EFFECTS OF LYSINE AND ENERGY LEVELS ON GROWTH PERFORMANCE THIGH MUSCLE COMPOSITION AND UTILIZATION OF NUTRIENTS IN BROILER CHICKS

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Summary

The effects of dietary levels of lysine and energy on growth performance, the content of DNA, RNA and protein in liver, thigh muscle composition and nutrient utilization in broiler chicks were investigated in an experiment involvies with 2 levels of dietary energy (starter (finisher)): 3,200 (2900) · 2,900 (2700) kcal ME/kg) and 6 levels of lysine (starter (finisher)): 0.6(0.5), 0.8(0.7), 1.0(0.9), 1.2(1.1), 1.4(1.3), and 1.6(1.5)% was carried out. A total number of 384 male broiler chicks was used for a period of 7 weeks.

Body weight gain of 1.0(0.9)% lysine level group was significantly ($p < 0.01$) higher than that of any other groups. Interaction between lysine and energy in the feed intake was observed ($p < 0.05$). Present data indicate that the content of DNA in liver tissues was significantly ($p < 0.05$) different by the levels of lysine, namely, 1.0(0.9)% or 1.2(1.1)% lysine level groups showed higher content than other groups ($p < 0.01$). Dietary levels of 1.2(1.1)% or 1.6(1.5)% lysine groups showed the highest protein content in thigh muscle tissues than that of any other groups ($p < 0.05$). Interaction between energy and lysine in the content of protein of thigh muscle tissues was shown ($p < 0.01$). The level of 0.6% lysine group showed the highest fat content in thigh muscle tissues than any other groups. Interaction between lysine and energy in the content of crude ash and crude fat of thigh muscle tissues was observed ($p < 0.01$).

Apparent amino acid availability of arginine, glycine and threonine ($p < 0.01$), phenylalanine ($p < 0.05$) were significantly affected by the levels of lysine and interaction between lysine and energy was found only in arginine ($p < 0.01$).

(**Key Words** : Lysine, Energy, Lysine-Energy Interaction, Broiler Chicks)

Introduction

Chicks reduce their voluntary feed intakes when offered diets severely deficient in lysine (Sibbald and Wolynetz, 1984). There are several reports that carcass fatness can be reduced by increasing amino acid concentration (Velu et al., 1971; Mabray and Waldroup, 1981). When the lysine supply is reduced, a greater proportion of the ingested energy is deposited as fat (Sibbald and Wolynetz, 1986). The body weight response to dietary energy level will occur only when adequate amino acid level is employed. Although the response to supplementary lysine has not been consistent, raising dietary lysine to the requirement increased the proportions of water and protein in chickens while decreasing the proportion of fat. Scaton et al. (1978) conducted work showing that carcass fat decreased and moisture increased as the percent protein and lysine in the diet increased. Velu et al. (1972) noticed that carcass fat was maximized at a lower concentration of dietary L-lysine HCl than was needed to maximize weight gain and feed consumption.

When first limiting in the diet, the addition of lysine to the broiler chick's diet in an adequate level, usually increases voluntary feed intake and body weight gain. Numerous works have shown that supplementary lysine can improve the performance of birds fed low protein diet (Waibel and Johnson, 1961; Sell and Hodgson, 1966; Waldroup et al., 1976; Sibbald and Wolynetz, 1986). Sibbald and Wolynetz (1986) reported that the lysine required for maximum weight gain was about 0.96% of diet, protein accretion continued

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to increase at greater lysine concentrations and the gain of energy as protein increased, whereas that of energy as fat tended to decrease according to the increase of dietary lysine.

Polyamines are synthesized to play a integral role in controlling cell division and growth of all mammalian cells investigated, and have been implicated in processes such as stimulation of DNA, RNA and protein synthesis (Pegg, 1986). The initial substrates for polyamine synthesis are the amino acids, that is, arginine and methionine. Arginine is metabolized to ornithine by the reaction catalyzed by the mitochondrial enzyme arginase activity which was increased by dietary lysine supplements (Austic and Nesheim, 1970; Robbins and Baker, 1981).

The present experiment was carried out to investigate the effect and interaction of dietary lysine and energy on growth performance, the content of DNA, RNA and protein in liver, thigh muscle quality and nutrient utilizability in broiler chicks when fed diets containing different levels of dietary lysine and energy.

Materials and Methods

Experimental Design

In this study the experimental diets contained two levels of energy (starter: 3,200 or 2,900 kcal ME/kg; finisher: 2,900 or 2,600 kcal ME/kg) with six levels of dietary lysine (starter: 0.6, 0.8, 1.0, 1.2, 1.4 and 1.6%, respectively; finisher: 0.5, 0.7, 0.9, 1.1, 1.3 and 1.5%, respectively). The level of protein was fixed (starter: 21%, finisher: 19%) during the 7 weeks of experiment. All treatments in this experiment had 4 replicates with 8 birds in each replicate.

Experimental Animals, Period and Location

Experimental animals used in this experiment were broiler chicks of Arbor Acres strain, supplied from Hanil Poultry Breeding Farm. At 3 days of age, experimental animals were chosen to have similar initial body weight and fed the experimental diets for 7 weeks. A total of 384 male birds were used in present study.

Experimental Diet

The basal diet was formulated to be low in lysine (starter: 0.6%, finisher: 0.5%). The basal diet I and II of starting period (0-3 weeks) was formulated to contain 21% crude protein (N × 6.25) and 3,200 kcal ME/kg. The composition of basal diet of growing period is presented in table 1. The composition of basal diet I and II of finishing period (4-7 weeks) was presented in table 1. Each basal diet used in each period was supplemented with five levels of L-lysine monohydrochloride (HCl) produced by Miwon Corp., Seoul, Korea in the proportions shown in table 2, to prepare diets differed in lysine content. All the nutrients except energy, protein and lysine content were formulated to meet the National Research Council requirement (NRC, 1984).

Method of Experiment

All the birds were raised in battery cages made of steel wire and housed in a room with 24 hours light and air ventilation. During the pre-experimental period of 3 days the chicks were received a commercial diet. Experimental diets and drinking water were provided *ad libitum* during the entire experimental period. Chicks grouped to have uniform mean body weight were allocated into the respective experimental groups. Body weight and feed intake were checked weekly on a replication basis. Body weight gains were calculated by the differences between the initial body weight and final body weight. Feed efficiency was calculated by dividing the amount of feed consumed with the corresponding body weight gain. During the feeding trial, mortality was also recorded.

Metabolic Trial

To investigate the nutrient utilizability of experimental diets, the metabolizability coefficients was calculated by total fecal collection method during 7 days at the end of feeding trial. Three chicks per each treatment were selected for metabolism trial. All chicks employed for the metabolism trial were caged in metabolism cages individually and experimental diets and water were fed *ad libitum*. After four days of preliminary period for adaptation, total excreta were collected four times a day for next three days to avoid the contamination of foreign materials such as feed, feathers and scales. Total excreta were pooled, and one-third of these excreta was dried in an air-forced drying oven at 60℃ for 72 hours to gain constant dry weight. All the sample

TABLE 1. FORMULAR AND CHEMICAL COMPOSITION OF THE BASAL DIET I AND II FOR BROILER CHICKS

Basal diets	Starter (0-3 weeks)		Finisher (4-7 weeks)	
	I	II	I	II
Ingredients (%) :				
Corn, yellow	62.9	63.3	66.5	52.5
Soybean meal	8.3	7.3	3.9	2.2
Corn gluten meal	16.9	11.7	10.3	10.5
Feather meal	1.0	4.9	4.7	3.6
Wheat bran	4.0	8.4	10.2	26.8
Tallow	2.5	–	–	–
Limestone	1.0	1.0	1.0	1.0
Vit-min mixture[1]	0.3	0.3	0.3	0.3
Salt[2]	0.3	0.3	0.3	0.3
Ca_2PO_4	1.7	1.7	1.7	1.7
Antibiotics[3]	0.1	0.1	0.1	0.1
Variables[4]	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0
Chemical composition :				
Energy (kcal ME/kg)	3209	2912	2908	2611
Crude protein (%)	21.14	21.12	19.24	19.21
Calcium (%)	1.03	0.63	1.07	1.08
Phosphorus (%)	0.72	0.61	0.68	0.66
Lysine (%)[4]	0.60	0.60	0.50	0.50

[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}, 0.008 mg; Ca-d pantothenate, 8 mg; Niacin, 25 mg; Folic aicd, 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-baciteracin was used.

[4] See table 2.

TABLE 2. FORMULA AND CHEMICAL COMPOSITION OF LYSINE MIXTURES USED FOR VARIABLE PART IN EXPERIMENTAL DIETS

Treatment		L_1	L_2	L_3	L_4	L_5	L_6
Ingredients (%) :							
Starting	Lysine		0.20	0.40	0.60	0.80	1.00
	Sand[1]	1.00	0.80	0.60	0.40	0.20	–
Finishing	Lysine	–	0.20	0.40	0.60	0.80	1.00
	Sand[1]	1.00	0.80	0.60	0.40	0.20	–
	Total	1.00	1.00	1.00	1.00	1.00	1.00
Chemical compositon (%)[2] :							
Starter	Lysine	0.60	0.80	1.00	1.20	1.40	1.60
Finisher	Lysine	0.50	0.70	0.90	1.10	1.30	1.50

[1] Acid washed sand was used.

[2] Calculated value.

prepared in this way were ground with Wiley mill and analyzed for proximate composition and mineral content.

Protein, DNA and RNA Assay

Liver and muscle tissues sample for protein, DNA and RNA assay were extracted by potassium acetate and 3:1 (v/v) ethyl ether: ethanol according to the modified method of Merchant et al. (1964). Protein was measured according to the method of Lowry et al. (1951) with bovine serum albumin (BSA) as the standard. The DNA was determined according to Labarca and Paign (1980) with calf thymus DNA as the standard. The RNA (Volkin and Cohn, 1954) was measured with yeast RNA as the standard.

TABLE 3. BODY WEIGHT GAIN, FEED .NTAKE, FEED EFFICIENCY AND MORTALITY OF BROILER CHICKS AS AFFECTED BY THE LEVELS OF DIETARY LYSINE AND ENERGY (0-7 WEEKS)

Item / Treatment		Initial body weight (g)	Final body weight (g)	Body weigh gain (g)	Feed intake (g)	Feed efficiency	Mortality (%)
Energy (kcal ME/kg)	Lysine (%)						
	0.6-0.5	57.1	928.0^{D}	870.9^{D}	2743.9^{E}	3.19^{A}	15.6
	0.8-0.7	57.2	1698.2^{C}	1641.0^{C}	4225.9^{C}	2.58^{B}	1.4
3,200-2,900	1.0-0.9	57.5	2093.8^{A}	2036.3^{A}	4652.1^{ABC}	2.28^{BCD}	6.3
	1.2-1.1	58.0	2075.0^{A}	2017.0^{A}	4471.0^{ABC}	2.22^{CD}	6.0
	1.4-1.3	57.1	2106.3^{A}	2049.2^{A}	4808.9^{A}	2.35^{BCD}	3.1
	1.6-1.5	57.8	1782.7^{BC}	1724.9^{BC}	3678.6^{D}	2.15^{D}	15.6
	0.6-0.5	58.2	954.2^{D}	896.0^{D}	2962.5^{E}	3.31^{A}	6.3
	0.8-0.7	57.7	1765.2^{BC}	1707.5^{BC}	4230.1^{C}	2.48^{BC}	6.3
2,900-2,600	1.0-0.9	57.5	2029.5^{AB}	1972.0^{AB}	4724.1^{AB}	2.40^{BCD}	6.3
	1.2-1.1	57.6	1968.8^{AB}	1911.2^{AB}	4424.1^{ABC}	2.31^{BCD}	3.1
	1.4-1.3	57.4	2067.0^{ABC}	1882.2^{ABC}	4371.3^{ABC}	2.32^{BCD}	9.4
	1.6-1.5	58.0	1962.5^{AB}	1904.5^{AB}	4328.2^{BC}	2.27^{BCD}	12.5
Among lysine levels							
0.6-0.5		57.6	941.1^{D}	883.5^{D}	2853.2^{D}	3.23^{A}	10.9^{AB}
0.8-0.7		57.5	1731.7^{C}	1674.2^{C}	4228.0^{B}	2.53^{B}	7.8^{AB}
1.0-0.9		57.5	2061.6^{A}	2004.1^{A}	4688.1^{C}	2.34^{C}	6.3^{AB}
1.2-1.1		57.8	2021.9^{AB}	1964.1^{AB}	4447.6^{C}	2.27^{C}	1.6^{B}
1.4-1.3		57.2	2056.6^{AB}	1965.7^{AB}	4590.1^{C}	2.34^{C}	6.3^{AB}
1.6-1.5		57.9	1872.6^{BC}	1814.7^{BC}	4003.4^{C}	2.21^{C}	14.1^{A}
Among energy levels							
3,200-2,900		57.7	1786.6	1731.9	4096.7	2.45	8.3
2,900-2,600		57.4	1769.9	1723.8	4173.4	2.52	7.3
Significance (Probability)[1]							
Lysine effect		–	–	< 0.01	< 0.01	< 0.01	NS
Energy effect		–	–	NS	NS	NS	NS
L × E interaction				NS	< 0.05	NS	NS

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

[1] NS means non-significant.

Chemical Analyses

Proximal analyses and minerals of experimental diets, excreta and ether extract in thigh muscle were conducted according to the methods of AOAC (1990). Amino acid composition in experimental diets and feces were analyzed by using Automatic Amino Acid Analyser (LKB, Model 4150-alpha). Gross energy (GE) in the diets and metabolizable energy (ME) were analysed by using Adiabatic Oxygen Bomb Calorimeter (Model 1241, Parr Instrument Co., Molin, IL).

Statistical analysis

Statistical analysis for the present data were carried out by compairing means according to Duncan's multiple range test (Duncan, 1955), using General Linear Model (GLM) of SAS (1985) package program with IBM-PC (IBM, 16 bit AT).

TABLE 4. EFFECT OF LYSINE AND ENERGY ON NUTRIENT UTILIZATION OF BROILER CHICKS (%)

Item / Treatment		Nutrients				Metabolizable energy
		Crude protein	Crude fat	Crude ash	Total carbohydrate	
Energy (kcal ME/kg)	Lysine (%)					
3,200-2,900	0.6-0.5	61.75	76.94^{ABC}	37.39	82.97	78.20
	0.8-0.7	49.00	82.99^{AB}	32.85	84.17	75.28
	1.0-0.9	79.44	79.59^{ABC}	45.65	90.32	87.10
	1.2-1.1	63.78	63.65^{CD}	47.10	71.02	72.83
	1.4-1.3	67.16	88.38^{AB}	29.31	86.35	81.27
	1.6-1.5	65.79	94.29^{A}	21.72	75.08	80.29
2,900-2,600	0.6-0.5	51.06	76.72^{ABC}	34.67	83.63	75.47
	0.8-0.7	59.57	70.33^{AB}	38.56	81.05	77.05
	1.0-0.9	68.27	74.52^{ABC}	31.12	79.08	76.63
	1.2-1.1	45.10	48.29^{CD}	27.28	63.71	72.74
	1.4-1.3	50.58	81.66^{AB}	22.25	78.71	70.88
	1.6-1.5	65.32	93.70^{A}	29.72	74.23	74.83
Among lysine levels						
0.6-0.5		56.41^{b}	76.83^{B}	36.03	83.30	76.84
0.8-0.7		54.29^{b}	76.69^{B}	35.71	82.61	76.16
1.0-0.9		73.85^{a}	77.26^{B}	38.39	84.70	81.87
1.2-1.1		54.44^{b}	55.97^{C}	37.19	67.36	72.79
1.4-1.3		57.21^{b}	84.35^{AB}	25.07	81.76	75.04
1.6-1.5		65.56^{ab}	94.00^{A}	25.76	74.65	77.56
Among energy levels						
3,200-2,900		64.33	80.54	36.06	81.37	79.04
2,900-2,600		56.65	74.20	30.60	76.73	74.60
Significance (Probability)[1]						
Lysine effect		< 0.05	< 0.01	NS	NS	NS
Energy effect		NS	< 0.05	NS	NS	NS
L × E interaction		NS	NS	NS	NS	NS

^{ABCD} Mean values with different superscripts within the same column are significantly different ($p < 0.01$).
^{ab} Mean values with different superscripts within the same column are significantly different ($p < 0.05$).
[1] NS means non-significant.

Results and Discussion

Growth Performance

As presented in table 3, the highest body weight gain was obtained at 1.0(0.9)-1.2(1.1)% lysine groups with 3,200(2,900) kcal ME/kg. The lowest body weight gain was obtained from 0.6(0.5)% lysine group with 3,200(2,900) kcal ME/kg, 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$). Among lysine levels, lysine had an effect on the body weight gain ($p < 0.01$). But there was no interaction between energy and lysine level in body weight gain. These results agreed with that of Sibbald and Wolynetz (1986). They reported that responses to dietary lysine are independent of the fat content of the diet within the range of 20 to 80 g/kg. Feed intake showed the significant ($p < 0.01$) difference among treatment groups. Chicks fed a diet containing 1.0(0.9)% or 1.4(1.3)% lysine group showed hig-

TABLE 5. EFFECT OF LYSINE AND ENERGY ON THE CONTENT OF DNA, RNA AND PROTEIN IN LIVER TISSUES

Item / Treatment		DNA (mg/g)	RNA (mg/g)	Protein (mg/g)	RNA/DNA	Protein/DNA
Energy (kcal ME/kg)	Lysine (%)					
	0.6-0.5	2.36^{bc}	15.73	86.25^{BC}	6.67	36.55
	0.8-0.7	0.58^{c}	5.68	51.46^{C}	9.79	88.72
3,200-2,900	1.0-0.9	4.08^{ab}	5.13	94.15^{BC}	1.26	23.08
	1.2-1.1	2.75^{abc}	21.36	103.27^{BC}	7.77	37.55
	1.4-1.3	2.53^{bc}	22.07	86.32^{BC}	8.72	34.12
	1.6-1.5	4.70^{ab}	41.20	118.60^{BC}	8.77	25.23
	0.6-0.5	2.76^{abc}	5.21	103.51^{BC}	1.89	37.56
	0.8-0.7	1.78^{bc}	18.43	230.88^{A}	10.35	129.70
2,900-2,600	1.0-0.9	3.94^{abc}	4.24	97.09^{BC}	1.08	24.46
	1.2-1.1	6.09^{a}	8.80	103.27^{AB}	1.44	16.96
	1.4-1.3	4.33^{ab}	4.65	86.32^{BC}	1.07	19.94
	1.6-1.5	1.70^{bc}	42.51	75.64^{C}	25.00	44.49
Among lysine levels						
0.6-0.5		2.56^{AB}	10.47^{b}	94.88	4.28^{B}	37.02
0.8-0.7		1.18^{B}	12.06^{b}	141.21	10.07^{B}	109.21
1.0-0.9		4.01^{A}	4.68^{b}	94.12	1.17^{B}	23.86
1.2-1.1		4.41^{A}	15.08^{b}	140.31	4.61^{B}	27.26
1.4-1.3		3.43^{AB}	13.36^{b}	94.89	4.90^{B}	27.03
1.6-1.5		3.20^{AB}	41.85^{a}	97.12	16.89^{A}	34.86
Among energy levels						
3,200-2,900		2.83	18.53	89.52^{b}	6.81	45.55^{b}
2,900-2,600		3.43	13.97	131.32^{a}	7.16	40.88^{a}
Significance (Probability)[1]						
Lysine effect		< 0.05	NS	NS	< 0.01	NS
Energy effect		NS	NS	< 0.01	NS	< 0.05
L × E interaction		NS	NS	NS	NS	NS

^{ABC} Mean values with different superscripts within the same column are significantly different ($p < 0.01$).
^{abc} Mean values with different superscripts within the same column are significantly different ($p < 0.05$).
[1] NS means non-significant.

best feed intake with 3,200(2,900) kcal ME/kg and 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$). But among energy levels, there is no significant difference. Especially, interaction between lysine and energy in feed intake was observed to be significnat ($p < 0.05$). The worst feed efficiency was obeserved at 0.6(0.5)% lysine group with 3,200(2,900) kcal ME/kg and 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$).

Nutrient utilization

The effects of dietary lysine and energy on the utilization of the nitrogen, crude fat, crude ash, total carbohydrate and metabolizable energy are summarized in table 4. Nitrogen availability was significantly ($p < 0.05$) affected by lysine levels. Among lysine levels, 1.0(0.9)% lysine group showed the highest (73.85%) nitrogen availability. Among energy levels, there was no significant

TABLE 6. EFFECT OF LYSINE AND ENERGY ON THE CONTENT OF PROTEIN, FAT AND MOISTURE IN THIGH MUSCLE TISSUES

Item / Treatment		Protein (mg/g)	Crude fat (mg/g)	Moisture (%)
Energy (kcal ME/kg)	Lysine (%)			
	0.6-0.5	85.0^{B}	87.4^{BC}	59.2
	0.8-0.7	61.8^{B}	42.1^{EF}	50.4
3,200-2,900	1.0 0.9	67.4^{B}	36.1^{EF}	50.3
	1.2-1.1	208.1^{A}	55.1^{DE}	42.4
	1.4-1.3	68.6^{B}	78.2^{CD}	44.5
	1.6-1.5	99.7^{B}	50.4^{EF}	59.4
	0.6-0.5	64.9^{B}	111.5^{AB}	47.6
	0.8-0.7	63.3^{B}	97.5^{ABC}	49.2
2,900 2,600	1.0-0.9	90.9^{B}	44.2^{EF}	45.3
	1.2-1.1	107.0^{B}	36.3^{EF}	43.4
	1.4-1.3	140.7^{AB}	119.7^{A}	51.4
	1.6-1.5	203.1^{A}	27.0^{F}	49.5
Among lysine levels				
0.6-0.5		74.9^{AB}	99.4^{A}	53.4^{A}
0.8-0.7		62.9^{B}	69.8^{B}	49.8^{A}
1.0-0.9		79.2^{A}	40.2^{C}	47.8^{AB}
1.2-1.1		157.5^{A}	45.7^{C}	42.9^{B}
1.4-1.3		104.6^{AB}	49.0^{C}	48.0^{AB}
1.6-1.5		151.4^{A}	39.2^{C}	54.5^{A}
Among energy levels				
3,200-2,900		111.7	72.9^{b}	51.0
2,900-2,600		98.4	58.2^{a}	47.7
Significance (Probability)[1]				
Lysine effect		< 0.05	< 0.01	NS
Energy effect		NS	< 0.05	NS
L. × E interaction		< 0.05	< 0.01	NS

^{ABCEF} Mean values with different superscripts within the same column are significantly different ($p < 0.01$).
^{ab} Mean values with different superscripts within the same column are significantly different ($p < 0.05$).
[1] NS means non-significant.

TABLE 7. EFFECT OF LYSINE AND ENERGY ON APPARENT AMINO ACID AVAILABILITY (%)

Treatment		ARG	HIS	ILE	LEU	LYS	MET	THR	VAL	PRO	GLY	SER	PHE	TYR	Mean
Energy (kcal ME/kg)	Lysine (%)														
	0.6-0.5	86.0^{BC}	71.1	92.3	96.2	90.0	92.3	92.1	91.6	85.2	52.7^{A}	95.0	95.1^{A}	93.9	87.2
	0.8-0.7	68.9^{D}	56.1	89.9	94.9	88.3	88.3	85.6	91.9	79.1	68.7^{AB}	90.5	93.5^{AB}	92.3	83.7
3,200-2,900	1.0-0.9	90.1^{ABC}	82.3	93.2	97.5	91.3	87.3	93.3	91.8	95.7	83.6^{A}	94.9	96.1^{A}	95.0	91.7
	1.2-1.1	99.1^{A}	74.9	93.0	97.2	87.7	90.8	83.3	93.6	95.6	87.6^{A}	89.6	93.9^{A}	95.5	90.9
	1.4-1.3	94.3^{AB}	80.5	82.7	96.7	93.2	85.3	89.0	87.0	87.4	60.6^{AB}	92.2	84.8^{C}	84.9	86.0
	1.6-1.5	94.9^{AB}	74.0	93.1	96.1	93.6	90.4	93.0	96.6	79.9	92.2^{A}	91.1	93.4^{AB}	86.9	90.4
	0.6-0.5	69.6^{D}	81.3	91.1	95.0	85.2	90.4	87.6	90.5	85.2	50.8^{BC}	93.2	93.5^{AB}	91.2	85.7
	0.8-0.7	89.0^{ABC}	75.9	88.4	94.1	81.2	80.9	86.0	85.8	79.1	30.1^{C}	91.6	91.3^{ABC}	91.0	81.9
2,900-2,600	1.0-0.9	99.1^{A}	80.1	94.9	97.2	88.3	92.3	94.7	96.3	95.7	87.9^{A}	96.7	95.8^{A}	96.0	93.5
	1.2-1.1	97.7^{A}	68.9	90.1	95.3	84.0	89.4	86.6	94.0	95.6	78.2^{AB}	91.5	90.3^{ABC}	89.1	88.5
	1.4-1.3	97.1^{A}	61.3	88.4	94.5	79.1	69.1	90.8	91.2	87.4	88.3^{A}	93.3	89.6^{ABC}	82.2	85.6
	1.6-1.5	83.4^{C}	61.6	86.5	94.4	92.9	83.1	92.5	91.5	79.9	84.9^{A}	93.5	86.6^{BC}	86.0	85.9
Among lysine levels															
0.6-0.5		77.8^{C}	76.2	91.7	95.6	87.6	91.3	89.8^{AB}	91.6	85.1	51.7	94.1	94.3	93.9	86.2
0.8-0.7		78.9^{C}	66.0	89.2	94.5	84.7	84.6	85.8^{B}	88.9	73.4	49.4	91.1	92.4	92.3	82.4
1.0-0.9		94.6^{AB}	81.2	94.0	97.3	89.8	89.8	94.0^{A}	94.0	91.2	85.7	95.8	96.0	95.0	92.2
1.2-1.1		98.4^{AB}	71.9	91.6	96.3	85.8	90.1	84.9^{B}	93.8	88.3	82.9	90.5	92.1	95.5	89.4
1.4-1.3		96.0^{A}	69.0	86.2	95.3	84.8	75.6	90.1^{AB}	89.5	85.5	77.2	92.8	87.7	84.9	85.7
1.6-1.5		89.2^{B}	67.8	89.8	95.2	93.3	86.7	92.8^{A}	94.1	83.3	88.6	93.8	90.0	86.9	88.6
Among energy levels															
3,200-2,900		88.6	72.7	91.2	96.4^{a}	90.5^{a}	89.3	89.4	92.4	87.1	75.0	92.7	93.3	91.8	88.5
2,900-2,600		89.3	71.5	89.9	95.1^{b}	85.1^{b}	84.2	89.7	91.5	81.9	70.0	93.3	92.1	89.2	86.4

^{ABCDb} Mean values with different superscripts within the same column are significantly different ($p < 0.01$).
^{abcd} Mean values with different superscripts within the same column are significantly different ($p < 0.05$)

difference. Interaction between lysine and energy was not found in nitrogen availability. Crude fat utilization was found to be the highest at 1.6 (1.5)% lysine group with 3,200(2,900) kcal ME/kg and 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$). The lowest crude fat utilization was found at 1.2% lysine group with 3,200(2,900) kcal ME/kg and 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$). Among energy levels, there was no significant difference in crude fat utilization and interation between energy and lysine was not found. In ash and total carbohydrate utilization, lysine and energy had no effect on the utilization and there was no significant difference and interaction between lysine and energy was not found.

DNA, RNA and Protein in Liver Tissues

In order to determine the cellular activity of liver, the content of DNA, RNA and protein were measured. The content of DNA was the highest in 1.0(0.9)% and 1.6(1.5)% with 3,200 kcal ME/kg and 1.2(1.1)% lysine with 2,900 kcal ME/kg ($p < 0.01$). Among lysine levels, 1.0 (0.9)% and 1.2(1.1)% lysine groups indicated to be the higher than any other groups ($p < 0.01$). These results were supported by Robbinson and Baker (1981) and Austic and Nesheim (1970) who found that dietary lysine supplements increased the arginase activity of mitochondria. The enzyme catalyzed arginine which is initial substrate for polyamine synthesis.

The content of RNA was significantly difference among lysine levels ($p < 0.05$). Chicks fed diet containing 1.6(1.5)% lysine showed the highest RNA content ($p < 0.05$). Protein content is the lowest in 0.8(0.7)% lysine with 3,200(2,900) kcal ME/kg and 1.6 (1.5)% lysine with 2,900(2,600) kcal ME/kg ($p < 0.01$) and highest in 0.8(0.7)% lysine with 2,900(2,600) kcal ME/kg. The interaction between lysine and energy was observed significantly ($p < 0.01$). In the ratio of RNA/DNA and protein/DNA, there was no significant difference between groups. But among lysine levels, 1.6(1.5)% lysine group showed the highest RNA/DNA ratio ($p < 0.01$) and the level of 2,900(2,600) kcal ME/kg showed the highest protein/DNA ratio than 3,200(2,900) kcal ME/kg groups ($p < 0.05$).

Chemical Composition in Thigh Muscle Tissues

Chicks fed diet containing 1.2(1.1)% lysine with 3,200(2,900) kcal ME/kg and 1.6(1.5)% lysine with 2,900(2,600) kcal ME/kg showed the highest value in the content of crude protein of thigh muscle tissues ($p < 0.01$). Thus, it was thought that the balance between lysine and energy was needed for the accretion of protein.

Interaction between lysine and energy was found in crude protein of thigh muscle tissues ($p < 0.05$). Crude fat content was the highest at 1.4(1.3)% lysine group with 2,900(2,600) kcal ME/kg and the lowest at 1.6(0.5)% lysine group with 2,900(2,600) kcal ME/kg ($p < 0.01$). Among energy levels, 3,200(2,900) kcal ME/kg groups showed the higher fat content than 2,900 (2,600) kcal ME/kg groups ($p < 0.05$). In moisture content, among lysine levels, 1.2(1.1)% lysine showed the lowest ($p < 0.01$).

Apparent Amino Acid Availability

In arginine availabilty, 1.2% lysine and 1.0 (0.9)-1.4(1.3)% lysine groups showed the highest availability with 3,200(2,900) kcal ME/kg or 2,900(2,600) kcal ME/kg, respectively ($p < 0.01$). It was thought that the balance between lysine and arginine was important in arginine availability. In leucine and lysine availability, 3,200 (2,900) kcal ME/kg group showed higher availability than 2,900(2,600) kcal ME/kg ($p < 0.05$). Chicks fed a diet containing 1.0% lysine level with both energy groups showed the highest phenylalanine availability ($p < 0.01$). In threonine availability, among lysine levels, 1.0% and 1.6% lysine showed the highest availability ($p < 0.01$). In tyrosine availability, 1.0% lysine with 2,900(2,600) kcal ME/kg group showed the highest value ($p < 0.05$). Among lysine levels, chicks fed diets containing 1.0(0.9)%-1.6(1.5)% lysine levels showed the highest value and 0.6(0.5)%, 0.8(0.7)% lysine group represented the lowest value ($p < 0.01$).

Literature Cited

A.O.A.C. 1990. Official methods of analysis. 15th ed. Washington, D.C.

Austic, R. E. and M. C. Nesheim. 1971. Arginine and creatine interrelationships in the chick. Poultry Sci. 51:1098.

Austic, R. E. and M. C. Nesheim. 1970. Role of kidney arginase in variations of the arginine requirements of chicks. J. Nutr. 100:855.

Duncan, D. B. 1955. Multiple range and multiple F tests. Biometric. 11:1.

Labarca, C. and K. Paign. 1980. A simple, rapid and sensitive DNA assay procedure. Anal. Biochem. 102:344.

Lowry, O. H., N. J. Rosebrough, A. L. Farr and R. J. Randall. 1951. Protein measurement with the folin phenol reagent. J. Biol. Chem. 193:265.

Mahray, C. J and P. W. Waldroup. 1981. The influence of dietary energy and amino acid levels on abdominal fat pad development in the broiler chicken. Poultry Sci. 60:151.

Merchant, D. T., R. M. Kant and W. H. Murphy. 1964. Extraction of nucleic acids and proteins. Handbook of cell and organ culture, pp 161-162, Burgess Publishing Company, Mpls., Minn.

NRC. 1984. Nutrient requirements of poultry. National Academic Press, Washington D.C.

Pegg, A. E. 1986 Present advances in the biochemistry of polyamines in eukaryotes. Biochem. J. 234:249.

Robbins, K. R. and D. H. Baker. 1981 Kidney arginase activity in chickens fed diets containing deficient or excessive concentrations of lysine, arginine, histidine, or total nitrogen. Poultry Sci. 60:829.

Seaton, K. W., O. P. Thomas, R. M. Gous and E. H. Bossard. 1978 The effect of diet on liver glycogen and body composition in the chick. Poultry Sci. 57:692

Sell, J. L. and G. C. Hodgson. 1966. Wheat soy-bean meal rations for laying hens. Poultry Sci. 45:247.

Sibbald, I. R. and M. S. Wolynetz. 1986. Effects of dietary lysine and feed intake on energy utilization and tissue synthesis by broiler chicks. Poultry Sci. 65:98.

Sibbald, I. R and M. S. Wolynetz. 1984. A longitudinal studies of energy and nitrogen excretion by fasted cockerels. Poultry Sci. 63:691.

Velu, J. G., H. M. Scott and D. H. Baker. 1972. Body composition and nutrient utilization of chicks fed amino acid diets containing graded amounts of either isoleucine or lysine. J. Nutri. 102:741.

Velu, J. G., P. H Baker and H. M. Scott. 1971. Protein and energy utilization by chicks fed graded levels of a balanced mixture of crystalline amino acids. J. Nutri. 101:1249.

Volkin, E. and W. E. Cohn. 1954. Methods of biochemical analysis. In: D. Glick, ed. vol. 1, pp. 298. Interscience Publishers Inc., New York

Waible, P. E. and E. L. Johnson. 1961. Effect of protein, corn-soybean oil meal diets and amino acid supplementation on performance of laying hens. Poultry Sci. 41:293.

Waldroup, P. W., R. J. Mitchell, J. K. Payne and K. R. Hazen. 1976. Performance of chicks fed diets formulated to minimize excess levels of essential amino acid. Poultry Sci. 55:243.