

Excess cations reduce lysine transport into kidney cells and the subsequent induction of kidney arginase. This concept is supported by the observation that uptake of cationic amino acids by three different cell types is inhibited by certain neutral amino acids in combination with alkalic metal ions (Thomas et al., 1971). An excess of cations over anions, such as supplied by sodium bicarbonate, reduces the effect of excess lysine in two ways. Firstly, it decreases the induction of kidney arginase and spares the limiting amino acid arginine. Secondly, when more arginine is available for protein synthesis, growth rate is improved and all amino acids, including lysine, are used for protein synthesis. Thus, the concentration of lysine in the amino acid pools is also reduced.

3. Effects on Femur Bone

Femur bone formation and calcification as influenced by levels of dietary sodium and lysine are summarized in table 6. Generally, birds having long tibia and femur were heavier than those having short ones.

Medium level (1.2%) lysine and 1.2% sodium supplemented group (ML-1.2) showed slightly heavier bone weight and the longest length. The

TABLE 6. EFFECTS OF LYSINE AND SODIUM ON THE FEMUR BONE IN BROILER CHICKS (DEFATTED DRY MATTER BASIS)

Treatment[1]	Weight (g)	Length (cm)	Ash content (%)	Ca (%)	P (%)
LL-0.4	6.9^{BC}	4.9^{BC}	29.5	11.4	5.0
LL-0.8	6.4^{C}	3.4^{C}	31.5	11.1	5.5
LL-1.2	6.2^{C}	3.1^{C}	29.6	12.1	4.9
ML-0.4	7.9^{A}	6.6^{AB}	30.0	12.4	5.1
ML-0.8	7.7^{AB}	7.1^{A}	31.9	12.3	5.5
ML-1.2	7.9^{A}	7.7^{A}	30.4	11.3	5.0
HL-0.4	7.7^{AB}	7.4^{A}	29.9	11.0	4.6
HL-0.8	7.9^{A}	7.4^{A}	30.5	11.5	4.8
HL-1.2	7.3^{AB}	4.8^{BC}	33.2	10.9	5.3
Among lysine levels					
LL	6.49^{B}	3.80^{B}	30.21	11.54	5.15
ML	7.84^{A}	7.11^{A}	30.77	12.00	5.19
HL	7.73^{A}	6.73^{A}	30.98	11.12	4.84
Among Na supplemented levels					
0.4	7.49	6.3	29.80	11.59	4.91
0.8	7.36	6.0	31.30	11.66	5.26
1.2	7.15	5.2	30.85	11.44	5.04

[1] LL, ML and HL represent the levels of the lysine, and 0.4, 0.8, 1.2 represent $NaHCO_3$ supplemented levels in diets.

[A,B,C] Mean values with different superscripts within the same column are significantly different ($p < 0.01$).

lowest bone weight and length were shown in low lysine and 1.2% sodium supplemented group (*LL*-1.2). Calcium, phosphorus and crude ash in the femur were not influenced by treatment. Dietary sodium levels did not affect femur weight, and crude ash, Ca and P contents. Pepper et al. (1952) and Slinger et al. (1951) suggested that dietary lysine levels affected femur weight, femur length and P content with significant ($p < 0.01$) difference. However the lysine levels did not influence the crude ash, calcium and phosphorus contents.

Interactions between lysine and sodium were significantly ($p < 0.05$) shown in femur weight, but the other components in femur were not significantly different. Increasing sodium supplemented levels caused a gradual decrease in femur weight and length, eventhough there was no significant difference.

4. Nutrient Utilization

The effects lysine and sodium on the utilization of the dry matter, nitrogen, crude fat, crude ash, total carbohydrate are summerized in table 7.

The effect of dietary lysine level had statistically singificant ($p < 0.01$) difference on nitrogen utilization. Among the lysine levels, 1.2% lysine group was superior to nitrogen utilization of low (0.6%) and high (1.8%) lysine group. But dietary sodium levels did not affect nitrogen utilization ($p > 0.05$) and there was no interaction between lysine and sodium.

Crude fat utilization was affected by the level of dietary lysine ($p < 0.01$). At the low level of dietary lysine, crude fat utilization was significantly lower than other treatment ($p < 0.05$).

The best utility of total carbohydrate was obtained at medium lysine (1.2%) level and the worst at low lysine (0.6%) level. Total carbohydrate utilization of these two groups were 93.7 %, and 89.55%, respectively.

TABLE 7. EFFECTS OF LYSINE AND SODIUM LEVELS ON NUTRIENT UTILIZATION OF BROILER CHICKS (%)

Treatment[1]	Dry matter	Nitrogen	Ether extract	Crude ash	Total carbohydrate	Energy
LL-0.4	76.1	71.8^{c}	86.1^{c}	43.3	89.5^{cd}	83.9^{c}
LL-0.8	76.9	73.8^{c}	86.7^{bc}	45.1	89.1^{d}	83.6^{c}
LL-1.2	77.2	72.5^{abc}	86.0^{c}	53.1	90.0^{bcd}	84.0^{c}
ML-0.4	78.0	76.1^{ab}	90.9^{abc}	39.7	92.9^{abc}	87.0^{ab}
ML-0.8	75.7	76.3^{a}	91.6^{ab}	46.0	93.8^{a}	87.9^{a}
ML-1.2	77.2	75.7^{ab}	92.0^{a}	29.0	94.4^{a}	84.8^{bc}
HL-0.4	75.2	72.6^{abc}	90.1^{abc}	56.7	91.1^{abcd}	83.6^{c}
HL-0.8	77.4	71.5^{bc}	89.0^{abc}	46.2	93.2^{ab}	85.6^{abc}
HL-1.2	78.2	70.2^{c}	90.1^{abc}	41.9	91.1^{abcd}	84.5^{bc}
Among lysine levels						
LL	76.7	72.69^{B}	86.28^{B}	47.16	89.55^{c}	83.85^{B}
ML	77.3	75.99^{A}	91.48^{A}	38.23	93.70^{a}	86.59^{A}
HL	76.9	71.43^{B}	89.71^{A}	48.27	91.80^{b}	84.53^{B}
Among Na supplemented levels						
0.4	76.4	72.46	89.01	46.57	91.16	84.83
0.8	76.6	73.88	89.07	45.77	92.04	85.71
1.2	77.9	72.77	89.38	41.33	91.86	84.44

[1] LL, ML and HL represent the levels of the lysine, and 0.4, 0.8, 1.2 represent $NaHCO_3$ supplemented levels in diets.

[A,B] Mean values with different superscripts within the same column are significantly different ($p < 0.01$).

[a,b,c,d] Mean values with different superscripts within the same column are significantly different ($p < 0.05$).

Energy utilization was affected by the level of dietary lysine. In the medium level of dietary lysine, energy utilization was significantly ($p < 0.01$) higher than other treatments. But there was no interrelationship between lysine level and supplemented sodium.

In the all treatments, dry matter and ash digestibility was not significantly different. In general, feed utilization increased considerable with 1.2% lysine level group. The utilization of all nutrients was not affected by dietary sodium levels ($p > 0.05$).

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