Performance and Carcass Composition of Broilers under Heat Stress : I. The Effects of Dietary Energy and Protein

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ABSTRACT : An experiment was conducted to determine the effects of dietary energy and protein on performance and carcass composition of broilers under heat stress during the growing period (3-6 weeks). A factorial arrangement of three levels of energy (3.0, 3.2, and 3.4 kcal/g), three levels of protein (18, 20, and 22%), and two rearing temperatures were used in this study. Groups of birds were kept under 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 (feed : gain) (FC), carcass weight (CW), carcass yield (YP), breast meat (BM), abdominal fat (AF), drumsticks (DS), and thighs (TH) percentages were determined at the end of the experiment. Hot cycling temperature significantly ($p<0.05$) decreased BW, WG, FI, CW, and BM, increased FC, YP, DS, and TH but did not affect AF. High energy significantly ($p<0.05$) increased BW, WG, CW, YP, AF, and TH, decreased FI and FC but did not affect BM or DS. This improvement was observed only under moderate temperature resulting in significant ($p<0.05$) energy by temperature interaction. High protein significantly ($p<0.05$) increased BW, WG, CW and BM, decreased AF but did not affect FI, FC, YP, DS, or TH. There were no significant protein by temperature interactions for any of the parameters tested except CW. It is concluded, under the conditions imposed in this experiment, that increasing dietary energy did not alleviate the depressing effect of heat stress while increasing dietary protein up to 22% improved the performance of broilers irrespective of rearing temperature. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 6 : 914-922*)

Key Words : Heat Stress, Energy, Protein, Broilers, Performance

INTRODUCTION

There are few and conflicting reports that examined the interaction of environmental temperature and dietary nutrient concentrations on performance of broiler chicks. Hot ambient temperature has been shown to decrease broiler performance. Han and Baker (1993) reported that weight gain and feed intake were reduced in broiler chicks at high temperature. Hurwitz et al. (1980) and Cahaner et al. (1993) showed that growth rate and feed efficiency were adversely affected in broiler chicks reared under high temperature. Similarly, Cahaner and Leenstra (1992) reported that high temperature reduced body weight, body protein gain, and feed and protein efficiency.

The reduction in feed intake during periods of heat stress is expected to alter energy and protein intake. Therefore, attempts were made to alleviate the adverse effects of high ambient temperature by varying dietary energy and protein levels. Adams et al. (1962a) showed that increasing energy level did not reduce growth rate depression under hot cycling temperature. Mickelberry et al. (1966) and Dale and Fuller (1980) found that increasing energy level in the diet improved growth rate and feed conversion of broiler reared at 29℃. Similarly, Sinurat and Balnave (1985) and Lott et al. (1992) reported that increasing dietary energy increased growth and improved feed conversion at both high and thermoneutral temperatures.

Reduced intake of a complete diet implies a reduced intake of protein, which may partly account for the reduced growth rate under heat stress (Cowan and Michle, 1978). Combs (1970) suggested that increasing protein and/or amino acid concentration may be beneficial at high temperatures. Studies conducted with broiler kept at 21 or 32℃ and fed diets containing increased concentration of protein showed that even when the intake of protein was the same at both temperature, growth rate was markedly reduced under high ambient temperature (Adams et al., 1962a, b; Adams and Rogler, 1968; Kubena et al., 1972). Similarly, Cowan and Michie (1978) reported that diets with increased concentration of protein did not appear to reduce the growth depression of broilers kept under 26 or 31℃.

Elevated ambient temperature has been shown to alter carcass traits. Howlider and Rose (1989) and Chwalibag and Eggum (1989) found that high environmental temperature increased fat content. Smith (1993) reported that whole carcass weight and carcass parts weight from birds reared at moderate temperature were greater than those reared at high temperature. Also, high temperature reduced yield of breast meat (Howlider and Rose, 1989) this reduction was higher in males than in females (Leenstra and Cahaner, 1992).

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The objective of this study is to test the effect of varying dietary energy and protein on performance and carcass composition of broiler chicks under heat stress (cycling hot temperature).

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 until it reached approximately 24℃. Light was provided continually using incandescent light. All birds were vaccinated against Newcastle diseases 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 National Research Council (NRC, 1994) (table 1).

On day 22, 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 arrangement of two environmental temperatures, three energy levels and three levels of protein were 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 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 (hot temperature).

Dietary treatments were a factorial arrangement of three energy levels (3.0, 3.2 and 3.4 kcal/g) and three protein levels (18, 20 and 22%). Each dietary treatment was randomly allocated to four replicate pens under each temperature regimen. Feed and water were provided for *ad libitum* consumption. Diet composition, calculated and determined analyses are shown in table 1. Crude protein was determined by Kjeldahl procedure (Association of Official Analytical Chemists, 1984).

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

Ingredients	Starter	Grower								
		A	B	C	D	E	F	G	H	J
Corn	462.8	676.3	600.8	529.2	629.2	553.6	482.5	582.1	506.4	435.7
Soybean meal	405.1	258.4	324.3	358.1	267.1	333.1	393.4	275.8	341.9	401.7
Vegetable oil	77.7	8.6	21.8	33.9	47.1	60.3	72.3	85.6	98.8	110.8
Limestone	11.6	12.3	12.2	12.0	12.2	12.0	11.9	12.1	11.9	11.8
Dical phosphate	12.1	11.4	10.8	10.3	11.5	10.9	10.5	11.6	11.1	10.6
Vitamin-mineral[1]	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
DL-Methionine	1.3	0.2	0.0	0.0	0.2	0.0	0.0	0.3	0.0	0.0
L-Lysine	0.0	3.1	0.7	0.0	2.9	0.5	0.0	2.7	0.3	0.0
L-Threonine	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.3	0.0	0.0
Salt (NaCl)	4.4	4.5	4.5	4.4	4.5	4.5	4.4	4.5	4.5	4.5
Calculated Analysis										
MEn, kcal/g	3.20	3.00	3.00	3.00	3.20	3.20	3.20	3.40	3.40	3.40
CP, %	23.00	18.00	20.00	22.00	18.00	20.00	22.00	18.00	20.00	22.00
Lysine, %	1.40	1.25	1.25	1.38	1.25	1.25	1.38	1.25	1.25	1.38
TSAA, %	0.94	0.76	0.81	0.86	0.76	0.81	0.86	0.76	0.81	0.86
Threonine, %	0.91	0.73	0.82	0.90	0.73	0.82	0.90	0.73	0.82	0.90
Arginine, %	1.56	1.19	1.36	1.53	1.19	1.37	1.53	1.20	1.38	1.54
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	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Determined Analysis										
CP, %	23.15	17.87	20.70	22.37	18.45	21.01	22.21	17.98	20.01	22.57

[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.

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 average daily feed intake and feed conversion (gram feed:gram gain) were determined for the period of 22-42 d. Mortality was recorded daily during the experiment.

On day 42, all birds were deprived of feed for approximately 12 h before being slaughter 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 obtained before it was killed by exsanguination. Birds were bled for approximately 2 minutes, scalded at 60℃ for approximately 1.5 minutes, and were 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 without giblets was weighed to determine carcass yield. Abdominal fat pad was removed and weighed. Breast, 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:

$$Y_{ijnk} = \mu + E_i + P_j + T_n + EP_{ij} + ET_{in} + PT_{jn} + EPT_{ijn} + e_{ijnk}$$

Where Y_{ijnk} is the individual observation; μ is the experimental mean; E_i is the effect of i^{th} energy level; P_j is the effect of j^{th} protein level, T_n is the effect of the nth temperature; EP_{ij} is the energy by protein interaction; ET_{in} is the energy by temperature interaction; PT_{jn} is the protein by temperature interaction; EPT_{ijn} is the energy by protein 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:

$$Y_{ijnmk} = \mu + E_i + P_j + T_n + S_m + EP_{ij} + ET_{in} + ES_{im} + PT_{jn} + PS_{jm} + TS_{nm} + EPT_{ijn} + EPS_{ijm} + ETS_{inm} + PTS_{jnm} + EPTS_{ijnm} + e_{ijnmk}$$

Where Y_{ijnmk} is the individual observation; μ is the experimental mean; E_i is the effect of i^{th} energy level; P_j is the effect of j^{th} protein level, T_n is the effect of the n^{th} temperature; S_m is the effect of the m^{th} sex; EP_{ij} is the energy by protein interaction; ET_{in} is the energy by temperature interaction; ES_{im} is the energy by sex interaction; PT_{jn} is the protein by temperature interaction; PS_{jm} is the protein by sex interaction; TS_{nm} is the temperature by sex interaction; EPT_{ijn} is the energy by protein by temperature interaction; EPS_{ijm} is the energy by protein by sex interaction; ETS_{inm} is the energy by temperature by sex interaction; PTS_{jnm} is the protein by temperature by sex interaction; $EPTS_{ijnm}$ is the energy by protein by temperature by sex interaction; e_{ijnmk} is random error. Percentage data were subjected to arc sine transformation prior to analysis (Snedecor and Chocran, 1980); however, actual percentage data are reported. Statements of significance were based on $p \leq 0.05$.

RESULTS

Performance

There were significant temperature, dietary energy, dietary protein and dietary energy by temperature interaction effects on body weight (BW) and weight gain (WG) (table 2).

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

Energy (kcal/g)	Protein (%)	Body weight (g)		Weight gain (g/d)	
		Temperature[1]			
		High	Moderate	High	Moderate
3.0	18	1460	1500	38.2	40.1
	20	1356	1638	33.1	46.8
	22	1528	1720	41.4	50.6
3.2	18	1379	1634	34.5	46.4
	20	1369	1615	34.1	45.4
	22	1449	1691	37.6	49.4
3.4	18	1448	1738	37.6	51.5
	20	1396	1786	35.5	53.6
	22	1452	1770	37.6	53.1
SEM[2]		36		2.6	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0001	
Energy (E)		0.0400		0.0392	
Protein (P)		0.0269		0.0299	
T×E		0.0415		0.0471	
T×P		0.2215		0.2384	
E×P		0.5102		0.5209	
T×E×P		0.5862		0.5756	

[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).

Hot cycling temperature significantly reduced BW and WG. Increasing energy level improved BW and WG for birds that were kept at moderate temperature but not at hot cycling temperature resulting in significant energy by temperature interaction. High levels of protein significantly improved BW and WG irrespective of temperature.

Hot cycling temperature and high dietary energy significantly reduced feed intake (table 3).

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

Energy (kcal/g)	Protein (%)	Feed intake (g/d)		Feed conversion (g/g)	
		Temperature[1]			
		High	Moderate	High	Moderate
3.0	18	94.0	106.9	2.47	2.87
	20	87.2	112.0	2.64	2.40
	22	100.6	112.1	2.44	2.22
3.2	18	86.9	106.0	2.54	2.29
	20	86.1	100.9	2.58	2.16
	22	89.8	108.5	2.40	2.20
3.4	18	86.5	108.6	2.34	2.11
	20	84.0	109.4	2.37	2.04
	22	82.9	106.6	2.21	2.01
SEM[2]		3.2		0.14	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0127	
Energy (E)		0.0034		0.0009	
Protein (P)		0.1900		0.0697	
T×E		0.1157		0.2745	
T×P		0.5434		0.2632	
E×P		0.2560		0.7928	
T×E×P		0.3559		0.3988	

[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 conversion (FC) of birds that were kept under moderate temperature was significantly better than those kept under hot cycling temperature. High dietary energy significantly improved FC at both temperatures while dietary protein did not influence FC (table 3). Mortality (data not shown) was not affected by treatments.

Daily intakes of energy and protein are presented in table 4. High ambient temperature significantly reduced daily energy intake and protein intake. Increasing dietary energy significantly increased daily energy intake only for birds grown under moderate temperature resulting in significant dietary energy by temperature interaction. High dietary energy significantly reduced protein intake. Daily protein intake was significantly increased as dietary protein increased irrespective of rearing temperature or dietary energy level.

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

Energy (kcal/g)	Protein (%)	Energy intake (kcal/d)		Protein intake (g/d)	
		Temperature[1]			
		High	Moderate	High	Moderate
3.0	18	281.9	320.5	16.9	19.2
	20	261.5	336.0	17.4	22.4
	22	301.8	336.4	22.1	24.7
3.2	18	278.1	339.1	15.6	19.1
	20	275.9	323.0	17.2	20.2
	22	287.4	347.3	19.8	23.9
3.4	18	294.0	369.1	15.6	19.5
	20	285.5	371.9	16.8	21.9
	22	281.7	362.6	18.2	23.5
SEM[2]		10.3		0.6	
ANOVA (p-value)					
Temperature (T)		0.0001		0.0001	
Energy (E)		0.0012		0.0019	
Protein (P)		0.2220		0.0001	
T×E		0.0264		0.1011	
T×P		0.5784		0.3312	
E×P		0.2663		0.1374	
T×E×P		0.4036		0.3099	

[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 (CW) and carcass yield data are summarized in table 5. There were significant temperature, dietary energy, dietary protein, sex, dietary energy by temperature interaction, and dietary protein by temperature interaction effects on CW. Hot cycling temperature significantly reduced CW. As dietary energy or dietary protein increased, CW increased only when birds were reared under moderate temperature resulting in significant dietary energy by temperature and dietary protein by temperature interactions, respectively. Females CW were significantly lower than males. There were significant temperature, dietary energy, and dietary energy by temperature interaction effects on carcass yield. Hot cycling temperature significantly increased carcass yield. Increasing dietary energy increased carcass yield only when birds were reared under hot cycling temperature resulting in significant dietary energy by temperature interaction.

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

Energy (kcal/g)	Protein (%)	Sex[3]	Carcass weight[1] (g)		Carcass yield[2] (%)	
			Temperature[4]			
			High	Moderate	High	Moderate
3.0	18	F	936	946	68.4	65.0
		M	1099	1037	67.5	65.7
	20	F	974	1018	66.9	64.3
		M	979	1095	70.9	67.8
	22	F	969	1112	67.0	66.8
		M	1007	1233	66.6	66.4
3.2	18	F	933	959	67.3	66.7
		M	973	1213	66.8	66.6
	20	F	843	999	66.7	66.9
		M	964	1247	66.1	67.4
	22	F	885	1125	67.4	67.9
		M	1037	1180	67.8	66.9
3.4	18	F	874	1121	67.6	67.8
		M	1070	1238	68.1	68.0
	20	F	916	1142	68.3	66.3
		M	986	1224	68.9	66.7
	22	F	936	1126	68.2	67.4
		M	1087	1257	68.5	68.9
SEM[5]			47		0.9	
ANOVA (p-value)						
Temperature (T)			0.0001		0.0041	
Energy (E)			0.0040		0.0400	
Protein (P)			0.0047		0.6220	
Sex (S)			0.0001		0.1102	
T×E			0.0545		0.0314	
T×P			0.0345		0.2554	
T×S			0.7436		0.7728	
E×P			0.5691		0.3056	
E×S			0.7779		0.2225	
P×S			0.5584		0.0952	
T×E×P			0.2265		0.1355	
T×E×S			0.2900		0.9799	
T×P×S			0.8485		0.8825	
E×P×S			0.5574		0.0717	
T×E×P×S			0.0959		0.7186	

[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 data are summarized in table 6. Breast meat was significantly affected by temperature, dietary protein, dietary energy by temperature interaction, and dietary protein by sex interaction. Hot cycling temperature significantly reduced breast meat.

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

Energy (kcal/g)	Protein (%)	Sex[2]	Breast[1] (%)		Abdominal fat[1] (%)	
			Temperature[3]			
			High	Moderate	High	Moderate
3.0	18	F	21.2	20.8	1.7	1.2
		M	21.1	20.6	1.0	1.1
	20	F	20.9	21.0	1.2	1.3
		M	22.9	22.2	1.0	0.9
	22	F	22.4	22.7	0.7	1.0
		M	21.7	22.0	1.7	1.0
3.2	18	F	21.2	21.4	1.5	1.6
		M	20.2	21.4	1.3	1.4
	20	F	20.2	21.4	1.5	1.3
		M	19.9	22.3	1.1	1.0
	22	F	20.9	22.7	1.1	1.3
		M	20.7	21.7	1.1	0.7
3.4	18	F	20.8	21.5	1.5	2.0
		M	20.8	21.2	1.3	1.7
	20	F	21.2	20.1	1.4	1.5
		M	21.2	21.3	1.3	1.0
	22	F	21.3	22.2	1.3	1.1
		M	21.1	21.8	1.2	0.9
SEM[4]			0.5		0.2	
ANOVA (p-value)						
Temperature (T)			0.0057		0.6832	
Energy (E)			0.0739		0.0032	
Protein (P)			0.0012		0.0001	
Sex (S)			0.9657		0.0001	
T×E			0.0024		0.9485	
T×P			0.3548		0.8660	
T×S			0.7755		0.2235	
E×P			0.2980		0.9223	
E×S			0.5391		0.8318	
P×S			0.0036		0.7022	
T×E×P			0.3713		0.1106	
T×E×S			0.5566		0.3354	
T×P×S			0.6010		0.2735	
E×P×S			0.6495		0.7844	
T×E×P×S			0.5741		0.3742	

[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).

High dietary protein significantly increased breast meat. Increasing dietary energy increased breast meat only when birds were reared under moderate temperature resulting in dietary energy by temperature interaction. As dietary protein increased, breast meat increased only in females resulting in significant dietary protein by sex interaction. Dietary energy, dietary protein and sex but not temperature affected abdominal fat. High dietary energy significantly increased abdominal fat. In contrast, high dietary protein significantly reduced abdominal fat. Abdominal fat was significantly higher in females than in males.

Temperature and sex (table 7) significantly affected drumstick percentage. Hot cycling temperature significantly increased drumsticks. Drumsticks were significantly higher in males than in females. There were significant temperature, energy, sex and energy by protein interaction effects on thigh percentage. High temperature and high dietary energy significantly increased thigh percentage. Thigh percentage was significantly higher in males than in females. Low dietary protein reduced percentage thighs only when low energy was fed, resulting in significant dietary protein by dietary energy interaction (table 7).

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

Energy (kcal/g)	Protein (%)	Sex[2]	Thighs[1] (%) Temperature[3] High	Thighs[1] (%) Temperature[3] Moderate	Drumsticks[1] (%) Temperature[3] High	Drumsticks[1] (%) Temperature[3] Moderate
3.0	18	F	10.9	9.6	10.1	9.5
		M	10.7	10.3	10.5	10.2
	20	F	10.9	10.6	9.9	9.2
		M	11.5	11.2	10.9	10.3
	22	F	10.9	10.6	10.0	9.9
		M	10.6	10.7	10.3	10.3
3.2	18	F	10.8	10.4	10.1	9.7
		M	10.7	10.8	10.3	10.1
	20	F	10.5	10.7	10.0	9.6
		M	10.7	11.0	10.4	10.3
	22	F	10.9	10.8	9.7	9.8
		M	10.7	10.8	10.3	10.2
3.4	18	F	10.6	10.9	10.1	10.0
		M	11.3	11.3	10.5	9.8
	20	F	10.9	10.7	10.2	10.0
		M	11.0	10.9	10.4	9.8
	22	F	11.0	10.9	10.0	9.8
		M	11.5	10.7	10.8	9.9
SEM[4]			0.3		0.3	
ANOVA (p-value)						
Temperature (T)			0.0364		0.0001	
Energy (E)			0.0099		0.6442	
Protein (P)			0.1012		0.9584	
Sex (S)			0.0113		0.0001	
T×E			0.0766		0.3435	
T×P			0.4887		0.5989	
T×S			0.4400		0.8163	
E×P			0.0296		0.8246	
E×S			0.6668		0.1564	
P×S			0.1527		0.8303	
T×E×P			0.0636		0.3533	
T×E×S			0.2151		0.2752	
T×P×S			0.6712		0.5596	
E×P×S			0.5924		0.1056	
T×E×P×S			0.8359		0.9748	

[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 reduces broiler performance during the growing period. This observation was demonstrated repeatedly by several work groups (Cowan and Michie, 1978; Sinurat and Balnave, 1985; Balnave and Oliva, 1991; Lott et al., 1992; Cahaner and Leenstra, 1992; Leenstra and Cahaner, 1992; Smith, 1993). Similarly, in the current experiment BW, FI, and WG were significantly reduced by approximately 15, 18, and 25%, respectively, and FC was increased by about 8%, under hot cycling temperature. Feed intake is inversely related to environmental temperature (Cowan and Michie, 1978; El Husseiny, 1980; Cerniglia et al., 1983). Heat stress is, thus, expected to reduce nutrients intake. Dale and Fuller (1980) showed that 63% of the depression in broiler performance under heat stress was the result of reduced feed intake. Therefore, the NRC (1994) suggested that nutrient concentration showed be adjusted when environmental temperature changes since the requirements are expressed as percentage of the diet.

Increasing dietary energy or protein mostly produces favorable results under thermoneutral conditions. This was clearly shown in the current experiment and by others (Dale and Fuller, 1980; Sinurat and Balnave, 1985; Holsheimer and Veerkamp, 1992; Lott et al., 1992).

In the current experiment, we examined different levels of dietary energy and protein to study the effect of hot cycling temperature on broiler chicks' performance. High dietary energy improved broiler performance at moderate temperature, but failed to improve performance under hot cycling temperature. Mickelberry et al. (1966), Dale and Fuller (1980), Sinurat and Balnave (1985) and Lott et al. (1992) reported that high dietary energy improved broiler performance under high temperature. In these studies, they used diets containing 3.2 to 3.5 kcal/g and high constant temperature of 29 to 35℃. Our results disagree with these reports. The results of the current experiment showed that dietary energy in the range of 3.2 to 3.4 kcal/g has little effect on broiler performance under heat stress. The different responses to energy level observed in the current experiment and those reported by other investigator could be explained by the use of hot cycling temperature and hot constant temperature, respectively.

Dale and Fuller (1980) reported that increasing dietary energy from 3.19 to 3.53 kcal/g improved weight gain by about 5.4% and feed conversion by about 12.4% in 14℃ environment but under 31℃ was only about 2.2 and 6.3% for weight gain and feed conversion, respectively. Similarly, Reece and McNaughton (1982) reported that high energy level improved body weigh by about 3.1% and feed conversion by about 5% at 18℃ but not at 26.7℃. Both of these studies involved moderate heat stress similar to the conditions (hot cycling temperature) imposed in the current experiment.

The beneficial effect of increasing dietary energy to alleviate heat stress was seen in extreme heat stress (as in the case of constant temperature) but not under moderate heat stress (as in the case of cyclic temperature). The conclusion is supported by the finding of Hurwitz et al. (1980), who showed that the maintenance energy requirement was low between 24 and 28℃, but increased as the temperature was raised. Therefore, improvement of broiler performance by increasing dietary energy was not seen in the current experiment since birds were maintained under the range of temperature of less than 30℃ for 12 h/d under which maintenance energy requirement were minimal.

The effect of dietary protein on broiler performance under heat stress is controversial. Combs (1970) suggested that increasing dietary protein and/or amino acids concentration might be beneficial under heat stress. However, several studies showed that increasing dietary protein did not appear to reduce growth depression under heat stress (Adams et al., 1962a, b; Adams and Rogler, 1968; Kubena et al., 1972; Cowan and Michie, 1978; Geraert et al., 1991).

In the current experiment, high dietary protein level improved most of parameters investigated irrespective of rearing temperature. This finding disagree with earlier reports. Several factors could explain these differences. First, broiler chicks of varied inherent growth rate, and protein and fat deposition respond differently to dietary protein when reared under heat stress (Cahaner and Leenstra, 1992; Cahaner et al., 1995). Second, the effect of dietary protein observed in the current experiment might be confounded by variation in dietary amino acids although all amino acids satisfied the minimal requirements. Third, most studies utilized constant high temperature to induce heat stress; whereas in the current experiment hot cycling temperature was used. Therefore, cycling temperature regimen would be expect to allow birds some relief from heat stress and to allow birds to dissipate heat increment associated with dietary protein when the temperature falls.

Hot cycling temperature decreased carcass weight, breast meat yield and increased carcass yield. This is in agreement with the finding of Smith (1993) and Ain Baziz et al. (1996) who reported that whole carcass weight and carcass parts weight from birds at low temperature were greater than those under hot cycling or constant temperature. Similarly, Howlider and Rose (1989) reported that hot temperature reduced yield of breast meat. Kubena et al. (1972), Howlider and Rose (1989) and Chwalibag and Eggum (1989) reported that hot environmental temperature increased fat content. However, abdominal fat was not affected by temperature in the current experiment.

High levels of dietary energy increased carcass weight, carcass yield and abdominal fat, but had no effect on breast meat yield. The effect of dietary energy on abdominal fat is in agreement with those reported by others (Griffiths et al., 1977; Summers and Leeson, 1979; Mabray and Woldroup, 1981; Jackson et al., 1982).

High levels of dietary protein in the current experiment increased percentage breast and decreased percentage of abdominal fat. Similarly, Bartov et al. (1974), Holsheimer (1975), Bedford and Summers (1985) and Fancher and Jensen (1989) found that increasing dietary protein content reduced abdominal fat pad and carcass fat and increased carcass protein content.

Fisher (1984) reported that reducing the energy to protein ratio increased lean tissue accretion and reduced abdominal fat deposition. The mechanism where by dietary protein suppresses carcass fat is not well understood. However, it has been speculated that the reduction in abdominal fat with high dietary protein could be attributed to an increase in energy expenditure and an increase in heat increment in degrading excess amino acids (Bartov, 1979).

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