Effect of zinc sulfate and organic chromium supplementation on the performance, body temperature, carcass characteristics, tibia ash and serum biochemical parameters of Japanese quails under heat stress conditions

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Abstract This study was conducted to investigate the effects of different levels of zinc sulfate and chromium picolinate on performance, body temperature, carcass characteristics, tibia ash and serum biochemical parameters of Japanese quails under heat stress condition. The birds (n = 540; 7-d-old) were randomly assigned to 9 treatment groups consisting of 3 replicates of 20 birds each in a 3 × 3 factorial arrangement of treatments (zinc; chromium). Birds were kept in floor cages in a temperature controlled room at either thermoneutral zone or heat stress for 8 h/d (0900 to 1700 h) until the end of the study, and fed a basal (control) diet or the basal diet supplemented with either 40 or 80 mg of Zn as $ZnSO_4$ and 500 or 1000 µg Cr as CrPic/kg of diet. A linear decrease in feed intake and improvement in feed conversion ratio were found in Zn and Cr supplemented quails reared under heat stress conditions. Chromium supplementation increased daily weight gain linearly.Quails body temperature before and during heat stress tends to decrease linearly as dietary Zn and Cr supplementation increased. Supplementation with Zn decreased the relative weight of the small intestine, rectum, and weight to length ratio of the small intestine. Tibia ash was increased with Zn and Cr supplementation. Supplementation of quail's diet with Zn and Cr did not have any effect on serum biochemical parameters. The results of this study revealed positive effects of Zn and Cr supplementation on the performance, body temperature, carcass characteristics and tibia ash of quails under heat stress. It seems that supplementation of the quail's diets with 80 mg/kg $ZnSO_4$ and 1000 µg/kg CrPic can be greatly helpful for improving the adverse effects of heat stress.

Keywords: zinc, chromium, performance, body temperature, heat Stress, quail

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Introduction

Heat stress is one of the serious concerns in poultry production that affects important economical parameters negatively (Niu et al, 2009). When the bird exposes to high ambient temperature, a series of consecutive events appears in it`s body, finally damages the bird`s product from any type. Ward and Peterson (1973) perceived that plasma level of zinc was lower in broilers were exposed to high ambient temperature (33-35°C) rather than those were reared under thermoneutral condition (18-22 °C). Since the production of free radicals escalates under heat stress condition (Mujahid *et al.,* 2005), it seems to be beneficial to use elements in the poultry diets that someway take part in cleaning of oxidant agents.

Zinc is an element that is required for the biological function of more than 300 enzymes. One of the major functions of zinc is participation in the antioxidant defense system of the body (Prasad and Kucuk, 2002). The mechanism whereby the zinc plays the role is not well recognized yet, but it is thought that Zn increases synthesis of metallothionein protein as scavenger of free radicals (Oteiza *et al.,* 1996). In the pancreas, Zn with playing a protective role against oxidative damages, aids to this organ to secret digestive enzymes, leads to increased nutrients digestibility (Sahin *et al.,* 2009). Under heat stress condition, excretion of zinc from the body is intensed (Belay and Teeter, 1996). Zinc influence utilization of feed via participating in the metabolism of carbohydrates, fats and proteins advantageously (MacDonald, 2000).

About the effect of zinc on the performance of poultry under heat stress condition conflicting reports have been published. Bartlett and Smith (2003) report that different dietary levels of zinc have no effects on the performance and plasma concentration of zinc in broilers under heat stress condition while Sahin et al. (2005) stated that performance and carcass quality of quails fed a zinc supplemented diet was improved under heat stress condition.

Chromium participates in structure of an organometallic molecule called the glucose tolerance factor (GTF) that stimulates insulin receptors to pair with this hormone (Mertz, 1993). Many other functions has been reported for chromium such as participation in metabolism of lipids, proteins and nucleic acids. It has been established that Cr^{3+} shows antioxidative properties from itself in the body (Tezuka *et al.*, 1991). Furthermore, Cr improves health and subsequent performance via aiding to immune system (Mallard and Borgs, 1997). Chromium is not a particularly toxic element in its trivalent form, and a wide margin of safety exists between the normal amounts ingested and those likely to produce deleterious effects. (McDonald et al, 2011). Stress depletes the body's stores of chromium and increases the need for this element (Hayirli, 2005). Finally, some reports exist that confirm the positive effects of chromium on digestibility of nutrients in animals (kim *et al.*, 1997; sahin *et al.*, 2001; Onderci *et al.*, 2003; Emami *et al.*, 2012).

This experiment was conducted to investigate the effects of different levels of zinc sulfate and chromium picolinate on performance, body temperature, carcass characteristics and serum biochemical parameters of Japanese quails under heat stress condition.

Materials and methods

Birds, treatments and management

Five hundred and forty 7-day-old Japanese quails (mixed-sex) were housed in floor cages in a temperature controlled room at either thermoneutral zone or heat stress (to reach panting) for 8 h/d (0900 to 1700 h) until the end of study (35 d), and fed a basal (control) diet or the basal diet supplemented with either 40 or 80 mg of Zn as ZnSO4 and 500 or 1000 µg Cr as CrPic [1] per kilogram of diet. The birds were randomly assigned to 9 treatment groups consisting of 3 replicates of 20 birds each in a 3 × 3 factorial arrangement of treatments (zinc; chromium). The quail's diet was formulated to meet the NRC requirements (NRC, 1994) of meat Japanese quails as shown in Table 1. Feed (in mesh form) and fresh water were offered *ad libitum* throughout the experiment.

Sample and data collection

Growth performance (feed intake, body weight gain and feed conversion ratio) were recorded weekly. For meas uring body temperature 3 birds were selected randomly from each cage, marked and used until the end of the experimental period. Rectal temperature, as a measurement of body temperature, was obtained using digital thermometer (±0.1° C) by insertion approximately 3cm into the cloaca. In this study, the rectal temperatures of birds were measured weekly, once before applying heat stress (07-09 a.m.) and once in duration of applying heat stress (14-16 p.m.).

Two male quail from each cage (three birds per treatment) was also randomly selected for blood sampling on day 35. Blood samples were collected from the Jugular vein via cervical cutting of the quails. After letting samples stand for 30 minutes on ice, they were centrifuged at 3000×g for 10 min and aliquots were transferred into microfuge tubes. Sera were then frozen at -20°C until biochemical analyses. Serum level of glucose was measured by glucose oxidase method. Serum levels of cholesterol, triglyceride, HDL and albumin were measured using respective kits (Ziest-Chemie, Tehran) according to guidelines. The LDL was determined by the Friedewald formula.

Table 1. Ingredient and composition of basal diet

Ingredient	Amount (g/kg)
Maize	457
Soyabean meal (CP 44%)	472.6
Soybean oil	40
Oyster shell	13
Dicalcium phosphate	7.5
Salt	3.6
DL-Methionine	1.3
Vitamin-mineral premix*	5
Total	1000
Chemical composition	
ME_n, MJ/kg	12.30
Crude protein (g/kg)	242.8
Lysine (g/kg)	13.9
DL-Methionine (g/kg)	5.03
Methionine + Cycteine (g/kg)	8.97
Calcium (g/kg)	8.07
Non-phytin P (g/kg)	3.06
Sodium (g/kg)	1.54
Linoleic acid (g/kg)	31.94
Crude fiber (g/kg)	43.14

*provided the following per kg of diet: retinol acetate 3.1 mg, thiamine 1.8 mg, riboflavin 6.6 mg, niacin 30 mg, pantothenic acid 10 mg, pyridoxine 3 mg, folic acid 1 mg, cyanocobalamine 15 µg, biotin 0.1 mg, cholecalciferol 0.05 mg, alpha-tocopherol acetate 18 mg, menadion 2 mg, choline chloride 0.4 g, Fe 50 mg, Mn 100 mg, Zn 85mg, Cu 10 mg, Se 0.2 mg and I 1 mg.

[1] Chromium picolinate

Table 2. Effects of zinc sulfate and chromium picolinate on performance in Japanese quail reared under heat stress condition

Treatments		FI (g/b/d)	BWG	FCR
Chromium (µg/kg)	Zinc (mg/kg)			
0	0	21.83[a]	6.80	3.21[a]
	40	18.75[c]	6.62	2.84[b]
	80	19.67[b]	6.93	2.84[b]
500	0	19.35[b]	6.89	2.81[bc]
	40	18.39[cd]	6.68	2.75[bcd]
	80	18.32[d]	6.78	2.70[cde]
1000	0	18.30[d]	6.94	2.64[de]
	40	18.14[d]	6.94	2.62[e]
	80	18.54[cd]	7.04	2.63[de]
SEM		0.219	0.0363	0.0355
Main effect means				
Zinc				
0		19.83[a]	6.88	2.88[a]
40		18.43[c]	6.75	2.74[b]
80		18.84[b]	6.92	2.72[b]
Chromium				
0		20.08[a]	6.79[b]	2.96[a]
500		18.69[b]	6.78[b]	2.75[b]
1000		18.33[c]	6.98[a]	2.63[c]
Probabilities				
Source of variation				
Zinc effect		<0.01	0.0963	<0.01
Chromium effect		<0.01	0.0338	<0.01
Zinc × Chromium effect		<0.01	0.5213	<0.01
Polynomial contrast				
Linear zinc		<0.01	0.5986	<0.01
Quadratic zinc		<0.01	0.0372	0.0216
Linear chromium		<0.01	0.0234	<0.01
Quadratic chromium		<0.01	0.1652	0.1558

[a,b] Means with different superscripts in the same column differ significantly, p<0.05.

Carcass components of the quails that were bled, separated and weighed with a digital scale. Left tibia bone was taken from each bird. Bone ash was determined using whole tibia, which were cleaned following parboiling to facilitate flesh removal, prior to drying, and fat extraction by refluxing for 8h in petroleum ether and ashing (12h, 600°C). Tibia ash was expressed as a percentage of the dry defatted sample (AOAC, 1995).

Statistical analyses

The data were analyzed using the GLM procedure of SAS software (SAS Institute, 2007). Duncan multiple range test was used to detect (P<0.05) differences among treatment means. Linear and quadratic polynomial contrasts were used to evaluate the effect of different levels of zinc and chromium.

Results

Performance parameters

The effects of supplemental Zn and Cr on growth performance of Japanese quails are shown in Table 2. Our results showed that Zn supplementation decreased feed intake (FI) quadratically and improved feed conversion ratio (FCR) linearly but had no significant effect on body weight gain (BWG). Cr supplementation decreased FI and FCR while increased BWG linearly. A significant interaction between Zn and Cr was observed for FI and FCR. Chicks fed diet contained 1000 µg Cr and 40 mg Zn per kg, showed the lowest FI and FCR. In general, dietary combined supplementation of Zn and Cr decreased FI and FCR to a greater degree compared to supplementation with Zn and Cr separately.

Rectal temperature

Table 3 shows weekly body temperature of quails. Statistical analysis showed strong significant differences in rectal temperature between before applying heat stress and during heat stress in all of the timeframes. The main effects of Zn were significant on days 14 before stress (P<0.05), 21 before and during stress (P<0.01), 28 during stress (P<0.05) and 35 during stress (P<0.01). Rectal temperature decreased linearly as dietary levels of Zn

Table 3. Rectal temperature of Japanese quails supplemented with different levels of zinc sulfate and chromium picolinate reared under heat stress condition (°C)

		14		21		28		35	
Chromium (µg/kg)	Zinc (mg/kg)	BHS[1]	DHS[2]	BHS	DHS	BHS	DHS	BHS	DHS
0	0	41.10	42.83	40.97	42.53	41.20	42.33[a]	40.93	41.80[a]
	40	40.97	42.40	40.87	42.23	40.87	41.83[b]	40.80	41.53[b]
	80	40.90	42.47	40.80	42.07	40.87	41.73[bc]	40.67	41.37[bc]
500	0	40.73	42.13	40.93	42.30	40.87	41.83[b]	40.67	41.37[bc]
	40	40.73	42.33	40.83	41.93	40.87	41.83[b]	40.73	41.23[cde]
	80	40.63	42.57	40.77	41.80	40.80	41.43[c]	40.77	41.30[cd]
1000	0	40.63	42.00	40.77	41.67	40.87	41.40[c]	40.63	41.07[ef]
	40	40.37	42.00	40.70	41.37	40.87	41.67[bc]	40.67	41.13[de]
	80	40.40	42.27	40.67	41.40	40.87	41.60[bc]	40.57	40.90[f]
SEM		0.0506	0.0631	0.0228	0.0787	0.0304	0.0595	0.0271	0.0517
Main effect means									
Zinc									
0		40.82[a]	40.32	40.89[a]	42.17[a]	40.98	41.86[a]	40.74	41.41[a]
40		40.69[ab]	42.24	40.80[b]	41.84[b]	40.87	41.78[a]	40.73	41.30[b]
80		40.64[b]	42.43	40.74[b]	41.76[b]	40.84	41.59[b]	40.67	41.19[c]
Chromium									
0		40.99[a]	42.57[a]	40.88[a]	42.28[a]	40.98	41.97[a]	40.80[a]	41.57[a]
500		40.70[b]	42.34[a]	40.84[a]	42.01[b]	40.84	41.70[b]	40.72[ab]	41.30[b]
1000		40.47[c]	42.09[b]	40.71[b]	41.48[c]	40.87	41.56[b]	40.62[b]	41.03[c]
Probabilities									
Source of variation									
Zinc effect		0.0405	0.2649	<0.01	<0.01	0.1075	0.0226	0.3161	<0.01
Chromium effect		<0.01	<0.01	<0.01	<0.01	0.1075	<0.01	0.0136	<0.01
Zinc × Chromium effect		0.6114	0.0710	0.9569	0.6910	0.1510	<0.01	0.1312	0.0171
Polynomial contrast									
Linear zinc		0.0157	0.3352	<0.01	<0.01	0.0501	<0.01	0.1645	<0.01
Quadratic zinc		0.4514	0.1869	0.6324	0.0907	0.4296	0.4820	0.5575	1.00
Linear chromium		<0.01	<0.01	<0.01	<0.01	0.0972	<0.01	<0.01	<0.01
Quadratic chromium		0.6362	0.8657	0.1615	0.0560	0.1744	0.4400	0.8138	1.00

[a,b] Means with different superscripts in the same column differ significantly, p<0.05.
[1]BHS: before heat stress
[2]DHS: during heat stress

increased.
The main effects of Cr were significant in all of the timeframes (P<0.01) except before stress on day 28. Rectal temperature decreased linearly as dietary levels of Cr increased (P<0.05).
The interaction of Zn with Cr was significant only during heat stress on days 28 (P<0.01) and 35 (P<0.05). In both timeframes the highest rectal temperature was related to control group. The lowest rectal temperature during heat stress on day 28 was related to birds that supplemented with 1000 µg/kg Cr while on day 35 it was related to birds that supplemented with a combination of 80 mg/kg Zn and 1000 µg/kg Cr.

Carcass characteristics

Carcass characteristics of quails at the end of the experimental period are shown in table 4. The results of the present study showed that the relative weight of the small intestine and jejunum decreased linearly (P<0.01) as dietary levels of Zn increased. Zn supplementation also decreased linearly the relative weight of the duodenum, ileum, large intestine and weight to length ratio of the small intestine (P<0.05). The relative weight of the crop, proventriculus, gizzard, liver, pancreas and weight to length ratio of the large intestine were not affected by Zn supplementation. Cr supplementation had no effect on carcass characteristics.

Tibia Ash

The main effects of Zn and Cr on tibia ash content were statistically significant (P<0.05, table 4).Tibia ash increased linearly as dietary levels of Zn and Cr increased (P<0.05).
No interaction was detected for Zn and Cr on carcass characteristics.

Table 4. Carcass characteristics of Japanese quails supplemented with different levels of zinc sulfate and chromium picolinate reared under heat stress condition

Treatments: Chromium (μg/kg)	Treatments: Zinc (mg/kg)	Crop[1]	Proventriculus[1]	Gizzard[1]	Duodenum[1]	Jejunum[1]	Ileum[1]	Small intestine[1]	Rectum[1]	Liver[1]	Pancreas[1]	Heart[1]	W/LSI[2]	W/LR[3]	Tibia ash[4]
0	0	0.182	0.353	1.917	0.753	0.747	0.635	2.133	0.190	2.070	0.242	0.854	0.0752	0.0859	53.48
	40	0.180	0.383	1.613	0.650	0.701	0.529	1.880	0.149	2.257	0.207	0.781	0.0634	0.0782	57.61
	80	0.193	0.440	1.937	0.655	0.596	0.410	1.660	0.168	2.203	0.314	0.887	0.0626	0.0799	57.84
500	0	0.253	0.409	1.957	0.688	0.798	0.593	2.080	0.156	2.190	0.254	0.830	0.0664	0.0667	55.59
	40	0.171	0.405	1.877	0.682	0.741	0.503	1.927	0.170	2.140	0.274	0.866	0.0695	0.0894	56.67
	80	0.280	0.419	2.150	0.494	0.542	0.403	1.440	0.136	2.470	0.291	0.831	0.0532	0.0570	59.25
1000	0	0.199	0.448	1.957	0.622	0.668	0.493	1.783	0.187	2.423	0.286	0.826	0.0625	0.0794	59.60
	40	0.222	0.414	1.743	0.668	0.761	0.408	1.837	0.138	2.330	0.293	0.844	0.0651	0.0723	57.86
	80	0.238	0.395	1.803	0.546	0.558	0.459	1.560	0.131	2.400	0.272	0.760	0.0592	0.0718	61.91
SEM		0.0134	0.00908	0.0473	0.0198	0.0212	0.0222	0.0495	0.00546	0.0435	0.00843	0.0124	0.00154	0.00291	0.614
Main effect means															
Zinc															
0		0.211	0.403	1.943	0.688[a]	0.737[a]	0.574[a]	1.999[a]	0.178[a]	2.228	0.261	0.837	0.0680[a]	0.0773	56.22[b]
40		0.191	0.401	1.744	0.667[a]	0.734[a]	0.480[ab]	1.881[a]	0.152[b]	2.242	0.258	0.830	0.0660[a]	0.0800	57.38[ab]
80		0.237	0.418	1.963	0.565[b]	0.566[b]	0.424[b]	1.553[b]	0.145[b]	2.358	0.292	0.826	0.0583[b]	0.0696	59.66[a]
Chromium															
0		0.185	0.392	1.822	0.686	0.681	0.525	1.891	0.169	2.177	0.254	0.841	0.0670	0.0813	56.31[b]
500		0.235	0.411	1.994	0.622	0.694	0.500	1.816	0.154	2.267	0.273	0.842	0.0630	0.0710	57.17[b]
1000		0.220	0.419	1.834	0.612	0.662	0.453	1.727	0.152	2.384	0.284	0.810	0.0622	0.0745	59.79[a]
							Probabilities								
Source of variation															
Zinc effect		0.4111	0.6998	0.1260	0.0152	0.0002	0.0175	<0.01	0.0208	0.4074	0.1267	0.9324	0.0118	0.2905	0.0357
Chromium effect		0.3404	0.4629	0.2565	0.1650	0.6876	0.3315	0.1206	0.2685	0.1617	0.2700	0.4696	0.2629	0.3130	0.0292
Zinc × Chromium effect		0.6734	0.1769	0.7015	0.3039	0.2964	0.4596	0.1885	0.1254	0.5019	0.0813	0.1316	0.1367	0.1964	0.4417
Polynomial contrast															
Linear zinc		0.4538	0.5096	0.8604	0.0069	0.0002	0.0054	<0.01	0.0083	0.2260	0.0915	0.7141	0.0048	0.2576	0.0121
Quadratic zinc		0.2723	0.6061	0.0453	0.2591	0.0167	0.6476	0.1251	0.3553	0.5804	0.2417	0.9655	0.2948	0.2722	0.6042
Linear chromium		0.3174	0.2317	0.9144	0.0829	0.6024	0.1486	0.0426	0.1380	0.0604	0.1148	0.3050	0.1309	0.3211	0.0113
Quadratic chromium		0.2817	0.7859	0.1044	0.4421	0.4956	0.7925	0.9198	0.5238	0.8788	0.7916	0.5053	0.5477	0.2459	0.4197

[a,b] Means with different superscripts in the same column differ significantly, $p<0.05$.
[1]: Values are expressed as a percentage of live body weight.
[2]: Weight to length ratio of small intestine (g/cm)
[3]: Weight to length ratio of rectum (g/cm)
[4]: Values are expressed as a percentage of tibia weight

Serum biochemical parameters

The effects of different levels of Zn and Cr on serum biochemical parameters (glucose, triglyceride, HDL, LDL, cholesterol and albumin) were not significant (Table 5).

Discussion

Performance parameters

Supplementing diets with Zn and Cr improved growth performance of Japanese quails under heat stress. The proven role of Zn and Cr in metabolism of carbohydrates, lipids, proteins and nucleic acids is in accrediting of this argument. Although the exact biochemical mechanism of how high dietary Zn decreases feed intake and subsequent growth is not clear yet, however the concentration of the element in brain does not appear to be a factor (Sandoval *et al.*, 1998). Reduced feed intake could be associated with losing of appetite (Brink *et al.*, 1950) or reduced palatability of the diets containing high levels of Zn (Fox, 1989) as well. Although there are no reports about negative effect of high levels of chromium picolinate on the palatability of diet, but it can be considered in the investigation of the reasons for reduced FI. Zn plays a role in cell division and proliferation (Rubin, 1972; Rubin and Koide, 1973) and activity of more than 300 enzymes in the body (Prasad and Kucuk, 2002). In the heat stress condition, the need for Zn intensifies; so, feed efficiency and growth performance decline if this requirement not to be supplied (Ensminger *et al.*, 1990). Furthermore, the proven role of Zn in increasing nutrients digestibility under heat and cold stress (Onderci *et al.*, 2003; Sahin and Kucuk, 2003) can plays an important role in utilization of con

Table 5. Serum biochemical parameters of Japanese quails supplemented with different levels of zinc sulfate and chromium picolinate reared under heat stress condition

Treatments		Glucose	Triglyceride	Cholesterol	HDL	LDL	Albumin
Chromium (μg/kg)	Zinc (mg/kg)	(mg/dl)	(mg/dl)	(mg/dl)	(mg/dl)	(mg/dl)	(g/dl)
0	0	304.00	191.00	149.00	93.00	65.63	0.933
	40	299.33	191.00	164.33	90.67	66.03	1.033
	80	319.67	190.33	134.67	86.33	64.83	1.067
500	0	288.67	194.33	125.67	78.67	66.50	1.033
	40	312.00	170.00	120.00	76.33	57.73	1.000
	80	337.00	174.00	158.33	85.33	66.57	1.090
1000	0	315.00	197.33	124.67	76.00	56.27	1.190
	40	346.00	179.00	131.67	91.67	72.27	1.100
	80	293.67	195.67	142.67	81.67	58.70	1.000
SEM		5.992	3.816	5.609	2.357	1.981	0.0283
Main effect means							
Zinc							
0		302.56	194.22	133.11	82.556	62.80	1.052
40		319.11	186.67	138.67	86.222	65.34	1.044
80		316.78	180.00	145.22	84.444	63.37	1.052
Chromium							
0		307.67	190.78	149.33	90.000	65.50	1.011
500		312.56	179.44	134.67	80.111	63.60	1.041
1000		318.22	190.67	133.00	83.111	62.41	1.097
Probabilities							
Source of variation							
Zinc effect		0.4668	0.3708	0.6982	0.8283	0.8728	0.9925
Chromium effect		0.7617	0.4326	0.4623	0.2594	0.8315	0.5079
Zinc × Chromium effect		0.1548	0.7930	0.4183	0.5334	0.3378	0.4396
Polynomial contrast							
Linear zinc		0.3302	0.4519	0.4037	0.7543	0.9128	1.0000
Quadratic zinc		0.4528	0.2355	0.9679	0.6033	0.6151	0.9037
Linear chromium		0.9911	0.3792	0.2639	0.2615	0.5526	0.2577
Quadratic chromium		0.2016	0.8142	0.6026	0.2265	0.9368	0.8425

sumed feed.

Improved performance parameters such as FCR in Cr supplemented quails can be related to Cr anti-stress properties and it`s booster effects on insulin, leads to more efficient utilization of nutrients and improved FCR. In addition, Cr increased nutrients digestibility by playing an antioxidant role in pancreas that results in decreased FCR. Cr also has an internal interplay with DNA templates leads to stimulation of the RNA synthesis (Okada *et al.,* 1983).

The weight gain of the birds is mainly related to muscle tissue and most of this tissue is protein. Due to the proven role of RNAs in protein synthesis, the role of Cr in nucleic acids metabolism also can be another reason for the improved feed conversion ratio in Cr supplemented birds. According to our findings, it seems that Cr has been more effective than Zn in improving FCR. Bartlett and Smith (2003) investigated the effects of diets with different levels (34, 68 and 181 mg/kg) of Zn as a polyamino acid complex on performance of broilers either in a thermoneutral or heat stress condition and observed no improvement in this parameters. Sahin et al. (2005) used different levels (30 and 60 mg/kg) of zinc sulfate and zinc picolinate in diet of quails reared under heat stress condition. They found an improvement in FI, BWG and FCR in Zn supplemented quails.

Uyanik et al. (2005) reported that supplementation of diet with 20, 40, 80 or 100 mg/kg $CrCl_3$ had no effect on performance of Japanese quails but in a newer study that was conducted by Sahin et al. (2010), supplementation of diet with 400 and 800 µg/kg $CrCl_3$ and CrPic improved performance of Japanese quails under heat stress condition.

Rectal temperature

There is so far no report regarding the effect of Zn supplementation on rectal temperature in poultry.

It is obvious that reduction of body temperature is useful and essential under heat stress condition.

Moonsie-Shageer and Mowat (1993) used 0.2, 0.5 and 1 ppm chromium yeast in diet of stressed feeder steer calves and observed reduction in rectal temperature. Reduction of body temperature in Zn and Cr supplemented treatments is probably related to decreased feed intake and declined heat production. Improved immune response and antioxidant status of quails also can be the reasons. In summary, under heat stress condition production of oxidant agents such as peroxide ion and other free radicals intensifies and the body health will be compromised. Finally, all of this events increases the body temperature significantly that will not be a desirable event, especially under heat stress condition. Zn and Cr lower body temperature through improving immune parameters such as heterophil to lymphocyte ratio and playing an antioxidant role against free radicals.

Carcass characteristics

Namra *et al.* (2008) showed dietary supplementation of quails with 50 mg/kg Zn as both organic and inorganic forms had no effect on the relative weight of the heart, liver, gizzard, testes, spleen, and bursa. Also, Noori et al. (2012) reported that supplementation of broiler diets with different levels of Cr (200, 400 and 800 µg/kg) had no effect on the relative weight of the liver, spleen and heart. Improved intestinal characteristics in this study can be attributed to improved nutrients digestibility.

Tibia ash

Ao et al. (2007) reported that supplementation of broiler chicks with Zn increased tibia ash linearly. There is no available report for quails under heat stress. It seems that the process of bone mineralization occurs as more appropriate by providing Zn and establishing a proportionality between the elements in the composition of bones under heat stress condition.

With increasing the level of Cr in the diet, tibia ash increased linearly ($P<0.05$). We could not find any report concerning the effect of Cr supplementation on tibia ash. Birds need more Cr in heat stress conditions and it is needed for bone mineralization similar to Zn. Therefore, using this supplement in this situation can be beneficial. Under heat stress condition minerals mobilization from bones to plasma intensifies to provide urgent needs of the body, so this compromises the process of bone mineralization (Sahin *et al.,* 2009).

Serum biochemical parameters

Sahin *et al.* (2005) showed that supplementation of quails diet with 30 and 60 mg/kg $ZnSO_4$ and ZnPic had no effect on plasma cholesterol under heat stress condition. Uyanik *et al.* (2001) used 20, 40 and 80 mg/kg $ZnSO_4$ in diet of broiler chicks and reported that plasma glucose amount was decreased in birds supplemented with 80 mg/kg Zn.

Kim *et al.* (2009) used 1000 and 2000 µg/kg Cr in pig's diet under heat and cold stress condition and did not observe any significant effect on the level of glucose. Also, in another work adding different levels of $CrCl_3$ (20, 40, 80 and 100 mg/kg) to quail diets had no effect on plasma level of triglycerides, total cholesterol, HDL, total protein, albumin and globulin but decreased plasma glucose and LDL levels. (Uyanik *et al.,* 2005).

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بررسی تاثیر سولفات روی و کروم آلی بر عملکرد، دمای بدن، خصوصیات لاشه، خاکستر استخوان درشت‌نی و فراسنجه‌های خونی بلدرچین ژاپنی در شرایط تنش گرمایی

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چکیده این آزمایش به منظور بررسی اثرات استفاده از سطوح مختلف سولفات روی و پیکولینات کروم بر عملکرد، دمای بدن، خصوصیات لاشه خاکستر استخوان درشت‌نی و فراسنجه‌های خونی بلدرچین ژاپنی در شرایط تنش گرمایی انجام گردید. پرندگان (۵۴۰ قطعه، سن ۷ روزگی) به طور تصادفی در ۹ تیمار که هر تیمار دارای ۳ تکرار با ۲۰ قطعه بلدرچین بود، تقسیم شدند. آزمایش به صورت فاکتوریل ۳×۳ شامل سطوح مختلف مکمل روی (صفر، ۴۰ و ۸۰ میلی‌گرم/کیلوگرم) و کروم (صفر، ۵۰۰ و ۱۰۰۰ میکروگرم/کیلوگرم) انجام شد. پرندگان بر روی بستر پرورش داده شدند و از سن ۷ روزگی تا انتهای آزمایش روزانه به مدت ۸ ساعت (۹ تا ۱۷) در معرض تنش گرمایی قرار گرفتند. نوع مکمل روی و کروم مورد استفاده در آزمایش به ترتیب سولفات روی و پیکولینات کروم بود. با افزایش سطح مکمل روی و کروم در جیره، مصرف خوراک به طور خطی کاهش و ضریب تبدیل بهبود یافت(P<۰/۰۱). استفاده از مکمل کروم افزایش وزن روزانه را نیز به طور خطی افزایش داد (P<۰/۰۵). دمای کلواک جوجه ها با افزایش سطح روی و کروم به طور خطی کاهش نشان داد. با افزودن روی به جیره وزن نسبی روده کوچک(P<۰/۰۱)، رکتوم و نسبت وزن:طول در روده کوچک (P<۰/۰۵) کاهش یافت. با افزودن مکمل روی و کروم به جیره پرندگان، خاکستر استخوان درشت‌نی افزایش نشان داد (P<۰/۰۵). روی و کروم تاثیر معنی‌داری بر فراسنجه های خونی نداشتند. نتایج این آزمایش نشان دهنده اثرات مفید استفاده از مکمل روی و کروم بر عملکرد، دمای بدن، خصوصیات لاشه و استحکام استخوان می باشد. به نظر می رسد مکمل کردن هر کیلو گرم جیره بلدرچین‌ها با ۸۰ میلی گرم سولفات روی و ۱۰۰۰ میکروگرم پیکولینات کروم می تواند در کاهش اثرات مضر تنش گرمایی مفید باشد.