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GROWTH PERFORMANCE AND BIOCHEMICAL PARAMETERS OF HEAT-STRESSED GROWING RABBITS IN RESPONSE TO DIETARY CHROMIUM PICOLINATE AND VITAMIN E SUPPLEMENTATION

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ABSTRACT

The present study investigates the effects of chromium picionate and vitamin E (α-tocopherol acetate) supplementation on growth performance, serum metabolites, and antioxidant status of rabbits exposed to a high ambient temperature (34 °C). Forty Newzealand rabbit (4-w-old) were divided into five groups, 8 rabbits per group. Rabbits were fed a basal diet without or with supplementation with either 300 μg of chromium / kg, 250 mg of α-tocopherolacetate/kg of diet, or a combination of 300 μg of chromium and 250 mg α-tocopherolacetate/kg of diet. Body weight, body gain, feed intake and feed conversion ratio (FCR) were recorded. The experiment lasted for 8 weeks. At end of the experiment, blood samples were collected and sera were separated and used for determination of glucose, total lipid, triglycerides, cholesterol, cortisol, catalase, super-oxide dismutase (SOD), GSH and malonyldialdehyde (MDA).

The results indicated that heat stress inversely affected the growth performance parameters, increased serum glucose, cholesterol, MDA, and decreased total protein, albumen, globulin, GSH, catalase and SOD. Separately or as a combination, supplemental chromium and vitamin E significantly increased live weight, feed intake and improved feed conversion ratio ($P < 0.05$). Separately or as a combination, supplemental chromium and vitamin E increased serum concentration of total protein but decreased cortisol, glucose, and cholesterol concentrations ($P < 0.05$). Supplemental chromium and vitamin E also decreased MDA concentrations ($P < 0.05$) and increased catalase, SOD and GSH. Results of the present study show that dietary supplementation of chromium and vitamin E, particularly as a combination, improved the performance, and antioxidant status of growing rabbits exposed to heat stress. Such a combination of supplements can offer a potential protective mangerial practice in preventing heat stress-related losses in performance of growing rabbits.

INTRODUCTION

High environmental temperature induces physiological stress in rabbits leading to production losses because of their quite poor thermoregulation ability due to their un-functional sweet glands (**Marai et al., 1991; 2001**). Some consequences of heat stress affect digestive system functions, with impaired appetite, growth and feed efficiency (**Donkoh, 1989; Siegel, 1995**) and thyroid activity (**Edens and Siegel, 1975; Freeman and Crapo, 1982**) thus negatively influence the performance of animals and increased incidence of diseases. These effects can also reflect on the levels of some blood metabolites (**Bani et al., 2005**). Relatively few experimental works are available on the effects of high environmental temperature on metabolic profile of the rabbits reared in commercial farms (**Bani et al., 2005**). Plasma T3 and T4, important growth promoters in animals, are reduced during heat stress (**Sahin et al., 2001; 2002a; b**) and appear to be related to feed intake (**Bollengier-Lee et al., 1998; 1999**).

Several methods are available to alleviate a part of the negative effects of high environmental temperature on performance of animals. Because it is expensive to cool animal buildings, such methods are focused mostly on the dietary manipulations. In this respect, vitamin E and chromium are used in the animal diet. Vitamin E metabolism is reduced during the heat stress (**Njoku, 1986; Kutlu. and Forbes, 1993; Whitehead et al., 1998**). Vitamin E is known to be a lipid component of biological membranes and is considered a major chain-breaking antioxidant (**Sahin and Küçük 2001**). Vitamin E is mainly found in the hydrocarbon part of membrane lipid bilayer towards the membrane interface and in close proximity to oxidase enzymes, which initiate the production of free radicals during heat stress (**Jacob, 1995**). Vitamin E, therefore, could protect cells and tissues from oxidative damage induced by free radicals which increased during heat stress. In addition, it was reported that vitamin E plays a role in selenium metabolism, and selenium is required for normal functions of pancreas (**Gallo-Torres, 1980; Bendich et al., 1984**).

Because of the reported benefits of chromium supplementation in broiler under heat stress (**Sahin et al., 2002c, 2003**), also because of the fact that stress condition increased chromium mobilization from the tissues that is irreversibly excreted through the urine (**Borel et al., 1984; Mertz, 1992; Anderson, 1994**), and also, because most rabbit diets are basically composed of plant origin ingredients, which have usually low content of chromium (**Giri et al., 1990**), chromium supplementation could alleviate a part of the negative effect of high environmental temperature on the performance of animals. Although Cr is not currently considered an essential trace element for animals, this micronutrient may play a nutritional and physiological role. Moreover, the National Research Council (**NRC, 1995**) has recommended 300 µg Cr /kg diet for laboratory animals. Supplementation with an organic source of Cr such as chromium picolinate has greater biological availability (Kim et al., 1996a; b), may prove to be beneficial to rabbits under heat stress because rabbits may obtain more Cr despite lowered feed consumption. The chromium is also involved in carbohydrate, lipid, protein and nucleic acid metabolic functions (Ohba et al., 1986; McCarty, 1991). Research on animals has confirmed that chromium from organic complex such as chromium picolinate, nicotinate and high chromium yeast is absorbed more efficiently, about 25-30 % more than inorganic compounds like chromium chloride ($CrCl_3$), which are poorly absorbed (1-3 %) regardless of dose or dietary chromium status (Mowat, 1994; Olin et al., 1994; Underwood and Suttle, 1999).

Measurement of some blood parameters has a substantial merit in understanding metabolic changes in heat-stressed rabbits. Therefore, the objective of this study was to evaluate the effects of dietary supplementation of vitamin E and chromium on growth performance, some blood metabolites and antioxidant status as well as enzyme activities in Newzealand rabbits reared under heat stress (31 °C).

MATERIALS AND METHODS

Diets:

A basal control diet was formulated using NRC (2000) guideline to contain 17% crude protein and 2630 Kcal DE / kg. Ingredients and chemical compositions of the diet are shown in Table I. The diet supplied the recommended requirements of NDF, CP, Ca, P, ADF and DE. The feed ingredients were prepared (berseem hay was chopped and horse bean straw was ground) and mixed with other ingredients (soybean meal, wheat bran, sodium chloride, sodium bicarbonate, DL-methionine, and a mineral and vitamin premix). Small amounts of the basal diet were first mixed with the respective amounts of vitamin E and/ or chromium picolinate as a small batch and then with a larger amount of the basal diet until the total amount of the respective diets were homogeneously mixed and then prepared in a pelleted form with 5 mm diameter.

Animals:

Forty New Zealand White male rabbits (4 weeks old); randomly assigned according to their initial body weights into five groups; were used in a feeding trial. The rabbits were distributed each in individual cage and thereafter were divided into 5 equal groups (8 rabbits each), the first group (control -ve) fed a control basal diet (without chromium and vitamin E supplementation and not subjected to heat stress). The second group (control +ve) fed the control basal diet (without chromium and vitamin E supplementation and subjected to heat stress). The other 3 groups were subjected to heat stress and fed on diets supplemented either with chromium as chromium picolonate; (300 μg/kg of diet), vitamin E (dl-α-tocopheryl acetate; 250 mg/ kg of diet) or both of them. Vitamin E (ROVIMIX E-50 SD; fairly stable source of vitamin E in feed) and chromium were provided by a commercial company (Roche, Egypt). The experimental design is presented in table 2.

The rabbits had ad libitum access to the diets and water throughout the experimental period. The diets were provided regularly at 0800 daily and the remained diets were recorded and the daily feed intake for each rabbit and for each group were determined and totalized every 2 weeks. Body weight and FCR for individual rabbit were determined every two weeks through the experimental period.

Housing:

Rabbits in the first group (control -ve) were kept in a closed pen with partial environmental control. Forced ventilation system allowed the pen temperature to be maintained at 20 ± 2 °C and 60 % relative humidity. While, the other four groups were kept in a closed building and subjected to heat stress condition (34 ± 2 °C and 75 - 80 % relative humidity) using electrical brooders for 24 h / day during the experiment (8 weeks). A cycle of 16 h of light and 8 h of darkness schedule was used throughout the experiment. The experiment was conducted during July to September. 2006. The rabbits were housed in galvanized wire cages (30 x 30 x 35 cm per rabbit) with metal feeders and nipple drinkers. Fecal pellets and urine dropped from the cages were continuously collected and the house floor was cleaned, washed and disinfected daily.

Analytical methods:

Chemical analysis of the basal diet was performed using the method of **Van Soest et al. (1991)** for NDF and **Goering and Van Soest (1970)** for ADF, ADL. Procedures of **AOAC (1995)** were used for determination of DM, ash, crude protein, ether extract and crude fiber. Non-fibrous carbohydrates (NFC) of diet were determined following the procedure of **Theander et al. (1995)**.

At the end of the experiment, blood samples were collected from 6 rabbits from each treatment, centrifuged at 3000 rpm for 10 min. and sera were collected and stored at -20°C for later analysis. Serum samples were thawed at room temperature and cortisol concentrations were determined using commercially available radioimmunoassay kits (Liaison_ T3, and T4 Byk-Sangtec Diagnostica, Dietzenbach-Germany; Immulite 2000 ACTH, L2 KAC2, DPC, LA). Serum glucose **(Trinder and Ann, 1969)**, total protein **(Henry, 1964)**, albumin **(Doumas, 1971)**, triglyceride **(Kodltscheck and Umbreit, 1969)** and cholesterol **(Roeschlau et al., 1974)** concentrations were determined using already prepared analyzing chemical kits, while serum globulin was estimated by the difference between total protein and serum albumin. Also, cortisol, catalase, and superoxide dismutase were measured using biochemical analyzer (Technicon RA-XT, NY). Also, malonyldialdehyde (MDA) was determined according to Ohkawa et al. (1978).

Statistical analysis:

Data were subjected to analysis of variance using general models (GLM) procedure of SAS (1996). Comparisons between means were performed using F test at a significance level of 0.05.

RESULTS AND DISCUSSION

Growth performance :

The average weight gain, feed intake, and feed conversion ratio for the experimental heat stressed rabbits fed on diets supplemented with commercial chromium picionate and / or vitamin E are presented in Table 3. Body weight differed significantly (P < 0.05) due to the heat stress and dietary inclusion of chromium picionate and / or vitamin E. Heat stress resulted in significantly (P < 0.05) adverse effects on all growth performance parameters. Comparison with that of non-stressed rabbits, final body weight, average daily gain, and average daily feed intake of heat stressed rabbits were lowered by 17.03, 22.56 %, and 13.42 %, respectively and feed conversion was increased by 12.04 %. The adverse effects of heat stress on performance of rabbits were reported by many authors (**Marai et al., 1991; Marai and Habeeb, 1994**) who found that final body weight, average daily gain, and average daily feed intake were declined by 14.1, 21.4, and 2.9%, respectively for rabbits reared in summer season on comparison to those reared in winter season. The decrease in growth performance due to heat stress could be attributed to decline in feed consumption. **Chiericato et al. (1996)** and **Marai et al. (2001)** reported that reduction in live body weight and daily body gain weight due to heat-stress conditions may be attributed to the negative effects of heat-stress on appetite and consequent decrease in feed consumption. The decrease in feed consumption is due to impairment of appetite as a result to stimulation of the peripheral thermal receptors by the environmental temperature to transmit suppressive nerve impulses to the appetite centre in the hypothalamus; that causes that phenomenon: suppresses the production of hormone releasing factors, resulted in decrease in pituitary hormones secretion that inversely affects the protein synthesis and blood compounds and so decrease body gain.

Also, the increase in serum cortisol concentration during heat stress (Table 5) inhibits protein synthesis in tissues and increase protein and lipid catabolism (**Sahin et al., 2001**). Additionally, the adverse effects of heat stress on the performance of the rabbits may be due to decreased digestibility and dietary nutrients utilization. **Wallis and Balnave (1984)** found that the digestibility of amino acids was decreased by a high environmental temperature in broilers. Similarly, **Zuprizal et al. (1993)** have shown that true digestibility of protein and amino acids decreased as the temperature increased from 21 to 32 °C. **Hai et al. (2000)** reported that the activities of trypsin, chymotrypsin, and amylase decreased significantly by a high temperature (32 °C). The reason for the decrease in digestive enzymes is uncertain. However, **Osman and Tanios (1983)** speculated that it is because of adjustment of the pancreas in birds accustomed to a hot environment.

Dietary chromium supplementation improved the growth performance parameters of the heat stresses rabbits (Table 3, 4). **Sands** and **Smith (1999; 2002)** reported that dietary chromium picolinate (CrPic) improved the growth performance of heat-distressed broiler chickens. **Onderci et al. (2005)** found that dietary chromium supplementation promoted the growth rate and feed efficiency of growing poultry and these beneficial effects of chromium appear to be greater under stress. On this concept, **Sahin et al. (2005)** reported that supplementing the diet of heat-stressed quails (34 °C for 8 h/d) with CrPic (400 µg of Cr/kg) improved live weight gain, feed intake, feed efficiency and carcass traits. The improvement of growth performance of the heat stressed rabbits due to chromium supplementation could be attributed to increase of chromium mobilization from tissues and its excretion due to stress and also depresses ascorbic acid synthesis (**Anderson, 1987; McDowell, 1989**); thus stress may exacerbate a marginal chromium deficiency or an increased chromium requirement, implying that chromium should be supplemented as shown in the present study. **Wallis and Balnave (1984)** and **Zuprizal et al. (1993)** found that the digestibility of protein and amino acids were decreased by a high environmental temperature in broilers. Similarly, **Zuprizal et al. (1993)** have shown that true digestibility of protein and amino acids decreased as the temperature increased from 21 to 32°C. The results of **Sahin and Sahin (2002)** and **Sahin et al. (2005)** showed that retention of nitrogen and Ca, P, Zn, Fe as well as Cr, are improved and excretion decreased by supplemental chromium. Since chromium (postulated to be antioxidant) has a protective effect on pancreatic tissue against oxidative damage (**McDowell, 1989; Preuss et al., 1997**), they may help pancreas to function properly including secretions of digestive enzymes, thus improving digestibility and retention of nitrogen.

Dietary vitamin E supplementation improved the growth performance parameters of the heat stresses rabbits namely body weight, body gain, and feed intake (Table 3 and 4). **Sahin et al. (2003)** reported that vitamin E supplementation improved the performance and live weight of laying Japanese quails reared under high ambient temperature. The improvement of growth performance parameters of heat stresses rabbits due to vitamin E supplementation could be attributed to increase in feed intake and nutrients utilization. At temperatures above or below thermoneutral zone, corticosteroid secretion increases as a response to stress (**Sahin et al., 2001**). By decreasing synthesis and secretion of corticosteroids, vitamin E alleviates the negative effects of stress. It has been also postulated that the improved performance of poultry resulted from a decrease in protein-derived gluconeogenesis (**Orban et al., 1993**). Also, it was found that dietary vitamin E inclusion resulted in a better performance, and apparent digestibility (**Sahin et al., 2003**). **Sahin and Kucuk (2001)** reported that 250 or 500 mg/kg vitamin E supplementation in diets increased feed intake and improved live weight gain of Japanese quails reared under heat stress (34 °C). **Sahin et al. (2001)** and **Sahin and Kucuk (2001)** reported that digestibility of nutrients (DM, OM, CP, and EE) were higher when vitamin E was included into diet in broiler Japanese quails reared chronic heat stress. Additionally, vitamin E could increase T3, T4 and TSH that improve the performance (**Sahin et al., 2002a; b**).

Serum metabolites :

The results of the present study indicated that heat stress elevated serum glucose and cholesterol concentration which could be attributed to increased cortisol (Table 5). Increasing concentrations of cortisol was parallel to increases in serum glucose and cholesterol concentrations. This result was probably due to the greater catabolic effect (or concentration) of cortisol, yielding more of glucose in the serum. Increases in concentrations of glucose may be attributed to increased glucocorticoid secretion which increases glucogenesis. Results of the present study showed that a combination of 250 mg of vitamin E and 300 µg chromium picolinate / Kg provided the greatest performance, namely body weight, body gain, feed intake and feed conversion ratio; in the rabbits reared under heat stress than supplementation of either chromium or vitamin E alone (Table 3). This finding could indicate synergetic effects for both vitamin E and chromium picolinate. It was reported that overall antioxidant potential has been reported to possibly be more efficient and crucial than single antioxidant nutrients (**Sahin et al., 2005**).

Similar effects of chromium and vitamin E existed as evidence that serum glucose, and cholesterol concentrations decreased, while protein concentrations increased by supplemental dietary vitamin E and chromium (Table 5). Serum concentration of cortisol was also lower with supplemental dietary vitamin E and chromium, indicating a lowered response to heat stress with supplementation of these two nutrients. With supplemental dietary vitamin E, **Sahin et al. (2001)** reported that vitamin E supplementation increased plasma protein concentration while markedly decreased blood ACTH, glucose and cholesterol concentrations in heat-stressed (34 °C) Japanese quails.

The significant decline in plasma total proteins and total lipids (Table 5) concentrations due to heat stress was similar to the results of **Habeeb et al. (1997)** and **El-Masry et al. (1994)**.

Reductions in blood metabolites under high environmental temperatures may be due to the decrease in feed intake and subsequent reduction of metabolism or to dilution of blood and body fluids as a result to the increase in water intake. During heat stress, plasma corticosterone concentration increased (**Bollengier-Lee et al., 1999**), whereas glucose, total protein, albumin, triglyceride, and cholesterol concentrations decreased (**Feenster, 1985; Puthpongsiriporn et al., 2001**).

Oxidation indices:

The results of the present study also indicated that heat stress elevated plasma cortisol concentration which was significantly higher than that of the non-stressed rabbits (Table 4). Serum concentration of cortisol was decreased with supplemental dietary vitamin E, and / or chromium and the decrease in cortisol was more pronounced in stressed rabbits fed the diet supplemented with the combination of 250 mg of vitamin E and 300 µg chromium picolinate / Kg; probably indicating a lowered response to heat stress with supplementation of these nutrients. Similarly, **Sahin et al. (2003)** reported that heat stress elevated plasma corticosterone concentration which was significantly reduced with vitamin E supplementation in a broiler diet. **Pechova** and **Pavlata (2007)** concluded that stresses elevated plasma corticosterone concentration which was significantly reduced with chromium supplementation in diets of different animal species

At the present study, dietary vitamin E and chromium caused decreases in serum MDA concentrations. This is consistent with previous studies (**Sahin et al., 2001; 2003**) that indicated that supplemental vitamin E linearly increased serum vitamin E and decreased MDA concentrations. It is known that heat stress leads to generation of free radicals. This free radicals can damage cell membranes by inducing lipid peroxidation of polyunsaturated fatty acids in the cell membrane (**Sahin et al., 2003; 2005**), resulting in abnormal membrane integrity during heat stress. Also, the results are similar to that of **Sahin et al. (2002a; b)**, who reported that supplemental vitamin E reduced MDA concentrations in serum and liver of Japanese quails reared under heat stress (34°C). Vitamin E is well accepted as the first line of defense against lipid peroxidation. By its free radical quenching activity, it breaks chain propagation and thus terminates free radical attack to polyunsaturated fatty acids of biomembranes at an early stage (**Webster, 1983**). Similar to results of the present study, **Morrissey et al. (1997)** reported that dietary supplementation of chicken diets with α-tocopherol markedly decreased MDA concentration.

The results indicated that heat stress increased free radicals which indicated by increased MDA and decreased the cellular antioxidant defenses which indicated by decreased antioxidant enzyme activities as catalase, GSH and SOD. **Gülinnaz et al. (1998)** reported that stresses increased oxidative damage of tissues and high doses of vitamin E protected against peroxidation and so increased catalase enzyme in renal and cardiac tissues of stressed rats. **Hauswirth and Nair (1975)** recorded a decrease in tissue and serum catalase in vitamin E deficient rats. **Ognjanovic et al. (2003)** reported that vitamin E exhibited a protective role on toxic effects of cadmium on the hematological values, lipid peroxide concentration as well as on enzymatic and non-enzymatic components of antioxidant defense system and so increased activity of antioxidant defense enzymes: copper zinc containing superoxide dismutase (SOD), catalase, glutathione peroxidase and glutathione reductase as well as concentrations of non-enzymatic components of antioxidant defense system as reduced glutathione, vitamin C and vitamin E.

An improve in growth performance and serum metabolites in rabbits in the present study could have been due to positive effects of vitamin E and/or chromium, alleviating the negative effects of heat stress. More specifically, the combination of vitamin E and chromium provided the greatest performance. It is apparent that a combination of dietary vitamin E and chromium supplementation offers a feasible way to reduce the losses in performance due to heat stress. Overall antioxidant potential has been reported to possibly be more efficient and crucial than single antioxidant nutrients **(Bendich et al., 1984)**. From the results of the present study, it could be concluded that a combination of 250 mg of vitamin E and 300 µg of chromium provides the greatest performance in rabbits reared under heat stress. Such a combination can be considered as a protective management practice in a rabbit diet, ameliorating the detrimental effects of heat stress.

Table 1. Ingredients and nutrients composition of the experimental basal diet (as fed basis)

Ingredients	%
Berseem hay (Egyptian)	36.00
Horse-bean straw	4.75
Corn grain, yellow	28.38
Soybean meal, 44%	15.50
Wheat bran	12.00
Molasses, sugar cane	2.00
Common salt	0.10
Sodium bicarbonate	0.80
Vitamin-minerals premix*	0.25
DL-methionine	0.22
Nutrient composition	
DM	90.80
CP	16.40
CF	14.00
NDF	28.00
ADF	18.70
Cellulose	13.39
Lignin	3.10
Hemicellulose	9.30
Ash	9.40
EE	3.20
NFC	34.80
Ca	0.61
P	0.38
Na	0.31
Cl	0.32
DE (Mcal / Kg)*	2.63

*provide per kg diet: vitamin A (palmitate), 12,000 IU; vitamin D (cholecalciferol, 2,500 IU; vitamin E (α-tocopherol), 12 mg; vitamin K_3 (menadione), 2.5 mg; vitamin B_1, 1.2 mg; vitamin B2, 6 mg; pantothenic acid, 12 mg; folic acid, 1.2 mg; niacin, 36 mg; pyridoxine, 2 mg; vitamin B_{12}, 0.01 mg; biotin, 0.06 mg; , Choline, 100 mg; iron, 36 mg; copper, 5 mg; manganese, 72 mg; zinc, 60 mg, iodine, 0.45 mg,; selenium, 0.12 mg.

Table 2. Experimental design

Groups	Treatments		
	Heat stress 34 °C	Cr piclonate 300 μg/ Kg	Vitamin E 250 mg/ Kg
I (Control -ve)	-	-	-
II (Control +ve)	+	-	-
III (Cr piclonate)	+	+	-
IV (Vitamin E)	+	-	+
V (Cr piclonate + Vit. E)	+	+	+

Table 3. Effects of dietary chromium picolinate and/ or vitamin E supplementation on body weight (g) development of the heat stressed Newzealand white rabbit

	Non-stressed	Heat stressed groups			
	Control	Control	Cr piclonate	Vitamin E	Cr piclonate + Vit. E
Initial (4 wks)	645 ± 17.23	656 ± 12.36	659 ± 12.78	643 ± 13.22	655 ± 15.11
8	1194^{a} ± 32.11	980^{b} ± 21.27	1210^{a} ± 24.30	1189^{a} ± 19.76	1182^{a} ± 32.04
[illegible]	1690^{a} ± 36.24	1378^{b} ± 33.13	1669^{a} ± 25.16	$164[illegible]^{a}$ ± 16.67	1710^{a} ± 20.35
10	2313^{a} ± 30.26	1957^{b} ± 36.21	2287^{a} ± 25.43	2210^{a} ± 20.46	2306^{a} ± 39.21
12	2824^{a} ± 49.45	2343^{c} ± 66.11	2769^{ab} ± 67.32	2674^{b} ± 55.14	2837^{a} ± 71.21

abc Means in the same row with different superscripts are significantly different ($P < 0.05$).

Table 4. Effect of dietary chromium picolinate and / or vitamin E supplementation on growth performance of heat stressed rabbits

	Control	Heat stressed rabbit groups			
		Control	Cr picolonate	Vitamin E	Cr picolonate + Vit. E
4- 6 wks					
Average weight gain, g/day	39.22 ± 2.17^{a}	23.14 ± 3.62^{b}	39.36 ± 4.10^{a}	39.00 ± 2.93^{a}	37.64 ± 3.15^{a}
Average feed consumption, g/day	88.25 ± 4.23^{a}	56.00 ± 5.16^{b}	90.92 ± 6.19^{a}	92.43 ± 7.23^{a}	89.23 ± 6.16^{a}
Average feed conversion ratio	2.25 ± 0.06^{c}	2.42 ± 0.08^{a}	2.31 ± 0.09^{bc}	2.37 ± 0.12^{ab}	2.37 ± 0.05^{ab}
6-8 wks					
Average weight gain, g/day	36.07 ± 6.32^{a}	28.43 ± 7.21^{b}	32.78 ± 3.28^{a}	32.71 ± 4.49^{b}	37.71 ± 4.68^{a}
Average feed consumption, g/day	106.77 ± 6.22^{a}	94.10 ± 7.23^{b}	100.31 ± 8.08^{ab}	106.31 ± 9.13^{a}	105.15 ± 8.34^{a}
Average feed conversion	2.96 ± 0.03^{b}	3.31 ± 0.08^{a}	3.06 ± 0.11^{b}	3.25 ± 0.08^{a}	3.08 ± 0.12^{b}
8-10 Wks					
Average weight gain, g/day	43.86 ± 6.62	41.36 ± 5.23	44.14 ± 6.85	40.21 ± 5.69^{a}	42.57 ± 4.10^{a}
Average feed consumption, g/day	151.06 ± 5.98	157.17 ± 9.13	153.17 ± 6.41	141.54 ± 5.98^{b}	137.28 ± 7.83^{b}
Average feed conversion	3.46 ± 0.06	3.80 ± 0.07	3.47 ± 0.09	3.52 ± 0.11^{a}	3.52 ± 0.11^{a}
10-12 Wks					
Average weight gain, g/day	36.50 ± 5.10^{a}	27.57 ± 6.26^{b}	34.43 ± 6.13^{a}	33.14 ± 7.20^{a}	37.93 ± 4.39^{a}
Average feed consumption, g/day	159.51 ± 7.34^{ab}	130.41 ± 6.78^{c}	154.25 ± 9.33^{b}	151.78 ± 7.02^{b}	164.24 ± 7.96^{a}
Average feed conversion	4.37 ± 0.08^{c}	4.73 ± 0.06^{a}	4.48 ± 0.07^{b}	4.58 ± 0.15^{b}	4.33 ± 0.09^{c}
Allover performance (4- 12 wks)					
Average total weight gain, g/d	38.91 ± 6.19^{a}	30.13 ± 5.14^{b}	37.68 ± 4.92^{a}	36.27 ± 6.45^{a}	38.96 ± 5.50^{a}
Average total feed consumption, g/d	126.38 ± 7.31^{a}	109.42 ± 6.14^{b}	124.66 ± 7.06^{a}	123.02 ± 8.15^{a}	125.85 ± 8.14^{a}
Average feed conversion ratio	3.24 ± 0.09^{c}	3.63 ± 0.11^{a}	3.30 ± 0.09^{bc}	3.39 ± 0.12^{b}	3.23 ± 0.07^{c}

[abc] Means in the same row with different superscripts are significantly different ($P < 0.05$).

Table 6. Effect of dietary chromium picolinate and / or vitamin E supplementation on serum metabolites and oxidation indices of heat stressed rabbits

	Non-stressed	Heat stressed rabbit groups			
	Control	Control	Cr piclonat	Vitamin E	Cr piclonate + Vit. E
Serum meatbolites					
Glucose (mg/dl)	94.25 ± 2.23 ^{d}	146.36 ± 2.18 ^{a}	118.25 ± 2.23 ^{b}	122.11 ± 3.76 ^{b}	106.11 ± 4.23 ^{c}
Total cholesterol (mg/dl)	99.3 ± 2.78 ^{d}	137.1 ± 3.59 ^{a}	115.7 ± 4.39 ^{b}	118.5 ± 3.51 ^{b}	104.4 ± 3.06 ^{c}
Total lipid (g/dl)	8.07 ± 0.22 ^{d}	4.13 ± 0.15 ^{a}	6.85 ± 0.17 ^{b}	6.92 ± 0.21 ^{b}	6.30 ± 0.19 ^{c}
Triglycerides (mg/dl)	151.5 ± 1.47 ^{c}	196.8 ± 1.90 ^{a}	163.7 ± 1.11 ^{b}	166.2 ± 2.04 ^{b}	154.7 ± 1.66 ^{c}
Total protein(g/dl)	6.53 ± 0.15 ^{a}	5.13 ± 0.09 ^{b}	6.41 ± 0.12 ^{a}	6.13 ± 0.05 ^{a}	6.38 ± 0.09 ^{a}
Albumin (g/dl)	4.23 ± 0.11 ^{a}	3.36 ± 0.12 ^{b}	4.14 ± 0.09 ^{a}	4.13 ± 0.06 ^{a}	4.18 ± 0.49 ^{a}
Globulin (g/dl)	2.30 ± 0.06 ^{a}	1.77 ± 0.12 ^{c}	2.27 ± 0.12 ^{a}	2.00 ± 0.06 ^{b}	2.20 ± 0.04 ^{ab}
Oxidation indices					
Cortisol (ng/ml)	9.63 ± 0.43 ^{c}	18.47 ± 0.67 ^{a}	11.31 ± 0.52 ^{b}	11.73 ± 0.50 ^{b}	8.59 ± 0.69 ^{c}
MDA (nmol/ml)	4.54 ± 0.031 ^{b}	7.13 ± 0.074 ^{a}	4.70 ± 0.068 ^{b}	4.67 0.045 ^{b}	4.51 ± 0.033 ^{b}
Catalase (nmol/ml)	0.355 ± 0.007 ^{a}	0.279 ± 0.002 ^{c}	0.319 ± 0.004 ^{b}	0.312 ± 0.004 ^{b}	0.349 ± 0.005 ^{a}
SOD (nmol/ml)	62.07 ± 1.336 ^{a}	38.02 ± 0.824 ^{c}	56.07 ± 0.655 ^{b}	54.57 ± 0.863 ^{b}	61.59 ± 0.653 ^{a}
GSH (nmol/ml)	72.76 ± 1.08 ^{a}	60.96 ± 1.93 ^{c}	69.08 ± 1.14 ^{b}	68.24 ± 0.90 ^{b}	70.44 ± 0.49 ^{ab}

^{abcd} Means in the same row with different superscripts are significantly different ($P < 0.05$).

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الملخص العربى

تأثير إضافة ڤيتامين هـ والكروم على معدلات النمو، وبعض قياسات مصل الدم فى الأرانب أثناء الإجهاد الحرارى

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أجريت هذه التجربة لدراسة تأثير إضافة ڤيتامين هـ والكروم فى علائق الأرانب النامية أثناء الإجهاد الحرارى على معدلات النمو، وبعض قياسات مصل الدم وبعض مؤشرات الإجهاد والأكسدة مثل هرمون الكورتيزول، methylmalondahyde (MDA)، إنزيمات catalase, superoxide dismutase . أجريت التجربة على أربعين أرنباً عمر 4 أسابيع، حيث قسمت إلى 5 مجموعات متساوية، غذيت المجموعة الأولى على عليقة ضابطة (بدون إضافة ڤيتامين هـ أو الكروم) وبدون التعرض للإجهاد الحرارى بينما غذيت المجموعة الثانية على العليقة الضابطة ولكن تحت الإجهاد الحرارى (33-35 درجة مئوية). أما المجموعات الثلاثة الأخرى كانت تحت الإجهاد الحرارى، وغذيت على العليقة الضابطة بالإضافة إلى إضافة ڤيتامين هـ (250 مجم/كجم)، بيكلونات الكروم (300 ميكروجرام / كجم) أو كلاهما معاً، وغذيت الأرانب لمدة 8 أسابيع تم خلالها تعيين وزن الأرانب وكمية العلف المستهلك لكل أرنب ولكل مجموعة كل إسبوعين، كما تم حساب معدلات التحويل الغذائى، وفى نهاية التجربة تم جمع عينات دم من 5 أرانب فى كل مجموعة ثم تم فصل مصل الدم ليستخدم فى تعيين الجلوكوز، البروتين، الكوليستيرول، الدهون الكلية وكذلك بعض الإنزيمات والهرمونات الدالة على حالة الأكسدة والإجهاد الحرارى مثل methylmalondahyde (MDA)، إنزيمات catalase, superoxide dismutase.

ويمكن إيجاز أهم النتائج فيما يلى :-

- الإجهاد الحرارى أدى إلى نقص معنوى فى وزن الأرانب وكمية العلف المستهلك ومعدل التحويل الغذائى.
- أدى إضافة ڤيتامين هـ أو الكروم فى علائق الأرانب أثناء الإجهاد الحرارى إلى تحسين معنوى فى وزن الأرانب وكمية العلف المستهلك ومعدل التحويل الغذائى.
- أدى إضافة ڤيتامين هـ والكروم معاً فى علائق الأرانب أثناء الإجهاد الحرارى إلى تحسين معنوى فى وزن الأرانب وكمية العلف المستهلك ومعدل التحويل الغذائى.
- الإجهاد الحرارى أدى إلى زيادة معنوية فى تركيز الجلوكوز والكوليسترول فى السيرم بينما أدى إضافة ڤيتامين هـ أو الكروم فى علائق الأرانب أثناء الإجهاد الحرارى إلى تحسين معنوى (النقص) فى تركيزهما.
- الإجهاد الحرارى أدى إلى زيادة معنوية فى تركيز MDA و cortisol ونقص معنوى فى catalase و superoxide dismutase فى السيرم بينما أدى إضافة ڤيتامين هـ أو الكروم فى علائق الأرانب أثناء الإجهاد الحرارى إلى نقص فى تركيز MDA و cortisol وزيادة فى catalase, superoxide dismutase.

تشير نتائج هذه الدراسة إلى أنه ينصح بإضافة ڤيتامين هـ أو الكروم أو كلاهما معاً فى علائق الأرانب أثناء الإجهاد الحرارى حيث أنه يمكنها تقلل من الآثار الضارة التى تنتج عن الإجهاد الحرارى.