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The effects of dietary organic selenium supplementation on growth performance, blood metabolites, and antioxidant enzyme activity in fattening lambs

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Abstract

This study aimed to evaluate the effects of dietary organic selenium (Se) supplementation on growth performance, hematological parameters, and selected blood metabolites in fattening Baluchi lambs. A total of 24 male lambs (initial body weight; BW, 18.4 ± 1.7 kg) were assigned to a completely randomized design with four dietary treatments and six replicates per treatment over a 75-day period. Prior to the experimental phase, lambs were acclimated to individual cages and a basal diet for two weeks. The dietary treatments included a control group (basal diet without organic selenium supplementation) and three experimental groups receiving 0.25, 0.5, and 0.75 mg Se/kg feed in the form of an organic selenium-methionine supplement. The results indicated that selenium supplementation had no significant effect on average daily feed intake, final body weight, average daily gain (ADG), or feed conversion ratio (FCR). Furthermore, there were no notable alterations in hematological parameters, including red and white blood cell counts, hematocrit values, or hemoglobin concentrations, attributed to selenium supplementation. Likewise, the levels of thyroid hormones, specifically triiodothyronine (T3), tetraiodothyronine (T4), and thyroid-stimulating hormone (TSH), did not exhibit any significant changes in relation to dietary selenium intake. Importantly, the activity of blood glutathione peroxidase (GPX) demonstrated a linear increase corresponding to increased selenium supplementation. Additionally, a quadratic influence of dietary supplemental Se on blood urea concentration was observed. Specifically, lambs receiving 0.25 mg and 0.5 mg of Se/kg of diet revealed elevated concentrations of circulating urea compared to those on the control diet. However, no significant differences were detected in malondialdehyde, creatinine, triglycerides, or cholesterol levels among treatment groups. In conclusion, the administration of dietary organic selenium at levels up to 0.75 mg/kg did not influence growth performance nor demonstrated any negative effects on blood cells and metabolic status of the lambs. Nevertheless, it resulted in a notable enhancement of glutathione peroxidase activity, underscoring the pivotal role of organic selenium in enhancing the antioxidant system of fattening lambs.

Key words: Antioxidant enzyme, Fattening lambs, Growth performance, Hematology, Selenium

Introduction

Sheep farming is an essential source of livelihood for many rural and nomadic communities in Iran. The growing human population and the increasing demand for animal proteins, particularly mutton, have necessitated the expansion of intensive lamb fattening systems in the country (Valizadeh, 2015). However, the

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productivity of sheep farming is often constrained by various challenges, including infectious diseases, parasitic infestations, nutrient deficiencies as well as the harsh environmental conditions (Mousaie, 2021). To enhance the animals' health and production, the use of metabolic modifiers such as vitamins, minerals, hormones, and dietary additives has been widely explored (Dominguez-Vara et al, 2009; Mousaie et al, 2014).

Minerals are essential for physiological processes, structural integrity, and cellular function in livestock. Among these, selenium plays a crucial role in maintaining health and metabolic functions. Selenium is a key component of at least 25 selenoproteins, particularly glutathione peroxidase and thioredoxins. These selenoproteins contribute to antioxidant defense mechanisms by protecting biological membranes against oxidative damage caused by free radicals. Such oxidative stress can arise from metabolic processes, infections, parasitic burdens, environmental stressors, and the oxidation of dietary unsaturated fats (Tapiero et al, 2003; NRC, 2005; Suttle, 2010). Additionally, selenium serves as a cofactor for iodothyronine deiodinases, which regulate thyroid hormone activity and basal metabolism (Suttle, 2010).

The National Research Council (NRC, 2005) recommends dietary selenium levels between 0.1 and 0.4 mg/kg for sheep. However, it has been shown that dietary Se supplementation even more than 1 mg/kg of diet exerts no toxicity but improves growth performance of sheep (Chauhan et al, 2016; Mousaie, 2021). Nevertheless, these requirements may be affected by several factors, such as the physiological stage of the animal, prevailing environmental conditions, the specific composition of the diet, and the production status of the sheep. In regions where soil selenium concentrations are adequate for plant uptake, the necessity for dietary supplementation may be obviated. However, disparities in soil selenium levels and the variability in plant absorption efficiencies result in inconsistent selenium concentrations in forages and grains. As a result, many commercial sheep farming practices commonly incorporate selenium into mineral supplements to guarantee sufficient intake levels (Suttle, 2010; McDonald et al, 2010).

Studies on the effects of selenium supplementation on feed intake, growth performance and blood metabolites in small ruminants have yielded inconsistent results. Some studies have reported improvements in growth performance in lambs (Kumar et al, 2009; Mousaie et al, 2014) and goats (Shi et al, 2011; Song et al, 2015) following selenium supplementation, whereas others found no significant effects (Alimohamady et al, 2013). Similarly, the impact of selenium on blood metabolites has been variable. In one study, dietary supplementation with 0.5, 2, and 4 mg of Se, as selenium-yeast in goats enhanced antioxidant activity and increased thyroxine (T4) levels, but had no effect on triiodothyronine (T3) concentrations (Shi et al, 2017).

Despite extensive research, the effects of selenium supplementation on animal growth performance and metabolic indicators remain inconsistent. While several studies have reported improvements in performance and blood metabolic profiles following selenium supplementation (Kumar et al., 2009; Chauhan et al., 2016; Mousaie, 2021), others have found no significant effects (Alimohamady et al., 2013). Notably, the selenium requirements of local breeds remain insufficiently characterized. Additionally, different nutritional plans, environmental conditions, variable soil and feed selenium contents, different doses of supplemental selenium, and various sources of selenium could significantly influence the outcomes. Furthermore, the response of fattening Baluchi lambs to organic selenium supplementation in diets enriched with

soybean oil has not been adequately researched. Then, this research aimed to evaluate the effects of various doses of dietary organic selenium supplementation on growth performance, hematological parameters, and blood metabolic indices in Baluchi male lambs kept under optimal rearing conditions, where lambs were maintained within suitable environmental parameters and received the necessary nutrients through a balanced diet, in contrast to the studies conducted in heat stress conditions. This methodology allows for a unique assessment of selenium's role in antioxidant defense mechanisms and metabolic functions.

Materials and Methods

This study was conducted at the Research Institute of Zabol, Zabol, Iran, using 24 male Baluchi lambs (4–5 months old) with an average initial body weight of 18.4 ± 1.7 kg. The experiment followed a completely randomized design with four dietary treatments and six replicates per treatment over a 75-day period (15 days for adaptation and 60 days for data collection).

Animal Housing and Experimental Design

The lambs were housed individually in metabolic cages and acclimatized to the environmental conditions and basal diet before the initiation of the experiment. Following the acclimation phase, the lambs were randomly assigned to one of four dietary treatments: 1) Control group: Basal diet without organic selenium (Se) supplementation, 2) Basal diet supplemented with 0.25 mg Se/kg feed from an organic selenium-methionine (SeMet) source (Availa® Se 1000 containing 1 g Se/kg supplement; Zinpro, USA), 3) Basal diet supplemented with 0.5 mg Se, as SeMet/kg feed, and 4) Basal diet supplemented with 0.75 mg Se from SeMet source per kg of feed. The selenium concentrations in the supplemented diets were calculated based on the purity of the SeMet supplement. The experimental diets (Table 1) were formulated using the Small Ruminant Nutrition System (SRNS, version 5105/9/1) to meet the nutritional requirements of growing lambs. The basal diet consisted of 65% concentrate and 35% forage and was provided as a total mixed ration (TMR) to ensure uniform nutrient intake. The Se content of basal diet was 0.17 mg/kg diet (Calculated from NRC, 2001). The lambs were fed once daily at 08:00 AM, with the daily feed allowance adjusted based on individual voluntary intake.

Table 1: Ingredients and feed composition of basal diet

Ingredient (g/kg)	
Alfalfa hay	315
Wheat straw	35
Barley grain	370
Soybean meal	115
Wheat bran	100
Soybean oil	40
Salt	5
Vitamin-mineral premix[1]	10
Calcium carbonate	10
Chemical composition	
Metabolizable energy (Mcal/kg)[2]	2.51
Organic matter (g/kg)	919
Crude protein (g/kg)	151
Ether extract (g/kg)	60
Neutral detergent fiber (g/kg)	322
Acid detergent fiber (g/kg)	200
Calcium[2] (g/kg)	9
Phosphorus[2] (g/kg)	4
Selenium (mg/kg)[3]	0.17

[1]Contained (g/kg premix; DM basis): Ca, 196 g; P, 30 g; Na, 50 g; Mg, 18 g; Zn, 3 g; Fe, 3 g; Mn, 2 g; Cu 300 mg, Co 100 mg; I 100 mg; Se 10 mg. Vitamin A, 500,000 IU; Vitamin D, 100,000 IU; and Vitamin E, 100 mg.
[2]Calculated from SRNS (2010).
Calculated from nutrient composition data in the NRC (2001).

Measurements and Blood Sampling

Feed refusals were collected each morning, and their weights were recorded to calculate daily dry matter intake (DMI). DMI was determined as the difference between the total feed offered and the feed refused on a dry matter basis. Fresh drinking water was provided *ad libitum* throughout the experiment. Body weight

was measured at the beginning and end of the experimental period following an overnight fasting period to minimize gastrointestinal content variation.

Blood samples were collected at the end of the trial after overnight fasting. Serum samples were obtained by allowing blood to coagulate, followed by centrifugation at 3,500 rpm for 15 minutes, and subsequently stored at -20°C for further biochemical analyses. Additionally, whole blood samples were collected into tubes containing anticoagulant for the determination of glutathione peroxidase (GPX) activity and hematological parameters, including red blood cell (RBC) count, white blood cell (WBC) count, hemoglobin concentration, and hematocrit level.

Hematological and Biochemical Analyses

Hematological parameters (RBC count, WBC count, and hemoglobin concentration) were measured using an automated blood cell counter (Celltac, Japan), while hematocrit levels were determined using standard microhematocrit tubes.

The concentration of GPX enzyme was assessed using commercial assay kits (Randox-Ransod, UK). To measure GPX activity, hemolysates of red blood cells were prepared, and enzyme activity was expressed relative to hemoglobin concentration.

Serum biochemical parameters, including, urea, creatinine, cholesterol, and triglycerides, were quantified using commercial diagnostic kits (Pars Azmoun, Tehran, Iran) and an automated biochemical analyzer (BT 3500, Spain).

Chemical Analysis

The chemical composition of the feed was determined in accordance with AOAC procedures (AOAC, 2005). The ash content was determined through the combustion of the samples in an electrical furnace (method 942.05, AOAC, 2005). The quantity of organic matter was ascertained by deducting the ash content from the dry matter. Crude protein (CP; Kjeldahl N × 6.25) was analyzed by the Block Digestion Method with a copper catalyst followed by steam distillation to boric acid (Method 2001.11) using a 2100 Kjeltec distillation unit. Neutral detergent fiber (NDF, Van Soest et al., 1991) and acid detergent fiber (ADF, method 973.18, AOAC, 2005) were quantified using a fiber analysis device in accordance with established standard references. The dietary ether extract was assessed using the Soxhlet method (method 920.39, AOAC, 2005). Feed metabolizable energy (ME), as well as calcium and phosphorus content, were estimated using the SRNS software, while selenium concentration was determined through NRC (2001) software.

Statistical Analysis

Statistical analyses were performed using the MIXED procedure of SAS software (version 9.1, SAS Institute, 2003). The statistical model considered treatment effect as a fixed factor and initial body weight as a covariate for the analysis of daily weight gain, feed intake, and feed conversion ratio.

Data on daily feed intake were analyzed using a repeated measures model, incorporating treatment, time (day or week), and the interaction between treatment and time as fixed effects, with animal as a random effect. The differences among the least square means (LSMEANS) were tested using the PDIFF option if a value of $P \leq 0.05$ was detected. Trends were considered when $0.05 < p < 0.10$, and results are reported as least square means. For other variables, the statistical model used was as follows:

$Y_{ij} = \mu + T_i + e_{ij}$

where, Y_{ij} = observed dependent variable, μ = overall mean, T_i = fixed effect of treatment, and e_{ij} = residual error.

Results

Feed intake and Growth Performance

The results of feed consumption and growth performance of fattening lambs are presented in Table 2. Feed intake was not affected by dietary tyreatments (P>0.05). Additionally, the inclusion of SeMet in the diet had no significant effect on final body weight, average daily gain (ADG), or feed conversion ratio (FCR).

Blood metabolites

The effects of supplemental organic Se on blood hematological parameters and thyroid hormones and biochemical parameters of fattening lambs are presented in Tables 3, and 4, respectively. Dietary selenium supplementation did not affect the levels of red blood cells (RBC), white blood cells (WBC), hematocrit, hemoglobin, triiodothyronine (T3), tetraiodothyronine (T4), T4:T3 ratio, TSH, MDA, creatinine, triglycerides, or cholesterol (P>0.05). However, the concentration of GPX was significantly increased with the administration of organic Se (P<0.05). In addition, circulating urea concentration exhibited a quadratic response to selenium supplementation (P<0.05). Lambs receiving 0.25 and 0.5 mg selenium/kg feed showed significantly higher blood urea concentrations compared to the control group. Furthermore, the 0.75 mg selenium group also demonstrated a trend toward increased urea levels (P=0.06).

Table 2: Effects of dietary organic selenium supplementation on feed intake and growth performance of fattening lambs

Item	Treatment[1]					P-value	
	Control	0.25 Se	0.5 Se	0.75 Se	SEM	Linear	Quadratic
DMI (g)	952	926	917	935	2.72	0.33	0.11
Initial BW (kg)	17.8	19.1	17.8	19	0.35	0.47	0.92
Final BW (kg)	29.8	31.0	30.5	30.9	0.38	0.42	0.62
ADG (g)	200	197	212	198	5.03	0.82	0.59
FCR	4.80	4.78	4.37	4.76	0.11	0.61	0.38

[1]Treatments: control (diet without organic selenium supplementation); 0.25 Se, 0.5 Se, and 0.75 Se, diets supplemented with 0.25, 0.5, and 0.75 mg of organic Se/kg of diet, respectively.
SEM, standard error of the means.

Table 3: Effect of dietary organic selenium supplementation on hematological parameters and thyroid hormones

Item	Treatment[1]					P-value	
	Control	0.25 Se	0.5 Se	0.75 Se	SEM	Linear	Quadratic
Red blood cells ($\times 10^6/\mu L$)	10.5	9.9	10.5	10.6	0.18	0.69	0.33
White blood cells ($\times 10^3/\mu L$)	11.3	11.6	10.3	11.4	0.49	0.80	0.69
Hematocrit (%)	44.8	39.9	43.7	42.5	0.97	0.72	0.35
Hemoglobin (g/dL)	11.6	11.3	12.0	11.8	0.18	0.44	0.82
Triiodothyronine (T3, ng/mL)	2.11	1.84	2.08	1.90	0.079	0.61	0.81
Thyroxine (T4, μg/dL)	8.09	7.80	8.41	8.19	0.216	0.65	0.93
T4:T3 Ratio	3.91	4.30	4.10	4.37	0.123	0.29	0.82

[1]Treatments: control (diet without organic selenium supplementation); 0.25 Se, 0.5 Se, and 0.75 Se, diets supplemented with 0.25, 0.5, and 0.75 mg of organic Se/kg of diet, respectively.
SEM, standard error of the means.

Table 4: Effect of dietary organic selenium supplementation on biochemical parameters

Item	Treatment[1]					P-value	
	Control	0.25 Se	0.5 Se	0.75 Se	SEM	Linear	Quadratic
Glutathione peroxidase (GPX, U/gHb)	55.6^{d}	62.5^{c}	69.5^{b}	73.8^{a}	1.58	0.0001	0.38
Malondialdehyde (nmol/mL)	0.71	0.77	0.75	0.79	0.013	0.10	0.61
Urea (mg/dL)	64.0^{b}	83.8^{a}	82.6^{a}	76.8^{ab}	2.71	0.08	0.01
Creatinine (mg/dL)	2.53	3.50	2.60	2.76	0.159	0.88	0.19
Triglyceride (mg/dL)	56.2	76.7	74.6	65.8	4.02	0.43	0.08
Cholesterol (mg/dL)	18.6	23.5	30.5	23.4	2.26	0.31	0.20

[1]Treatments: control (diet without organic selenium supplementation); 0.25 Se, 0.5 Se, and 0.75 Se, diets supplemented with 0.25, 0.5, and 0.75 mg of organic Se/kg of diet, respectively.
a, b, c, d: Means in a row with common superscript(s) do not differ at P>0.05.
SEM, standard error of the means.

Discussion

Feed intake and Growth Performance

The lack of dietary organic Se on the lambs' feed intake are consistent with the previous studies, where the supplementation of 0.3 mg Se/kg of diet from the yeast-derived Se source in fattening male lambs (Dominguez-Vara et al., 2009) and 0.2–0.4 mg Se/kg of both inorganic (sodium selenite) and organic (yeast-derived) Se in growing lambs (Alimohamady et al, 2013) did not influence daily feed intake. However, in contrast to the present study, Shi et al. (2011) reported that supplementing 0.3 mg Se/kg diet of organic or inorganic Se in post-weaning goats led to an increase in DMI. It appears that the beneficial effects of Se on feed intake are predominantly observed in situations where certain challenges exist. Then, the typical nutritional and environmental conditions established in this study likely allowed the animals to consume food in accordance with their requirements. Consequently, the feed intakes, expressed as a percentage of the average body weights of the animals in the control group and the treatment groups (0.25, 0.5, and 0.75), were approximately 4%, 3.8%, 3.7%, and 3.75%, respectively. These values indicate that the DMI of the fattening lambs was within an acceptable range (Mousaie, 2021).

The effects of Se supplementation on growth performance have also been variable in different studies. Similar to the present findings, several studies in lambs (Juniper et al., 2006; Dominguez-Vara et al., 2009; Vignola et al., 2009; Alimohamady et al, 2013) and calves (Gunter et al, 2003) reported no significant effect of Se supplementation on ADG. However, some studies have demonstrated improvements in growth performance following Se supplementation, including research on lambs (Mousaie et al, 2014) and goat kids (Shi et al, 2011; Song et al, 2015).

The discrepancies in the effects of Se supplementation on growth performance across studies may be attributed to various factors, including selenium source, dosage, duration of supplementation, dietary composition, animal breed, physiological status, and environmental conditions. One of the proposed mechanisms underlying the growth-promoting effects of Se is its role in enhancing iodothyronine deiodinase enzyme activity, which facilitates the conversion of T_4 to its more metabolically active form, T_3. This process has been suggested to positively influence metabolism and nutrient utilization, particularly amino acid metabolism (Alimohamady et al, 2013; Mousaie et al, 2014; Shi et al, 2017). Selenium supplementation in the present study did not

influence the thyroid hormone concentrations, which may explain its lack of effect on lamb growth performance. Notably, the type and dosage of Se supplementation are critical determinants of its efficacy. It is important to acknowledge that the relatively short duration of the experimental period may have limited the ability to fully elucidate the long-term effects of Se supplementation on growth performance and associated metabolic adaptations. Moreover, the lack of data on ruminal fermentation parameters and nutrient digestibility was constrained by the project's financial limitations.

In the present study, the mineral-vitamin premix provided approximately 0.1 mg of selenium per kilogram of diet, based on its selenium content and the amount included in the ration (Table 1). Furthermore, although the Se content of individual feed ingredients was not measured in this study, as estimated, the dietary components contributed additional selenium (0.17 mg Se/kg diet), thereby resulting in an overall Se concentration in the basal diet of approximately 0.27 mg/kg DM. The previous research has reported that the Se requirement of sheep ranges between 0.1 and 0.2 mg/kg of feed (Paiva et al, 2019), suggesting that the basal diet in the present study may have adequately met the Se needs of the lambs under the given management conditions. When dietary Se is adequate, additional supplementation may not enhance growth performance, as Se is not a direct growth promoter but rather an essential micronutrient supporting antioxidant and metabolic functions. In contrast, Se supplementation often improves growth performance only in selenium-deficient conditions, where its absence impairs metabolic efficiency, immune function, and thyroid hormone activity (Suttle, 2010).

Moreover, the Se requirement of livestock can vary depending on environmental and physiological factors. Selenium, as an antioxidant trace element, plays a crucial role in counteracting oxidative stress; hence, its dietary requirement is typically elevated under conditions such as heat stress, severe nutrient deficiencies, and disease challenges (Suttle, 2010). However, the present study was conducted under optimal management conditions, with adequate dietary energy and protein levels, potentially mitigating any additional Se requirement. Some studies suggest that fattening lambs exposed to heat stress may benefit from higher dietary Se concentrations (Mousaie, 2021).

Additionally, Se supplementation has been reported to enhance nutrient digestibility in some studies (Shi et al, 2011). This variability in response could be attributed to differences in basal diet composition, nutrient ratios, and feed ingredient interactions, which may influence the bioavailability and metabolic utilization of selenium.

Blood metabolites

Blood serves as a critical and reliable medium for assessing the health status and metabolic functions of livestock. Hematological and biochemical parameters are influenced by various factors, including nutrition, disease, parturition, parasitic infections, and environmental stressors. These parameters fluctuate throughout the breeding and production cycle; thus, their evaluation provides valuable insights into the physiological condition and overall well-being of livestock (Shi et al, 2017).

Regarding the effects of Se on hematological parameters, the findings of the present study are consistent with the previous research indicating that Se supplementation did not significantly influence WBC counts or WBC differentiation of lambs (Mohri et al, 2011). Similarly, Alimohamady et al. (2013) reported that dietary supplementation with 0.2 and 0.4 mg Se/kg of feed from inorganic (sodium selenite) and organic (Se-yeast) sources did not affect the RBC counts,

WBC counts, hemoglobin concentration, or hematocrit levels in male lambs. Additionally, Shi et al. (2017) observed no significant changes in the RBC count, hemoglobin concentration, or hematocrit in goats fed with 0.5, 2, or 4 mg of Se from Se-yeast sources. However, contradictory findings have been reported in some studies. For instance, Shi et al, (2017) found that Se supplementation increased the RBC count and hemoglobin concentration while reducing the WBC count.

The absence of significant changes in WBC count following Se supplementation in the present study may be attributed to the experimental conditions, particularly dietary Se concentrations. The previous research in goats has demonstrated that Se levels below 2 mg/kg of feed did not affect the WBC count, whereas supplementation at 2 and 4 mg/kg significantly increased WBC numbers (Shi et al, 2017). This suggests that the impact of Se on hematological parameters may be dose-dependent, with higher supplementation levels potentially exerting a more pronounced effect.

Thyroid hormones play a crucial role in regulating metabolism, growth, and overall physiological functions. Selenium contributes to thyroid hormone activity through the activation of iodothyronine deiodinase, an enzyme responsible for the conversion of thyroxine (T4) to the more metabolically active triiodothyronine (T3). This conversion enhances metabolic efficiency and potentially influences growth performance (Dominguez-Vara et al., 2009). Additionally, some adverse effects of Se deficiency on livestock health are linked to impaired thyroid hormone metabolism. For example, the ewes consuming Se-deficient diets (<0.02 mg/kg feed) exhibited reduced T3 and T4 concentrations (Suttle, 2010).

Consistent with the present study, Kumar et al, (2008) reported that Se supplementation at 0.3 mg/kg feed had no significant effect on thyroid hormone concentrations of the lambs. Similarly, a study in goats found that dietary Se at 0.5, 2, and 4 mg/kg did not influence T3 levels but significantly increased T4 concentrations (Shi et al, 2017). However, Alimohamady et al, (2013) observed that supplementation with 0.2 and 0.4 mg Se/kg increased T3 concentrations while reducing T4 levels and the T4/T3 ratio in the lambs. These discrepancies in findings may be attributed to differences in experimental conditions, Se sources, and supplementation levels (the ingredients-based and supplemental Se). Although TSH concentrations were not significantly affected by Se supplementation in the present study, the lambs receiving 0.5 and 0.75 mg Se/kg feed exhibited numerically lower TSH levels, suggesting a potential modulatory effect of Se on thyroid function.

According to the findings of the present study, dietary supplementation with organic Se significantly increased blood GPX activity, whereas MDA concentrations remained unaffected by the treatments. All Se-supplemented groups exhibited higher GPX activity compared to the control group. The measurement of tissue or red blood cell GPX activity serves as a reliable indicator of Se status and antioxidant defense capacity in animals. Approximately 98% of blood GPX activity is attributed to red blood cells, which are particularly susceptible to oxidative damage due to the presence of unsaturated fatty acids in their membranes (Dalir-Naghadeh et al, 2015; Mousaie, 2021). Selenium enhances antioxidant protection by increasing GPX activity, thereby reducing oxidative stress and protecting cell membranes from lipid peroxidation.

The results of the current study align with the previous research demonstrating that Se supplementation at 0.1 to 0.4 mg/kg feed improves blood GPX activity in sheep (Qin et al, 2007; Alimohamady et al, 2013; Cobanova et al, 2017). Additionally, studies have shown that feeding lambs diets containing oil and Se at 2 mg/kg feed, a

level exceeding the recommended requirement of 0.1-0.4 mg/kg feed, further increased GPX activity in both blood and liver tissue (Yu et al, 2008). These findings suggest that Se supplementation may be beneficial for sheep experiencing various forms of stress that adversely impact their blood antioxidant capacity, including pathological and parasitic diseases, as well as challenging environmental conditions and food shortages. Despite the absence of significant changes in total antioxidant capacity following the administration of Se nanoparticles and sodium selenite in suckling lambs (Mohammadi Rad et al., 2024), several studies suggest that elevated blood Se concentrations enhance total antioxidant capacity through two primary mechanisms: its incorporation into red blood cells as a component of GPX and its role in neutralizing free radicals (Shi et al, 2011; Dalir-Naghadeh et al, 2015). These mechanisms highlight selenium's importance in cellular defense against oxidative stress, particularly in ruminants supplemented with selenium-enriched diets. The observed linear increase in GPX activity suggests that Se supplementation primarily enhanced antioxidant defense mechanisms rather than promoting muscle accretion or energy utilization for growth. Under non-stress conditions, energy and nutrient partitioning prioritize maintenance functions, including antioxidant defense, rather than excessive tissue deposition.

The current research demonstrated that providing supplemental organic Se in the diet led to increased blood urea levels in lambs. While some studies have reported no significant effect of Se supplementation on blood urea concentrations in ruminants (Dominguez-Vara et al., 2009; Sethy et al., 2015), the observed changes in this study suggest a potential interaction between Se and protein metabolism. The available information regarding the interaction of Se with protein metabolism in the gastrointestinal tract of sheep is inadequate. The increased blood urea levels noted in the lambs receiving 0.25 and 0.5 mg of Se/kg of diet, in comparison to the control group, may be attributed to enhanced protein digestibility in the rumen. This improvement could have resulted in an elevation of ammonia levels, leading to increased urea synthesis. Elevated blood urea could indicate increased hepatic urea synthesis due to accelerated amino acid turnover, suggesting that Se may indirectly influence nitrogen metabolism via modulation of antioxidant or endocrine pathways (Toh et al, 2022). Nonetheless, the precise relationship between Se and rumen ammonia, as well as blood urea, has yet to be clarified. Blood urea levels in ruminants are primarily influenced by ruminal protein metabolism, ammonia production, and absorption, rather than the catabolism of tissue proteins (NRC, 2001; McDonald et al, 2010). A reduction in blood urea generally indicates improved nitrogen utilization for microbial protein synthesis in the rumen. However, there is limited research on selenium's influence on rumen microbial metabolism and nitrogen efficiency. To elucidate the mechanisms underlying the observed increase in blood urea concentrations, further research should incorporate in vitro fermentation assays and in vivo ruminal content sampling at different time points to assess potential effects on microbial activity and nitrogen utilization.

According to the results, blood creatinine, triglyceride, and cholesterol concentrations remained unaffected by Se supplementation. Consistent with these findings, the previous studies on lambs (Kumar et al, 2009; Dominguez-Vara et al, 2009; Mousaie et al, 2014) reported no significant changes in blood triglyceride concentrations following Se supplementation. The unchanged creatinine levels suggest that the administered Se doses did not negatively impact kidney function, while stable cholesterol concentrations indicate that Se did not influence lipid metabolism at the tested supplementation levels. However, there is a paucity of research regarding selenium's

effects on creatinine and cholesterol metabolism in sheep and goats, necessitating further investigations to clarify these relationships. It should be noted that while blood parameters provide useful systemic indicators, direct measurements of Se concentrations in feed and tissues were not conducted. Such analyses could offer deeper insight into selenium's bioavailability and mode of action.

The results of this study indicate that under optimal nutritional and environmental conditions and with growing lambs, the Se levels present in the vitamin-mineral premix and basal diet were sufficient to meet the animals' nutritional requirements. Consequently, Se supplementation did not influence feed intake, weight gain, or most blood parameters. However, supplementation with 0.25 to 0.75 mg/kg of organic Se resulted in a linear increase in GPX activity, suggesting an enhancement in cellular antioxidant capacity. These findings emphasize the possible role of organic Se in enhancing antioxidant defense mechanisms without greatly impacting growth performance, which may be important for breeders rearing sheep in systems prone to environmental or nutritional stress. Future research should focus on evaluating long-term effects and the impact of Se supplementation under different environmental and physiological conditions, such as heat stress or nutritional deficiencies, to better understand its role in ruminant metabolism and overall health. It is advisable to evaluate the potential impacts of organic Se on the lambs' rumen microbial fermentation process and feed digestibility.

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Conflict of interest

No conflicts of interest are declared by the authors.

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Ethics approval

This study was performed in compliance with the guidelines of the Iranian Council of Animal Care (1995).

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تأثیر مکمل سلنیوم آلی در رژیم غذایی بر عملکرد رشد، متابولیت‌های خون و فعالیت آنزیم‌های آنتی‌اکسیدانی در بره‌های پرواری

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چکیده

این مطالعه با هدف ارزیابی اثرات مکمل سلنیوم آلی (Se) در جیره غذایی بر عملکرد رشد، پارامترهای خون‌شناسی و متابولیت‌های خونی منتخب در بره‌های بلوچی پرواری انجام شد. در مجموع ۲۴ بره نر (وزن اولیه بدن؛ ۱/۷ ± ۱۸/۴ کیلوگرم) در یک طرح کاملاً تصادفی با چهار تیمار غذایی و شش تکرار برای هر تیمار در یک دوره ۷۵ روزه قرار گرفتند. قبل از مرحله آزمایش، بره‌ها به مدت دو هفته با قفس‌های انفرادی و یک جیره پایه سازگار شدند. تیمارهای غذایی شامل یک گروه کنترل (جیره پایه بدون مکمل سلنیوم آلی) و سه گروه آزمایشی دریافت کننده ۰/۲۵، ۰/۵ و ۰/۷۵ میلی‌گرم سلنیوم در کیلوگرم خوراک به شکل مکمل سلنیوم-متیونین آلی بود. نتایج نشان داد که مکمل سلنیوم تأثیر معنی‌داری بر میانگین مصرف خوراک روزانه، وزن نهایی بدن، میانگین افزایش وزن روزانه (ADG) یا ضریب تبدیل غذایی (FCR) نداشت. علاوه بر این، هیچ تغییر معنی‌داری در پارامترهای خون‌شناسی، از جمله تعداد گلبول‌های قرمز و سفید خون، مقادیر هماتوکریت یا غلظت هموگلوبین، که به مکمل سلنیوم نسبت داده شود، مشاهده نشد. به همین ترتیب، سطح هورمون‌های تیروئید، به ویژه تری‌یدوتیرونین (T3)، تترایدوتیرونین (T4) و هورمون محرک تیروئید (TSH)، هیچ تغییر معنی‌داری در رابطه با مصرف سلنیوم غذایی نشان نداد. نکته مهم این است که فعالیت گلوتاتیون پراکسیداز خون (GPX) افزایش خطی مربوط به افزایش مکمل سلنیوم را نشان داد. علاوه بر این، تأثیر درجه دوم سلنیوم مکمل غذایی بر غلظت اوره خون مشاهده شد. به طور خاص، بره‌هایی که ۰/۲۵ میلی‌گرم و ۰/۵ میلی‌گرم سلنیوم در کیلوگرم جیره دریافت می‌کردند، غلظت بالاتری از اوره در گردش خون را در مقایسه با بره‌های دریافت کننده جیره کنترل نشان دادند. با این حال، هیچ تفاوت معنی‌داری در سطح مالون دی آلدئید، کراتینین، تری‌گلیسیرید یا کلسترول در بین گروه‌ها مشاهده نشد. در نتیجه، استفاده از سلنیوم آلی در جیره غذایی تا سطوح ۰/۷۵ میلی‌گرم بر کیلوگرم، نه بر عملکرد رشد تأثیری گذاشت و نه هیچ اثر منفی بر سلول‌های خونی و وضعیت متابولیکی بره‌ها نشان داد. با این وجود، منجر به افزایش معنی‌دار فعالیت گلوتاتیون پراکسیداز شد که نقش محوری سلنیوم آلی را در تقویت سیستم آنتی‌اکسیدانی بره‌های پرواری برجسته می‌کند.

کلمات کلیدی: آنزیم آنتی‌اکسیدانی، بره‌های پرواری، عملکرد رشد، خون‌شناسی، سلنیوم

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