Lysine Requirement of Broilers as Influenced by Environmental Temperatures

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ABSTRACT Two experiments were conducted to determine the influence of 15.6 and 29.4° C. environmental temperatures on 2- to 4-week broiler lysine requirements. Weights for 4-week-old cockerels were maximum when either 1.10% dietary lysine in the 15.6° C. environment or 1.00% dietary lysine in the 29.4° C. environment were fed. Feed was used more efficiently by 4-week old cockerels fed either 1.10% dietary lysine in the 15.6° C. environment or 0.95% dietary lysine in the 29.4° C. environment.

Plasma free lysine concentrations from 4-week-old cockerels increased as dietary lysine increased. Total plasma free amino acid concentrations from chicks grown in a 15.6° C. environment were approximately 25% greater than from chicks grown at 29.4° C. Total plasma free amino acids for 4-week-old cockerels peaked when 1.05% dietary lysine in the cool environment and 0.95% dietary lysine in the warm environment were fed.

INTRODUCTION

Grau *et al.* (1946) reported that the lysine requirement of chicks is 0.96% of the diet. Milligan *et al.* (1951), Hill (1953) and Schwartz *et al.* (1958) reported that the lysine requirement of your broiler chicks is 1.00–1.10% of the diet. More recently, Velu *et al.* (1972) reported that body weights were maximized and feed consumptions reduced at a dietary lysine level of 0.95%.

Edwards *et al.* (1956), Mitchell (1959) and Summers and Fisher (1961) reported that the lysine requirements of chicks are related to rate of growth. Edwards *et al.* (1956) reported that the lysine requirement was 0.90% of the diet with slow growing birds and 1.10% of the diet with fast growing birds.

Researchers agree that elevated temperatures reduce feed consumption (Huston, 1965; Mickelberry *et al.*, 1966). Amino acid requirements, usually expressed as a percent of diet, may vary because of reduction in feed consumption at higher environmental temperatures.

Salmon (1958) reported that when a single amino acid is present in an animal's diet at levels not capable of supporting maximum synthesis of tissue proteins, any amino acid not fully used is in excess and must be eliminated from the body. Lewis and D'Mello (1967) reported that an excess of one amino acid enhances general catabolism and excretion of all amino acids, thus encourages the loss of other amino acids inadvertently. The mechanism may lead to a deranged pattern of free amino acids and, thereby, encourages the loss of the target amino acid.

May *et al.* (1972) reported plasma alanine, arginine, and tyrosine were reduced, but cystine, ornithine, and lysine were higher for chicks reared at 7.2° C. than for chicks reared in a 32.2° C. environment. These workers also reported that essential plasma amino acid concentrations were approximately 8% less in birds reared in the warm environment than in birds reared in the cool environment. Ohno and Tasaki (1972) reported that adult cockerel plasma free lysine was constant when dietary lysine increased from 0.21 to 0.63%, but was greater when dietary lysine was further increased up to 1.47%. Threonine, tryptophan, serine and alanine increased with an increase of dietary lysine from 0.21 to 1.47%. Arginine was constant when dietary lysine increased.

Waldroup *et al.* (1976) reported that diets with minimal excesses of added amino acids may be formulated and may result in improved performance under heat stress without impairing performance under more moderate environmental conditions. Kubena *et al.* (1972) reported that in an attempt to compensate for the reduced feed consumption, dietary amino acid consumption, or protein consumption at higher environmental temperatures, diet nutrients are normally increased 5 to 10%. Because lysine is the second most limiting amino acid in practical poultry diets and may, or may not, be added in sufficient quantities to meet the bird's metabolic needs under high and low environmental temperature conditions, a study was conducted to determine: (1) the lysine requirements of 1-day-old to 4-week-old broiler cockerels as affected by environmental temperature; and (2) the effect of dietary lysine and growth on blood plasma free amino acids.

EXPERIMENTAL PROCEDURE

In two experiments, 1280 one-day-old cockerels were placed in environmental chambers described by Reece and Deaton (1969) to provide two environmental temperature regimes. Chicks in both regimes were brooded in batteries for 7 days at 32.2°C. Temperature for one group of cockerels in each experiment was then decreased to 23.9°C. until they were 14 days old. The temperature for these cockerels was then lowered to 15.6°C. and remained at this temperature until the chicks were 28 days old. The temperature for the other group of cockerels was decreased to 29.4°C. when they were 7 days old and remained at this temperature until they were 28 days old. For simplicity, the temperatures are called cool environment (15.6°C.) and warm environment (29.4°C.).

A corn-sesame meal-corn gluten meal diet was fed in experiment 1, and a corn-soybean meal-corn gluten meal diet was fed in experiment 2 (Table 1). L-lysine HCl (98%) was added to the basal diet in 0.05% increments to furnish dietary lysine levels of between 0.80 and 1.15% in experiment 1 and between 0.85 and 1.20% in experiment 2. Diets in both experiments were fed to four replicates of 10 chicks each from 1 day to 28 days old. Chick weights were determined at 14 and 28 days old and feed efficiencies were determined for the 0- to 14- and 0- to 28-day test period.

Blood was collected from three 4-week-old birds from each replicate in experiment 2 by heart puncture and pooled for amino acid analyses. Pooled blood plasma for each diet was obtained by centrifugation and was deproteinized by the method reported by Schraff and Wool (1964). Plasma free amino acids were

TABLE 1.—*Composition of low lysine basal diets*

Ingredient	Composition, % Experiment 1	Composition, % Experiment 2
Yellow corn	72.45	68.58
Sesame meal, 42%	8.00	. . .
Soybean meal, 49%	. . .	13.70
Corn gluten meal, 61%	16.85	13.70
Dicalcium phosphate (22% Ca, 18.5% P)	1.81	1.84
Limestone	0.37	1.13
Salt	0.25	0.25
Vitamin and mineral mix[1]	0.25	0.25
Methionine hydroxy analogue-Ca (93%)	0.02	0.05
Animal fat	. . .	0.50
Totals	100.00	100.00
Calculated analyses		
Crude protein, %	20.00	21.10
Metabolizable energy, kcal/kg.	3080	3221
Calcium, %	0.85	0.90
Available phosphorus, %	0.45	0.45
Lysine, %	0.51	0.80
Methionine plus cystine, %	0.90	0.86
Arginine, %	1.09	1.13

[1] The broiler premix furnished the following amounts of other ingredients per kilogram of feed: Vitamin A, palmitate, gelatin coated, 6614 I.U.; vitamin D_3, 1654 I.C.U.; vitamin E, 2.2 I.U.; riboflavin, 4.4 mg.; niacin, 27.6 mg.; d-pantothenic acid, 8.8 mg.; folic acid, 275.6 mcg.; vitamin B_{12}, 8.8 mcg.; choline chloride, 551 mg.; ethoxyquin, 55 mg.; menadione sodium bisulfite complex, 2.8 mg. or menadione sodium bisulfite, 1.7 mg.; pyridoxine, 0.55 mg.; manganese, 66.25 mg.; zinc, 44 mg.; iodine, 1.25 mg.; iron (in sulfate form), 20 mg.; copper (in sulfate form), 2 mg.

TABLE 2.–*Effect of environmental temperature on 2- and 4-week lysine requirements based on chick weight, experiment 1*

Dietary lysine, %	Mean chick body weight, g.					
	2-week results			4-week results		
	Temperature, °C[1]			Temperature, °C[1]		
	23.9	29.4	Mean	15.6	29.4	Mean
.80	142[e]	144[f]	143	480[d]	401[c]	440
.85	171[d]	168[e]	170	482[d]	424[c]	453
.90	182[c]	185[d]	184	510[cd]	469[b]	490
.95	188[c]	196[c]	192	545[bc]	522[a]	534
1.00	200[b]	203[b]	202	558[ab]	535[a]	546
1.05	210[ab]	212[ab]	211	588[a]	546[a]	567
1.10	212[a]	213[ab]	212	595[a]	542[a]	568
1.15	213[a]	214[a]	214	574[a]	535[a]	554
Mean[1]	190[a]	192[a]		542[a]	497[b]	

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

determined by a Technicon[1,2] amino acid analyzer. Plasma tryptophan and ornithine concentrations were not determined.

A factorially-arranged randomized complete block design was used in each experiment conducted. Data were examined statistically by analysis of variance (Steel and Torrie, 1960). Significant differences among means were separated by Duncan's new multiple range test (1955). All statements of significant differences refer to the 5% level of probability.

RESULTS AND DISCUSSION

Experiment 1. Dietary lysine levels of between 0.80 and 1.15% in 0.05% increments were fed in experiment 1 to determine lysine requirement as related to environmental temperature. Weights were maximum for 2-week-old cockerels fed 1.05% dietary lysine in both cool and warm environments (Table 2). Composite 2-week-old cockerel weights were not significantly different between environments. However, 4-week-old cockerel weights were maximum when they were fed either 1.00% dietary lysine in the cool environment or 0.95% in the warm environment. Significantly larger composite 4-week chick weights were found in the cool environment as compared to the warm environment.

Feed conversion results are shown in Table 3. A lower dietary lysine level (1.00%) was required to use feed more efficiently during the 0- to 2-week growing period than was required to maximize weight of 2-week-old cockerels (1.05%; see Table 2) in either experiment. Feed was most efficiently used when 1.00% and 0.95% dietary lysine were fed to chicks reared in the cool and warm environments, respectively, during the 0- to 4-week growing period.

Lysine requirement for 2- to 4-week-old cockerels was greater in the cool environment than in the warm environment. Because 4-week-old cockerels in the cool environment were larger, these results compare to those of Edwards *et al.* (1956) and Mitchell (1959) who suggested that lysine requirement increases as percentage growth increases. Mitchell (1959) suggested differences in amino acid needs were based upon differences in percentage growth rate and the requirement for tissue maintenance. Lysine requirements in this experiment were very similar to that found by Milligan *et al.* (1951); Hill (1953); Schwartz *et al.* (1958) and Velu *et al.* (1972).

Edwards *et al.* (1956) found that when wheat gluten was fed as the protein source, growth was maximum at a lysine level of 0.90%. Edwards also found that when sesame meal was used as the protein source, larger growth was obtained at 1.10% dietary lysine. Because they found differences in lysine re-

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TABLE 3.—*Effect of environmental temperature on 0- to 2- and 0- to 4-week lysine requirements based on feed conversion, experiment 1*

	Feed/gain					
	0- to 2-week results			0- to 4-week results		
	Temperature, °C[1]			Temperature, °C[1]		
Dietary lysine, %	23.9	29.4	Mean	15.6	29.4	Mean
.80	1.90[d]	1.70[e]	1.80	1.86[de]	1.97[e]	1.92
.85	1.83[d]	1.61[d]	1.72	1.82[cd]	1.91[d]	1.86
.90	1.72[c]	1.45[c]	1.58	1.76[ab]	1.77[c]	1.76
.95	1.60[b]	1.42[bc]	1.51	1.77[bc]	1.64[a]	1.70
1.00	1.41[a]	1.35[ab]	1.38	1.70[a]	1.65[a]	1.68
1.05	1.38[a]	1.33[a]	1.36	1.85[de]	1.64[a]	1.74
1.10	1.36[a]	1.32[a]	1.34	1.86[de]	1.69[ab]	1.78
1.15	1.36[a]	1.32[a]	1.34	1.90[e]	1.72[bc]	1.81
Mean[1]	1.57[b]	1.44[a]		1.81[b]	1.75[a]	

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

quirements as a result of different growths when different protein sources were fed, experiment 2 was conducted to determine lysine requirements of broiler chicks at different environmental temperatures when soybean meal was fed as the protein source in place of sesame meal.

Experiment 2. Chick weights were lower when a corn-sesame meal-corn gluten meal basal diet was fed in experiment 1 than had been experienced when practical corn-soybean meal diets were fed in similar battery trials at this station. Corn gluten meal is one protein that is low in lysine. Therefore, corn gluten meal was used to formulate a low lysine basal when corn and soybean meal were the basic ingredients. The lysine level of the corn-soybean meal-corn gluten meal basal diet used in experiment 2 (Table 1) was 0.80%. Feed conversion and chick weight results are shown in Tables 4 and 5.

Higher dietary lysine levels were required to maximize weights of 4-week-old cockerels in the cool environment than in the warm environment (Table 4). Temperatures in the cool environment were lowered from 32.2°C. to 23.9°C. when test chicks were 7 days old and remained at this temperature until chicks were

TABLE 4.—*Effect of environmental temperature on 2- and 4-week lysine requirements based on chick weight, experiment 2*

	Mean chick body weight, g.					
	2-week results			4-week results		
	Temperature, °C[1]			Temperature, °C[1]		
Dietary lysine, %	23.9	29.4	Mean	15.6	29.4	Mean
.85	186[f]	161[d]	174	502[d]	385[d]	444
.90	227[e]	204[c]	216	656[c]	542[c]	599
.95	234[de]	232[b]	233	680[c]	640[b]	660
1.00	250[cd]	253[b]	252	738[b]	706[a]	722
1.05	262[bc]	278[a]	270	749[b]	714[a]	732
1.10	272[ab]	289[a]	280	752[ab]	748[a]	748
1.15	283[ab]	280[a]	282	792[a]	714[a]	753
1.20	284[a]	290[a]	287	771[ab]	721[a]	746
Mean[1]	250[a]	248[a]		705[a]	646[b]	

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

TABLE 5.–*Effect of environmental temperature on 0- to 2- and 0- to 4-week lysine requirements based on feed conversion, experiment 2*

	Feed/gain					
	0- to 2-week results			0- to 4-week results		
Dietary	Temperature, °C[1]			Temperature, °C[1]		
lysine, %	23.9	29.4	Mean	15.6	29.4	Mean
.85	1.86[c]	1.66[c]	1.76	2.20[c]	2.12[c]	2.16
.90	1.79[c]	1.57[c]	1.68	1.92[b]	1.82[b]	1.87
.95	1.69[b]	1.41[b]	1.55	1.90[b]	1.65[a]	1.78
1.00	1.66[b]	1.41[b]	1.54	1.90[b]	1.63[a]	1.76
1.05	1.38[a]	1.32[ab]	1.35	1.74[a]	1.63[a]	1.68
1.10	1.35[a]	1.29[a]	1.32	1.72[a]	1.60[a]	1.66
1.15	1.32[a]	1.29[a]	1.30	1.73[a]	1.61[a]	1.67
1.20	1.32[a]	1.24[a]	1.28	1.70[a]	1.58[a]	1.64
Mean[1]	1.55[b]	1.40[a]		1.85[b]	1.70[a]	

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

14 days old; thus, environmental temperatures had an impact at a very early age. A dietary lysine level of either 1.05% for 2-week-old cockerels or 1.00% for 4-week-old cockerels was required to maximize chick weights in the warm environment.

Feed was more efficiently used when 1.05% dietary lysine was fed to 1-day-old to 2-week-old cockerels reared in either the cool or the warm environment (Table 5). Feed was also more efficiently used when 1.05% dietary lysine was fed to 1-day-old to 4-week-old cockerels in the cool environment. However, in the warm environment feed was more efficiently used when 0.95% dietary lysine was fed to 1-day-old to 4-week-old cockerels. Average feed conversion was less in the cool environment.

Plasma free amino acid concentrations for 4-week-old cockerels fed different dietary lysine levels are shown in Table 6 (cool environment) and Table 7 (warm environment). Total plasma free amino acids reached a peak at 1.05% dietary lysine in the cool environment and 0.95% dietary lysine in the warm environment.

Plasma free lysine of 4-week-old cockerels increased with increasing dietary lysine until the dietary lysine level of 1.05% was reached (Table 6). Threonine decreased with increasing dietary lysine levels for chicks reared in the cool environment. Plasma free arginine was greater for chicks reared in the cool environment when 0.90% dietary lysine as compared to 0.85% dietary lysine was fed.

When chicks were reared in the warm environment, plasma free lysine increased with increasing dietary lysine levels (Table 7). As was apparent in the cool environment, plasma threonine decreased with increasing dietary lysine until the dietary lysine level of 1.10% was fed to chicks. Differences in plasma arginine due to feeding dietary lysine were not significant.

Differences in glutamic acid in the cool environment were not significant. Also, when chicks were reared in the warm environment, differences in histidine, phenylalanine, arginine, alanine, and glycine due to feeding dietary lysine were not significant. Total plasma free amino acids were approximately 25% greater from chicks grown in the cool environment than from chicks grown in the warm environment (Tables 6 and 7).

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TABLE 6.—*Effect of dietary lysine on plasma amino acid concentrations from 4-week-old broilers in the cool environment (experiment 2)*

Amino acid	Plasma amino acid concentrations, ug./ml.								
	Dietary lysine, %[1]								
	.85	.90	.95	1.00	1.05	1.10	1.15	1.20	Mean
Essential									
Methionine	26.06^{b}	28.50^{ab}	31.34^{a}	31.88^{a}	33.72^{a}	29.12^{ab}	20.66^{c}	19.34^{c}	27.58
Cystine	18.04^{b}	21.54^{a}	22.82^{a}	21.99^{a}	24.57^{a}	23.12^{a}	15.52^{b}	15.52^{b}	20.39
Lysine	58.28^{c}	63.72^{c}	100.12^{b}	110.35^{b}	152.53^{a}	156.79^{a}	152.78^{a}	143.90^{a}	117.31
Arginine	73.23^{b}	117.24^{a}	120.02^{a}	121.12^{a}	129.45^{a}	120.40^{a}	70.58^{b}	74.46^{b}	103.31
Threonine	176.70^{a}	149.01^{ab}	154.88^{ab}	150.92^{ab}	139.94^{b}	125.29^{bc}	108.77^{cd}	79.74^{d}	135.66
Valine	46.16^{b}	46.79^{b}	55.82^{ab}	54.68^{ab}	60.44^{a}	62.69^{a}	43.93^{b}	42.20^{b}	51.59
Leucine	49.84^{d}	66.84^{c}	76.49^{b}	79.82^{b}	97.43^{a}	102.37^{a}	65.51^{c}	66.23^{c}	75.57
Histidine	40.30^{abc}	33.41^{bcd}	44.41^{a}	40.82^{abc}	42.38^{ab}	38.40^{abcd}	28.72^{d}	31.27^{cd}	37.46
Phenylalanine	37.38^{b}	47.53^{ab}	47.44^{ab}	47.26^{ab}	57.58^{a}	53.30^{a}	40.12^{b}	39.22^{b}	46.23
Isoleucine	22.70^{c}	24.46^{bc}	27.76^{abc}	27.49^{abc}	31.36^{a}	30.05^{ab}	23.39^{c}	22.13^{c}	26.17
Non-essential									
Tyrosine	52.28^{b}	54.53^{b}	56.10^{b}	52.92^{b}	62.74^{ab}	70.28^{a}	50.66^{b}	50.07^{b}	56.20
Glycine	57.31^{bcd}	60.99^{abcd}	63.40^{abc}	62.31^{abcd}	70.09^{a}	66.96^{ab}	50.58^{d}	32.37^{cd}	60.50
Glutamic acid	74.52^{a}	65.12^{a}	79.14^{a}	72.58^{a}	70.52^{a}	72.40^{a}	71.12^{a}	66.02^{a}	71.43
Aspartic acid	21.00^{d}	21.51^{cd}	27.11^{abcd}	27.60^{abc}	29.93^{ab}	29.76^{ab}	30.85^{a}	23.98^{bcd}	26.47
Serine	117.18^{a}	103.00^{a}	116.23^{a}	115.30^{a}	117.06^{a}	112.79^{a}	82.72^{b}	81.12^{b}	105.68
Alanine	110.08^{cd}	128.62^{bc}	135.51^{abc}	144.10^{ab}	150.66^{ab}	163.43^{a}	154.36^{ab}	84.22^{d}	133.87
Total	981.06	1032.81	1158.59	1161.14	1270.40	1257.15	1010.27	891.79	1095.40

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

TABLE 7.–*Effect of dietary lysine on plasma amino acid concentrations from 4-week-old broilers reared in the warm environmental temperature (experiment 2)*

Amino acid	Plasma amino acid concentrations, ng./ml.								
	Dietary lysine, %[1]								
	.85	.90	.95	1.00	1.05	1.10	1.15	1.20	Mean
Essential									
Methionine	23.52^{a}	23.20^{a}	23.45^{a}	19.62^{ab}	18.03^{b}	19.85^{ab}	21.50^{ab}	21.20^{ab}	21.30
Cystine	18.61^{b}	17.46^{bc}	22.21^{a}	18.07^{b}	14.13^{c}	15.44^{bc}	16.34^{bc}	15.72^{bc}	17.25
Lysine	15.82^{e}	19.29^{e}	27.36^{e}	48.89^{d}	59.23^{d}	73.00^{c}	101.81^{b}	134.78^{a}	60.02
Arginine	70.13^{a}	76.12^{a}	90.37^{a}	76.74^{a}	68.25^{a}	61.22^{a}	61.96^{a}	62.12^{a}	70.86
Threonine	170.39^{a}	145.70^{ab}	129.42^{b}	123.15^{b}	89.09^{b}	87.86^{c}	87.66^{c}	86.64^{c}	114.99
Valine	28.90^{c}	33.40^{bc}	37.89^{abc}	39.82^{abc}	42.36^{abc}	44.53^{ab}	44.22^{ab}	48.02^{a}	39.89
Leucine	51.36^{b}	58.85^{ab}	67.43^{a}	66.02^{a}	60.89^{ab}	67.94^{a}	66.29^{a}	60.08^{ab}	62.36
Histidine	27.69^{a}	27.29^{a}	27.40^{a}	29.76^{a}	27.83^{a}	32.32^{a}	34.60^{a}	34.61^{a}	30.19
Phenylalanine	39.52^{a}	38.03^{a}	40.69^{a}	38.82^{a}	36.84^{a}	37.45^{a}	36.37^{a}	34.88^{a}	37.82
Isoleucine	16.10^{c}	18.60^{bc}	23.45^{ab}	23.07^{ab}	19.10^{bc}	21.61^{abc}	22.76^{ab}	25.24^{a}	21.24
Non-essential									
Tyrosine	69.52^{a}	66.79^{ab}	67.56^{ab}	67.66^{ab}	59.03^{abc}	55.34^{bcd}	53.74^{cd}	46.28^{d}	60.74
Glycine	53.35^{a}	48.21^{a}	55.52^{a}	50.91^{a}	44.46^{a}	44.65^{a}	46.89^{a}	44.65^{a}	48.58
Glutamic acid	63.17^{b}	63.55^{b}	63.13^{b}	73.76^{ab}	63.32^{b}	80.43^{ab}	83.88^{a}	85.60^{a}	72.10
Aspartic acid	17.88^{c}	18.93^{c}	18.94^{c}	22.46^{bc}	23.88^{bc}	27.40^{b}	36.72^{a}	37.11^{a}	25.42
Serine	83.72^{ab}	73.09^{ab}	91.72^{a}	74.52^{ab}	75.63^{ab}	76.60^{ab}	75.72^{ab}	66.78^{b}	77.22
Alanine	71.26^{a}	70.22^{a}	94.08^{a}	99.58^{a}	89.35^{a}	90.20^{a}	85.01^{a}	73.86^{a}	84.20
Total	820.94	798.73	880.62	872.85	791.42	835.84	875.47	877.57	842.11

[1] Means within a column or row and without a common superscript are significantly different ($P<0.05$).

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