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The Effect of Total Sulfur Amino Acids on Performance and Carcass Composition of Broilers under Heat Stress

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Abstract. An experiment was conducted to determine the effect of total sulfur amino acids (TSAA) on the performance of broiler chicks and carcass composition under heat stress during the growing period (3-6 weeks). A factorial arrangement of three levels of dietary protein (18, 20, and 22%), three levels of dietary TSAA (0.78, 0.86, and 0.94%), and two rearing temperatures was used in this study. Birds were kept under either moderate temperature (25±1 C/24 h) or hot cyclic temperature (26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h). Body weight (BW), weight gain (WG), feed intake (FI), feed efficiency (FE), carcass weight (CW), dressing (DP), breast meat (BM), abdominal fat (AF), drumsticks (DS), and thighs (TH) percentage were determined at the end of the experiment. High ambient temperature significantly ($P < 0.05$) decreased BW, WG, FI, and CW and varying dietary protein and/or TSAA failed to overcome this observed reduction in the performance. It is concluded that dietary TSAA level above the NRC recommendation had no significant effect on broilers reared at both moderate and high temperatures.

Introduction

Methionine is the first limiting amino acid in corn-soybean based diets. Varying dietary protein is expected to alter amino acid requirements and hence the first limiting amino acid. Reports on the amino acid requirements of broiler chicks during the grower period are few and are conflicting. Jensen *et al.* [1] and Hickling *et al.* [2] reported that increasing dietary total sulfur amino acids (TSAA) improved broilers performance under moderate temperatures. Moreover, Pack and Schutte [3], Morris *et al.* [4], and Baker *et al.* [5] reported that dietary TSAA needed to optimize feed efficiency was higher than that needed for maximum growth of broilers.

TSAA requirements as a function of dietary protein are also conflicting. Jensen *et al.* [1] and Mendonca and Jensen [6] reported that the requirements of broiler chicks for TSAA increased as the level of dietary protein increased beyond 20% of the diet. In contrast, Kassim and Suwanpradit [7] found that dietary TSAA supplementation had no effect on broilers performance, and that dietary protein level did not affect the TSAA requirements.

At high ambient temperature, reports on the requirements of broiler chicks for TSAA during the growing period (3-6 wk) are also limited and confilicting. Leyden and Balnave [8] reported that methionine requirement under high ambient temperature is similar to that under moderate temperature. Al-Nasser *et al.* [9], however, reported that supplemental DL-Methionine improved body weight gain of broilers reared under high temperatures. In contrast, Balnave and Oliva [10] reported that high ambient temperature reduced amino acids digestibility, and showed that increasing methionine:TSAA ratio reduced growth and feed intake, and increased feed conversion.

The objective of this study was to examine the effect of dietary TSAA on broiler chicks' performance and carcass composition under heat stress.

Materials and Methods

Birds and management

One thousand and eight 1-day-old sexed Hybro broiler chicks obtained from a local hatchery were assigned randomly to 36 floor pens (1.6 X 1.0 m) with 32 males or females/pen. The pens were equipped with tubular hanging feeders and automatic waterers. Birds were brooded at 33 C during the first week with the brooding temperature being reduced 3 C/week until it reached 24 C. 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 slightly exceeded all nutrient specifications of the NRC [11] (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 levels of dietary protein and three levels of dietary TSAA was used during the growing period of 22-42 d. Thirty-six groups of birds were kept under approximately 25±1 C for 24 h/day (moderate temperature) in one section of the house. The other thirty-six were reared in another section of the house under hot cyclic temperature of 26-34 C for 6 h, 34±1 C for 12 h, and 34-26 C for 6 h (high temperature). The temperature was regulated using air conditions and thermostatically controlled electrical heaters. Average relative humidity during the experiment was 40% and 30% in the moderate and cyclic temperatures, respectively.

The nine-isocaloric dietary treatments were a factorial arrangement of three protein levels (18, 20 and 22%) and three TSAA levels (0.78, 0.86 and 0.94%). Each dietary treatment was randomly allocated to four replicate pens under each temperature regimen. Feed and water were provided for *ad libitum* consumption. Diets' composition, calculated and determined analyses are shown in Table 1.

Table 1. Composition of the experimental diets

Ingredients	Starter	Grower Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9
	(g/kg)									
Corn	475.6	567.5	568.3	569.1	643.5	644.3	645.0	720.8	721.5	722.4
Soybean meal	394.4	353.9	352.5	351.2	287.5	286.2	284.8	219.3	217.9	216.5
Vegetable oil	74.3	29.4	29.1	28.7	16.0	15.7	15.4	2.4	2.0	1.7
Limestone	9.5	10.1	10.1	10.1	10.3	10.3	10.3	10.4	10.4	10.4
Dicalcium phosphate	15.8	10.6	10.6	10.6	11.1	11.1	11.2	11.7	11.7	11.7
Vit.&Min. premix[1]	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0	25.0
DL-Methionine	1.0	0.0	0.9	1.7	0.7	1.5	2.3	1.3	2.2	3.0
L-Lysine	0.0	0.3	0.3	0.4	2.7	2.7	2.8	5.1	5.2	5.2
L-Thrionine	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.9	0.9
Salt	4.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Total	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Calculated Analysis										
ME, kcal/g	3.20	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02	3.02
CP, %	23.00	22.00	22.00	22.00	20.00	20.00	20.00	18.00	18.00	18.00
Lysine, %	1.34	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
TSAA, %	0.90	0.78	0.86	0.94	0.78	0.86	0.94	0.78	0.86	0.94
Thrionine, %	0.90	0.86	0.86	0.86	0.77	0.77	0.77	0.76	0.76	0.76
Argnine, %	1.53	1.44	1.44	1.44	1.26	1.26	1.26	1.08	1.08	1.08
Calcium, %	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
Sodium, %	0.20	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Laboratory analysis										
CP, %	23.01	22.241	22.02	22.12	19.90	19.96	20.66	18.37	18.37	18.44

[1] Vitamin and mineral premix supplied per kilogram of diet 9.6 mg pantothenic acid, 28 mg niacin, 400 mg choline chloride, 1.2 mg folic acid, 4 mg biotin, 16 mg virginiamycin, 100 mg antioxidants, 72 mg manganese, 6 mg copper, 48 mg zinc, 40 mg iron, .4 mg iodine, .08 mg selenium, 10,000 IU vitamin A, 2,400 IU vitamin D_3, 4 IU vitamin B, 4 IU vitamin B_2, 16 IU vitamin E, 2.4 IU vitamin K, 1.2 PPB vitamin B_{12}, .18 PPM vitamin B_6.

Measurements

Performance: Body weight was determined per pen at 22 and 42 days of age and average daily gain was calculated. Feed was weighed at 22 and 42 days of age and average daily feed intake and feed conversion (gram feed:gram gain) were determined.

Carcass traits: All birds were deprived of feed for approximately 12 h before being slaughtered for carcass trait 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 before it was killed by exsanguination. Birds were bled for approximately 2 minutes, scalded at 60 C for approximately 1.5 minutes, and were then placed into a rotary drum mechanical picker. 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 dressing 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® [12]. The following model was used:

$$Y_{ijnk} = \mu + P_i + M_j + T_n + PM_{ij} + PT_{in} + MT_{jn} + PMT_{ijn} + e_{ijnk}.$$

Where Y_{ijnk} is the individual observation; μ is the experimental mean; P_i is the effect of $_i$th protein level; M_j is the effect of $_j$th TSAA level, T_n is the effect of the $_n$th temperature; PM_{ij} is the protein by TSAA interaction; PT_{in} is the protein by temperature interaction; MT_{jn} is the TSAA by temperature interaction; PMT_{ijn} is the protein by TSAA 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® [12]. The following model was used:

$$Y_{ijnmk} = \mu + P_i + M_j + T_n + S_m + PM_{ij} + PT_{in} + PS_{im} + MT_{jn} + MS_{jm} + TS_{nm} + PMT_{ijn} + PMS_{ijm} + PTS_{inm} + MTS_{jnm} + PMTS_{ijnm} + e_{ijnmk}.$$

Where Y_{ijnmk} is the individual observation; μ is the experimental mean; P_i is the effect of $_i$th protein level; M_j is the effect of $_j$th TSAA level, T_n is the effect of the $_n$th temperature; S_m is the effect of $_m$th sex; PM_{ij} is the protein by TSAA interaction; PT_{in} is the protein by temperature interaction; PS_{im} is the protein by sex interaction; MT_{jn} is the TSAA by temperature interaction; MS_{jm} is the TSAA by sex interaction; TS_{nm} is the temperature by sex interaction; PMT_{ijn} is the protein by TSAA by temperature interaction; PMS_{ijm} is the protein by TSAA by sex interaction; PTS_{inm} is the protein by temperature by sex interaction; MTS_{jnm} is the TSAA by temperature by sex interaction; $PMTS_{ijnm}$ is the protein by TSAA by temperature by sex interaction; e_{ijnmk} is random error. Percentage data were subjected to arc sine transformation prior to analysis; however, actual percentage data are reported. Treatment means, when significant, were separated using Duncan's multiple range test. Statements of significance were based on $P \leq 0.05$.

Results

Performance

Body weight (BW) and daily weight gain (WG) data are summarized in Table 2. High temperature significantly reduced both BW and WG. Feed intake (FI) and feed conversion (FC) data are presented in Table 3. High ambient temperature significantly reduced FI. As shown in Tables 2 and 3, there were no significant effects of dietary protein and/or TSAA on BW, FI, WG or FC under either moderate or high temperatures. Mortality was very low and was not affected by treatments (data not show). The main effects of dietary protein, dietary TSAA and ambient temperature are presented in Table 7.

Carcass composition

Carcass weight (CW) and dressing yield data are summarized in Table 4. There were significant temperature, dietary protein level, sex and dietary TSAA by sex interaction effects on CW. High ambient temperature significantly reduced CW whereas high dietary protein level significantly increased CW. Dietary TSAA had no significant effect on CW. Females' CW was significantly lower than that of males. High dietary

TSAA increased CW only for males, thus resulted in a significant TSAA by sex interaction. Ambient temperature, dietary protein level, dietary TSAA and sex had no significant effects on dressing yield percentage. There was a significant ambient temperature by dietary protein level by TSAA by sex interaction effect on dressing yield percentage.

Table 2. The effect of protein, TSAA and temperature on body weight and weight gain of broiler chicks grown to 42 days of age

		Body weight (g)		Weight gain (g/d)	
Dietary		Ambient temperature[1]			
Protein (%)	TSAA (%)	HT	MT	HT	MT
18.0	0.78	1427	1496	37.2	40.6
	0.86	1351	1491	33.7	40.4
	0.94	1455	1449	38.6	38.3
20.0	0.78	1398	1523	35.9	41.8
	0.86	1441	1515	37.9	41.4
	0.94	1443	1610	38.0	46.0
22.0	0.78	1448	1532	38.3	42.2
	0.86	1480	1575	39.8	44.3
	0.94	1435	1503	37.6	41.0
SEM[2]		46		2.2	
Source of variation[3]		Probability			
Temperature		.0001		.0001	
Protein		NS		NS	
TSAA		NS		NS	

[1] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (HT) or constant 25±1 C (MT).
[2] Standard error of the mean (n= 4 replicates of 7 males and 7 females each).
[3] No significant interactions.

Table 3. The effect of protein, TSAA and temperature on feed intake and feed conversion of broiler chicks grown to 42 days of age

		Feed intake (g/d)		Feed conversion (g/g)	
Dietary		Ambient temperature[1]			
Protein (%)	TSAA (%)	HT	MT	HT	MT
18.0	0.78	91.7	101.3	2.48	2.55
	0.86	87.1	98.1	2.60	2.44
	0.94	94.1	97.4	2.45	2.50
20.0	0.78	88.9	98.4	2.49	2.36
	0.86	89.9	103.9	2.40	2.53
	0.94	89.7	104.6	2.36	2.28
22.0	0.78	95.7	101.6	2.54	2.41
	0.86	95.2	103.4	2.42	2.34
	0.94	92.5	100.4	2.49	2.46
SEM[2]		3.1		0.09	
Source of variation[3]		Probability			
Temperature		.0001		NS	
Protein		NS		NS	
TSAA		NS		NS	

[1] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (HT) or constant 25±1 C (MT).
[2] Standard error of the mean (n= 4 replicates of 7 males and 7 females each).
[3] No significant interactions.

Table 4. The effect of protein, TSAA, temperature and sex on carcass weight and dressing percentage of broiler chicks grown to 42 days of age

			Carcass weight (g)		Dressing yield (%)[1]	
Dietary			Ambient temperature[2]			
Protein (%)	TSAA (%)	Sex[3]	HT	MT	HT	MT
18.0	0.78	F	864	976	66.3	66.6
	0.78	M	1038	1089	66.3	66.0
	0.86	F	850	1067	66.0	66.7
	0.86	M	998	1073	67.2	65.9
	0.94	F	955	891	66.3	64.6
	0.94	M	1066	1135	66.5	66.1
20.0	0.78	F	928	944	66.9	65.4
	0.78	M	1082	1193	66.3	66.9
	0.86	F	964	1018	65.9	65.9
	0.86	M	1074	1119	66.3	65.6
	0.94	F	885	1060	66.1	67.0
	0.94	M	1112	1203	67.7	66.4
22.0	0.78	F	920	997	65.3	66.0
	0.78	M	1053	1122	65.9	65.5
	0.86	F	1006	941	66.9	65.2
	0.86	M	1042	1174	65.3	66.4
	0.94	F	918	962	66.4	66.2
	0.94	M	1128	1212	66.9	65.9
SEM[4]			45		0.6	
Source of variation[5]			Probability			
Temperature (T)			.0001		NS	
Protein (P)			.0215		NS	
TSAA			NS		NS	
Sex (S)			.0001		NS	
TSAA x S			.0478		NS	
T x P x S x TSAA			NS		.0031	

[1] ((carcass weight/body weight following feed deprivation) x 100).
[2] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (HT) or constant 25±1 C (MT).
[3] F= females, M= males.
[4] Standard error of the mean (n= 12 males or females per treatment).
[5] Only significant interactions are shown.

Abdominal fat and breast weight data as percentage of live body weight are summarized in Table 5. There were no significant effects of ambient temperature, dietary protein level, dietary TSAA, or sex, and there were no significant interactions on breast meat yield percentage. Abdominal fat percentage was significantly affected by dietary protein level, sex and ambient temperature by dietary protein level by dietary TSAA by sex interaction. Ambient temperature and dietary TSAA had no effect on abdominal fat percentage. High dietary protein level significantly decreased abdominal fat percentage. Abdominal fat percentage was significantly higher in females than in males.

Drumsticks and thighs data as percentage of live body weight are summarized in Table 6. Ambient temperature, dietary protein level and dietary TSAA had no significant effect on drumsticks percentage.

Table 5. The effect of protein, TSAA, temperature and sex on abdominal fat and breast of broiler chicks grown to 42 days of age

			Abdominal fat (%)[1]		Breast (%)[1]	
			Ambient temperature[2]			
Dietary Protein (%)	TSAA %)	Sex[3]	HT	MT	HT	MT
18.0	0.78	F	1.2	1.2	19.8	22.2
	0.78	M	0.8	1.1	21.5	21.5
	0.86	F	1.1	1.5	21.6	22.5
	0.86	M	1.2	0.9	21.3	21.4
	0.94	F	1.2	1.1	22.2	21.7
	0.94	M	1.0	1.0	21.4	21.8
20.0	0.78	F	1.0	0.9	21.8	22.0
	0.78	M	0.9	1.0	21.5	21.3
	0.86	F	1.3	0.9	22.0	22.7
	0.86	M	0.9	1.0	21.6	21.7
	0.94	F	0.9	1.1	21.7	22.4
	0.94	M	0.9	0.7	22.0	22.3
22.0	0.78	F	0.8	1.0	21.9	21.2
	0.78	M	0.7	0.8	21.1	21.2
	0.86	F	1.0	0.8	22.4	22.0
	0.86	M	0.6	0.8	20.9	21.1
	0.94	F	0.9	0.8	21.9	21.7
	0.94	M	0.7	0.8	22.1	22.1
SEM[4]			0.1		0.6	
Source of variation[5]			Probability			
Temperature (T)			NS		NS	
Protein (P)			.0001		NS	
TSAA			NS		NS	
Sex (S)			.0004		NS	
T x P x TSAA x S			.0087		NS	

[1] As percentage of body weight.
[2] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (HT) or constant 25±1 C (MT).
[3] F= females, M= males.
[4] Standard error of the mean (n= 12 males or females per treatment).
[5] Only significant interactions are shown.

Drumsticks percentage were significantly higher in males than in females. There were significant ambient temperature and sex effects on thighs percentage. High ambient temperature significantly increased thighs percentage. Dietary protein level and dietary TSAA had no significant effect on thighs percentage. Thighs percentage were significantly higher in males than in females. The main effects of dietary protein, dietary TSAA, ambient temperature and sex are presented in Table 8.

Discussion

In the current experiment, high ambient temperature significantly reduced BW, WG, and FI by about 6, 10, and 9%, respectively, whereas FC was not significantly affected by ambient temperature. These results agree with a previous finding in our laboratory [13] and with others [14-19].

Table 6. The effect of protein, TSAA, temperature and sex on drumsticks and thighs of broiler chicks grown to 42 days of age

Dietary protein (%)	TSAA (%)	Sex[3]	Drumsticks (%)[1] HT	Drumsticks (%)[1] MT	Thighs (%)[1] HT	Thighs (%)[1] MT
			Ambient temperature[2]			
18.0	0.78	F	9.9	9.6	11.6	10.5
	0.78	M	10.4	9.8	10.9	10.6
	0.86	F	9.4	9.5	10.8	10.7
	0.86	M	10.3	9.7	11.1	11.2
	0.94	F	9.9	9.3	10.3	9.9
	0.94	M	10.0	9.9	11.6	10.8
20.0	0.78	F	9.8	9.8	10.8	10.1
	0.78	M	9.6	10.2	11.0	10.8
	0.86	F	9.5	9.7	10.4	10.2
	0.86	M	10.1	9.8	11.0	10.6
	0.94	F	10.3	9.4	10.7	10.9
	0.94	M	10.5	9.7	11.2	10.9
22.0	0.78	F	9.4	9.4	10.6	10.8
	0.78	M	9.9	9.8	11.0	10.8
	0.86	F	9.4	9.5	11.3	9.9
	0.86	M	9.3	10.1	11.3	11.0
	0.94	F	10.0	9.9	10.4	10.1
	0.94	M	10.0	10.2	11.1	10.4
SEM[4]				0.3		0.3
Source of variation[5]			Probability			
Temperature (T)				NS		.0001
Protein (P)				NS		NS
TSAA				NS		NS
Sex (S)				.0061		.0001

[1] As percentage of body weight.
[2] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (HT) or constant 25±1 C (MT).
[3] F= females, M= males.
[4] Standard error of the mean (n= 12 males or females per treatment).
[5] Only significant interactions are shown.

Table 7. Main effect of protein, TSAA and temperature on body weight, weight gain, feed intake and feed conversion of broiler chicks grown to 42 days of age

Effect		Body weight (g)	Weight gain (g/d)	Feed intake (g/d)	Feed conversion (g/g)
Dietary protein level (%)	18	1444	38.1	94.9	2.50
	20	1488	40.2	95.9	2.40
	22	1495	40.5	98.1	2.44
Dietary TSAA (%)	0.78	1470	39.3	96.3	2.46
	0.86	1475	39.6	96.3	2.45
	0.94	1482	39.9	96.4	2.43
Ambient temperature[1]	High	1431^{B}	37.4^{B}	91.7^{B}	2.47
	Moderate	1521^{A}	41.4^{A}	101.0^{A}	2.43

[1] Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (high) or constant 25±1 C (moderate).
$^{A-B}$Means within a column and variable with no common superscript differ significantly ($P < .05$).

Table 8. Main effect of protein, TSAA, temperature and sex on carcass weight and the percentage of dressing yield, breast yield, abdominal fat, drumsticks and thighs of broiler chicks grown to 42 days of age

Effect		Carcass weight[1]	Dressing yield[2]	Breast yield[3]	Abdominal fat[3]	Drumsticks[3]	Thighs[3]
		(g)	(%)				
Dietary protein level (%)	18	1000^{B}	66.2	21.6	1.10^{A}	9.8	10.8
	20	1049^{A}	66.4	21.9	0.94^{B}	9.9	10.7
	22	1040^{A}	66.0	21.6	0.81^{C}	9.7	10.7
Dietary TSAA (%)	0.78	1017	66.1	21.4	0.95	9.8	10.8
	0.86	1027	66.1	21.8	1.00	9.7	10.8
	0.94	1044	66.3	21.9	0.92	9.9	10.7
Ambient temperature[4]	High	994^{B}	66.4	21.6	0.94	9.9	11.0^{A}
	Moderate	1065^{A}	66.0	21.8	0.96	9.7	10.6^{B}
Sex	Female	953^{B}	66.1	21.9	1.03^{A}	9.6^{B}	10.6^{B}
	Male	1106^{A}	66.3	21.5	0.88^{B}	10.0^{A}	11.0^{A}

[1]Carcass weight without giblets but with abdominal fat pad.
[2]Dressing percentage (carcass weight/live weight following feed deprivation X 100).
[3]Percentage of live body weight after feed deprivation.
[4]Birds were kept at either cyclic temperature of 26-34 C/6 h, 34±1 C/12 h, and 34-26 C/6 h (high) or constant 25±1 C (moderate).
[A-C]Means within a column and variable with no common superscript differ significantly ($P < .05$).

The depression in the performance of chicks at high environmental temperature is partly the result of a decreased feed consumption. Dale and Fuller [20] reported that about 63% of the depression in broilers performance could be explained by decreased feed intake at high temperatures. High temperature significantly decreased carcass weight by about 7%, and significantly increased thighs percentage by about 4%; as compared with moderate temperature. These results are in agreement with previous findings reported in the literature [15, 21-24]. However, the effect of high ambient temperature on abdominal fat content in chicks is inconsistent. In the current experiment there was no significant effect of high temperature on abdominal fat. This is in agreement with the findings of Suk and Washburn [25] and Ain Baziz *et al.* [18] who reported no differences in abdominal fat of broilers reared at 26.7 C and 21.1 C, or at high cyclic temperature. But, EL-Husseiny and Creger [26], Balnave and Oliva [10], and Mendes *et al.* [24] reported that high ambient temperature enhanced deposition of abdominal fat in broiler chicks. In contrast, Al-Batshan and Hussein [13] found that abdominal fat was significantly reduced in broiler reared at high cyclic temperature. This inconsistent effect of ambient temperature on fat deposition may be explained by the finding that birds of varied inherent growth rate respond differently to dietary manipulations [23].

The effect of dietary protein content in isoenergetic diets on broilers performance at high ambient temperature was investigated previously by other research workers and most of their studies were conducted at high constant temperature. In accordance with the current results, these studies showed that high dietary protein failed to improve broilers performance at high environmental temperatures [27-29]. But, Cerniglia *et al.* [30] and Al-Batshan and Hussein [13] reported that high dietary protein improved weight gain and feed conversion in broiler chicks. In contrast, Cahaner *et al.* [23] showed that high dietary protein reduced body weight gain of broilers as compared with low dietary protein.

In the current experiment, high dietary protein above 20% significantly increased chicks' carcass weight only at moderate temperature. The abdominal fat of chicks was significantly reduced, which could be attributed mainly to the narrow calorie to protein ratio and partly to the increased heat increment when high level of dietary protein was used. This is in agreement with results of Bedford and Summers [31], Leenstra [32], Fancher and Jensen [33], Marks [34], Wang *et al.* [35] and Moran *et al.* [36].

There was no improvement in broilers performance when high levels of TSAA were added to their diets at both temperatures. Excess dietary TSAA level had no effect on chicks' BW, WG, FI, or FC. This result is in agreement with that of Leyden and Balnave [8] who reported that the requirement of broiler chicks for methionine is similar at high and moderate ambient temperatures. The results of the current experiment, however, disagree with those of Al-Nasser *et al.* [9] who found that increasing DL-Met improved weight gain of the broilers reared under high temperature and with the results of Balnave and Oliva [10] who reported that increasing Met:TSAA ratio in diets for broiler chicks reduced their feed intake and growth, and increased their feed conversion under high environmental temperature.

Chicks' carcass composition was not affected when high levels of TSAA were fed. High levels of dietary TSAA did not change the carcass composition of chicks reared at either high or moderate temperature. The lack of significant interactions between temperature by protein, temperature by TSAA, and temperature by protein by TSAA indicated that the requirements of chicks for dietary protein and TSAA were similar under the temperature range investigated in the current experiment. It is concluded that under the experimental conditions imposed in the current experiment, the recommendations of the NRC [11] for TSAA are sufficient to maintain a satisfactory broilers performance under heat stress.

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تأثير الأحماض الأمينية الكلية المحتوية على كبريت على أداء ومكونات ذبيحة كتاكيت اللحم المعرضة لإجهاد حراري

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(قدم للنشر في ١٤١٩/٢/١٢هـ؛ وقبل للنشر في ١٤٢٠/٨/١٤هـ)

ملخص البحث. أجريت هذه التجربة لدراسة تأثير الأحماض الأمينية الكلية المحتوية على كبريت على أداء ومكونات ذبيحة كتاكيت اللحم المعرضة لإجهاد حراري خلال فترة النمو (٣-٦ أسابيع). درس في هذه التجربة ثلاثة عوامل هي البروتين (١٨ و ٢٠ و ٢٢٪)، والأحماض الأمينية الكلية المحتوية على كبريت (٠,٧٨ و ٠,٨٦ و ٠,٩٤٪)، ودرجتين حراريتين. تم تربية نصف العدد من الطيور في جزء من العنبر تحت درجة حرارة معتدلة (٢٥ ± ١ °م) وباقي الطيور في جزء آخر من العنبر تحت درجة حرارة مرتفعة بنظام تتابعي (٢٦-٣٤ °م لمدة ٦ ساعات، ثم ٣٤ ± ١ °م لمدة ١٢ ساعة، ثم ٣٤-٢٦ °م لمدة ٦ ساعات). عند نهاية فترة التجربة تم قياس كل من وزن الطيور الحي، معدل الزيادة في النمو، كمية العلف المأكولة، كفاءة التحويل الغذائي، وزن الذبيحة، نسبة التصافي، وزن الصدر، وزن دهن البطن، وزن الساق، ووزن الفخذ.

وجد أن درجة الحرارة البيئية المرتفعة كان تأثيرها معنويًا ($P < 0.05$) إذ عملت على خفض كل من وزن الطيور الحي، معدل الزيادة في النمو، كمية العلف المأكول، ووزن الذبيحة، وأن رفع محتوى العلائق من البروتين و/أو الأحماض الأمينية الكلية المحتوية على كبريت فشل في تعويض هذا الانخفاض. يقترح من نتائج هذه التجربة أن زيادة مستوى الأحماض الأمينية الكلية المحتوية على كبريت بالعلائق عما هو موصى به ليس له أي تأثير على كتاكيت اللحم المرباة في درجات حرارة معتدلة أو مرتفعة.