EFFECTS OF LYSINE LEVEL AND Na+K–Cl RATIO ON LYSINE-ARGININE ANTAGONISM, BLOOD pH, BLOOD ACID-BASE PARAMETERS AND GROWTH PERFORMANCE IN BROILER CHICKS

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Summary

To determine the effect of sodium plus potassium to chloride ratio and lysine level on blood pH, blood acid-base parameters, lysine-arginine antagonism and growth performance, four hundred and thirty two chicks of 3 days age were used in a completely randomized 3x3 factorial experiment. Variables contained three levels of lysine (0.8, 1.2 and 1.6%) and dietary electrolyte (100, 200 and 300 mEq/kg). Birds fed 200 mEq/kg electrolyte had the best growth rate and feed efficiency, followed by those fed 300 mEq/kg and 100 mEq/kg electrolyte. It is proposed that high levels of dietary electrolyte may improve the growth of chicks fed diets containing excess lysine by increasing lysine catabolism. High or low levels of lysine and dietary electrolyte resulted in higher mortality than those of optimum level (1.2%) of lysine and 200 mEq/kg of electrolyte balance. When the electrolyte level was increased, the pH, pCO_2, base excess, HCO_3^- and total CO_2 of blood plasma were increased. The utilization of nutrients was changed when the electrolyte and lysine were manipulated. Plasma chloride tended to be greater in chicks receiving high chloride diet and was the highest in chicks fed the high lysine diet. Plasma sodium and potassium were unaffected by dietary lysine. Diet containing high lysine decreased the level of arginine and excess dietary electrolyte increased arginine level in plasma. It may be concluded that cation supplementation tended to alleviate the lysine-arginine antagonism but chloride exacerbated. Tibia bone length and ash contents were significantly affected by electrolyte balance and lysine level.

(Key Words: Lysine, Electrolyte Balance, Growth Performance, Lysine-Arginine Antagonism)

Introduction

It is well-established that dietary mineral balance or, more specifically, electrolyte balance, can affect growth and feed efficiency of poultry. Sodium, potassium and chloride are essential elements required by the chick. In addition to supplying these elements in sufficient quantities, the nutritionist must also be concerned about the balance between these electrolytes. Leach (1979) and Austic (1980; 1984) have discussed the importance of dietary electrolytes in acid-base phenomena on metabolism could lead to the more effective use of electrolytes in nutrition. There is an evidence that acid-base balance or lysine level influences growth rate of broiler chicks (Melliere and Forbes, 1966; Sauveur and Mongin, 1978a; 1978b; Austic, 1984; Adekunmisi and Robbins, 1987). 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 depressed weight gain later was shown to be due to a lysine-arginine antagonism (O'Dell et al., 1982; Jones, 1964) where in excess dietary lysine increases the arginine requirement. The detrimental effects of excess lysine can be overcome by increasing the dietary level of arginine (Austic and Nesheim, 1970; Austic and Scott, 1975). Austic et al. (1977) suggested that dietary supplementation with excess mineral anions, such as chloride, may have the opposite effect of potassium on lysine metabolism. The present study was conducted to determine the effect of Na+K-Cl ratio and lysine level on blood pH, blood acid-base parameters, lysine-arginine antagonism and growth performance in broiler chicks.

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Materials and Methods

To investigate the interrelationship of dietary sodium, potassium and chloride to lysine-arginine antagonism, an experiment with 3x3 factorial arrangement was conducted. In this study the dietary treatments consisted of 3 levels of dietary lysine [0.8%, low lysine level (LL); 1.2%, optimum lysine level (OL); 1.6%, high lysine level (HL)], and 3 levels of dietary electrolyte (100 mEq/kg, 200 mEq/kg and 300 mEq/kg). All treatments had 6 replicates with 8 birds in each replicate. Animals used in the present study were broiler chicks of Maniker strain. At 3 days of age experimental animals were chosen to have similar initial body weight and fed the experimental diets for 7 weeks.

The basal diets for starter (0-4 weeks) and finisher (4-7 weeks) were a practical-type corn-soybean meal ration, which met the nutrient requirement of the broiler chick (NRC, 1977). The basal diet for starter was formulated to contain approximately 23% crude protein (N x 6.25) and 3100 kcal of metabolizable energy per kg of diet (table 1). The basal diet for finisher contained 20% crude protein (Nx6.25) and 3200 kcal of metabolizable energy per kg of diet (table 1). Mixtures containing various level of lysine, sands, sodium bicarbonate and calcium chloride replaced the variable part of the basal diet to prepare experimental diet (table 2 and 3). All the birds were raised in batteries made of steel wire and housed in a room with 24 hours illumination and air ventilation. Three-days old chicks had been offered each experimental diet and tapwater ad libitum throughout the experimental periods. Body weight and feed intake were recorded weekly. During feeding trial mortality was recorded per treatment.

To determine the nutrient utilizability of the experimental diets, a metabolic trial was carried out by total collection method for 7 days at the end of feeding trial. After four days of preliminary period for acclimatization of the new environment and management, total excreta from birds were collected six times a day to avoid the contamination of foreign materials such as feed, feather and scale and then pooled, and dried in a drying oven at 60°C for 72 hours. All the excreta prepared in this way were ground with Wiley mill and analyzed for proximate composition, lysine and arginine content. All the proximate analyses of experimental diets and excreta were conducted by AOAC (1984) methods.

Four birds per treatment were randomly sacrificed for bone and blood collections after feeding trial. Left tibia was removed from brids. The bones were excised, cleaned of adhering tissue and extracted for 12 hours with 95% ethanol in a soxhlet apparatus followed by a 10-hour extraction with ethyl ether. Blood samples were collected from the carotid artery with 23-gauge needle

TABLE 1. FORMULA AND CHEMICAL COMPOSITION OF THE BASAL DIET FOR GROWING AND FINISHING BROILER CHICKS (0 7 WEEKS)

	Starter	Finisher
	Contents (%)	
Ingredients:		
Corn, yellow	56.00	56.00
Soybean oil meal	20.00	20.00
Corn gluten meal	14.50	8.00
Fish meal	2.00	2.00
Wheat	2.00	5.00
Soybean oil	0.50	4.00
Vit.-min. mixture[1]	0.30	0.30
Antibiotics[2]	0.10	0.10
Salt[3]	0.30	0.30
Tricalcium phosphate	1.60	1.13
Limestone	0.50	0.03
Variables	2.20	3.14
Total	100.00	100.00
Chemical composition:		
Energy(ME, kcal/kg)[4]	3100	3200
Crude protein (%)	23.00	20.00
Calcium (%)	1.00	0.90
Phosphorus (%)	0.70	0.60
Lysine (%)	0.80	0.80
Arginine (%)	1.30	1.20
Sodium (%)	0.16	0.16
Potassium (%)	0.67	0.65
Chloride (%)	0.22	0.22

[1] Vit.-min. mixture contains followings in a kg: Vitamin A, 2,000,000 IU; Vitamin D_3, 400,000 IU; Vitamin E, 900 IU; Vitamin K, 200 mg; Thiamin, 100 mg; Riboflavin, 1,200 mg; Vitamin B_6, 200 mg; Vitamin B_{12}, 1,500 mg; Pantothenate, 1,500 mg; Niacin, 2,000 mg; Folacin, 60 mg; Choline 3,000 mg; Iron, 4,000 mg; Copper, 500 mg; Zinc, 9,000 mg; Iodine, 250 mg; Cobalt, 100 mg; Dried yeast, 20,000 mg.

[2] Zinc-bacitracin was used.

[3] Refined table salt.

[4] Calculated value.

TABLE 2. FORMULA AND CHEMICAL COMPOSITION OF MIXTURES USED FOR VARIABLE PART IN EXPERIMENTAL DIETS (0 - 4 WEEKS)

Treatment[1]	LL			OL			HL		
Items	100	200	300	100	200	300	100	200	300
Ingredients (%):									
Lysine	–	–	–	0.381	0.381	0.381	0.790	0.790	0.790
Sand[2]	1.621	2.022	1.182	1.240	1.641	0.801	0.831	1.232	0.392
$NaHCO_2$		0.178	1.018	–	0.178	1.018	–	0.178	1.018
$CaCl_2 \cdot 2H_2O$	0.579	–	–	0.579	–	–	0.579	–	–
Total	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Chemical composition (%)[3]:									
Lysine	0.8	0.8	0.8	1.2	1.2	1.2	1.6	1.6	1.6
Sodium	0.159	0.208	0.438	0.159	0.208	0.438	0.159	0.208	0.438
Potassium	0.665	0.665	0.665	0.665	0.665	0.665	0.665	0.665	0.665
Chloride	0.496	0.215	0.215	0.496	0.215	0.215	0.496	0.215	0.215

[1] LL = Low lysine level.
OL = Optimum lysine level.
HL = High lysine level.
[2] Acid washed sand was used.
[3] Calculated percentage in feed.

TABLE 3. FORMULA AND CHEMICAL COMPOSITION OF MIXTURES USED FOR VARIABLE PART IN EXPERIMENTAL DIETS (4 - 7 WEEKS)

Treatment[1]	LL			OL			HL		
Items	100	200	300	100	200	300	100	200	300
Ingredients (%):									
Lysine	0.016	0.016	0.016	0.424	0.424	0.424	0.832	0.832	0.832
Sand[2]	2.571	2.916	2.076	2.163	2.508	1.668	1.755	2.100	1.260
$NaHCO_3$	–	0.208	1.048	–	0.208	1.048	–	0.208	1.048
$CaCl_2 \cdot 2H_2O$	0.553		–	0.553	–	–	0.553	–	–
Total	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14	3.14
Chemical composition (%)[3]:									
Lysine	0.8	0.8	0.8	1.2	1.2	1.2	1.6	1.6	1.6
Sodium	0.159	0.216	0.446	0.159	0.216	0.446	0.159	0.216	0.446
Potassium	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654	0.654
Chloride	0.484	0.217	0.217	0.484	0.217	0.217	0.484	0.217	0.217

[1] See the table 2.
[2] See the table 2.
[3] See the table 2.

attached to 1 ml heparinized syringe. Within 15 minutes following blood collection, blood samples were analyzed for pH, pCO_2, pO_2, base excess, bicarbonate and total CO_2 using an Automated Blood Gas Analyzer (Mitutoyo, Japan), calibrated for chicken blood. Blood samples collected were centrifuged at 3,000 rpm for 20 minutes. For the analysis of plasma mineral, the plasma proteins was precipitated with a 10% trichloroacetic acid solution. An aliquot of clear supernatant obtained by centrifugation was used to determine the blood sodium, potassium and chloride. Plasma sodium and potassium levels were measured by using atomic absorption spectrophotometer (Shimadzu, Model AA625). Chloride levels of plasma were determined by titration method (Schales and Schales, 1941).

The plasma proteins for amino acid analysis were precipitated with a sulfosalicylic acid solution. Plasma lysine and arginine levels were analysed by automatic amino acid analyzer (LKB, Model 4150 alpha). Data collected were subjected to analysis of variance with significant differences among treatment means determined by the Duncan's multiple range test (Duncan, 1955).

Results and Discussion

The data of growth performance obtained in the experiment are summarized in table 4. The data showed that the highest body weight gain was obtained at OL-200 mEq/kg group and the lowest body weight gain at LL-100 mEq/kg group. Chicks fed OL-300 mEq/kg diet also showed good result in body weight gain as similar to OL-200 mEq/kg group. Body weight gain of LL-100 mEq/kg, OL-200 mEq/kg and OL-300 mEq/kg group were 1965.5, 2353.7 and 2349.0 grams, respectively. The use of dietary electrolyte balance (Na+K−Cl, mEq/kg) was conceived by Mongin and Sauveur (1977). Their results showed an optimum electrolyte balance of 250 mEq/kg for the growth of young chickens. Previous studies had reported interactions between dietary anions and cations on the growth of poultry (Nesheim et al., 1964: Milliere and Forbes, 1966: Leach and Nesheim, 1972). However, the majority of published reports on the effects of dietary electrolytes

TABLE 4. BODY WEIGHT GAIN, FEED INTAKE, FEED EFFICIENCY AND MORTALITY IN BROILER CHICKS (0 - 7 WEEKS)[1,2]

Dietary Lysine	Treatment E/B(mEq/kg)[3]	Initial body weight (g)	Final body weight (g)	Body weight gain (g)	Feed intake (g)	Feed efficiency (feed/gain)	Mortality (%)
	100	54.6	2020.1	1965.5±108[D]	4884.4±137[D]	2.49±.09[BC]	25.00
LL	200	54.8	2338.6	2283.9±110[AB]	5455.7±141[AB]	2.39±.06[DE]	4.17
	300	54.6	2279.2	2224.6± 74[B]	5409.3±178[BC]	2.43±.05[CD]	10.42
	100	54.8	2306.7	2251.9± 57[AB]	5639.4± 97[A]	2.50±.05[BC]	10.42
OL	200	54.9	2408.6	2353.7± 71[A]	5394.8±130[BC]	2.29±.03[F]	2.08
	300	54.5	2403.4	2349.0±105[A]	5483.8±187[AB]	2.34±.02[EF]	2.08
	100	54.9	2126.9	2071.9± 95[CD]	5375.2±106[BC]	2.59±.08[A]	22.92
HL	200	54.7	2234.3	2179.7± 90[BC]	5430.8±104[AB]	2.49±.07[BC]	12.50
	300	54.6	2123.4	2068.8±128[CD]	5230.6±132[C]	2.53±.10[AB]	20.83
Significance (probability)[4]							
Lysine effect				< 0.01	NS	< 0.01	< 0.01
Electrolyte effect				< 0.01	< 0.01	< 0.01	< 0.01
Interaction				< 0.01	< 0.01	NS	NS

[1] Mean values with different superscript within the same column are significantly different ($p < .01$).
[2] Values are mean ± SD : n = 6.
[3] E/B, Electrolyte Balance.
[4] NS means non-significant.

was carried out with purified diets, employing different stocks from the modern broiler-type chickens. In addition, experimental periods were short. The present study in which broiler chickens were grown on practical type diets has confirmed the conclusions of Mongin and Sauveur (1977), with the optimum electrolyte balance for growth was found to be 200-300 mEq/kg.

Among the lysine levels, growth rate of optimum lysine group was superior to those of low or high lysine group with significant difference ($p < .01$). The results agreed with previous studies (Seaton et al., 1978: Edwards et al., 1956: Grau et al., 1946). Chicks fed high level (1.6%) of dietary lysine had significantly poorer ($p < .01$) weight gain than that of low level (0.8%) of dietary lysine. The poorer weight gain of high level of dietary lysine group may be due to lysine-arginine antagonism. Among the electrolyte levels, the best body weight gain was obtained at 200 mEq/kg group. Chicks fed low level (100 mEq/kg) of electrolyte had significantly lower ($p < .01$) body weight gain than other levels (200 and 300 mEq/kg) of electrolyte. Johnson and Karunajeewa (1985) showed that chicks fed diet containing between 250 and 300 mEq/kg had the excellent growth. In the present study, however, the best growth was obtained at 200 mEq/kg group. Also, there was an interaction between lysine and dietary electrolyte on body weight gain.

As presented in table 4, the highest feed consumption was obtained at OL-100 mEq/kg group and the lowest at LL-100 mEq/kg group. Among the lysine levels, no significant differences were found in feed consumption. Significantly less feed has been consumed by the chicks fed diets containing low level of lysine. Among the electrolyte levels, feed consumption of 200 mEq/kg group tended to be increased with significant differences ($p < .01$). The lowest feed consumption was obtained at 100 mEq/kg group. The effect of chloride on feed intake may be due to alter tissue patterns of the basic amino acids in a detrimental manner resulting in decreased feed intake except optimum lysine level. The effects of lysine and electrolyte levels on feed efficiency during experimental periods are also shown in table 4. The best feed efficiency was obtained at

TABLE 5. BLOOD VALUES OF BROILER FED DIETS WITH DIFFERENT LEVELS OF LYSINE AND ELECTROLYTES[1,2]

Dietary Treatment		pH	pCO_2	pO_2	Base excess	HCO_3	Total CO_2
Lysine	E/B(mEq/kg)[3]		—— mm Hg ——		mEq/liter	—— mm Hg ——	
LL	100	7.20±.07	50.4±4.5	53.3± 3.9	−7.93±2.6[ab]	19.7±1.5	21.3±1.4
	200	7.22±.06	52.8±8.9	51.8±16.2	−6.05±1.6[a]	20.3±0.3	22.2±0.5
	300	7.24±.08	54.4±6.1	52.1± 3.2	−6.43±1.8[a]	20.7±0.4	21.9±0.2
OL	100	7.16±.05	47.8± 5.9	55.2± 5.9	−12.30±2.3[a]	17.6±1.0	19.8±1.1
	200	7.21±.06	49.5±10.0	56.1±10.1	−7.43±3.7[b]	18.8±0.7	20.2±1.0
	300	7.23±.08	63.5±20.2	38.3±24.5	−7.80±0.4[ab]	19.5±2.6	21.0±2.7
HL	100	7.05±.03	48.9±1.1	57.7± 4.3	−12.40±2.0[b]	17.5±1.8	19.0±1.8
	200	7.17±.05	54.3±3.8	50.1±10	−10.45±2.6[ab]	17.7±1.5	19.7±1.6
	300	7.19±.07	66.0±3.0	41.6± 4.5	−7.88±2.9[ab]	19.9±1.9	21.6±1.8
Significance (probability)[4]							
Lysine effect		<0.03	NS	NS	<0.02	<0.04	NS
Electrolyte effect		NS	NS	NS	NS	NS	NS
Interaction		NS	NS	NS	<0.03	NS	NS

[1]Value are mean ± SD: n = 4.
[2]Mean values with different superscript within the same column are significantly different ($p < .05$).
[3]E/B, Electrolyte Balance.
[4]Means non-significant.

OL-200 mEq/kg group and the worst at HL-100 mEq/kg group ($p < .01$). Feed efficiencies of these two treatment groups were 2.29 and 2.59, respectively. Both the lysine and the electrolyte level had significant effect on feed efficiency ($p < .01$), but there was no interaction. Among the electrolyte levels, the best feed efficiency was obtained at 200 mEq/kg groups and the worst at 100 mEq/kg groups. The high level of chloride appeared to result in impairment of weight gain, feed consumption and the efficiency of feed utilization. These results are in agreement with those of previous investigators (Calvert and Austic, 1981; Scott and Austic, 1978).

Scott and Austic (1978) reported improved growth of chicks fed high lysine diets when the diets were supplemented with potassium salts, although there was no change in feed efficiency. They thought that the beneficial effect of monovalent cations could be partially attributed to restoration of normal tissue patterns of lysine and arginine, and consequently improved appetite. As presented in table 4, the highest mortality was observed at LL-100 mEq/kg group and the lowest at OL-200 mEq/kg and OL-300 mEq/kg groups. Mortalities of these three treatments were 25.00, 2.08 and 2.08%, respectively. Among the lysine levels, mortality of high lysine treatment group was significantly higher ($p < .01$) than that of other groups.

Results obtained on the blood parameters are summarized in table 5. Blood pH, pCO_2, base excess, bicarbonate and total CO_2 were increased, when the electrolyte levels were increased. The result may be due to the alkalogenic effect of sodium. The pO_2 pressure, however, tended to be higher for 100 mEq/kg diet than for those of the other diets. Blood bicarbonate levels increased with increasing blood pH, in agreement with the results of Cohen et al. (1972) and Hurwitz et al. (1974). The highest pH obtained in the present study was lower than those of other worker's. In fact, this difference may be due to the fact that birds were anesthetized with ethyl ether for blood sampling. Several investigators have shown significant changes in blood pH and bicarbonate level when the electrolyte balance of the diet is manipulated. When the sodium and chloride con-

TABLE 6. EFFECTS OF LYSINE AND ELECTROLYTE LEVELS ON NUTRIENT AVAILABILITY AND NITROGEN RETENTION OF BROILER CHICKS (%)[1,2]

Dietary Treatment		Dry matter	Nitrogen retention	Ether extract	Total carbohydrate	Lysine	Arginine
Lysine	E/B(mEq/kg)[3]						
	100	76.53±1.6	73.75±1.1^{D}	82.38±1.1^{C}	79.30±0.9^{D}	74.58± .6^{F}	75.50± .4^{CD}
LL	200	77.23±3.2	74.55±1.5^{D}	85.60±1.9^{AB}	80.58±0.8^{D}	79.35±1.5^{D}	77.20±1.0^{B}
	300	77.53±2.8	74.60±1.2^{D}	85.33±1.1^{B}	80.40±0.9^{D}	80.70± .7^{C}	77.83±1.0^{B}
	100	77.35±1.9	79.78±3.1^{C}	85.80±1.3^{AB}	83.75±1.0^{BC}	83.23± .9^{B}	83.48±1.9^{A}
OL	200	79.78±0.8	85.98±1.4^{A}	87.23±1.6^{AB}	85.95±1.3^{A}	85.25± .5^{A}	84.30±1.2^{A}
	300	80.03±1.4	83.50±0.9^{B}	87.75±0 9^{A}	84.25±1.2^{B}	84.55± .6^{A}	85.20± .7^{A}
	100	76.78±0.7	79.58±1.3^{C}	85.80±1.4^{AB}	83.45±0.8^{BC}	77.58± .7^{B}	74.73±1.5^{D}
HL	200	8.48±1.2	81.53±1.4^{BC}	86.33±1.4^{AB}	83.13±0.4^{BC}	79.63± .5^{CD}	76.75± .9^{BC}
	300	78.35±1.3	79.40±0.9^{C}	85.90±0.8^{AB}	82.73±0.7^{C}	78.40±1.0^{DE}	75.30±1.1^{CD}
Significance (probability)[4]							
Lysine effect		< 0.04	< 0.01	<0.01	< 0.01	< 0.01	< 0.01
Electrolyte effect		< 0.04	< 0.01	<0.01	< 0.03	< 0.01	< 0.01
Interaction		NS	< 0.01	NS	NS	< 0.01	NS

[1] Mean values with different superscript within the same column are significantly different ($p < .01$).
[2] Values are mean ± SD: n = 4.
[3] E/B, Electrolyte Balance.
[4] NS means non-significant.

tents of the diet were altered to provide a lower Na+K–Cl ratio, blood pH, pCO_2 and bicarbonate concentration significantly decreased as many investigators reported (Johnson and Karunajeewa, 1985; Cohen et al., 1972; Cohen and Hurwitz, 1974; Hamilton and Thompson, 1980). Cohen and Hurwitz (1974) observed an increase in blood pH and bicarbonate concentration while manipulating the dietary Na+K/Cl ratio. In comparing the results of these investigators to the work presented here, the depressing effect of the dietary chloride on blood pH and base excess is similar, but did not significantly decrease.

The effect of lysine and dietary electrolyte on the utilization of the dry matter, ether extract, total carbohydrate, lysine and arginine, and retention of nitrogen are summarized in table 6. In general, nutrient utilizability increased considerably ($p < .01$) at optimum level of lysine (1.2%) and electrolyte (200mEq/kg). Dry matter utilizability was affected by level of lysine and dietary electrolytes ($p < .05$). In the utilizability of total carbohydrate and retention of nitrogen, the highest value was obtained at OL-200 mEq/kg group ($p < .01$).

There was an interaction in nitrogen retention between levels of lysine and electrolyte. Among the lysine levels, the best nitrogen retention and total carbohydrate utilizability were obtained at optimum lysine level ($p < .01$). Chicks fed diets containing high electrolyte levels were better than those of low electrolyte levels in nitrogen retention ($p < .01$) and total carbohydrate utilizability ($p < .05$) with significant differences. Crude fat utilizability was affected by the level of lysine ($p < .01$) and electrolyte ($p < .01$), but no interaction was found. The best utilizability of crude fat was obtained at OL-300 mEq/kg and the worst at LL-100 mEq/kg group. In lysine and arginine utilization, the highest utilization obtained at OL-200 mEq/kg and OL-300 mEq/kg group and the lowest at LL-100 mEq/kg and HL-100 mEq/kg group, respectively ($p < .01$). The utilization of these four groups were 85.25, 85.20, 74.58 and 74.73%, respectively. Among the lysine levels, arginine utilization was highly decreased ($p < .01$)

TABLE 7. EFFECTS OF LYSINE AND DIETARY ELECTROLYTE ON THE PLASMA LYSINE, ARGININE, SODIUM, POTASSIUM, CHLORIDE AND SODIUM PLUS POTASSIUM TO CHLORIDE RATIO IN BROILER CHICKS[1,2]

Dietary Treatment		Dry matter	Lysine	Arginine	Sodium	Potassium	Chloride
Lysine	E/B(mEq/kg)[3]		--------- (μg/ml) ----------		---------- mEq/liter ------		
	100	10.55± .8^{F}	53.65±1.2^{B}	135.73±5^{C}	4.14±.2	135.23±5^{AB}	4.64
LL	200	17.33±1.7^{E}	48.35± .5^{C}	149.78±6^{B}	4.03±.2	112.21±6^{C}	41.60
	300	15.55± .8^{E}	59.08±1.1^{A}	156.25±4^{AB}	4.08±.2	122.49+6^{BC}	37.84
	100	74.40±3.3^{D}	26.60±1.9^{E}	137.30±3^{C}	4.02±.3	125.37±9^{BC}	15.94
OL	200	84.38±1.4^{C}	25.45±2.0^{E}	152.05±5^{AB}	3.96±.7	123.62±5^{BC}	32.39
	300	83.03± .9^{C}	32.50±2.2^{D}	159.50+5^{A}	4.35±.1	119.35±9^{BC}	44.50
	100	169.58±3.9^{B}	10.80±1.2^{G}	141.50±5^{C}	4.21±.4	141.00±15^{A}	4.71
HL	200	184.20±4.3^{A}	20.55± .7^{F}	150.78±4^{B}	3.57±.6	122.11+12^{BC}	32.23
	300	183.53±6.1^{A}	18.25±3.7^{F}	157.57±8^{AB}	4.29±.3	119.87± 5^{BC}	42.18
Significance (probability)[4]							
Lysine effect		< 0.01	< 0.01	NS	NS	NS	
Electrolyte effect		< 0.01	< 0.01	< 0.01	< 0.04	< 0.01	
Interaction		< 0.05	< 0.01	NS	NS	NS	

[1]Mean values with different superscript within the same column are significantly different ($p < .01$).
[2]Values are mean ± SD, n = 4.
[3]E/B: Electrolyte Balance.
[4]NS means non-significant.

in high lysine (1.8%) group. Among the electrolyte levels, the utilizability of lysine and arginine was significantly affected by dietary electrolyte levels ($p < .01$).

The concentration of lysine, arginine and electrolytes in plasma affected by levels of lysine and dietary electrolyte are presented in table 7. Plasma lysine and arginine levels were significantly different among treatments ($p < .01$).

Plasma chloride tended to be greater in chicks receiving high chloride diets and were highest in chicks fed the high lysine diet. The concentration of arginine in plasma increased while lysine decreased. This result was in good agreement with Stutz et al.(1971). Using crystalline amino acid diets, Zimmerman and Scott (1965) also found that levels of lysine in plasma of chicks decreased inversely with the level of dietary arginine. In the present study, chicks fed high lysine diet had low level of arginine ($p < .01$) in plasma. In general, plasma and kidney arginine concentrations were inversely related to lysine concentration. It is also significant that potassium acetate or sodium bicarbonate, particularly with low level of arginine supplementation, tended to increase the free arginine and decrease the free ornithine concentrations in plasma and kidney. Since the chick cannot synthesize arginine and dietary potassium acetate or sodium bicarbonate increase the arginine concentration in the amino acid pools, the high cation-anion ratio appears to reduce the catabolism of arginine. Excess dietary lysine interferes with arginine utilization in the chick, at least in part, by increasing renal arginase activity which thereby increases argine degradation (Austic and Nesheim, 1972).

Potassium and sodium are the most effective metal cations, if supplemented 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). And Austic and Calvert (1981) have subsequently suggested that variations in dietary electrolytes affected the antagonism by altering the acid-base balance of the bird. In the role of dietary cations on lysine-arginine antagonism, high levels of dietary potassium decrease kidney argi-

TABLE 8. EFFECTS OF LYSINE AND ELECTROLYTES ON THE TIBIA BONE GROWTH IN BROILER CHICKS (DEFATTED DRY MATTER BASIS)[1,2]

Dietary Treatment		Weight (g)	Length (g)	Ash content (%)
Lysine	E/B(mEq/kg)[3]			
LL	100	6.78±.54	9.40±.38[b]	36.0 ±.43[d]
	200	7.07±.84	10.38±.54[a]	36.52±.43[cd]
	300	7.46±.36	10.60±.32[a]	36.87±.46[bcd]
OL	100	7.42±.93	10.73±.65[a]	38.01±1.24[ab]
	200	7.73±.51	10.77±.36[a]	38.25± .61[a]
	300	7.75±.53	10.67+.52[a]	37.66±1.34[abc]
HL	100	7.31±1.52	10.43±.45[a]	36.63±.30[bcd]
	200	7.24±1.05	10.57±.84[a]	36.55±.16[cd]
	300	7.53± .68	10.30±.48[a]	36.69±.87[bcd]
Significance (probability)[4]				
Lysine effect		NS	NS	< 0.02
Electrolyte effect		NS	NS	< 0.02
Interaction		NS	< 0.03	NS

[1] Mean values with different superscript within the same column are significantly different ($p < .05$).
[2] Values are mean ± SD: n = 4.
[3] E/B, Electrolyte Balance.
[4] NS means non-significant.

nase activity, increase muscle protein synthesis and decrease bacterial urease activity in chicks (Stutz et al., 1972). High dietary potassium also markedly increases the activity of hepatic lysine-α-ketoglutarate reductase and increases lysine catabolism by over 250% as measured by conversion of ^{14}C-lysine to respiratory CO_2 (Austic et al., 1977; Scott and Austic, 1978). It is possible that excess cations reduce lysine transport into kidney cells and the subsequent induction of kidney arginase. Dietary lysine did not affect plasma sodium or potassium but electrolyte balance significantly affected plasma cation and anion ($p < .01$). Chicks fed calcium chloride increased level of chloride in plasma. In addition, the chicks fed high lysine diet containing 1.2% arginine had greater amount of circulating chloride than chicks fed the other diets, suggesting that the lysine-arginine antagonism and anion exacerbated the antagonism in this study.

The influence of electrolytes on bone mineralization has received relatively little attention. The studies of this field have been related to tibia dyschondroplasia in chickens (Halley et al., 1987; Hardy, 1984; Egwuatu et al., 1983). As shown in table 8, tibia bone length and ash content were significantly affected by dietary treatment ($p < .05$). Tibia bone weight was not affected by both lysine and dietary electrolyte levels. Statistical analysis indicated that each dietary variable had a significant effect on the bone ash of the chickens. There appears to be a good correlation between tibia weight and length. Increasing cation levels caused a gradual increase in bone ash, but a maximum bone ash value was obtained at 200 mEq/kg group with 1.2% lysine. This result was in agreement with those of Hardy (1984) and Gardiner (1962). Gillis (1948) reported a reduction of bone ash in potassium-deficient chicks. Later, Gillis (1950) suggested that the reduction in calcification due to a potassium deficiency was mediated through an influence on phosphorus rather than calcium metabolism. In the present study, the results showed that higher dietary electrolyte levels gradually increased bone length and ash content.

In conclusion, it would be suggested that dietary electrolyte levels influence on growth rate, feed intake, feed efficiency, bone composition, blood pH, base excess and nutrient utilizability in broiler chick. Also, dietary lysine levels influence on these parameters and the effect may be modified by electrolyte levels in the diet.

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