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EFFECT OF THE DIFFERENT TYPES OF CHROMIUM SUPPLEMENTATION ON THE PRODUCTIVE PERFORMANCE, KIDNEY AND LIVER FUNCTIONS OF BROILER UNDER THE HEAT STRESS CONDITIONS

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ABSTRACT

The purpose of this research was to determine the effect of common types of chromium supplementation on productive performance, Kidney and Liver function indices, Antioxidant indices, economic efficiency and European production efficiency factor in broiler chickens. A total of 120 unsexed broiler chicks (Arbor Acres) at 7 days of age were randomly distributed into 4 experimental groups with 6 replicates of 5 birds. Birds of the first (T1) group served as the control group were fed the basal diet without any addition, the 2nd (T2) group was fed diets containing 2mg/kg chromium chloride ($CrCl_3$) as a powder, the 3rd (T3) group was fed diets containing 2mg/kg chromium yeast (CrY) as a powder, and 4th (T4) group was fed diets containing 0.2mg/kg chromium nano (CrN) as a powder. During the period (25-27) and (31-33) days, the all treatments from T1 to T4 were exposed to heat stress for 4 hours per day (10:00 AM to 2:00 PM) at (34°C) and (70-75%) relative humidity. Chicks fed diet with CrN and CrY to broiler chicks diets led to a significant ($p \leq 0.05$) improvement in body weight (BW), body weight gain (BWG), feed consumption (FC), feed conversion ratio (FCR), economic

efficiency (EE), European production efficiency factor (EPEF), liver and kidney functions as evidenced by the increased Alkaline phosphatase (ALP) and decrease in aspartate aminotransferase (AST) and alanine aminotransferase (ALT) while, it was not significant differences in the serum uric acid, creatinine and uric acid/creatinine ratio. It also added CrN under heat stress lead to significantly ($p \leq 0.05$) increased serum superoxide dismutase (SOD) and glutathione peroxides (GSH-Px).

Keywords: broiler, Chromium, chloride, yeast, nano, heat stress, performance.

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INTRODUCTION

In Egypt, the ambient temperature can rise over the course of the summer for long periods in addition to its sudden rise, Frequent heat, and humid waves have more unsafe effects. Therefore, poultry production suffered great losses every year due to heat stress (HS) **(Wang *et al.*, 2022)**, which leads to economic losses for poultry farmers. Temperatures during these periods reach 42°C most of the time and relative humidity reaches 75% **(Tawfeek *et al.*, 2014)**. HS in broilers has been calculated to specifically stifle the immune system, resulting in disappointment in chicken response to immunization and immune system involvement. Stressed poultry can be identified by frequent panting, decreased feed consumption, increased water use and excreta water content also, decreased immune efficiency, and expanded investment costs to mitigate the effects of environmental change **(Rajkumar *et al*., 2015)** and heat shock protein (HSP70). Heat stress has also been shown to increase the activities of antioxidant enzymes, such as SOD, GSH-Px, and catalase (CAT). Increased antioxidant enzyme responses to activities to increased levels of responsive oxygen species (ROS) are aimed at maintaining steady-state concentrations of free radical production.

Supplemental dietary chromium, especially at 1200 ppb, may offer a chance for preventive management practice in preventing the adverse effects of HS on broiler performance. The main part of chromium in the digestion process is the stimulation of insulin activity through its proximity to organometallic particles and glucose resistance **(Sahin *et al.*, 2002)**. Insufficiency of Cr may lead to reduced susceptibility to the effect of insulin on tissues which leads to disturbance of carbohydrate and fat metabolism and consequently poor growth rate also, Cr-Pico was found to specifically raise weight due to increased feed intake and to support immune function by enhancing cell- and brachial-mediated immune responses in broiler chickens, improvement in body weight and body weight gain **(Mohammed *et al.*, 2014)**.

This study aims to investigate the negative impact of heat stress on poultry production in Egypt and suggest potential solutions to mitigate its effects, such as supplementing dietary chromium to improve broiler performance and liver and kidney function.

MATERIAL AND METHODS

The fieldwork of the present study was carried out at the poultry research unit (El-Bostan farm), Faculty of Agriculture, Damanhour University, during the period from June to July 2021, A total number of 120 unsexed broiler chickens (Arbor Acers) were acquired from a commercial hatchery (Cairo Poultry Company), wing banded and randomly divided keeping similar initial body weight (7 days of age) with a mean body weight of 172.8±1.23g were randomly distributed into four experimental groups (treatments) in a straight run experimental design with six replicates of five birds in each for a 28-day (from 7 to 42 days of age). Each replicate was kept in battery brooders in wire cages (55×50×35 cm length-width-height). Birds of the 1st group served as the control group (T1) and was fed the basal diet without any addition, the 2nd (T2) group was fed diets containing 2mg/kg Chromium chloride ($CrCl_3$) as a powder, the 3rd (T3) group was fed diets containing 2mg/kg Chromium yeast (CrY) as a powder, and 4th (T4) group was fed diets containing 0.2mg/kg Chromium nano (CrN) as a powder. During the period (25-27) and (31-33) days, the treatments from T1 to T4 were exposed to heat stress for 4 hours per day (10:00 AM to 2:00 PM) at (34°C) and (70-75%) relative humidity.

Table 1: Composition and calculated analysis of experimental basal diets fed to broiler chicks from 7 - 42 days of age

Ingredients	Starter diet, 1-21 d of age	Finisher diet 22-42 d of age
Yellow corn, kg	490	550
Soybean meal 48% CP, kg	420	358
Di-calcium phosphate, kg	20	15
Limestone, kg	10	12.5
NaCl, kg	3	3
Vitamin+ mineral premix[1], kg	3	3
Dl-Methionine, kg	2.5	2.5
L- Lysine, kg	1.5	2.0
Vegetable oil[2], kg	50	54
Total	1000	1000
ME	3035	3135
CP	229	208
Ca	9.5	9.1
Available P	5.2	4.2
Methionine	6.0	5.6
TSAA	9.6	9.1
Lysine	13.7	12.6
Ether extra	47	48
Crude fiber	33	38
Ash	55	52
Dry matter	901	912

[1] Vit+Min mixture provides per kg of the diet: vitamin A (retinyl acetate) 24mg, vitamin E (dl-α-tocopheryl acetate) 20mg, menadione 2.3mg, Vitamin D_3 (cholecalciferol) 0.05mg, riboflavin 5.5mg, calcium pantothenate 12mg, nicotinic acid 50mg, choline chloride 600mg, vitamin B12 10µg, vitamin B6 3mg, thiamine 3mg, folic acid 1mg, d-biotin 0.50mg. Trace mineral (mg per kg of diet): Mn 80 Zn 60, Fe 35, Cu 8, Se 0.60. [2] A mixture of soybean oil, cotton seed oil and sunflower at 33.33% of each. ME, metabolic energy; CP, crude protein; Ca, calcium; TSAA, total sulfur amino acids

All experimental birds were maintained under similar environmental conditions. Chicks were fed *ad libtium*, experimental diets explained in Table (1) and given free access to water throughout the 42 days. A light schedule of 23h light and 1 hr dark was applied until the 7th day while a 20h of light and 4h of dark schedule was provided from day 8 to 42d of age. The average outdoor minimum and maximum temperature and relative humidity during the experimental period were 21.2 and 24.2°C and 56.7 and 58.7%, respectively. The brooding temperatures (indoor) were 30, 27 and 24-21°C during 7-14. 15-21, 22-42 days of age, respectively. Chicks were raised using common management practices for broiler chicks. Chicks were vaccinated with Nobilis NDV Clone 30, Gumboro, and Clone with Gumboro at days 7, 14, 21 and 28 days of age, respectively. The vaccines were obtained from (Merck and Co., Inc., Intervet, Cairo, Egypt).

Studied traits

Body weight (BW) and feed consumption (FC) per replicate were recorded weekly, then body weight gain (BWG) and feed conversion ratio (FCR: g feed consumed/g weight gain) were calculated. Body weight gain within each replicate was calculated based on 6 weeks intervals from 7 to 42 days of age. The accumulative BWG for the entire experimental period (7-42 d) was calculated for each experimental treatment.

Feed consumption

Feed consumption was recorded at five intervals (7-14, 15-21, 22-28, 29-35 and 36-42d of age) and accumulated feed consumption (7-42d of age) was calculated for each treatment group. The average of feed consumed was calculated in grams for each experimental group and divided by the number of birds in each group, feed conversion ratio (g feed /g gain) was calculated every week intervals (7-14, 15-21, 22-28, 29-35 and 36-42d of age) and accumulated FCR (7-42d of age) for each treatment as units kilograms of feed consumption to produce one unit of BWG during each period, using the following equation: FCR= [FI (g)/ BWG (g)].

Kidney function

Serum creatinine level (mg/ dl) was estimated according to **Husdan and Rapoport (1968)**, and serum uric acid level (mg/ dl) was measured according to the method explained by **Patton and Crouch (1977)**. The uric acid to creatinine ratio was also calculated by dividing the total level of uric acid of the total level by creatinine.

Liver function

The transaminase enzyme activities of serum aspartate aminotransferase (AST) and serum alanine aminotransferase (ALT), as U/L were determined by the calorimetric method of **Reitman and Frankel (1957)**. Alkaline phosphatase (ALP, U/L) concentration was determined according to the colorimetric method of **John and Bauer (1982)**.

Oxidative status

The determination of total antioxidative capacity (TAC, mM/L) is performed by the reaction of antioxidants in the sample with a defined amount of exogenously provided hydrogen peroxide (H_2O_2). The serum antioxidants in the sample eliminate a certain amount of the provided H_2O_2. The residual H_2O_2 is determined calorimetrically by an enzymatic reaction which involves the conversion of 3, 5, dichloro -2- hydroxyl as described by **Koracevic et al., (2001)**. Malondialdehyde (MDA, µmol/L) was determined as a thiobarbituric acid-reactive substance (TBARS) in serum by the method of **Placer et al., (1966)**.

Economical evaluation

Economical evaluation for all experimental treatments was made as below;

Economical efficiency = Total revenue-Total cost/ Total cost

Where:
Total revenue = BW × meat price (growing phase)
Total cost = Feed cost + Cost of supplementation + Other costs
Relative economical efficiency = (Economic efficiency/ control economic efficiency) × 100

Statistical analysis

Statistical analysis was done using the GLM procedure of statistical analysis software of SAS Institute (**SAS** ver. 9.2, SAS® 2009) using one-way analysis of variance according to the following formula: $Y_{ij} = \mu + T_i + e_{ij}$

Where: Y_{ij}= The observation of the statistical measured,
μ= The general overall mean,
T_i= The effect of treatment,
e_{ij}= The experimental random error.

Before analyses, arcsine transformation was done to normalize data distribution. The mean difference at $p \leq 0.05$ was tested using Tukey’s HSD (honestly significant difference) test. The replicate was the experimental unit.

RESULTS

Growth Performance

Body weight: Table 2 shows the effect of chromium on BW of Arbor Acres broilers during experimental periods (7, 14, 21, 28, 35, and 42 days of age). The results showed that adding CrY or CrN to the diet of the broiler chicks led to a significant (P≤0.05) improvement in BW compared to the control group at the age of 14 and 42 days. However, adding chromium to the diet of broiler chicks in CrN form at the age of 28 and 35 days led to a significant (P≤0.05) improvement in BW compared to all other groups, while the addition of any of the different types of chromium had no effect on BW at the age of 21 days.

Table 2: Effect of chromium supplementation on body weight of broiler chicks under heat stress conditions during period 7-42 days of age

Items	Control	$CrCl_3$	Cr-yeast	Cr-Nano	SEM	P value
BW, g at 7 d	173	173	172	171	0.67	0.911
BW, g at 14 d	432^b	434^b	447^a	449^a	1.44	0.0001
BW, g at 21 d	836	836	840	845	1.56	0.189
BW, g at 28 d	1396^c	1422^b	1422^b	1435^a	1.55	0.0001
BW, g at 35 d	1896^d	1907^c	1927^b	1946^a	2.03	0.0001
BW, g at 42 d	2089^c	2324^b	2414^a	2426^a	11.2	0.0001

SEM= Standard error of mean; $CrCl_3$= chromium chloride; BW= body weight

^{a,b,c} Means within rows with different letter superscripts are significantly different based on statistical analysis (P≤0.05).

Body weight gain: Table 3 shows the effect of chromium on BWG of Arbor Acres broilers during 7-42 days of age. The results indicated that adding CrY or CrN to the diet of the broiler chicks led to a significant (P≤0.05) improvement in BWG at the age of 7-14, 36-42, and 7-42 days. In the period from 29-35 days, it was found that the addition CrN lead to a significant (P≤0.05) increase in BWG compared to the control group. While, at the age of 22-28 days, adding Cr Cl_3 was significantly (P≤0.05) better in BWG compared to the control group.

Table 3: Effect of chromium supplementation on body weight gain of broiler chicks under heat stress conditions during period 7-42 days of age

Items	Control	$CrCl_3$	Cr-yeast	Cr-Nano	SEM	P value
BWG, g at 7-14 d	258^b	261^b	274^a	278^a	1.66	0.0001
BWG, g at 15-21 d	408	396	393	396	1.78	0.057
BWG, g at 22-28 d	554^c	590^a	581^b	588^{ab}	2.70	0.0001
BWG, g at 29-35 d	499^b	484^c	504^{ab}	511^a	2.24	0.001
BWG, g at 36-42 d	194^c	416^b	487^a	480^a	20.9	0.0001
BWG, g at 7-42 d	1916^c	2150^b	2241^a	2255^a	23.6	0.0001

SEM= Standard error of mean; $CrCl_3$= chromium chloride; BWG= body weight gain
^{a,b,c} Means within a rows with different letter superscripts are significantly different based on statistical analysis (P≤0.05).

Feed consumption: Data for FC of broiler chicks during the experimental periods are shown in Table 4. The results indicated that adding CrN to the diet of the broiler chicks in the period from 7-14, 36-42, and 7-42 led to a significant (P≤0.05) increase FC compared to all other groups. Furthermore, The addition of CrN in the period from 22-28 days led to a significant (P≤0.05) decreased FC compared to the control group.

Feed conversion ratio: Data for FCR of broiler chicks during the experimental periods are shown in Table 5. The results showed that adding Cr Cl$_3$ in the periods from 7-14 and 15-21 days, gave the best FCR compared to the rest of the other totals, while in the period from 22-28 days, adding CrN led to a significant ($P \leq 0.05$) improvement FCR Compared to the other two groups of chrome, as well as compared to the control group. Whereas, at the age of 36-42, the addition of chromium of various types led to a significant ($P \leq 0.05$) improvement FCR compared to the control group. Also, the addition of CrY in the period from 29-35 and 36-42 resulted in a significant ($P \leq 0.05$) improvement FCR compared to all other groups.

Table 4: Effect of chromium supplementation on feed consumption of broiler chicks under heat stress conditions during period 7-42 days of age

Items	Control	CrCl$_3$	Cr-yeast	Cr-Nano	SEM	P value
FC, g at 7-14 d	258^{c}	255^{d}	274^{b}	285^{a}	2.09	0.0001
FC, g at 15-21 d	481^{a}	456^{c}	444^{d}	470^{b}	2.72	0.0001
FC, g at 22-28 d	799^{ab}	809^{a}	794^{b}	775^{c}	4.36	0.0001
FC, g at 29-35 d	890^{a}	814^{c}	773^{d}	840^{b}	7.91	0.0001
FC, g at 36-42 d	587^{c}	805^{b}	806^{b}	929^{a}	22.4	0.0001
FC, g at 7-42 d	3018^{c}	3139^{b}	3093^{b}	3302^{a}	19.5	0.0001

SEM= Standard error of mean; CrCl$_3$= chromium chloride; FI= feed intake
^{a,b,c} Means within rows with different letter superscripts are significantly different based on statistical analysis ($P \leq 0.05$).

Table 5: Effect of chromium supplementation on feed conversion ratio of broiler chicks under heat stress conditions during period 7-42 days of age

Items	Control	CrCl$_3$	Cr-yeast	Cr-Nano	SEM	P value
FCR, g/g at 7-14 d	1.00^{b}	0.98^{c}	1.00^{b}	1.03^{a}	0.010	0.0001
FRC, g/g at 15-21 d	1.18^{a}	1.15^{b}	1.13^{b}	1.19^{a}	0.010	0.0001
FCR, g/g at 22-28 d	1.44^{a}	1.37^{b}	1.37^{b}	1.32^{c}	0.010	0.0001
FCR, g/g at 29-35 d	1.78^{a}	1.68^{b}	1.53^{c}	1.65^{b}	0.020	0.0001
FCR, g/g at 36-42 d	3.04^{a}	1.95^{b}	1.66^{b}	1.94^{b}	0.100	0.0001

FCR, g/g at 7-42 d	1.57^a	1.46^b	1.38^c	1.47^b	0.010	0.0001

SEM= Standard error of mean; Cr Cl_3= chromium chloride; FCR= feed conversion ratio
^{a,b,c} Means within rows with different letter superscripts are significantly different based on statistical analysis (P≤0.05)

Kidney and liver function indices

Table 6 presented the effects of different forms of chromium on renal and liver function indices. The results indicate that there were no significant differences in the serum uric acid, creatinine, and uric acid/creatinine ratio, however, blood serum creatinine levels were decreased numerically in the groups fed CrN and CrY compared with the control group but insignificantly.

The serum levels of ALP, AST, and ALT content showed significant effects from the dietary treatments. Serum ALP was significantly (P≤0.05) higher in the groups of CrN and CrY than that of the other groups. On the other hand, the control group significantly (P≤0.05) reduced ALP compared with the other treatments. The results indicate that CrN group significantly (P≤0.05) decreased ALT compared with Cr Cl_3 and the control groups. Similarly, the serum AST of the group supplemented with CrN followed by CrY had a significantly (P≤0.05) lower AST than that supplemented with Cr Cl_3 and the control groups.

Table 6: Effect of chromium supplementation on kidney function indices of broiler chicks under heat stress conditions at 42 days of age

Items	Control	$CrCl_3$	Cr-yeast	Cr-Nano	SEM	P value
Kidney functions						
Uric acid, mg/dl	3.00	2.90	2.77	2.73	0.050	0.2888
Creatinine, mg/dl	0.733	0.667	0.533	0.533	0.035	0.1569
UA/Create	4.11	4.89	5.22	5.36	0.230	0.3971
Liver functions						
ALP, U/L	13.5^c	14.0^b	14.5^a	14.4^a	0.09	0.0001

ALT, U/L	36.3^{a}	36.3^{a}	35.0^{b}	33.3^{c}	0.48	0.0003
AST, U/L	61.0^{a}	58.7^{b}	56.7^{c}	52.7^{d}	0.57	0.0001
AST/ALT ratio	0.596	0.619	0.618	0.633	0.01	0.2722

SEM= Standard error of mean; Cr Cl_3= chromium chloride; UA/Create= Uric acid/ creatinine ratio; ALP= Alkaline phosphatase ALT= Alanine transaminase; AST= Aspartate transaminase; AST/ALT ratio= Alanine transaminase to Aspartate transaminase.

^{a,b,c} Means within rows with different letter superscripts are significantly different based on statistical analysis ($P \leq 0.05$).

Evidence indicated that the groups supplemented with CrN and CrY improved liver and kidney functions as evidenced by the increased ALP and decrease in AST and ALT.

Antioxidant indices

The effects of different forms of chromium supplementation on the antioxidant indices at 42 days old broiler chickens under HS are presented in Table 7. It was observed that different dietary supplementation significantly ($P \leq 0.05$) affects serum MDA, SOD, and GSH-Px but did not affect TAC. Broiler chickens' fed diets supplemented with CrY followed by CrN showed a significantly lower MDA than Cr Cl_3 and the control groups. Supplementation with CrN, significantly ($P \leq 0.05$) increased serum SOD compared with Cr Cl_3 and the control groups. Also, Broiler chickens' fed diets supplemented with CrN showed a significantly ($P \leq 0.05$) greater GSH-Px than the control group, but differences in GSH-Px were not significant among different forms of chromium supplementations.

Table 7: Effect of chromium supplementation on antioxidant indices of broiler chicks under heat stress conditions at 42 days of age

Items	Control	$CrCl_3$	Cr-yeast	Cr-Nano	SEM	P value
TAC, mg/dl	418	423	426	425	1.21	0.2030
MAD, nmol/ml	1.47^{a}	1.07^{b}	0.43^{d}	0.90^{c}	0.07	0.0001
SOD, mg/dl	259^{c}	260^{bc}	269^{ab}	275^{a}	1.92	0.0003
GSH-Px, mg/dl	12.1^{b}	12.7^{ab}	12.9^{ab}	13.6^{a}	0.16	0.0333

SEM= Standard error of mean; $CrCl_3$= chromium chloride; TAC= total antioxidant capacity; MDA= Malondialdehyde; SOD= Superoxide dismutase; GSH-Px = Glutathione peroxidase.

^{a,b,c} Means within a rows with different letter superscripts are significantly different based on statistical analysis (P≤ 0.05).

Economic efficiency

The effect of supplementation of different chromium forms on final body weight, total Cost, total revenue, net revenue, EE and EPEF were presented in Table 8. Results indicated that the CrN and CrY groups significantly improved the final body weight during 7-42 days of age compared with the other experimental groups. On the contrary, chicks fed basal diet without supplementation and exposure to heat stress had a significantly (P≤0.05) lower total cost than the other experimental groups.

Table 8: Effect of chromium supplementation on the economic efficiency of broiler chicks under heat stress conditions during period 7-42 days of age

Items	Control	$CrCl_3$	Cr-yeast	Cr-Nano	SEM	P value
FBW, kg	2.09^c	2.32^b	2.42^a	2.43^a	0.02	0.0001
Total Cost, EP	25.1^c	27.1^b	27.1^b	28.8^a	0.23	0.0001
Total revenue, EP	62.7^c	69.7^b	72.4^a	72.8^a	0.70	0.0001
Net revenue, EP	37.6^d	42.6^c	45.3^a	44.0^b	0.51	0.0001
EE, %	149^c	157^b	167^a	152^c	1.25	0.0001
EPEF	316^d	379^c	416^a	394^b	6.75	0.0001

SEM= Standard error of mean; FBW= final body weight; EE= economic efficiency; EPEF= European production efficiency factor.

^{a,b,c,d} Means within a rows with different letter superscripts are significantly different based on statistical analysis (P≤0.05).

DISCUSSIONS

The high ambient temperature reduced significantly the productive performance of broilers. Chromium had a beneficial influence on productivity, and these effects could be shown in animals that were under stress due to environmental, nutritional, and hormonal stress **(Toghyani *et al.*, 2006; Tawfeek *et al.*, 2015; Huang *et al.*, 2016).** In heat-stressed broilers, diets supplemented with 0.2 mg/kg of Cr (organic form) significantly enhanced FI and BWG **(Sahin *et al.*, 2017)**.

Enhanced feed consumption, digestion, absorption, and metabolism of given feed nutrients may be the cause of the treated group's greater BW growth. The current observation was consistent with the earlier research by **Haq *et al.*, (2016)**. Cr increased feed efficiency throughout the broiler's latter growth stages. Under HS, Cr may be essential for the nutrition, growth, and health of chickens. It improves growth efficiency. Also, according to **Rama Rao *et al.*, (2012)**, supplementing with Cr causes chickens to BWG more quickly.

These findings agree with **Samanta *et al.*, (2008)** who found that supplementing with $Cr Cl_3$ at a dose of 0.5 mg/kg significantly improved BWG and FCR. Meanwhile, **Zheng *et al.*, (2016)** found that 0.4 mg/kg of $Cr Cl_3$ had no significant effect on growth performance. Furthermore, some researchers indicated that treatments with $Cr Cl_3$, Cr-yeast, or Cr picolinate (CrPic) did not affect average daily gain, average daily FC, or FCR **(Król *et al.*, 2017; Lu *et al.*, 2019)**. Additionally, numerous studies demonstrated that supplementing chromium to the broiler feed, regardless of the source it came from, improved growth and carcass characteristics under HS **(Toghyani *et al.*, 2012; Huang *et al.*, 2016)**. **Zha *et al.* (2009)** found that under HS circumstances, organic chromium had an impact on growth performance but not inorganic chromium.

Similarly to these results, **Wang *et al.* (2022)** discovered that the average daily FC of the thermal neutral group was higher than that of the high ambient temperature group, as well as that of the 0.4 mg CrPic/kg group, which was higher than that of the high ambient temperature group ($p<0.05$). When compared to the high ambient temperature group, the average daily BWG of the 0.4 mg Cr-Pic/kg group was higher ($p<0.05$), while the average daily BWG of the high ambient temperature group was lower. The average daily FC and average daily BWG significantly increased in the 0.4mg Cr-Pic/kg supplemented group compared to the group exposed to high ambient temperature, demonstrating that dietary supplementation with chromium can lessen the severity of impaired performance caused by heat stress. This is consistent with other studies finding that chromium improves broiler growth performance under heat stress **(Huang *et al.,* 2016; Sahin *et al.,* 2017; Untea *et al.,* 2021)**. Also, According to **Sahin *et al.* (2002)**, supplemented with more chromium (200 to 1200 g/kg CrPic) raised BW and FC. In reality, studies demonstrated that supplementing chromium to feed could enhance broilers' growth rate under HS, but no such effect has been seen under normal conditions **(Zheng *et al.,* 2016; Huang *et al.,* 2016; Zha *et al.,* 2009; Lu *et al.,* 2019)**. We also observed that chromium supplementation might improve growth efficiency under HS. The influence of chromium in situations of HS has been examined not normal conditions with similar results **(Samanta *et al.,* 2008; Sahin *et al.,* 2017; Feng *et al.,* 2021)**.

Unlike the results reported, chromium supplementation (100 to 800 g/kg CrPic) did not have an impact on BW, FC, or FCR **(Kim *et al.,* 1996)**. In addition, **Ebrahimzadeh *et al.,* (2012)** reported that adding 200, 400, and 800 g Cr/kg Cr-Met to the diet had no significant influence on the FC of broilers under HS. However, other studies found that adding 500 and 1000 g Cr/kg Cr-Met to the diet significantly increased FC and BWG of broilers under HS **(Jahanian and Rasouli, 2015)**. According to **Rajalekshmi *et al.* (2014)**, the addition of 100, 200, 400, 800, 1600, and 3200 g Cr/kg to the diet had no significant impact on the FC of broilers under traditional feeding conditions; the addition of 400 µg Cr/kg organic chromium (Cr-Met, CrY, Cr-Nic, Cr-Pic) in the diet had no significant impact on average BWG, average daily FC and FCR **(Han *et al.,* 2021)**.

Also, **Xin *et al.* (2022)** discovered that the addition of various levels of Cr-yeast had no significant impact on the growth performance of broilers under heat stress during 23-42 days of age **(Sahin *et al.*, 2002; Akbari and Torki (2014)**. These variations in growth performance outcomes may be brought about by variations in stress environments and chromium concentrations.

The active role of chromium in glucose metabolism is typically acknowledged. It increases the sensitivity of tissue receptors to insulin and cellular glucose uptake, which in turn promotes glucose oxidation. According to theory, increased appetite, decreased blood sugar, and improved glucose absorption all help birds eat more food. In the absence of malnutrition, mal-adsorption factors, and especially diseases, increased FC may result in an increase in the BWG **(Hamidi *et al.*, 2021)**.

To evaluate for Cr toxicity, serum creatinine, and uric acid levels were measured; however, Cr did not affect these parameters, showing that supplemented Cr doses were not nephrotoxic **(Tahir *et al.*, 2019)**. The current results agree with those of **Bakhiet and Elbadwi (2007)**, who observed no impact of Cr supplementation on broiler serum uric acid. Plasma uric acid levels were not impacted (P>0.05) by Cr supplementation **(Karami *et al.*, 2018; Spears *et al.*, 2019)**.

Some previous studies contrary to the current findings, 0.2 g/kg Cr supplement decreased uric acid levels **(Onderci *et al.*, 2003 ; Tsahar *et al.*, 2006; Ma *et al.*, 2014)**. Also, **Samanta *et al.* (2008)** discovered that broilers given 0.5 or 1 g/kg Cr-Pic and those fed a control diet both had serum uric acid values that were identical. Furthermore, **Khalifah *et al.* (2022)** showed that Cr supplementation did not affect creatinine levels, it did lower uric acid concentration. Despite the fact that we did not notice any decreases in uric acid or creatinine levels, these findings suggest that Cr had no adverse affects on renal function.

The liver is an important organ for metabolism and immunity. Due to the loss of the cell membrane and mitochondrial structure that occurs when hepatocytes are damaged, the predominantly in hepatocytes present ALT and AST will escape from the cells and enter the blood, increasing the activities of ALT and AST in the serum **(Zhao *et al.*, 2017)**.

The current results are in line with those of **Xin *et al.* (2022)** who found that CrY significantly decreased the activities of AST ($p<0.05$). This is unlike to previous studies, **Tahir *et al.* (2019)** observed that supplemented Cr in diet did not affect blood ALT and AST levels **(Mohammed *et al.*, 2014; Sathyabama *et al.*, 2017; Arif *et al.*, 2019; Trivedi *et al.*, 2020)**. Moreover, **Bakhiet and Elbadwi (2007)** discovered no impact of Cr supplementation as Cr Cl_3 on serum AST in broilers. Chromium supplementation had no apparent effects on serum AST and ALT levels in growing Japanese quails **(Uyanik *et al.*, 2005; El-Kholy *et al.*, 2017).**

Serum AST activity is present in both the cytoplasm and the mitochondria, and as a result, the enzyme is generated even by moderate degenerative changes that happen in acute and sometime in chronic liver diseases. However, significantly higher values are noted in muscle damage **(Cruz *et al.*, 2018)**. Damage to the liver and muscles is indicated by the activity of the enzymes AST and ALT **(Cruz *et al.*, 2018)**. However, neither AST nor ALT activities in the current investigation indicated any negative effects of chromium supplementation as a feed additive in broiler diets and suggests that Cr concentrations used were not hepatotoxic.

Chromium has strong antioxidant properties and is considered the preferred mineral in poultry diets **(Samanta *et al.*, 2008; Sahin *et al.*, 2009; Rama Rao *et al.*, 2012)**. It is generally known that compared to inorganic chromium, organic chromium has a lower toxicity and a higher bioavailability **(Kim *et al.*, 1996; Piva *et al.*, 2003)**. Under conventional conditions, supplementing broilers with organic chromium can increase their growth, fast metabolism, and antioxidant capability **(Arif *et al.*, 2019; Van Hoeck *et al.*, 2020; Han *et al.*, 2021)**.

The body produces an excessive amount of free radicals when it is in an oxidised condition, which can damage the tissues and cells of the body. By scavenging free radicals, SOD and GSH-Px can inhibit the cascade reaction of oxygen free radicals, remove excess superoxide anion (O^-_2) from the body, and prevent cell oxidative damage **(Che *et al.*, 2016)**. GSH-Px is an essential peroxidase that can enhance the body's capacity to break down peroxide products **(Zhang *et al.*, 2016; Xin *et al.*, 2022)**.

This is similar to previous studies, the level of TAC increased with the supplementation 200 and 1600 g CrY/kg, while the level of GSH-Px increased with the supplementation 400 g CrY/kg diet. The level of TAC and SOD in the breast increased when 400 g of CrY/kg was supplemented. In addition, 400 µg CrY/kg can increase the TAC contents and the activity of SOD and GSH-Px in the broiler liver under stress. As a result, CrY may have significant antioxidant activity and may enhance broilers' antioxidant capacity **(Xin *et al.*, 2022)**. Our findings agree with those of **Saracila *et al.* (2022)** who found that TAC parameters did not demonstrate any significant variations among groups and reducing the concentration of MDA in thigh meat samples, the supplementation of Cr delayed the oxidation processes that had been detected.

The present investigation discovered that Cr functions as an antioxidant by increasing blood GSH activity and reducing MDA levels. Our findings are in line with those of **Attia *et al.* (2015)**, who found that supplementing chromium resulted in a reduced ($P \leq 0.05$) MDA concentration in laying hens under summer conditions than the control. Similarly, **Preuss *et al.* (1997),** supplementation of Cr-Pic to rats decreased MDA synthesis, a sign of lipid oxidation, and Cr functioned as an antioxidant. Also, **Anderson *et al.* (2001)** observed that rats who were given a diet supplemented with Cr also had significantly reduced serum MDA. **Mathivanan and Selvaraj (2003)** revealed that Cr supplementation in layer hens' diets act as antioxidants because of their potential to reduce oxidative stress **(Khalifah *et al.*, 2022)**.

Supplemental Cr improved the antioxidant activities in broiler chicks under heat stress in the current study. Further studies using different poultry species produced similar results **(Zhang *et al.*, 2009; Sahin *et al.*, 2010; Luo *et al.*, 2019)**. According to **Sahin *et al.*, (2010)**, Japanese quails had lower serum MDA concentrations after receiving supplementary Cr. In heat-stressed broilers, **Zhang *et al.* (2009)** discovered that CrY could increase TAC, GSH-Px, SOD, and catalase activity and reduce serum MDA concentrations. Similar results were reported by **Cheng *et al.* (2012)**, who found that adding 0.6-1.0 mg/kg Cr to the diet might enhance catalase, SOD, and GSH-Px activity while decreasing MDA levels in the blood of breeder cocks under heat stress.

Undoubtedly, a significant contributor to the economic losses in the chicken industry is heat stress, a physiological condition in which the body is unable to maintain a balance between heat production and body heat loss. These losses are the result of multiple physiological damages caused by heat stress in chickens, including reduced digestion and nutrient absorption, reduced production efficiency, decreased disease resistance, etc **(Nawaz *et al.*, 2021; Saracila *et al.*, 2021)**. There is proof that broilers require more vitamins and minerals due to heat stress **(Calik, 2022; Livingston *et al.*, 2022)**. Furthermore, supplementing Cr to a diet can help chickens under heat stress improve their performance in terms of production, nutrient metabolism, antioxidant status, and stress response **(Ghazi *et al.*, 2012; Jahanian and Rasouli, 2015; Khan *et al.*, 2016; Dalólio *et al.*, 2018)**.

In our results, chicks feeding diet with CrN and CrY had significantly higher total revenue while CrY significantly increased net revenue, EE, and EPEF and the lowest net revenue, EE and EPEF observed with the negative control group. These results confirmed with **El-Kelawy (2019)** discovered that Cr supplementation to diet of Japanese quails during 14-49 days (growth period) increased EE. In addition, **Hassan *et al.* (2020)** demonstrated that feeding diets supplemented with different Cr levels resulted in higher net return and EE values than the control diet, those supplemented with CrY had higher EE values.

CONCLUSION

Based on these results, it may be concluded that supplementation of dietary CrN and CrY to broiler chicks' diets led to a significant improvement BW, BWG, FC, FCR, EE, EPEF, and liver and kidney functions as evidenced by the increased ALP and decrease in AST and ALT while, it was not significant differences in the serum uric acid, creatinine, and uric acid/creatinine ratio. Supplementation with CrN under heat sress, significantly increased serum SOD and GSH-Px.

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الملخص العربي

تأثير أنواع مختلفة من الكروم على الأداء الإنتاجي ووظائف الكلى والكبد لكتاكيت التسمين تحت ظروف الإجهاد الحراري

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قسم الإنتاج الحيواني والداجني، كلية الزراعة، جامعة دمنهور، دمنهور، مصر

تم إجراء هذه التجربة بهدف دراسة تأثير استخدام أنواع مختلفة من الكروم على الأداء الإنتاجي، ووظائف الكلى والكبد، ومضادات الأكسدة، والكفاءة الاقتصادية ومعامل كفاءة الإنتاج الأوروبي في كتاكيت التسمين. تم استخدام عدد 120 كتكوتاً غير مجنسة من سلالة الأربور ايكرز عمر 7 أيام، تم توزيعها بصورة عشوائية إلى 4 معاملات كل معاملة بها 6 مقررات وكل مقررة بها 5 كتاكيت، وتم تغذيتها حسب احتياجات السلالة ووزعت كالاتي: المعاملة الأولى الكنترول (بدون أي اضافات علفية)، المجموعة الثانية تم تغذيتها على عليقة تحتوي على 2 مجم/ كجم كلوريد الكروم، المجموعة الثالثة كانت العليقة تحتوي على 2 ملجم/ كجم من خميرة الكروم، المجموعة الرابعة كانت العليقة تحتوي على 0.2 ملجم/ كجم من النانو كروم. وخلال الفترات (25-27) و(31-33) يومًا تم تعريض المعاملات كلها للإجهاد الحراري لمدة 4 ساعات يوميًا (10:00 صباحًا إلى 2:00 مساءً) على 34 درجة مئوية و70-75٪ رطوبة نسبية.

أظهر استخدام الاضافات العلفية فروق معنوية حيث كان أفضل المعاملات هو استخدام خميرة الكروم والنانو كروم إلى علائق كتاكيت التسمين حيث تحسن معنوياً وزن الجسم، ووزن الجسم المكتسب، والمستهلك من العلف، ومعامل التحويل الغذائي، والكفاءة الاقتصادية ومعامل كفاءة الإنتاج الأوروبي، ووظائف الكبد والكلى حيث زاد ALP وانخفاض كلٍ من AST وALT بينما لم يكن هناك فروق معنويه في نسبة حمض اليوريك في الدم والكرياتينين وحمض اليوريك/ نسبة الكرياتينين. كما أدت اضافة النانو كروم تحت ظروف الإجهاد الحراري إلى زيادة ملحوظة في SOD وGSH-Px في السيرم.