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Impact of Organic Chromium and Zinc on Growth Performance, Feed Intake, Hematological Profiles and Biochemical Indices of Growing Zaraibi Male Goats

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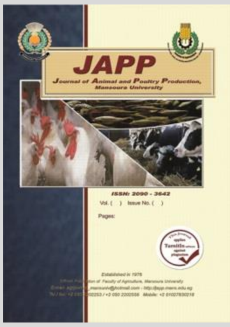

ABSTRACT

The purpose of this study was to evaluate the effects of chromium and zinc dietary supplements in an organic form on some productive performance and physiological responses in growing Zaraibi goats. Twenty eight male Zaraibi goats (4 months old, 15.72 ±1.40 kg BW) were allocated randomly into four treatment groups (7 animals in each). The first group (T1) was given a control diet without supplements. The control diet contained 3 mg/kg from organic chromium (Cr) was given to the second treatment group (T2). The third group (T3) received the control diet containing 40 mg/kg of organic zinc (Zn), whereas the fourth treatment group (T4) was fed on the control diet containing 3 mg Cr + 40 mg Zn/kg. The experimental period was 90 days included a 10-day digestibility trails. Results showed that, animals in groups T2, T3, and T4 had higher values for daily dry matter intake (DMI), final body weight (FBW), average daily gain (ADG), and total gain (TG) as compared to the control group (T1). Organic Cr and Zn supplementations improved feed efficiency and feed conversion ratio. The digestibility coefficients and feeding values of the treated groups were improved than those of the control group. The serum total antioxidant capacity, were significantly higher in groups fed Cr or Zn-diets than in the control group. Thus, administration of Cr and Zn in organic form has a significant impact on Zaraibi goats growth and digestion, as well as improved antioxidant and biochemical parameters.

***Keywords**: Zaraibi goats, chromium, zinc, growth performance, digesion, blood parameters.*

INTRODUCTION

Egypt's agricultural economy heavily depends on small ruminants, especially sheep and goats. Goats are widely recognized as a significant protein source in the human diet. In Egypt, goat population is estimated to be approximately 4.35 million head (Elshazly and Youngs 2019), which may assist in supplying the demand for meat. Goat farming constitutes a significant source of employment for a considerable portion of the state's population, including tribal members. The identification of micronutrient deficiencies poses challenges due to significant physiological alterations in the body. While the practical implications may be relatively limited, these deficiencies can lead to immunosuppression, oxidative stress, and poor growth performance, particularly during periods of stress and high metabolic demands. In the past decade, there has been a disparity in the profitability of small ruminants between underdeveloped and wealthy countries (Kashem *et al*., 2011; Shoshe *et al*., 2019).

Mineral supplements are frequently incorporated into animal diets due to their significance as essential nutrients. Minerals have been widely acknowledged as crucial elements for the maintenance of animal homeostasis and physiological function. Trace minerals commonly recognized as essential for maintaining enzyme function and hormone regulation (Nasem, 2016). Zinc (Zn) is a prevalent element within the animal body, playing significant roles in immunological function and developmental performance (Suttle, 2010). In general, organic minerals have the potential to be absorbed and shared to target cells with greater efficiency than inorganic minerals because they are absorbed via amino acid or peptide uptake processes (Zhang *et al*., 2018). However, previous studies on the ideal dietary zinc concentrations discovered variation in average daily gain (ADG), feed efficiency, feed intake, and body weight (Fadayifar *et al*., 2012). The impact of a combination of Zn sources (Zn amino acid complex with $ZnSO_4$) supplied at dietary quantities that meet or exceed NRC requirements has been studied to a lesser extent in fine-wool feeder lambs. (Knuth, 2020). In the late 1990s, chromium (Cr) was considered a fundamental mineral in domestic animal production. Previous studies have suggested a potential correlation between the supplementation of Cr and improved immune competence and stress resistance (Vargas-Rodriguez *et al*., 2014; Leiva *et al*., 2015). combination of Cr and yeast significantly affected rumen fermentation pattern and in vitro nutrient degradability (Mohanty, 2022). Previous research has shown that providing chromium to goats increases nutritional consumption (Haldar *et al*., 2009; Kumar *et al*., 2015). Chromium is an essential component of the glucose tolerance factor, exerting a significant influence on the metabolism of carbohydrates, proteins, and fats through the enhancement of insulin activity (Mertz, 1993). Chromium enhances insulin activity by

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enhancing its binding to target cell receptors and enhancing post-receptor signaling. Protein synthesis, amino acid transport effectiveness, protein cleavage rate, glucose uptake, and fat absorption are all increased by insulin Debski *et al*., 2004). In addition, chromium plays a role in the breakdown of lipids, proteins, and carbohydrates (Underwood and Suttle, 1999). The most deficient trace minerals in goat feed are Zn and Cr. In combination, mineral supplementsincluding Zn and Cr, enhanced feed conversion ratio, body weight growth, and nutrient utilization in goats (Kumar *et al*., 2015). Additionally, the Zn and Cr combination significantly improved the hematological and biochemical profile of goat blood. Goats with noticeably higher blood protein levels may produce more protein for body tissues. Minerals enhanced the body's ability to use glucose for energy production and cholesterol for the production of free fatty acids in the blood (kumar *et al.* 2020). Consequently, the current study was carried out to assess the best ratios for including these two minerals into the diet as well as how they affect goat growth, nutrient absorption, and blood components.

MATERIALS AND METHODS

This research was carried out at the Goat Research Unit, Minia University, Egypt's Agricultural Research and Experimental Center. The ethical committee for the care and use of animals, microorganisms, and living cell cultures in education and scientific research, Faculty of Agriculture, Minia university, El-Minya, Egypt, approved all experimental process carried out in the current study and issued it the following approval number: MU/FA/020/12/22.

Experimental animals, design, and management

Twenty eight Zaraibi buck goats (4 months old, 15.72 ±1.40 kg BW) were housed in separate wooden cages (1.8 × 2.1 m). The diet, was created to give goats the protein and energy they need for metabolism according to AFRC (1993). Table 1 is a list of the basic diet's components and chemical composition.

Table 1. Feed component and chemical assessment for the control diet given to goats (%DM basis)

Item	%	Nutrients analysis	%
Corn yellow	19.00	DM	91.46
Soybean meal	10.20	OM	91.61
Barley grain	33.00	CP	13.61
Straw	35.00	EE	2.34
Limestone	0.80	CF	16.61
Calcium phosphate dibasic	1.40	NDF	40.22
Premix	0.30	ADF	21.81
Food Salt	0.30	ADL	6.13
TOTAL	100%	Hemicellulose	18.42
Metabolizable protein (MP; g/kg)	93.36	Cellulose	15.68
Metabolizable energy (ME; MJ/kg)	10.04	NFE	59.05
		ASH	8.39

Two equal amounts of feed were served twice day 06:00 and 17:00 h. Potable water was available to the goats at all times. The experiment included control group fed a basal diet without supplementation (T1), the second group fed a basal diet with 3 mg of chromium/kg (T2), third group fed a basal diet with 40 mg of zinc/kg (T3), and the fourth group fed a basal diet with both 3 mg Cr and 40 mg Zn/kg (T4). This experiment utilized the organic form of chromium methionine (Availa® Cr 1000) and zinc chelate of lysine and glutamic acid (Availa® Zn 170), both manufactured by ZINPRO Company, USA. Using finely ground maize as a carrier, Cr and Zn were added to the premix and combined with concentrate. The 90-day experimental period included 10-day digestibility trails.

Growth performance

As the experiment commenced, the goats' average initial body weight (IBW) was taken before the goats had access to feed, then final body weight (FBW), the average daily weight gain (DWG), total gain (TG), and daily feed intake (DFI) were estimated. The feed conversion ratio (FCR) was determined using a ratio of feed intake to one gram of gain.

Digestible trial

In the final week of the study, dietary and feces samples were taken from each treatment. A portion of the composite samples was dried at 105 °C in a forced air oven until constant weight in order to measure the dry matter (DM). For laboratory examination, the remaining composite samples were crushed and dried at 70 ºC for a constant weight before being placed in firmly sealed jars. The DM, organic matter (OM), crude protein (CP), crude fiber (CF), ether extract (EE), and ash contents of these samples were determined using the methods of AOAC (2006). Neutral detergent fiber (NDF), acid detergent fiber (ADF), and acid detergent lignin (ADL) were also determined, according to Van Soest *et al*. (1991). The ratios of NDF to ADF and ADF to ADL were used to compute the concentrations of hemicellulose and cellulose, respectively. Using the acid-insoluble ash technique as an internal marker (Van Keulen and Young, 1977) the digestibility coefficients of DM, OM, CP, EE, CF, NDF, ADF, and NFE were assessed. To calculate the nutritional value of the experimental feeds, total digestible nutrients (TDN) and digestible crude protein (DCP) were utilized.

Blood parameters

At the end of experiment all bucks had their jugular veins punctured with 10 ml tubes to obtain blood samples, which were then analyzed. A container containing ethylene diamine tetra-acetic acid (EDTA) was filled with 1 ml of blood as an anticoagulant for the hematological assay.The remaining 9 ml of blood were transferred into a sterile vacutainer tube without the addition of any anticoagulants. The clear non-supernatant serum was rapidly extracted for oxidative stress marker and serum biochemistry analyses. The collected serum samples were stored until usage at -20 °C. According to Benjamin (1978), whole and fresh blood were examined as soon as they were collected to determine their hematological characteristics (hemoglobin, Hb; red blood cells, RBCs; packed cell volume, PCV; mean corpuscular volume, MCV; mean corpuscular hemoglobin, MCH; mean corpuscular hemoglobin concentration, MCHC; white blood cells, WBCs).

According to Gornal *et al.* (1949) and Doumas *et al.* (1971), commercial kits were used for assessing albumin and total serum protein, respectively. Calculations were performed for albumin/globulin ratio and globulin concentrations. Using commercial kits (Bio-diagnostic company, Dokki, Giza, Egypt), the following substances were calorimetrically measured: concentration of serum creatinine, urea, alkaline phosphatase, glucose, total cholesterol, triglycerides, and phospholipids. Activity of alanine aminotransferase (ALT) and aspartate aminotransferase (AST) was also determined in serum. High density lipoprotein (HDL) and total cholesterol levels were determined using the procedures described by Lopes-Virella *et al.* (1997). The serum low density lipoprotein (LDL) concentration was calculated using the Friedewald equation. The Friedewald equation, was used to calculate the estimated level of very low-density lipoprotein cholesterol (VLDL-c = Triacylglyceroles / 5). Using commercial (coat-A-count TKT3 and TKT4), radioimmunoassay methods were used to measure concentration of serum triiodothyronine (T3) and thyroxin (T4), then the T_3/T_4 ratio was calculated.

Antioxidant indices

The serum concentrations of total antioxidant capacity (TAC), activity of catalase (CAT) and superoxide dismutase enzyme (SOD), and level of malondialdehyde (MDA), as a lipid peroxidation marker, were measured in serum using a commercial colorimetric assay kits (Bio-diagnostic company, Dokki, Giza, Egypt) in accordance with the manufacturer's instructions.

Statistical analysis:

The following model was used to evaluate the data using SAS's (2001) general linear model approach for a completely randomized design:

$$Y_{ij} = \mu + A_i + E_{ij}$$

Where Y_{ij} = The studied trait; μ = The overall mean; A_i = The effect of treatments (i = 1,….4); and E_{ij} = The experimental error.

Using Duncan's multiple range test (1955), significant variations in mean values for all traits were detected.

RESULTS AND DISCUSSION

Growth performance

The productive performance findings showed that, adding supplements of 3 mg of organic Cr or 40 mg of organic Zn to the diet, alone or in combination, significantly increased ($P \leq 0.01$) FBW, ADG, TG, and feed conversion and feed effiicecy as compared to control. Only Zn addition to the diet significantly ($P \leq 0.01$) increased daily and total DMI and in comparison with other groups. Generally, bucks fed diet with the combination showed the best growth performance parameters (Table 2).

The observed improvement in growth performance parameters seen in bucks fed diets containing Cr, Zn, and Cr plus Zn compared to those fed the control diet may be in association with a significant improvement in most nutrient digestibility and nutritional value, all of which had an impact on their growth performance, as will be discussed later. The current findings are supported by those published by Domnguez-Vara *et al.* (2009). They found that adding Cr to the ration increased final live weight, total gain weight, and daily gain weight in Rambouillet sheep in a linear manner. Estrada *et al.* (2013) additionally examined at how much Cr-enriched yeast (either 1, 2, or 3 g/d) boosted sheep development. Zarczynska and Krzebietke (2020) noted that it has been discovered that Cr helps ruminants to grow and convert more feed into energy. Additionally, Farghaly *et al.* (2017) observed that the average daily gain (ADG) of the control group was lower than that of the Zn-SO4 and Zn-Met groups. Zinc sulphate and zinc methionine, when given to meals as dietary supplements, boosted lambs' average daily growth by roughly 25 and 24%, respectively, in comparison with the control group. According to Kumar *et al.* (2015), goats fed a ration containing combined organic Zn and Cr significantly ($P<0.05$) increased body weight and improved feed conversion ratio as compared to the control group. Additionally, recent studies have demonstrated that organic Zn promotes gut absorption and gastrointestinal tract growth, which in turn increases zinc retention and animal productivity (Feldmann *et al*., 2019; Chang *et al*., 2020).

Table 2. The impact of various treatments on growing lambs' productive performance.

	T1 (control)	T2 (Cr)	T3 (Zn)	T4 (Cr+Zn)	SEM	Sign.
Initial body weight (IBW, kg)	15.75	15.65	15.99	15.60	0.18	-
Final body weight (FBW, kg)	25.96^{c}	28.08^{b}	29.93^{a}	29.73^{a}	0.47	**
Average daily gain (ADG, g)	113.47^{c}	138.11^{b}	154.93^{a}	157.02^{a}	5.35	**
Total gain (TG, kg)	10.21^{c}	12.43^{b}	13.94^{a}	14.13^{a}	0.48	**
Daily dry matter intake (DMI, g)	667.40^{b}	676.25^{b}	712.64^{a}	686.39^{ab}	9.44	**
Total dry matter intake (TDMI, kg)	60.06^{b}	60.86^{b}	64.14^{a}	61.78^{ab}	0.85	**
Feed Efficiency (FE)	0.17^{b}	0.20^{a}	0.22^{a}	0.23^{a}	0.008	**
Feed conversion (FC)	5.88^{a}	4.90^{b}	4.60^{b}	4.37^{b}	0.23	**

a, b, and c means that the same row with different superscripts are different ($P < 0.05$). NS: no significant, ** $P < 0.01$

Nutrient utilization

The digestibility coefficients of DM, OM, CP, NDF, ADF, ADL, hemicellulose, cellulose, and nutritive values (TDN and DCP) significantly ($P \leq 0.01$) increased in all treatment groups compared to the control group. In comparison to Cr alone (T2) and control (T1) meals, digestibility coefficients of EE, CF, and NFE were higher ($P \leq 0.01$) with Zn alone (T3) and Zn plus Cr (T4) supplemented diets. Additionally, when compared to bucks fed the control diet, Cr-supplemented diet tended to have higher levels of EE, CF, and NFE, but this differences were not statistically significant ($P > 0.05$) (Table 3).

According to Kumar *et al.* (2015), Cr aids in stabilizing tissue-level amino acid requirements in order to retain adequate resources for optimal rumen fermentation (Martin *et al*., 1984). The ability of various enzymes involved in the digestion of proteins, lipids, and carbohydrates, such as amylase, lipase, trypsinogen, chemo trypsinogen, and some peptidases, to be Zn-dependent, may be increased in goat kids through Zn supplementation (Banerjee, 1988). Furthermore, it has been demonstrated that zinc is essential for proteolytic enzyme systems linked to the oxidation of muscle proteins. We can explain the positive increase in all nutrient digestibility for the T4 treatment, which contains both organic chromium and zinc, based on all the prior advantages of chromium and zinc supplementation.

The present results are consistent with those of Paul *et al.* (2005), who found that supplementing Black Bengal goats with 0.2 and 0.4 mg of (Cr) greatly improved the digestibility of DM, OM, and CP. Additionally, they asserted that the Cr-supplemented group consumed more DM, CP, and NDF than the control group did, as well as more OM and ADF (0.4 mg). The digestibility of OM and CP significantly increased when Black Bengal goat males that had been castrated were given doses of 0.5, 1.0, and 1.5 mg $CrCl_3$, according to Haldar *et al*. (2009). In the Hassan *et al*. (2016) study, the researchers added a daily dietary supplement of 30 mg of zinc per head to the calves' feeding schedule. According to the results of the digestibility experiments, adding Zn-methionine to the feeds that were put to the test significantly increased ($P < 0.05$) the digestibility of all nutrients when compared to the control group. Similar results were confirmed by Salama *et al*. (2003), who found that dairy goats supplemented with 1 g/day Zn-methionine in their diet enhanced the digestibility of DM, OM, and CP. Lambs' ability to digest cellulose and ADF was shown to be considerably ($P < 0.05$) increased when 20 mg of organic Zn was added to a meal containing 34 mg of inorganic Zn/kg DM, according to research by Garg *et al*. (2008). This finding suggests that organic Zn supplementation plays a positive effect in fiber degradation. According to Safaa *et al*. (2018), giving lambs two different amounts of zinc-methionine as a supplement boosted nutritional values expressed as TDN, DCP, and NFE ($P <$ 0.05) compared to control. According to Kumar *et al*. (2015), adding Zn and Cr supplements greatly increased the digestibility of DM, CF, EE, and OM in growing plants.

Table 3. The impact of various treatments on the nutritional values and nutrient digestibility coefficients of the experimental diets.

	T1 (control)	T2 (Cr)	T3 (Zn)	T4 (Cr+Zn)	SEM	Sign.
Dry Matter (DM)	66.14^{c}	67.05^{b}	69.29^{a}	69.66^{a}	0.25	**
Organic Matter (OM)	69.17^{c}	70.31^{b}	72.59^{a}	72.94^{a}	0.14	**
Crude Protein (CP)	71.69^{c}	73.23^{b}	76.62^{a}	76.72^{a}	0.27	**
Ether Extract (EE)	65.72^{b}	66.24^{b}	69.02^{a}	69.87^{a}	0.67	**
Crude Fiber (CF)	61.87^{b}	63.37^{b}	67.48^{a}	67.76^{a}	0.48	**
Neutral detergent fiber (NDF)	51.86^{c}	54.56^{b}	57.11^{a}	57.47^{a}	0.22	**
Acid detergent fiber (ADF)	45.35^{c}	47.12^{b}	47.89^{ab}	48.14^{a}	0.26	**
Acid detergent lignin ADL) (	10.00^{c}	11.40^{b}	12.16^{ab}	12.84^{a}	0.38	**
Hemicellulose	59.58^{c}	63.37^{b}	68.03^{a}	68.53^{a}	0.58	**
cellulose	59.17^{b}	61.09^{a}	61.86^{a}	61.95^{a}	0.40	**
Nitrogen free extract (NFE)	70.77^{b}	71.75^{b}	73.24^{a}	73.65^{a}	0.33	**
TDN	65.29^{c}	66.35^{b}	68.52^{a}	68.87^{a}	0.14	**
DCP	9.75^{c}	9.96^{b}	10.42^{a}	10.44^{a}	0.036	**

a, b, and c, means that the same row with different superscripts are different ($P < 0.05$). ** $P < 0.01$

Hematological parameters as affected by different levels of organic chromium and zinc.

Table (4) shows data on blood hematological parameters studied, such as Hb, PCV, RBCs, WBCs and Erythrocytic index, as affected by dietary treatments. Cr and Zn combinatin treatment of bucks at doses of (3 mg and 40mg/kg diet, respectavily) increased ($P < 0.05$) for Hb concentration, and MCV in comparison to the control treatment. PCV and RBCs increased ($P < 0.01$) when diets supplemented with Cr alone (T2), Zn alone (T3), and Zn + Cr (T4). While supplementing with Zn at 40 mg/kg alone or plus 3 mg/kg Cr improved WBCs count significantly ($P < 0.01$).

No significant difference were found between treatments in MCH.

Table 4. Hematological parameters as affected by different levels of Organic chromium and Zinc.

	T1 (control)	T2 (Cr)	T3 (Zn)	T4 (Cr+Zn)	SEM	Sign.
Hb, g/dl	10.51^{b}	11.22^{ab}	11.70^{ab}	12.11^{a}	0.410	*
PCV, %	44.00^{b}	48.50^{a}	53.50^{a}	56.50^{a}	1.181	*
RBCs, 10^6/µL	8.19^{c}	8.30^{b}	8.78^{a}	8.78^{a}	0.245	**
WBCs, 10^3/µL	8.71^{c}	9.43^{bc}	11.02^{ab}	11.96^{a}	0.769	**
MCV, Fl.	53.76^{b}	58.53^{ab}	61.01^{ab}	64.80^{a}	2.284	*
MCH, Pg.	12.84	13.54	13.34	13.86	0.562	-

a, b, c, and d Means in the same row with different superscripts are different ($P < 0.05$). NS: no significant, * $P < 0.05$, ** $P < 0.01$

One of the goals of the current study was to measure different blood components in order to determine how Zn and Cr supplementation affected buck growth performance and metabolism. According to the findings and the data gathered, dietary doses of Cr and Zn supplementation improved hematological markers. Smock *et al*. (2020) and other ruminant research in the past have consistently shown the beneficial effects of supplementary Cr on RBC and WBC numbers. Cr may be helpful in stressful situations, despite the fact that the reaction of blood cells to Cr ingestion in sheep has not been thoroughly researched. However, as noted by Dallago *et al*. (2013), opinions differ on whether it has a major impact on immune system operations and blood cells. In contrast, Seifalinasab *et al*. (2022) reported opposing findings, showing that Cr supplementation up to 0.5 mg had no effect on lambs' blood cell counts. Similar to this, Kegley *et al*. (1996) discovered no alteration in WBC counts in calves after Cr ingestion. It has been proposed that zinc has a role in the synthesis of erythrocytes and hemoglobin. Male goats residing at high altitudes with elevated erythrocytosis and blood hemoglobin levels have greater serum zinc levels, according to Gonzales *et al*. (2011). Zinc supplementation was found to raise RBC and Hb levels in studies by Dönmez and Keskin (1999) and Sobhanirad and Naserian (2012) in goats and cattle, respectively. These findings are supported by our findings, which showed a significant rise in RBC and Hb levels in the zinc-supplemented groups, which is in line with the findings of the research by Sobhanirad and Naserian (2012) and Dönmez and Keskin (1999). Additionally, alpha-aminolevulinic acid dehydrogenase, an enzyme implicated in the formation of hem, is known to contain zinc as a catalytic component (Aksu *et al*., 2011). The higher zinc content in RBCs compared to plasma, due to the presence of zinc-containing carbonic anhydrase enzymes, further supports the positive effect of adding zinc to the feed of goats (Ülger and Coşkun, 2003). It is worth noting that goats have smaller RBC diameter and higher RBC count compared to sheep, making them more responsive to zinc supplementation. The increase in hemoglobin and PCV% seen in the treatment groups supplemented with Zn and Cr, either separately or together, can be attributed to their antioxidant characteristics and capacity to improve the body's ability to produce, maintain, and function enzymes. According to Mohamed *et al.* (2023), these elements help to enhance immunity. In contrast to our findings, a study by Miller *et al.* (1989) found that adding 1000 ppm of zinc to cattle feed had no impact on the important metrics. In a research by Ott *et al.* (1966), lambs fed feed containing 4000 ppm and 6000 ppm zinc had higher hemoglobin concentrations, which resulted in higher levels of Hb and Hct. In a different study by Dönmez and Keskin (1999), Angora goats were fed for six months with a treatment diet enriched with 250 ppm zinc and a control ration containing 35 ppm zinc. Until the third month, RBC, Hb, and Hct levels did not change.

In conclusion, the findings of this study suggest that supplementing lambs with Cr and Zn can improve their hematological parameters. However, the effects of Cr on immune functions and blood cells remain inconclusive. Zinc supplementation, on the other hand, has shown positive effects on RBC and Hb levels in goats and cattle. The antioxidant properties of Zn-Cr and their impact on enzyme activity and immunity may explain the observed increase in hemoglobin and PCV% in supplemented groups. However, more investigation is required to properly comprehend the workings and optimum dose of Cr and Zn supplementation in ruminants.

Serum biochemical and thyroid hormones are affected by different levels of Organic chromium and zinc.

As demonstrated in Table 5, lambs fed Cr, Zn, and Cr plus Zn rations had significantly ($P < 0.01$) higher serum concentrations of total protein (TP), albumin, and globulin compared to lambs fed control rations. The glucose levels of lambs that received just chromium (Cr) was, however, significantly ($P < 0.01$) lower. In contrast, lambs fed zinc (Zn) either alone or in conjunction with chromium showed a substantial rise in glucose concentration when compared to lambs fed the control diet. In addition, the concentrations of plasma lipid profiles were found to be unaffected by the treatments, except for triglyceride levels. Furthermore, plasma lipid profile concentrations were not affected by treatments except that triglyceride had significantly ($P<0.05$) improved for lambs fed Zn alone and Zn plus Cr rations compared with those fed Cr alone and control rations. However, lambs fed either the control diet or the experimental diet had identical triglyceride levels. Cr alone. In addition, results showed that AST had increased significantly for lambs fed Cr + Zn-supplemented rations compared to the control treatment. There was no observed variation in alanine aminotransferase (ALT) levels or renal function among the different treatment groups. In addition, when compared to the control group, lambs fed with chromium (Cr), zinc (Zn), or a combination of both thyroid hormones showed considerable improvements in T3 and T4.

Each Cr, Zn, or combination supplement is effective at enhancing protein synthesis and metabolism, as indicated by the obvious enhancement of protein profiles in supplemented groups. The significant (P0.01) improvement in digestibility of CP and nutritive value of DCP observed in goats fed Cr, Zn, and Cr plus Zn ration supplemented diets, which led to the significant improvement in their FBW and ADG, may be related to the increase in serum TP. In addition, Cr supplementation increased glucose absorption by cells (Paul *et al.*, 2005), as evidenced by the chromium treatment's low blood glucose level. In this case, blood glucose would be available to be used as a source of ATP, supporting the body's synthesis of fat and protein (He, 2022; Sultana *et al.*, 2022). In addition, Kitchalong *et al.* (1995) observed that insulin appears to increase protein synthesis in lambs when Cr is present. They noted that when 3 mg/kg of food Cr supplementation was provided in comparison to the control group, albumin levels increased significantly ($P < 0.05$). Blood albumin content was higher BW 0.75 in males at 0.02 mg of Cr/kg than in control, according to Yari *et al.* (2010). As a result of the addition of Cr to the diet, Debski *et al.* (2004) discovered that the addition of Cr-yeast had a favorable effect on protein synthesis. Additionally, Dresler *et al.* (2016) noted that calves given Zn-Met had significantly greater blood total protein (TP) and albumin concentrations respectively. Zn supplementation is responsible for the reaction of increased serum glucose levels in goats fed Zn alone or Zn + Cr-supplemented diets, which is connected to the statistically significant ($P < 0.01$) increase in CF and NFE digestibility. Chromium can increase insulin sensitivity, as seen by the low blood glucose level in the current study (Table 4), This result could be explained by the fact that Zn is necessary for protein metabolism, digestion, glycolysis, DNA synthesis, and nucleic acid production, which is in accordance with Haldar *et al.*'s (2007) theory that it can enhance glucose tolerance. A spike in serum glucose levels could signify that the small intestine is now handling carbohydrate digestion instead of the rumen (McDonald *et al.*, 1995). Rapid hydrolysis and absorption of dietary carbohydrates in the gastrointestinal tract may be the cause of elevated blood glucose levels, which is in line with the findings of Abdel-Rahman *et al.* (2012). Therefore, the significant ($P < 0.01$) improvement in their FBW and ADG productivity seen in the present investigation may be explained by these increases in serum glucose concentrations for goats fed diets containing Zn. These results support Zeedan *et al.* 2008 and 2009a, b assertion that zinc supplementation increases blood glucose levels at various physiological phases. Additionally, Abu El-Ella *et al.* (2014) discovered that the addition of (25 or 50mg Zn) g/h/d significantly ($P < 0.05$) raised blood glucose concentrations during both stages (pregnancy and breastfeeding) in comparison to the control group. The addition of zinc to the meal was observed to have no impact on the plasma glucose level, in contrast to prior investigations of Angora goats and calves by Puchala *et al.* (1999) and Mandal and Dass (2010).

Blood lipids profile (HDL, LDL, cholesterol, and triglycerides) concentrations were within the normal levels without any changes due to mineral supplementation, except in serum triglycerides, which were affected by Zn, including in rations. Similarly, Uyanik (2001) found no significant difference in LD and cholesterol levels. Samsell and Spears (1989) and (Mooney and Cromwell, 1997) concluded that Cr did not affect serum cholesterol and serum triglycerides. In contrast, Griss *et al.* (2020) reported that organic chromium increased lambs' serum triglycerides and cholesterol levels. In contrast, Soumar *et al.* (2020) illustrated that blood cholesterol concentration was not affected due to lambs receiving zinc-methionine and chromium-methionine diets than lambs consuming control diet. In addition, Vellini *et al.* (2020) reported that bulls fed control ration had cholesterol levels comparable to those treated with ZnAA and ZnCr. However, the improvement in serum triglycerides observed in bulls supplemented with Zn alone or Zn plus Cr compared to the control group may be attributable to the significant improvement in ether extract digestibility coefficients (Table 3) observed in these Zn-containing rations.

Table 5. Protein profile, glucose, and lipids profile, liver and kidney functions, and Thyroid hormones as affected by different levels of Organic chromium and zinc.

	T1 (control)	T2 (Cr)	T3 (Zn)	T4 (Cr+Zn)	SEM	Sign.
Protein profile						
Total protein (g/dl)	7.08[d]	7.24[c]	7.39[b]	7.71[a]	0.03	**
Albumin (g/dl)	3.78[c]	3.85[b]	4.00[a]	4.07[a]	0.02	**
Globulin (g/dl)	3.31[b]	3.38[b]	3.40[b]	3.64[a]	0.05	**
Glucose (mg/dl)	101.62[c]	94.48[d]	125.28[a]	112.29[b]	0.34	**
Lipid profile						
HDL	76.92	78.39	79.92	80.59	0.96	-
LDL	101.93	99.56	98.28	97.79	1.65	-
Cholesterol (mg/dl)	208.18	203.97	200.20	201.09	2.09	-
Triglycerides (mg/dl)	110.93[b]	109.87[b]	120.08[a]	117.57[a]	1.79	*
Phospho L.	245.57	250.26	246.66	247.30	3.53	-
Liver functions						
ALT (U/ l)	18.16	18.18	18.44	18.59	0.27	-
AST (U/ l)	28.87[b]	30.03[ab]	30.16[ab]	31.29[a]	0.47	*
kidney functions						
Creatinine	21.21	21.18	20.86	20.57	0.29	-
Urea	1.13	1.11	1.08	1.06	0.02	-
Alkaline phosphatase	5.16	5.33	5.58	5.61	0.16	-
Thyroid hormones						
T_3 (ng/ml)	1.12[c]	1.24[b]	1.30[a]	1.33[a]	0.014	**
T_4 (µg/ml)	32.45[d]	37.82[c]	40.42[b]	47.08[a]	0.16	**
T_3/T_4 ratio	0.034[a]	0.033[b]	0.032[b]	0.028[c]	0.0003	**

[a, b, c, and d] **Means in the same row with different superscripts are different ($P < 0.05$). NS: no significant, * $P < 0.05$, ** $P < 0.01$**

Vellini *et al*. (2000) reported that the Zn amino acid complex and Zn plus Cr methionine in the diets increased AST activity (P 0.01). Consistent with our findings that AST activity increased with Zn alone and significantly increased with Zn-plus-Cr rations compared to the control, this result confirms that AST activity increased with Zn alone and significantly increased with Zn-plus-Cr rations. In addition, Daghash and Mousa (1999) observed an increase in AST activity in buffalo calves given 50 or 100 ppm Zn.

Considering the thyroid gland activities through its secretions, synthesis, and storage of thyroxin (T4) and triiodothyronine (T3) hormones, it is clear that rations that contain Cr, Zn, or a combination showed significant (P< 0.01) increases in the concentrations of both hormones. This result is compatible with the enhancement attained in final body weight as these hormones target the metabolic processes in the whole body (Husveth, 2011). It might imply an increase in the efficiency of T4 to T3 conversion and, consequently, its contribution to the improvement of ADG and final BW with Cr supplementation (Ghorbani *et al*., 2012). Furthermore, according to Yari *et al*. (2010), the T3:T4 ratio may be a good indicator of how effectively T4 is converted to T3. The improved T4 to T3 conversion efficiency at 0.02 mg of additional Cr/kg of BW0.75 and possible higher T3 demand for calves during summer are indicated by the increased T3:T4 ratio. In contrast, Cr supplementation had no impact on thyroid hormone concentrations or the T3 to T4 ratio, according to Kargar *et al.* (2018). In addition to its action in protein synthesis, Zn is essential for optimal thyroid function. It takes part in the T3 binding phase of the nuclear receptor (Liu *et al*. 2001). Total T3 levels were likewise elevated by additional Zn (Abou-Zeina *et al*., 2009; El-Nour *et al*., 2010). Thyrotropin-releasing hormone (TRH) and its function are both influenced by zinc (Zn). These results suggest a correlation between serum zinc levels and plasma T3 and T4 levels (Nishi *et al*., 1980; Aihara *et al*., 1984). Similar results were reported by EI-Sisy *et al.* (2008), who discovered that total T3 levels were considerably greater in diets fed to bucks and supplemented with zinc yeast than in the control group. The average level of total T4 was the same throughout the experiment, in contrast. According to Kececi and Keskin (2002), plasma Zn levels were significantly (P < 0.05) higher in the lamb and goat Zn groups (40 mg/kg DM for lambs and 35 mg/kg DM for goats) than they were in the control group. According to Mandal *et al.* (2008), adding zinc—whether from inorganic or organic sources—did not have an impact on the plasma levels of T3 and T4 in crossbred calves, which is in contrast to the results mentioned above.

Serum oxidative stress enzymes status

The oxidative stress-related TAC, CAT, SOD, and MDA enzymes played a significant role in the defense against free radical damage. Superoxide dismutase is the most crucial enzyme in oxidative stress. In addition, the TAC, SOD, and CAT values of Zn and Cr supplementation in T2 and T3 were significantly (P0.01) more significant than those of the T1 and control groups, as well as Cr supplementation in T2. In addition, it can be seen that the addition of T2: 3 mg chromium (Cr) /kg to the diet increased the activity of TAC, SOD, and CAT in a non-significant manner compared to the control group. whereas the addition of T3: 40 mg/kg diet zinc (Zn) and T4: 3 mg/kg diet creatine plus 40 mg/kg diet creatine and Zn had significant effects. as indicated in Table 6.

Serum concentrations of MDA decreased significantly (P<0.01) in goats fed Cr, Zn, and Cr plus Zn compared to those fed the control ration. Reactive oxygen species (ROS) and/or antioxidant defense are increased or decreased as a result of oxidative stress, which is caused by an imbalance in cellular redox processes. Lipid peroxidation is a crucial part of oxidative stress, which prevents antioxidants from working as protective agents. The first line of defense against superoxide anions is superoxide dismutase (SOD). Superoxide anion is split into hydrogen peroxide and oxygen molecules by SOD. The SOD-produced hydrogen peroxide continues to be harmful to cells and is a substrate for the catalase enzyme. Hydrogen peroxide is broken down by catalase in two unique ways: first, as a catalyst that produces water and oxygen as the final products; second, as a peroxidase. One of the most effective enzymes, catalase's reaction rate is limited by how frequently it collides with the substrate.

Table 6. The level of the serum oxidative stress enzymes as influenced by organic chromium and zinc

	T1 (control)	T2 (Cr)	T3 (Zn)	T4 (Cr+Zn)	SEM	Sign.
TAC (mM/g)	11.64[b]	11.89[b]	13.07[a]	13.13[a]	0.15	**
CAT(u/mg)	3.29[b]	3.72[b]	4.71[a]	4.95[a]	0.24	**
SOD (Ul/µmL)	1.09[c]	1.22[c]	2.68[a]	2.18[b]	0.11	**
MDA (nM/g)	2.57[a]	1.81[b]	1.78[b]	1.89[b]	0.12	**

[a, b, and c] Means in the same row with different superscripts are different ($P < 0.05$). ** $P < 0.01$.

Sethy *et al.* (2018) found that supplementation with Zn-methionine significantly (P0.05) enhanced CAT and SOD activities and significantly (P0.05) decreased MDA levels in comparison to control animals when investigating oxidative stress markers. Animals are more vulnerable to oxidative damage when zinc levels are low, a crucial antioxidant (Romanucci *et al*., 2011). Reduced reactive oxygen species (ROS), which higher zinc levels can cause, may have contributed to the lower MDA levels in the animals receiving zinc supplementation. In both in vitro and in vivo settings, Chvapil *et al*. (1973) showed that zinc had inhibitory effects on both endogenous and external lipid peroxidation. The observed enhance in superoxide dismutase (SOD) activity, according to Clemen and Waller (1987), was followed by an increase in catalase concentration. Our investigation found that Zn-methionine treatment reduced lipid peroxidation in chickens as shown by a decrease in plasma levels of malondialdehyde (MDA), which is consistent with the findings of Aksu *et al*. (2011). The results of Alimohamady *et al*. (2019) revealed that some oxidative enzymes, specifically Zn-Cu-superoxide dismutase and glutathione peroxidase, cooperate to efficiently eliminate free radicals and the byproducts produced when they break down. Superoxide dismutase produces hydrogen peroxide as a result of its scavenging activity. Glutathione peroxidase, which converts hydrogen peroxide to water, detoxifies the peroxides produced by the SOD action (Guan *et al*., 2017). Regardless of the source, Zn supplementation boosted RBC-SOD activity for the current investigation, which could be connected to enhancing synthesis, stabilizing, or slowing down degradation Jarosz *et al*., (2017). The increased SOD activity seen in Zn-supplemented groups is consistent with the findings of Fadayifar *et al*. [2012], who found that enhanced SOD activity in lambs required a 20 mg Zn/kg DM supplement. Similar to this, Nagalakshmi *et al*. (2009) showed higher SOD activity in lambs fed Zn-supplemented diets with 15 and 30 mg/kg as organic or inorganic sources compared to lambs fed a control diet. According to Nockels (1994), zinc helps the immune system by aiding energy production, boosting protein synthesis, protecting cell membranes from bacterial end products, facilitating the formation of antioxidant enzymes, and supporting lymphocyte replication and antibody production.

CONCLUSION

This study concluded that adding organic chromium and zinc to growing goats' diets at doses of 3 mg Cr and 40 mg Zn/kg significantly improved growth performance, nutritional values, physiological responses and some antioxidant blood indices (TAC, CAT, SOD, and MDA). Organic Cr and Zn combination may be more beneficial for improved goat performance and its physiological responses.

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تأثير الكروم والزنك العضوي على مؤشرات أداء النمو وتناول الغذاء والخصائص الدموية والمؤشرات البيوكيميائية لذكور الماعز الزرايبي النامية

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الملخص

هدفت هذه الدراسة إلى تقييم تأثير إضافة عنصري الكروم والزنك في صورة عضوية على الأداء الإنتاجي والاستجابات الفسيولوجية في ذكور الماعز الزرايبي النامية. تم تقسيم 28ذكراً من ذكور الماعز الزرايبي إلى أربع مجموعات تجريبية. تم تغذية حيوانات المجموعة الأولى على عليقة بدون أي إضافات كمجموعة ضابطة. كما تم تغذية حيوانات المجموعة الثانية على عليقة تحتوي على ٣ ملليجرام/كجم عليقة من عنصر الكروم. أما حيوانات المجموعة الثالثة فقد تمت تغذيتها على عليقة تحتوي علي ٤٠ ملليجرام /كجم عليقة من عنصر الزنك ، بينما تم تغذية حيوانات المجموعة الرابعة على عليقة تحتوي علي ٣ ملليجرام/كجم عليقة من عنصر الكروم بالإضافة الي ٤٠ ملليجرام /كجم عليقة من عنصر الزنك. وقد كانت مدة التجربة ٩٠ يوما أشتلمت علي ١٠ أيام تجربة هضم. أظهرت النتائج أن الحيوانات في المجموعات الثانية والثالثة والرابعة سجلت قيم اعلي من المجموعة الضابطة في كل من معدل التناول اليومي للمواد الجافة ، وزن الجسم النهائي ، الزيادة اليومية في وزن الجسم بالإضافة والزيادة الكلية في وزن الجسم. أدت إضافة كل من الكروم والزنك الي العليقة الي تحسين في كفاءة التغذية ونسبة التحويل ومعاملات الهضم وقيم التغذية في كل من المجموعة الثانية والثالثة والرابعة مقارنة بالمجموعة الضابطة. أيضا أدت تغذية الحيوانات في المجموعات الثلاثة المعاملة علي عليقة مضاف لها عنصري الكروم والزنك الي حدوث زيادة معنوية في القدرة الكلية المضادة للأكسدة ، نشاط انزيم الكتاليز وانزيم سوبر أكسيد ديسميوتاز مقارنة بالمجموعة الضابطة. وبناء علي هذه النتائج يمكن أن نوصي باستخدام عنصري الزنك والكروم كمحفزات للنمو وتحسين الاستجابات الفسيولوجية لقياسات الدم بالإضافة الي تحسين مؤشرات مضادات الأكسدة في حيوانات الماعز النامية.