Performance and Carcass Composition of Broilers under Heat Stress : II. The Effects of Dietary Lysine

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ABSTRACT : An experiment was conducted to determine the effect of lysine on performance and carcass composition of broilers under heat stress during the grower period (3-6 weeks). A factorial arrangement of three levels of dietary protein (18, 20, and 22%), three levels of dietary lysine (1.26, 1.39, and 1.52%), and two rearing temperature regimens were used in this study. Birds were kept under either moderate temperature (24±1℃/24 h) or hot cycling temperature (26-34℃/6 h, 34±1℃/12 h, and 34-26℃/6 h). Body weight (BW), weight gain (WG), feed intake (FI), feed conversion (FE), carcass weight (CW), carcass yield (CY), and percentages of breast meat (BM), abdominal fat (AF), drumsticks (DS), and thighs (TH) were determined at the end of experiment. Exposure to high ambient temperature significantly ($p<0.05$) decreased BW, WG, FI, FE, CW, BM, AF, and increased CY, DS, and TH. High dietary protein significantly ($p<0.05$) decreased AF and TH, and improved CW only under moderate temperature, resulting in significant ($p<0.05$) protein by temperature interaction. High dietary lysine significantly ($p<0.05$) decreased BW, WG, FI, CW, CY and AF, while BM was reduced only when high dietary protein was fed, resulting in significant ($p<0.05$) protein by lysine interaction. It is concluded that increasing dietary lysine adversely affected broilers' performance and carcass composition irrespective of rearing temperature. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 923-931*)

Key Words : Heat Stress, Lysine, Broilers, Performance

INTRODUCTION

Lysine is the second most limiting amino acid when broilers are fed corn-soybean basal diets. Reports on lysine requirements under moderate temperature during the growing period (3-6 wk) are few particularly under heat stress. Hickling et al. (1990), Moran and Bilgili (1990), Holsheimer and Veerkamp (1992), and Holsheimer and Ruesink (1993) reported that increasing lysine level improved gain, oven ready yield, and deposition of carcass protein and breast meat yield under thermoneutral temperature. Sibbald and Wolynetz (1986), Moran (1988), Summers et al. (1988), and Hickling et al. (1990), reported that increasing dietary lysine increased breast meat yield and reduced fat deposition. Moreover, Morris et al. (1987), Abebe and Morris (1990), and Han and Baker (1994) found that lysine needed to maximize feed conversion was higher than that needed to maximize growth.

There are few, and conflicting reports that investigated lysine requirements of broilers at high temperature. McNaughton et al. (1978) reported that the lysine requirement for maximal weight gain and feed conversion at high temperature was less than that needed at moderate temperature. In contrast, Han and Baker (1993) reported that heat stress increased the lysine requirement of female but not male chickens. More recently, Mendes et al. (1997) found that increasing lysine levels up to 1.2% did not improve weight gain, breast meat yield or attenuate the adverse effects of heat stress. Most of the studies reported on lysine involved moderate increase in dietary lysine and were mostly conducted at constant dietary protein level. Therefore, it was necessary to investigate further the effect of increasing dietary lysine in combination with various dietary protein concentrations on performance and carcass composition of broiler chicks under heat stress.

MATERIALS AND METHODS

Birds and husbandry

One thousand and eight 1-day-old Hybro chicks obtained from a local hatchery were assigned randomly to 36 floor pens (1.6×1.0 m) with 32 males or females/pen. Each pen was equipped with a tubular hanging feeder and an automatic waterer.

Birds were brooded at 33℃ during the first week with the brooding temperature being reduced (3℃/week) to approximately 24℃. Light was provided continually using incandescent lamps. All birds were vaccinated against Newcastle disease at one and 21 days of age. During the starter period (0 to 3 wk), chicks received a starter diet that met or exceeded all nutrient specifications of the NRC (1994) (table 1).

The experiment started on day 22. On this day, all birds were individually weighed and divided into similar weight groups (72 groups) of seven males and seven females per group (14 birds/pen). A factorial

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Table 1. Composition of the experimental diets (g/kg)

Ingredients	Starter	Grower								
		A	B	C	D	E	F	G	H	J
Corn	459.0	555.3	559.0	562.7	626.1	629.8	633.6	697.9	702.7	707.5
Soybean meal	410.7	359.6	354.9	350.2	297.8	293.1	288.3	234.5	228.5	222.6
Vegetable oil	78.3	36.0	35.0	34.0	23.6	22.6	21.5	10.9	9.7	8.4
Limestone	6.9	10.1	10.1	10.1	10.2	10.3	10.3	10.4	10.4	10.4
Dical phosphate	15.8	10.6	10.6	10.7	11.1	11.1	11.2	11.6	11.7	11.7
Vitamin-minaral[1]	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
DL-Methionine	0.0	0.1	0.2	0.2	0.7	0.7	0.8	1.3	1.4	1.4
L-Lysine	0.0	0.1	2.0	3.9	2.3	4.2	6.2	4.6	6.5	8.5
L-Thrionine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.8
L-Arginine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4
Salt (NaCl)	4.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Calculated analysis										
MEn, kcal/g	3.20	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05	3.05
CP, %	23.00	22.00	22.00	22.00	20.00	20.00	20.00	18.00	18.00	18.00
Lysine, %	1.38	1.26	1.39	1.52	1.26	1.39	1.52	1.26	1.39	1.52
TSAA, %	0.90	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
Methionine	0.54	0.45	0.45	0.45	0.48	0.48	0.48	0.51	0.52	0.52
Thrionine, %	0.92	0.87	0.86	0.85	0.78	0.78	0.78	0.78	0.78	0.78
Arginine, %	1.58	1.46	1.44	1.43	1.29	1.28	1.26	1.12	1.12	1.12
Tryptophan	0.30	0.27	0.27	0.27	0.24	0.24	0.24	0.21	0.21	0.20
Leucine	1.95	1.88	1.86	1.85	1.74	1.72	1.71	1.59	1.58	1.56
Isoleucine	1.15	1.07	1.06	1.06	0.94	0.93	0.92	0.82	0.81	0.79
Histidine	0.56	0.52	0.52	0.52	0.47	0.46	0.46	0.41	0.40	0.40
Valine	0.96	0.84	0.83	0.82	0.70	0.69	0.68	0.55	0.54	0.52
Phenylalanine	0.93	0.82	0.81	0.80	0.68	0.67	0.66	0.53	0.52	0.51
Cystein	0.36	0.34	0.34	0.34	0.31	0.31	0.31	0.28	0.27	0.27
Glycine	1.11	1.03	1.02	1.01	0.91	0.90	0.90	0.80	0.78	0.77
Serine	1.20	1.10	1.09	1.08	0.98	0.97	0.96	0.85	0.84	0.83
Tyrosine	0.53	0.46	0.45	0.45	0.38	0.38	0.37	0.30	0.29	0.29
Ca, %	1.00	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Available P, %	0.45	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Na, %	0.20	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Determined analysis										
CP, %	23.6	21.27	21.80	21.62	19.97	20.20	20.22	18.65	17.49	18.56

[1] Provided the following per kg of diet: vitamin A, 12,000 IU; vitamin D_3, 7,200 ICU; vitamin E, 20 IU; vitamin B_1, 2.5 mg; vitamin B_2, 5 mg; vitamin K, 3 mg; vitamin B_{12}, 1.5 ppb; pyridoxine, 0.225 ppb; pantothenic acid, 10 mg; niacin, 35 mg; choline chloride, 500 mg; folic acid, 1.5 mg; biotin, 0.1 mg; virginiamycin, 20 mg; antioxidant, 125 mg; Mn, 90 mg; Cu, 7.5 mg; Zn, 65 mg; Fe, 50 mg; Se, 0.1 mg.

arrangement of two environmental temperatures, three levels of protein and three levels of lysine was used during the period of 22-42 d. Thirty-six groups of birds were kept under approximately 24±1℃ for 24 h/day (moderate temperature) in one section of the house. The other thirty-six groups were housed in another section of the house under hot cycling temperature of 26-34℃ for 6 h, 34±1℃ for 12 h, and 34-26℃ for 6 h (high temperature).

Dietary treatments were a factorial arrangement of three protein levels (18, 20 and 22 %) and three lysine levels (1.26, 1.39 and 1.52%). Dietary protein was varied while maintaining minimal essential amino acids in order to determine whether the response of the birds was due to nonspecific nitrogen or to lysine per se. Each dietary treatment was randomly allocated to four replicate pens under each temperature regimen. Feed and water were provided *ad libitum*. Diets' composition, calculated and determined analysis are shown in table 1. Crude protein was determined by Kjeldahl procedure (Association of Official Analytical Chemists, 1984).

Measurements

Body weight was determined by pen at 22 and 42 days of age and average daily gain was calculated.

Feed was weighed back on day 42 and the average daily feed intake and feed conversion (feed:gain) were determined for the period of 22-42 d.

On day 42, all birds were deprived of feed for approximately 12 h before being slaughtered for carcass composition measurements. Three males and three females per pen were taken randomly (12 males and 12 females/treatment). At the time of slaughter, fasted body weight of each bird was recorded. Birds were exanguinated for approximately 2 minutes, scalded at 60℃ for approximately 1.5 minutes, then placed into a rotary drum mechanical picker for 1 minute. After the shanks, feet and head were removed, carcass was eviscerated by cutting around the vent to remove all of entrails except the lungs and kidneys. Carcass weight without giblets was weighed to determine dressing yield percentage. Abdominal fat pad was removed and weighed. Breast meat, drumsticks, and thighs were separated and weighed. All weights were recorded to the nearest gram.

Statistical analysis

Performance data were statistically analyzed by three-way ANOVA using the General Linear Models procedure of SAS (SAS Institute, 1985). The following model was used:

$$Y_{ijnk} = \mu + P_i + L_j + T_n + PL_{ij} + PT_{in} + LT_{jn} + PLT_{ijn} + e_{ijnk}$$

Where Y_{ijnk} is the individual observation; μ is the experimental mean; P_i is the effect of i^{th} protein level; L_j is the effect of j^{th} lysine level, T_n is the effect of the n^{th} temperature; PL_{ij} is the protein by lysine interaction; PT_{in} is the protein by temperature interaction; LT_{jn} is the lysine by temperature interaction; PLT_{ijn} is the protein by lysine by temperature interaction; e_{ijnk} is random error.

Carcass composition data were analyzed by four-way ANOVA using the General Linear Models Procedure of SAS (SAS Institute, 1985). The following model was used:

$$Y_{ijnmk} = \mu + P_i + L_j + T_n + S_m + PL_{ij} + PT_{in} + PS_{im} + LT_{jn} + LS_{jm} + TS_{nm} + PLT_{ijn} + PLS_{ijm} + PTS_{inm} + LTS_{jnm} + PLTS_{ijnm} + e_{ijnmk}$$

Where Y_{ijnmk} is the individual observation; is the experimental mean; P_i is the effect of i^{th} protein level; L_j is the effect of j^{th} lysine level, T_n is the effect of the n^{th} temperature; S_m is the effect of the m^{th} sex, PL_{ij} is the protein by lysine interaction; PT_{in} is the protein by temperature interaction; PS_{im} is the protein by sex interaction; LT_{jn} is the lysine by temperature interaction; LS_{jm} is the lysine by sex interaction; TS_{nm} is the temperature by sex interaction; PLT_{ijn} is the protein by lysine by temperature interaction; PLS_{ijm} is the protein by lysine by sex interaction; PTS_{inm} is the protein by temperature by sex interaction; LTS_{jnm} is the lysine by temperature by sex interaction; $PLTS_{ijnm}$ is the protein by lysine by temperature by sex interaction; e_{ijnmk} is random error.

Percentage data were subjected to arc sine transformation prior to analysis (Snedecor and Cochran, 1980); however, actual percentage data are reported. Statements of statistical significance were based on $p \leq 0.05$.

RESULTS

Performance

Body weight and weight gain data are summarized in table 2. High temperature or high dietary lysine (1.52%) significantly reduced body weight and weight gain. Dietary protein level had no effect on either of these measurements. There were no significant interactions on body weight and weight gain.

Table 2. The effect of temperature, dietary protein and lysine on body weight and weight gain of broilers between 22 and 42 days of age

Protein (%)	Lysine (%)	Body weight (g)		Weight gain (g/d)	
		Temperature[1]			
		High	Moderate	High	Moderate
18	1.26	1613	1816	43.3	53.0
	1.39	1613	1813	43.5	52.8
	1.52	1503	1794	38.1	51.8
20	1.26	1616	1830	43.5	53.7
	1.39	1536	1876	40.1	55.8
	1.52	1557	1832	40.8	53.7
22	1.26	1626	1844	43.9	54.4
	1.39	1579	1840	41.6	54.2
	1.52	1513	1781	38.8	51.5
SEM[2]		42		1.1	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0001	
Pretein (P)		0.8021		0.7550	
Lysine (L)		0.0445		0.0436	
T×P		0.6416		0.6764	
T×L		0.3579		0.4063	
P×L		0.8419		0.8660	
T×P×L		0.7287		0.7429	

[1] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).

[2] Standard error of the mean (n=4 replicates of 7 males and 7 females each).

Feed intake and feed conversion data are presented in table 3. High ambient temperature or high dietary lysine (1.52%) significantly reduced feed intake, while dietary protein had no effect on feed intake. Birds kept under moderate temperature had significantly improved feed conversion than those kept under high temperature. Dietary protein and dietary lysine had no effect on feed conversion. There were no significant interaction effects on feed intake or feed conversion.

Table 3. The effect of temperature, dietary protein and lysine on feed intake and conversion of broilers between 22 and 42 days of age

Protein (%)	Lysine (%)	Feed intake (g/d)		Feed conversion (g/g)	
		Temperature[1]			
		High	Moderate	High	Moderate
18	1.26	106.5	125.5	2.47	2.37
	1.39	106.0	121.3	2.44	2.30
	1.52	91.5	121.3	2.40	2.34
20	1.26	101.0	119.3	2.33	2.22
	1.39	103.0	121.3	2.55	2.20
	1.52	98.0	116.5	2.41	2.17
22	1.26	102.7	119.0	2.36	2.19
	1.39	97.3	121.0	2.34	2.23
	1.52	95.3	116.3	2.46	2.26
SEM[2]		3.1		0.07	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0001	
Pretein (P)		0.1606		0.1222	
Lysine (L)		0.0053		0.8599	
T×P		0.8018		0.3003	
T×L		0.3634		0.6778	
P×L		0.6216		0.4603	
T×P×L		0.2917		0.6292	

[1] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).

[2] Standard error of the mean (n=4 replicates of 7 males and 7 females each).

Daily protein and lysine intakes are shown in table 4. High ambient temperature significantly reduced daily protein and lysine intakes. Increasing dietary protein significantly increased daily protein intake proportional to each increment of dietary protein but had no effect on daily lysine intake. Similarly, daily lysine intake was significantly increased proportional to the increase in dietary lysine. This increase, however, was more pronounced for birds grown under moderate temperature resulting in significant temperature by dietary lysine interaction.

Table 4. The effect of temperature, dietary protein and lysine on protein intake and lysine intake of broilers between 22 and 42 days of age

Protein (%)	Lysine (%)	Protein intake (g/d)		Lysine intake (g/d)	
		Temperature[1]			
		High	Moderate	High	Moderate
18	1.26	19.17	22.59	1.34	1.58
	1.39	19.08	21.83	1.47	1.69
	1.52	16.47	21.83	1.39	1.84
20	1.26	20.20	23.85	1.27	1.50
	1.39	20.25	24.25	1.41	1.69
	1.52	19.60	23.30	1.49	1.77
22	1.26	22.59	26.18	1.29	1.50
	1.39	21.40	26.62	1.35	1.68
	1.52	20.96	25.58	1.45	1.77
SEM[2]		4.50		0.04	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0001	
Pretein (P)		0.0001		0.1815	
Lysine (L)		0.0054		0.0001	
T×P		0.5642		0.7468	
T×L		0.3840		0.0511	
P×L		0.7393		0.6679	
T×P×L		0.3285		0.2307	

[1] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).

[2] Standard error of the mean (n=4 replicates of 7 males and 7 females each).

Carcass composition

Carcass weight and carcass yield data are summarized in table 5. There were significant temperature, dietary lysine, sex, dietary protein by temperature interaction, and temperature by sex interaction effects on carcass weight. High temperature or dietary lysine (1.52%) significantly reduced carcass weight. Dietary protein level had no effect on carcass weight and carcass yield. Females' carcass weights were significantly lower than males'. As dietary protein increased, carcass weight increased only when birds were reared under moderate temperature resulting in significant dietary protein by temperature interaction. Males' carcass weights were reduced by high temperature more than that of females resulting in significant temperature by sex interaction. There were significant temperature and dietary lysine effects on carcass yield. High temperature significantly increased carcass yield, whereas dietary lysine (1.52%) significantly reduced carcass yield. Dietary protein level and sex had no effect on carcass yield. There were no significant interaction effects on carcass yield.

Table 5. The effect of temperature, dietary protein, lysine and sex on carcass weight and carcass yield of broilers at day 42 of age

Protein (%)	Lysine (%)	Sex[3]	Carcass weight[1] (g)		Carcass yield[2] (%)	
			Temperature[4]			
			High	Moderate	High	Moderate
18	1.26	F	1034	1129	68.7	67.4
	1.26	M	1122	1314	67.2	67.2
	1.39	F	976	1115	67.1	67.3
	1.39	M	1149	1252	68.5	67.2
	1.52	F	960	1083	67.0	66.0
	1.52	M	1101	1225	67.9	67.2
20	1.26	F	1005	1133	68.4	67.9
	1.26	M	1149	1353	67.6	67.0
	1.39	F	1016	1185	68.5	67.3
	1.39	M	1017	1322	68.7	67.1
	1.52	F	969	1134	68.7	67.4
	1.52	M	1150	1287	68.2	66.7
22	1.26	F	978	1140	68.7	66.5
	1.26	M	1113	1368	67.7	67.3
	1.39	F	998	1121	68.0	67.3
	1.39	M	1139	1388	68.3	67.5
	1.52	F	941	1111	67.7	66.6
	1.52	M	1028	1292	66.8	66.3
SEM[5]			37		0.53	
ANOVA (p-value)						
Temperature (T)			0.0001		0.0001	
Protein (P)			0.2268		0.1150	
Lysine (L)			0.0054		0.0326	
Sex (S)			0.0001		0.4506	
T×P			0.0461		0.6293	
T×L			0.9440		0.9349	
T×S			0.0247		0.5589	
P×L			0.5756		0.5607	
P×S			0.6021		0.2279	
L×S			0.8013		0.1233	
T×P×L			0.7768		0.6331	
T×P×S			0.3709		00.5377	
T×L×S			0.5577		0.1611	
P×L×S			0.3449		0.3148	
T×P×L×S			0.7414		0.8168	

[1] Carcass weight without giblets but with abdominal fat pad.
[2] Carcass yield (carcass weight/body weight following feed deprivation×100).
[3] F, females; M, males.
[4] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).
[5] Standard error of the mean (n=12).

Breast meat and abdominal fat weights as percentages of live body weight are summarized in table 6. Temperature, sex, and dietary protein by dietary lysine interaction significantly affected breast meat percentage. High temperature significantly reduced

Table 6. The effect of temperature, dietary protein, lysine and sex on breast and abdominal fat of broilers at day 42 of age

Protein (%)	Lysine (%)	Sex[2]	Breast[1] (%)		Abdominal fat[1] (%)	
			Temperature[3]			
			High	Moderate	High	Moderate
18	1.26	F	23.2	22.9	1.6	1.7
	1.26	M	21.9	22.8	1.8	1.6
	1.39	F	21.6	22.1	1.4	1.7
	1.39	M	21.4	22.6	1.2	1.2
	1.52	F	22.2	22.3	1.6	1.6
	1.52	M	22.6	22.8	1.3	1.3
20	1.26	F	22.4	23.7	1.6	1.7
	1.26	M	21.9	22.5	1.4	1.4
	1.39	F	21.8	23.3	1.4	1.5
	1.39	M	20.6	22.5	1.0	1.2
	1.52	F	22.8	23.4	1.3	1.3
	1.52	M	22.2	22.6	1.2	1.0
22	1.26	F	22.6	22.5	1.3	1.5
	1.26	M	21.1	22.3	1.2	1.3
	1.39	F	23.0	23.2	1.3	1.4
	1.39	M	22.7	23.5	1.1	1.4
	1.52	F	22.5	22.7	1.7	1.5
	1.52	M	21.5	22.2	1.0	1.2
SEM[4]			0.1		0.5	
ANOVA (p-value)						
Temperature (T)			0.0001		0.0043	
Protein (P)			0.7692		0.0332	
Lysine (L)			0.7521		0.0180	
Sex (S)			0.0028		0.0001	
T×P			0.1650		0.6200	
T×L			0.2092		0.1375	
T×S			0.1355		0.8210	
P×L			0.0006		0.2587	
P×S			0.0974		0.9487	
L×S			0.3024		0.3313	
T×P×L			0.7513		0.9060	
T×P×S			0.4051		0.5909	
T×L×S			0.8399		0.8816	
P×L×S			0.5383		0.3726	
T×P×L×S			0.8314		0.3034	

[1] As percentage of body weight.
[2] F, females; M, males.
[3] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).
[4] Standard error of the mean (n=12).

breast meat percentage. Breast meat percentage was significantly higher in females than in males. High dietary lysine (1.52%) significantly reduced breast meat percentage only when high dietary protein was fed. High temperature significantly decreased abdominal fat percentage. Increasing dietary protein to 20% or dietary lysine to 1.39% significantly reduced abdominal fat percentage and there was no further reduction in abdominal fat percentage with higher levels of dietary protein or dietary lysine. Abdominal fat percentage was significantly higher in females than in males. There were no significant interaction effects on abdominal fat percentage.

Drumsticks and thighs weights as percentages of live body weight are summarized in table 7. High temperature significantly increased drumsticks percentage. Drumsticks percentage was significantly higher in males than in females. Dietary protein and dietary lysine levels did not significantly affect drumsticks percentage. There were significant temperature, dietary protein, sex and dietary protein by dietary lysine interaction effects on thighs percentage. High temperature significantly increased, while high dietary protein (22%) significantly reduced, thighs percentage. Thighs percentage was significantly higher in males than in females. High dietary lysine reduced thighs percentage only when high dietary protein was fed resulting in significant dietary protein by dietary lysine interaction.

Table 7. The effect of temperature, dietary protein, lysine and sex on thighs and drumsticks of broilers at day 42 of age

Protein (%)	Lysine (%)	Sex[2]	Thighs[1] (%)		Drumsticks[1] (%)	
			Temperature[3]			
			High	Moderate	High	Moderate
18	1.26	F	11.6	11.1	10.6	10.6
	1.26	M	11.4	11.2	11.2	10.9
	1.39	F	11.3	11.1	11.0	10.6
	1.39	M	11.6	11.1	11.6	10.8
	1.52	F	11.5	11.2	10.8	10.5
	1.52	M	11.9	11.5	11.6	11.1
20	1.26	F	11.2	11.0	10.8	10.3
	1.26	M	11.3	11.4	11.1	11.0
	1.39	F	11.7	11.1	11.0	10.2
	1.39	M	12.9	11.3	11.5	10.7
	1.52	F	11.9	11.7	11.2	10.2
	1.52	M	12.1	11.4	11.2	10.6
22	1.26	F	11.5	10.9	10.7	10.4
	1.26	M	11.6	11.4	11.1	10.7
	1.39	F	11.1	10.9	10.6	10.3
	1.39	M	11.8	11.0	11.2	10.5
	1.52	F	11.2	11.1	10.9	10.5
	1.52	M	11.0	11.2	11.2	10.8
SEM[5]			0.6		0.3	
ANOVA (p-value)						
Temperature (T)			0.0001		0.0001	
Protein (P)			0.0021		0.1107	
Lysine (L)			0.2813		0.2944	
Sex (S)			0.0072		0.0007	
T×P			0.4887		0.7494	
T×L			0.1231		0.2927	
T×S			0.4022		0.3679	
P×L			0.0215		0.5897	
P×S			0.7868		0.3303	
L×S			0.2874		0.5631	
T×P×L			0.1090		0.7024	
T×P×S			0.5925		0.2677	
T×L×S			0.1052		0.7908	
P×L×S			0.3374		0.2688	
T×P×L×S			0.9162		0.6188	

[1] As percentage of body weight.

[2] F, females; M, males.

[3] Birds were kept at either hot cycling temperature of 26-34℃/6 h, 34±1℃/12 h and 34-26℃/6 h (High) or constant 24±1℃ (moderate).

[4] Standard error of the mean (n=12).

DISCUSSION

Heat stress adversely affects broiler performance and carcass composition. In the current experiment, high ambient temperature significantly reduced body weight, weight gain, and feed intake by about 14, 22, and 17%, respectively, and increased feed conversion ratio by about 8 when compared with moderate temperature. These results agree with previous finding of Al-Batshan and Hussein (1999) and others (Hurwitz et al., 1980; Austic, 1985; Cahaner and Leenstra, 1992; Cahaner et al., 1993; Belay and Tetter, 1996; Ain Baziz et al., 1996; Geraret et al., 1996; Mendes et al. 1997).

The depression in performance at high temperature is attributed partly to reduced feed consumption at high temperature (Dale and Fuller, 1980). Such reduction is expected to alter nutrient requirements during periods of heat stress. Therefore, the NRC (1994) suggested that high ambient temperature should be taken into consideration when diets are formulated. In order to compensate for the reduction in lysine intake, due to reduced feed intake under heat stress, excess dietary lysine levels were chosen in the current experiment. Despite that, excess levels of dietary lysine negatively affected almost all the parameters investigated in the current experiment. In addition, there were no significant interactions between temperature and dietary protein or dietary lysine on chicks' performance indicating that the effects of dietary protein and dietary lysine were similar under both temperatures.

High temperature, also, significantly decreased carcass weight and breast meat percentage by about 14 and 3%, respectively, but increased carcass yield, thighs percentage, and drumsticks percentage by about 1, 4, and 7%, respectively, compared with moderate temperature. These results are similar to those reported by Howlider and Rose (1989), Cahaner and Leenstra (1992), Smith (1993), Cahaner et al. (1993), and Mendes et al. (1997). There was an inconsistent effect of high ambient temperature on abdominal fat content. In the present experiment abdominal fat percentage was significantly reduced at high temperature by about 8%, thus contrasting with EL-Husseiny and Creger (1980), Balnave and Oliva (1991), and Mendes et al. (1997) who reported enhanced deposition of abdominal fat during high ambient temperature. On the other hand, no differences in abdominal fat of broilers reared at 26.7℃ or 21.1℃ (Suk and Washburn, 1995), or at high cycling temperature (Ain Baziz et al. 1996; Al-Batshan and Hussein, 1999) were reported. These discrepancies might be explained on the basis that birds of varied inherent growth rate respond differently to dietary manipulation (Cahaner et al., 1995).

The effect of dietary protein in isoenergetic diets on broiler performance at high temperature was investigated in many studies which showed that high dietary protein failed to improve broiler performance at high temperatures (Kubena et al., 1972; Cowan and Michie, 1978; Sinurat and Balnave, 1985). This is, also, in agreement with the results of current experiment. In contrast, Cahaner et al. (1995) observed that high dietary protein reduced weight gain as compared with low dietary protein. Moreover, under similar settings and experimental conditions used in the current experiment, Al-Batshan and Hussein (1999) reported that increasing dietary protein from 18 to 22% improved broilers' performance irrespective of ambient temperature. These contrasting results in broilers' response to dietary protein level could be explained by variation in dietary amino acids concentrations. In the current experiment, TSAA, for example, were held constant across dietary protein levels, whereas in the trail reported by Al-Batshan and Hussein (1999) dietary TSAA increased as dietary protein increased.

In the current experiment, high dietary protein (22%) significantly increased carcass weight only at moderate temperature. Abdominal fat percentage was significantly reduced when high dietary protein level was used. This is in agreement with results of others (Bedford and Summers 1985; Leenstra, 1986; Fancher and Jensen, 1989; Marks, 1990; Wang et al., 1991; Moran et al., 1992).

There was no improvement in broiler performance, when high levels of dietary lysine were added at both temperatures. This result is in agreement with that of Mendes et al. (1997) who showed that high dietary lysine levels, in excess of the NRC (1994) recommendation, had no effect on male broilers reared under high cycling temperature.

Carcass composition, however, was affected negatively when high dietary lysine levels were fed. High dietary lysine level significantly depressed carcass weight, carcass yield, but reduced abdominal fat percentage. Mendes et al. (1997) reported that dietary lysine up to 1.2% had no effect on carcass yield. In the current experiment, however, increasing dietary lysine level more than 1.39% decreased carcass yield. The reduction in abdominal fat percentage with increased dietary lysine levels might have been a true response to this amino acids rather than a reflection of an increase in the overall crude protein per se, similar to that observed by Summers et al. (1965), Cabel et al. (1987), Cabel et al. (1988), and Cabel and Waldroup (1991). Increasing dietary lysine did not improve breast meat percentage under both high and moderate temperature, nor did it appear to differ from that needed for weight gain and feed conversion. This is agreeable with the finding of Mendes et al. (1997) who reported absence of consistent improvements in breast meat percentage when dietary lysine was increased beyond the NRC (1994) recommendation in hot and thermoneutral temperatures.

The depressing effect of excess dietary lysine could be the result of an antagonism with argnine, although we do not suspect such antagonism occurred because the high lysine diet was supplemented with synthetic argnine. Another explanation is the effect of excess intake of lysine that suppressed birds' appetite (Bartov, 1979; Murice, 1981) and hence performance.

The result of the present study indicated that increasing dietary lysine in excess of 1.26% adversely affected broiler performance and carcass composition; this effect was more pronounced when high dietary protein was fed.

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