



Shiraz University



IJVR

ISSN: 1728-1997 (Print)
ISSN: 2252-0589 (Online)

Vol. 27

No. 2

Ser. No. 95

2026

IRANIAN JOURNAL OF VETERINARY RESEARCH



Original Article

Effect of dietary levels of hydroxy-selenomethionine on growth performance, meat quality, tissue selenium content and glutathione peroxidase activity in lambs

Alkan, N.¹ and Muruz, H.^{2*}

¹The Ministry of Agriculture and Forestry of the Republic of Turkey, Tokat Provincial Office, Tokat 60200, Turkey; ²Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Ondokuz Mayıs University, Kurupelit Campus, Samsun 55100, Turkey

*Correspondence: H. Muruz, Department of Animal Nutrition and Nutritional Diseases, Faculty of Veterinary Medicine, Ondokuz Mayıs University, Kurupelit Campus, Samsun 55100, Turkey. E-mail: habip.muruz@omu.edu.tr

 10.22099/ijvr.2026.54766.8249

(Received 4 Nov 2025; revised version 12 May 2026; accepted 2 Jun 2026)

This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-ncnd/4.0/>)

Abstract

Background: Organic Se sources such as hydroxy-selenomethionine (OH-SeMet) offer higher bioavailability than inorganic forms; however, their effects on Se deposition and meat quality in lambs remain insufficiently studied. **Aims:** This study aimed to determine the growth performance, slaughter performance, meat quality, serum glutathione peroxidase (GSH-Px) activity and Se content in the serum and *longissimus dorsi* (LD) muscle of lambs offered diets containing OH-SeMet at different doses or sodium selenite (SS). **Methods:** Twenty-one Kivırcık male lambs (3-4 months old; 26.96±4.83 kg body weight) were randomly allocated to three dietary treatments (n=7) in a randomized complete block design, following a 10-day adaptation period and 56-day feeding period. The experimental diets consisted of concentrate-based rations supplemented with Se at 0.2 mg/kg in the form of SS (45% Se; 0.44 g/ton) or at 0.2 and 0.4 mg/kg in the form of OH-SeMet (2% Se; 10 or 20 g/ton). At the end of experiment, blood samples were collected from all lambs, which were then slaughtered, and tissue samples were obtained for subsequent analysis. **Results:** Dietary OH-SeMet supplementation did not affect growth, slaughter performance, or meat quality but markedly increased Se concentrations in serum and LD muscle compared with SS (P<0.001). At 0.2 mg Se/kg, OH-SeMet elevated muscle Se by 61.17% versus SS, and increasing the OH-SeMet level to 0.4 mg Se/kg further increased muscle Se in a dose-dependent manner, while serum GSH-Px activity remained unchanged. **Conclusion:** The increased incorporation of OH-SeMet into muscle tissue may enhance the Se content of meat, thereby providing an additional dietary Se source for consumers of animal products; however, this may not necessarily translate into improvements in growth performance or meat quality.

Key words: Antioxidant, Growth, Lamb, Selenium, Tissue deposition

Introduction

Lamb fattening is a preferred production model due to its ability to generate high amounts of animal protein in a short period. Nutrition, production systems, and various health-related factors collectively influence both performance and meat quality (Bello *et al.*, 2016). Among nutritional factors, selenium (Se) has received considerable attention because dietary Se supplementation in livestock has been shown to improve growth performance (Shi *et al.*, 2011; Vieira *et al.*, 2022), enhance meat quality and antioxidant capacity in lambs (Kumar *et al.*, 2009), and strengthen the immune system in calves (Salles *et al.*, 2014). The biological functions of Se are primarily mediated through selenoproteins, which incorporate selenocysteine

(SeCys) as a key component. SeCys serves as the essential structural element of 25 distinct selenoproteins, including enzymes such as glutathione peroxidase (GSH-Px), thioredoxin reductase, and deiodinase. These selenoproteins are critically involved in regulating essential biological processes such as antioxidant defense, reproduction, and DNA synthesis (Zhang *et al.*, 2023). Selenium is also a key component of the muscular antioxidant system in ruminants, and it has been shown to improve major parameters related to meat quality (Vignola *et al.*, 2009; Grossi *et al.*, 2021; Tian *et al.*, 2022). This effect varies depending on species, Se form, and supplementation level (Wahyono *et al.*, 2023).

Sodium selenite (SS) is commonly included in lamb diets at 0.20 mg Se/kg dry matter (DM) to meet the Se requirements of lambs (NRC, 2007). However, this

inorganic form of Se is used solely for the synthesis of selenoenzymes and, unlike organic Se forms with higher bioavailability, it is not incorporated into non-specific body proteins and is largely excreted into the environment (Weiss, 2003). One of the organic forms of Se, selenoyeast (Se-yeast), which contains organically bound Se produced by yeast, has been approved for use as a feed additive, provided that $\geq 63\%$ of the total Se content is in the form of selenomethionine (SeMet) (EFSA, 2008, 2018, 2019). The principal advantage of supplementing Se in the form of SeMet, as opposed to inorganic Se sources, lies in its dual metabolic fate: a portion of SeMet is incorporated into the body's protein pool via the methionine metabolic pathway, while the remainder is metabolized similarly to other Se forms to fulfill immediate selenoprotein requirements (Weiss, 2003). This allows Se to be stored in animal body tissues, creating a reserve for future physiological use (Hosnedlova *et al.*, 2017; Surai *et al.*, 2018). In addition, the increased Se content resulting from the greater incorporation of SeMet into muscle tissue may serve as an additional dietary Se source for individuals consuming animal products (Kieliszek and Sandoval, 2023). However, it has been reported that the SeMet content of Se-yeast products does not always comply with the minimum 63%, and more recent evaluations have indicated that the proportion of inorganic Se often exceeds 3% (Vacchina *et al.*, 2021; Hachemi *et al.*, 2023a; Angaïts *et al.*, 2024). Such variability results in a less reliable product that may not consistently optimize the Se status of animals. In contrast, pure forms of organic Se, such as hydroxy-selenomethionine (OH-SeMet), provide a highly consistent source, with $\geq 98\%$ of the total Se present as OH-SeMet (EFSA, 2013). To date, the higher bioavailability and associated functional effects of OH-SeMet in comparison with SS and Se-yeast have been documented in broilers (Zhao *et al.*, 2017; Sun *et al.*, 2021), laying hens (Jlali *et al.*, 2013), pigs (Jlali *et al.*, 2014), beef cattle (Grossi *et al.*, 2021), and dairy cows (Li *et al.*, 2022). Given its efficient incorporation into body proteins, OH-SeMet may further enhance antioxidant protection in muscle (Sun *et al.*, 2021). However, to the best of our knowledge, no published studies have investigated the effects of stepwise OH-SeMet supplementation on meat quality in lambs.

According to Commission Implementing Regulation No. 427/2013 of 8 May 2013, the European Union has set the maximum allowable supplementation level for organic Se compounds at 0.2 mg Se/kg of feed. Nevertheless, increasing attention has been given to Se supplementation above recommended levels, with the aim of improving animal health, performance, and meat quality (Grossi *et al.*, 2021; Li *et al.*, 2025), and potentially supporting disease prevention and functional food production (Rayman, 2008; Fairweather-Tait *et al.*, 2010; Paiva *et al.*, 2019). In this context, we hypothesized that dietary OH-SeMet supplementation would increase Se deposition in serum and muscle tissues in a dose-dependent manner compared with SS,

and that this enhanced bioavailability might influence antioxidant status and meat quality. Therefore, the specific objectives of this study were to:

- (i) Evaluate the effects of OH-SeMet versus SS on growth and slaughter performance
- (ii) Assess post-mortem meat quality traits
- (iii) Determine Se concentrations in serum and *longissimus dorsi* (LD) muscle
- (iv) Measure serum GSH-Px activity in lambs fed diets supplemented with different levels of Se

Materials and Methods

Study location and ethical statement

The feeding trial was carried out at a private farm in the village of Çevreli in the Almus district of Tokat province, Turkey. Geographically, the study area is located at 40°17'56.66''N latitude and 36°51'03.84''E longitude.

The experiment was approved (2022/31-6/2022) by the Local Animal Ethics Committee of Ondokuz Mayıs University following guidelines of the European Union directive number 2010/63/EU (2010) regarding the care and use of animals for experimental and scientific purposes.

Animals, experimental design and dietary treatments

The feeding trial was conducted using 21 male Kivircik lambs (Body weight, BW: 26.96 $\pm$ 4.83 kg; age: 3-4 months old), which were sourced from the local market. Animals were weighed, immunized against common infections, and treated for both internal and external parasites of sheep. All lambs were kept in individual pens (2 $\times$ 1.25 m) with straw bedding and provided with individual feeding and watering. During the experimental period (September-November 2022), ambient temperature ranged approximately between 8 and 26°C, reflecting typical autumn conditions, with moderate relative humidity and natural ventilation without mechanical climate control. Photoperiod was not experimentally controlled; animals were exposed to the natural daylight cycle prevailing at this latitude (approximately 12.5 to 11 h light/day). No artificial lighting was applied.

The experiment was conducted using a randomized complete block design. At the beginning of the study, lambs were individually weighed and ranked in ascending order based on their body weight. The animals were then grouped into seven blocks, each consisting of three lambs, to ensure homogeneity based on initial body weight. Within each block, the three lambs were randomly assigned to one of three different treatment groups, resulting in seven lambs per treatment group. The experimental diets consisted of concentrate-based rations supplemented with Se at 0.2 mg/kg in the form of SS (45% Se; 0.44 g/ton) or at 0.2 and 0.4 mg/kg in the form of OH-SeMet (2% Se; 10 or 20 g/ton). Sodium selenite (45% Se) and OH-SeMet (Selisseo® 2% Se) for

animal feeding were obtained from O Kimya (Istanbul, Turkey) and Adisseo France S.A.S (Antony, France), respectively. The Se additives were added to a premix and then used to manufacture the concentrate feed. The Se content of the concentrate feeds was analytically measured as 0.31, 0.34, and 0.51 mg/kg DM for the SS-0.2, OH-SeMet-0.2, and OH-SeMet-0.4 groups, respectively. According to NRC (2007), the Se requirement of small ruminants is approximately 0.1-0.2 mg/kg DM, whereas the maximum tolerable concentration is 5 mg/kg DM. Thus, all dietary Se concentrations in the present study (0.31-0.51 mg/kg DM) exceeded the requirement while remaining well below the maximum tolerable level.

Concentrate feeds (Table 1) were formulated to meet or exceed the nutrient requirements recommended by the NRC (2007), except for Se. Concentrate was provided *ad libitum* and distributed twice daily at 09:00 and 17:00 h. Mixed grass hay, chopped to 4 cm length, was given as the forage source at 100 g/head/day. Concentrate feed and forage were provided in separate feeders. The forage allowance was completely consumed by all lambs throughout the experiment. Fresh drinking water was available *ad libitum* throughout the study. The study included a 10-day adaptation period followed by a 56-day experimental period.

Table 1: Concentrate feed ingredients and nutrient content of concentrate feed and grass hay

Ingredients	Quantity (g/kg DM)	
Barley	500	
Maize	173	
Soybean meal	150	
Sunflower meal	23	
Wheat bran	70	
Molasses	42	
Sodium bicarbonate	10	
Limestone	13	
Salt	10	
Vitamin-Mineral premix*	9	
Analyzed nutrient composition (g/kg DM)	Concentrate feed	Mixed grass hay
Dry matter	876	894
Crude protein	161	89
Ether extract	23	24
Crude ash	60	78
ADF (acid detergent fiber)	54	394
NDF (neutral detergent fiber)	164	571
Metabolizable energy ^{†,‡} (MJ/kg DM)	11.38	8.79

DM: Dry matter. * The provided vitamin-mineral premix per kg contains: Ca 130 g, P 65 g, Fe 1300 mg, Cu 200 mg, Zn 1200 mg, Mn 1000 mg, I 9 mg, Co 12 mg, Vitamin A 140,000 IU, Vitamin D 37,500 IU, Vitamin E 375 mg, Vitamin K 25 mg, Vitamin B1 25 mg, Vitamin B6 25 mg, Riboflavin 75 mg, Vitamin B12 0.28 mg, Nicotinic acid 300 mg, Pantothenic acid 200 mg, Folic acid 15 mg, Biotin 1.5 mg, [†] The metabolizable energy of the concentrate feed was calculated using standard table values for each ingredient, and [‡] The ME content of grass hay was estimated using the regression equation from Kirchgeßner and Kellner (1981): ME, MJ/kg DM = 14.70 - 0.15 × ADF, where ADF is expressed as % of DM

Growth performance

The body weight of the animals was measured using an automated electronic scale at the beginning of the

feeding trial and subsequently on days 14, 28, 42, and 56 prior to the morning feeding. Average daily gain (ADG) was calculated as the difference between final live weight and initial body weight, which was then divided by the number of feeding days. Daily offerings and orts of each treatment diet were measured and recorded throughout the experimental period for each experimental animal. The daily feed intake of individual lambs was calculated as the difference between the feed offered and the feed refused on a DM basis. Feed conversion ratio (FCR) was calculated as the ratio of dry matter intake (DMI) to BW gain. Samples of forage and concentrate were collected weekly throughout the trial period and stored at -20°C until nutrient analysis.

Blood sampling

On the final day of the experiment, blood samples were collected from lambs before the morning feeding, by jugular venipuncture, in sterile vacutainers with clot activator. The samples were allowed to clot at 4°C for 30 min and then centrifuged at 1300 × g for 10 min. The serum was divided into two 1.5 ml Eppendorf tubes: one stored at -20°C for Se analysis, and the other stored at -80°C for the determination of GSH-Px activity.

Slaughter performance

At the end of the trial, the lambs were fasted for 12 h before slaughter. All animals were processed following standard slaughterhouse procedures. Body weight and hot carcass weight were recorded immediately after slaughter, and carcasses were chilled at 4°C. After 24 h, they were reweighed to obtain cold carcass weight and calculate dressing percentage. Each carcass was divided along the backbone into two equal halves. A cut was made between the 12th and 13th ribs to expose the LD muscle. The muscle area and back-fat thickness were measured at this point. The LD cross-section was traced on paper and its area determined with a digital planimeter. Subcutaneous fat thickness was measured using a digital caliper.

Meat quality assessment

Muscle pH was determined using a calibrated digital pH meter (Testo 205, Testo AG, Germany) equipped with a penetration electrode. Measurements were carried out 24 h postmortem following storage at 4°C. For each sample, pH readings were taken from three different locations on the muscle surface, and the mean value was used for further analysis. Surface color was evaluated using a Minolta Chroma Meter CR-400 (Konica Minolta Inc., Japan). After a 24-hour blooming period at 4°C, color coordinates including lightness (L*), redness (a*), and yellowness (b*) were measured at three separate points on the sample surface. The average of these measurements was calculated for statistical assessment (Otto *et al.*, 2007). All measurements were conducted under ambient room temperature conditions. The left LD muscle was removed from each carcass and stored at -20°C until meat-quality and Se analyses. Drip loss was

determined as described by Rasmussen and Andersson (1996). About 70 g of muscle, cut to 3 cm thickness, was used to measure cooking loss (Honikel, 1998). Warner-Bratzler shear force (WBSF) was assessed with a texture analyzer (Instron 3343). After cooking, samples were cooled overnight at 4°C (Sazili *et al.*, 2005). Six to eight cores (1 cm² cross-section) were cut parallel to the muscle fibers and sheared, and WBSF was expressed as kg/cm² (Papinaho *et al.*, 1996).

Selenium analyses and glutathione peroxidase activity

Selenium content in feed, blood serum, and LD muscle was determined by ICP-MS (Agilent 7800, Agilent Technologies Inc., USA) at the Atatürk University Eastern Anatolia High Technology Research Center (DAYTAM), Erzurum. Serum GSH-Px activity was determined using a commercial colorimetric assay kit (SunLong Biotech Ltd., China). Absorbance was measured with a microplate reader (Epoch, BioTek Instruments, USA) according to the manufacturer's instructions. Results are presented in ng/ml.

Feed analyses

The samples of concentrate and forage were ground to pass through a 1-mm screen using a Wiley mill, and weekly samples were analyzed in duplicate. Dry matter (DM), ash, ether extract (EE), and crude protein (CP) were analyzed according to AOAC (2005). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the Van Soest *et al.* (1991) method using an ANKOM200 Fiber Analyzer (ANKOM Technology Corp., Fairport, NY).

Statistical analysis

Data were analyzed using SPSS computer software (ver. 16; SPSS Inc., Chicago, IL, USA). The Kolmogorov-Smirnov test was used to test whether growth performance data were normally distributed; the Shapiro-Wilk test was used for carcass characteristics, meat quality, serum and muscle Se content, and serum GSH-Px activity. Homogeneity of variances was evaluated using Levene's test to verify the assumption of homoscedasticity. Treatment effects were evaluated using a one-way analysis of variance (ANOVA) with block included in the model:

$$Y_{ij} = \mu + T_i + B_j + \varepsilon_{ij}$$

Where,

Y_{ij} : The observed response

μ : The overall mean

T_i : The fixed effect of dietary treatment ($i = 1, 2, 3$)

B_j : The random effect of block defined by initial body weight ($j = 1, \dots, b$)

ε_{ij} : The residual error term, assumed to be independently and normally distributed with mean 0 and variance σ^2

The block effect (initial body weight) was not significant for the analyzed variables ($P > 0.05$). When significant treatment effects were detected, mean values

were separated using Tukey's HSD test ($P < 0.05$).

Results

The growth performance parameters are shown in Table 2. Initial BW did not differ among treatments ($P = 0.987$), confirming that groups were homogeneous at the beginning of the experiment. Throughout the feeding trial, BW measured at days 14, 28, 42, and 56 showed no significant differences among the SS-0.2, OH-SeMet-0.2, and OH-SeMet-0.4 groups ($P > 0.90$ for all time points). Average daily gain was also unaffected by dietary treatments during any of the experimental periods ($P > 0.35$). Similarly, overall ADG across the 56-day trial was comparable among groups, averaging 0.25-0.26 kg/day ($P = 0.889$). Dry matter intake followed a similar trend, with no significant effects of Se source or level observed during any interval or for the overall feeding period ($P > 0.42$). Feed conversion ratio values did not differ significantly among groups in any period ($P > 0.31$). The overall FCR ranged from 4.97 to 5.19 and was unaffected by Se supplementation source or dose ($P = 0.732$). Daily Se intake was comparable between SS-0.2 (0.40 mg/d) and OH-SeMet-0.2 (0.43 mg/d), whereas OH-SeMet-0.4 resulted in a markedly higher intake (0.65 mg/d) ($P < 0.001$).

The effects of dietary Se source and level on slaughter performance and meat quality traits of lambs are summarized in Table 3. Neither hot carcass weight nor cold carcass weight differed significantly among the SS-0.2, OH-SeMet-0.2, and OH-SeMet-0.4 groups ($P = 0.993$ and $P = 0.997$, respectively). Similarly, cold dressing percentage, LD area, and fat thickness over the LD muscle were not affected by Se supplementation ($P > 0.65$). Post-mortem pH values of the LD muscle were comparable across treatments ($P = 0.968$). Meat color characteristics, including lightness (L^*), redness (a^*), and yellowness (b^*), also showed no significant differences among groups ($P > 0.19$ for all parameters). Furthermore, drip loss, cooking loss, and shear force values were not influenced by Se source or level ($P > 0.85$).

Selenium concentrations in both LD muscle and serum were markedly affected by dietary treatments (Table 4). Lambs supplemented with OH-SeMet had significantly higher Se concentrations compared with those receiving SS ($P < 0.001$). In the LD muscle, Se levels increased from 183.28 µg/kg in the SS-0.2 group to 295.40 µg/kg in the OH-SeMet-0.2 group and 421.39 µg/kg in the OH-SeMet-0.4 group, indicating a clear dose-dependent response. Similarly, serum Se concentrations were elevated with OH-SeMet supplementation, reaching 180.59 µg/L and 258.52 µg/L in the OH-SeMet-0.2 and OH-SeMet-0.4 groups, respectively, compared with 109.87 µg/L in the SS-0.2 group ($P < 0.001$).

Serum GSH-Px activity was not significantly affected by Se source or supplementation level, with values ranging from 18.15 to 19.13 ng/ml (Table 4, $P = 0.886$).

Table 2: Growth performance of lambs receiving diets containing supplementary selenium

Parameter	Period	SS-0.2 (n=7)	OH-SeMet-0.2 (n=7)	OH-SeMet-0.4 (n=7)	SEM	P-value
BW (kg)	Initial BW, kg	27.30	26.80	26.80	1.247	0.987
	d 14	31.64	30.38	31.26	1.298	0.928
	d 28	34.29	33.47	33.74	1.305	0.969
	d 42	37.25	37.00	36.89	1.243	0.993
	d 56	41.50	41.12	41.25	1.275	0.993
ADG (kg/d)	d 1-14	0.312	0.258	0.320	0.020	0.452
	d 15-28	0.190	0.222	0.178	0.012	0.359
	d 29-42	0.212	0.250	0.226	0.014	0.581
	d 43-56	0.302	0.296	0.312	0.015	0.921
	Overall	0.252	0.258	0.258	0.005	0.889
DMI (g/d)	d 1-14	929.48	926.92	928.07	22.971	0.999
	d 15-28	1206.63	1216.23	1237.32	18.497	0.811
	d 29-42	1447.83	1377.58	1449.11	24.526	0.426
	d 43-56	1648.08	1550.20	1552.12	46.928	0.657
	Overall	1308.00	1267.73	1289.13	25.064	0.827
FCR	d 1-14	3.24	3.73	3.04	0.211	0.415
	d 15-28	6.76	5.62	7.66	0.530	0.311
	d 29-42	6.90	5.95	6.64	0.357	0.566
	d 43-56	5.64	5.51	5.07	0.330	0.789
	Overall	5.19	4.97	5.01	0.115	0.732
Se intake (mg/d)	Overall	0.40 ^b	0.43 ^b	0.65 ^a	0.032	P<0.001

SS-0.2: Sodium selenite-0.2 mg Se/kg concentrate DM, OH-SeMet-0.2: Hydroxy-selenomethionine 0.2 mg Se/kg concentrate DM, OH-SeMet-0.4: Hydroxy-selenomethionine 0.4 mg Se/kg concentrate DM, SEM: Standard error of the mean, DMI: Dry matter intake, BW: Body weight, ADG: Average daily gain, and FCR: Feed conversion ratio. ^{a, b} Mean values with different superscripts in the same row show significant difference at the (P<0.05) level

Table 3: Slaughter performance and meat quality in LD muscle of lambs receiving diets supplemented with selenium sources

Parameter	SS-0.2	OH-SeMet-0.2	OH-SeMet-0.4	SEM	P-value
Hot carcass weight (kg)	18.90	18.74	18.78	0.580	0.993
Cold carcass weight (kg)	18.49	18.37	18.42	0.579	0.997
Cold dressing percentage (%)	45.00	45.10	45.07	0.048	0.672
LD area (cm ²)	15.64	15.96	15.66	0.148	0.650
Fat thickness over LD (cm)	0.57	0.58	0.56	0.011	0.865
pH	5.51	5.52	5.52	0.017	0.968
Color characteristics for LD_{24h}					
L* (lightness)	44.20	45.74	43.76	0.466	0.199
a* (redness)	15.92	14.79	15.57	0.291	0.284
b* (yellowness)	10.21	9.74	9.56	0.228	0.529
Drip loss (%)	3.27	3.25	3.34	0.065	0.854
Cooking loss (%)	23.70	23.61	23.58	0.104	0.904
Shear force (kg/cm ²)	2.93	2.98	3.02	0.070	0.890

SS-0.2: Sodium selenite-0.2 mg Se/kg concentrate DM, OH-SeMet-0.2: Hydroxy-selenomethionine 0.2 mg Se/kg concentrate DM, OH-SeMet-0.4: Hydroxy-selenomethionine 0.4 mg Se/kg concentrate DM, SEM: Standard error of the mean, and LD: *Longissimus dorsi*

Table 4: Selenium content of serum and LD muscle and serum GSH-Px activity of lambs receiving diets supplemented with selenium sources

Parameter	SS-0.2	OH-SeMet-0.2	OH-SeMet-0.4	SEM	P-value
LD Se (µg/kg)	183.28 ^c	295.40 ^b	421.39 ^a	27.207	P<0.001
Serum Se (µg/L)	109.87 ^c	180.59 ^b	258.52 ^a	17.099	P<0.001
Serum GSH-Px (ng/ml)	18.15	19.13	18.30	0.811	0.886

SS-0.2: Sodium selenite-0.2 mg Se/kg concentrate DM, OH-SeMet-0.2: Hydroxy-selenomethionine 0.2 mg Se/kg concentrate DM, OH-SeMet-0.4: Hydroxy-selenomethionine 0.4 mg Se/kg concentrate DM, SEM: Standard error of the mean, LD: *Longissimus dorsi*, Se: Selenium, and GSH-Px: Glutathione peroxidase. ^{a, b, c} Mean values with different superscripts in the same row show significant difference at the (P<0.05) level

Discussion

All Se doses used in the study were within the range recommended by NRC (2007), indicating that dietary Se supply was nutritionally adequate. In this context, the absence of differences in growth performance among animals in different groups likely reflects that physiological requirements for normal growth had already been met. Similar findings have been reported in beef cattle (Grossi *et al.*, 2021) and broilers (Tang *et al.*, 2021), where improved Se bioavailability increased tissue Se concentrations without affecting growth under standard rearing conditions. In contrast, positive effects of organic Se on growth and feed efficiency are more frequently observed under conditions associated with elevated oxidative or metabolic stress, as demonstrated in broilers (Sun *et al.*, 2021) and dairy cows (Sun *et al.*, 2019). The absence of such stressors in the present study likely limited the functional impact of Se source on growth performance.

The absence of growth differences was also reflected in carcass results. This outcome mainly follows from the close link between carcass and final body weights (Issakowicz *et al.*, 2013). Similar observations have been reported in lambs supplemented with SS or Se-yeast (Vignola *et al.*, 2009), suggesting that Se source alone is insufficient to modify carcass composition under adequate nutritional conditions. Evidence indicating positive effects of Se on carcass traits generally derives from Se-deficient or metabolically challenged animals (Juszczuk-Kubiak *et al.*, 2016; Tian *et al.*, 2022). Here, dietary Se was already adequate, which likely prevented such effects.

Selenium's antioxidant role can continue after slaughter by maintaining GSH-Px activity and slowing oxidation (DeVore *et al.*, 1983). Some studies have shown better meat quality with Se supplementation (Tang *et al.*, 2021; Tian *et al.*, 2022). In this study, both Se sources produced similar quality meat. The 0.2 mg Se/kg DM in the diets was likely enough to maximize GSH-Px activity in all groups. Although OH-SeMet increased Se retention, this did not translate into higher enzyme activity or better meat quality. Similar findings have been reported in lambs (Vignola *et al.*, 2009; Mariezcurrena-Berasain *et al.*, 2022), beef cattle (Huang *et al.*, 2023) and turkeys (Juniper *et al.*, 2011). Once tissue enzyme capacity is reached, extra Se does not further improve quality.

The differences observed in serum and muscle Se concentrations among treatments appear to reflect fundamental metabolic distinctions between organic and inorganic Se sources rather than merely differences in dietary supply. Serum Se is widely regarded as a sensitive biomarker of dietary Se source and supply (Hall *et al.*, 2013; Pecoraro *et al.*, 2022). Although the experimental period was limited to eight weeks, the consistent differences observed between treatments suggest that circulating Se concentrations reflected sustained alterations in systemic Se status during the supplementation period. Importantly, despite comparable

Se intake between the SS-0.2 and OH-SeMet-0.2 groups, lambs receiving OH-SeMet exhibited greater Se deposition in muscle tissue. This divergence suggests that the observed variation in tissue Se concentration cannot be attributed solely to intake level, but instead reflects source-dependent metabolic utilization. The mechanistic basis for this difference lies in the distinct metabolic fate of organic and inorganic Se forms. OH-SeMet provides Se in a form structurally analogous to SeMet, allowing its incorporation into the methionine pool and subsequent non-specific integration into structural body proteins. This process enables Se to accumulate in muscle tissue as a reversible storage reserve, thereby supporting a dose-responsive enrichment pattern. In contrast, inorganic Se sources such as SS undergo ruminal reduction to selenide and are primarily directed toward immediate selenoprotein synthesis or methylation for excretion once metabolic requirements are satisfied. Because inorganic Se cannot be incorporated into general body proteins, its capacity for long-term tissue retention is inherently limited. Furthermore, ruminal microbial transformations may reduce the proportion of inorganic Se that becomes systemically available (Galbraith *et al.*, 2016), contributing to the comparatively lower muscle Se deposition observed with sodium selenite supplementation. The enhanced tissue deposition associated with OH-SeMet supplementation in the present lamb study is consistent with findings reported in other species. Greater tissue Se accumulation with hydroxy-analogues of SeMet compared with inorganic sources has been demonstrated in pigs (Jlali *et al.*, 2014), poultry (De Marco *et al.*, 2021; Sun *et al.*, 2021; Tang *et al.*, 2021), beef cattle (Grossi *et al.*, 2021), and dairy cows (Sun *et al.*, 2017). These differences in muscle Se concentration are not only biologically relevant but also nutritionally meaningful. From a human health perspective, particularly for adults, the estimated amount of meat required to provide 55 µg of Se (IOM, 2000) ranged from 130 to 300 g across treatments. Because meat provides Se largely in organic forms (Ferreira *et al.*, 2021), the increased Se deposition achieved through OH-SeMet supplementation enhanced the Se density of lamb meat, thereby allowing the recommended daily intake to be met with smaller portion sizes.

The unchanged serum GSH-Px activity despite marked increases in serum and muscle Se indicates that selenoprotein synthesis had likely reached a functional plateau under the basal Se supply (Li and Sunde, 2016). Glutathione peroxidase activity reflects Se adequacy rather than total tissue Se content, and once physiological requirements are met, additional Se does not proportionally enhance enzyme activity due to hierarchical regulation of selenoprotein expression (Weiss, 2003; Li and Sunde, 2016). The elevated muscle Se concentrations observed with OH-SeMet supplementation therefore most likely represent expanded Se reserves within structural body proteins rather than increased allocation to active selenoenzymes. Comparable patterns have been reported in dairy cows,

where greater Se retention did not result in higher antioxidant enzyme activity when baseline Se status was already sufficient (Hachemi *et al.*, 2023b). Under conditions associated with increased oxidative stress, however, Se supplementation—particularly in organic forms—may exert a more pronounced effect on antioxidant systems (Gong and Xiao, 2018; Sun *et al.*, 2021). The lack of change in GSH-Px activity in the present study therefore likely reflects the attainment of Se sufficiency and the absence of oxidative challenge under the experimental conditions. Future research should assess OH-SeMet supplementation in lambs exposed to defined stress conditions and incorporate a broader range of oxidative biomarkers to better characterize functional antioxidant responses.

The present trial used individual animals as experimental units and uniform management to minimize confounding effects. Yet, the small sample size (n=21) and single-farm setting may have limited statistical power and external validity. In addition, meat oxidative stability during post-mortem storage was not evaluated, which restricts the interpretation of the practical implications of increased Se deposition for product shelf life and quality preservation. Furthermore, the duration of the study did not allow the assessment of potential long-term effects of sustained OH-SeMet supplementation on metabolic regulation or tissue Se dynamics. Despite these limitations, the results align with existing literature and provide clear evidence that OH-SeMet increases Se deposition in a dose-dependent way.

Overall, supplementing OH-SeMet at 0.2 mg Se/kg DM increased muscle Se by about 61% compared with SS, indicating greater Se deposition from the organic source. Increasing the supplementation level to 0.4 mg Se/kg DM further increased muscle Se by approximately 43%, indicating a dose-dependent response. These reserves could help animals cope with stress or poor Se availability in the environment. Practically, OH-SeMet appears to be a more efficient Se source for sheep diets. It may improve both animal health and the nutritional value of meat. Further work should evaluate its long-term impact under field conditions and in herds exposed to nutritional or oxidative stress.

Acknowledgement

This study was funded by the Scientific Research Projects Coordination Unit of Ondokuz Mayıs University (BAP04-B-2024-5166), Samsun, Turkey.

Conflict of interest

The Authors declare that there is no conflict of interest.

Research funding

This study was supported by the Scientific Research

Projects Coordination Unit of Ondokuz Mayıs University under Project No. BAP04-B-2024-5166.

Use of generative AI and AI-assisted technologies statement

The authors used generative AI solely for language editing and proofreading purposes. No AI tools were used in the design, execution, analysis, or interpretation of the research. The authors accept full responsibility for the content of this manuscript.

References

- Angaïts, A; Bierla, K; Szpunar, J and Lobinski, R (2024). Extraction recovery and speciation of selenium in Se-enriched yeast. *Anal. Bioanal. Chem.*, 416: 5111-5120. <https://doi.org/10.1007/s00216-024-05448-w>.
- AOAC (2005). *Official methods of analysis*. (18th Edn.), Association of Official Analytical Chemists, Arlington, VA (USA). Methods 930.15, 942.05, 920.39 and 984.13.
- Bello, JM; Mantecón, AR; Rodríguez, M; Cuestas, R; Beltran, JA and Gonzalez, JM (2016). Fattening lamb nutrition. Approaches and strategies in feedlot. *Small Rumin. Res.*, 142: 78-82. <https://doi.org/10.1016/j.smallrumres.2016.04.006>.
- De Marco, M; Conjat, AS; Briens, M; Hachemi, MA and Geraert, PA (2021). Bio-efficacy of organic selenium compounds in broiler chickens. *Ital. J. Anim. Sci.*, 20: 514-525. <https://doi.org/10.1080/1828051X.2021.1894994>.
- DeVore, VR; Colnago, GL; Jensen, LS and Greene, BE (1983). Thiobarbituric acid values and glutathione peroxidase activity in meat from chickens fed a selenium-supplemented diet. *J. Food Sci.*, 48: 300-301. <https://doi.org/10.1111/j.1365-2621.1983.tb14860.x>.
- EFSA (2008). Selenium-enriched yeast as source for selenium added for nutritional purposes in foods for particular nutritional uses and foods (including food supplements) for the general population. *EFSA J.*, 766: 1-42. <https://doi.org/10.2903/j.efsa.2008.766>.
- EFSA (2013). Scientific opinion on safety and efficacy of hydroxyl-analogue of selenomethionine as feed additive for all species. *EFSA J.*, 11: 3046. <https://doi.org/10.2903/j.efsa.2013.3046>.
- EFSA (2018). Assessment of the application for renewal of authorisation of selenomethionine produced by *Saccharomyces cerevisiae* CNCM I-3060 (selenised yeast inactivated) for all animal species. *EFSA J.*, 16: e05386. <https://doi.org/10.2903/j.efsa.2018.5386>.
- EFSA (2019). Assessment of the application for renewal of authorisation of selenomethionine produced by *Saccharomyces cerevisiae* NCYC R397 for all animal species. *EFSA J.*, 17: e05539. <https://doi.org/10.2903/j.efsa.2019.5539>.
- Fairweather-Tait, SJ; Collings, R and Hurst, R (2010). Selenium bioavailability: Current knowledge and future research requirements. *Am. J. Clin. Nutr.*, 91: 1484S-1491S. <https://doi.org/10.3945/ajcn.2010.28674J>.
- Ferreira, RLU; Sena-Evangelista, KCM; De Azevedo, EP; Pinheiro, FI; Cobucci, RN and Pedrosa, LFC (2021). Selenium in human health and gut microflora: Bioavailability of selenocompounds and relationship with diseases. *Front. Nutr.*, 8: 685317. <https://doi.org/10.3389/fnut.2021.685317>.

- Galbraith, ML; Vorachek, WR; Estill, CT; Whanger, PD; Bobe, G; Davis, TZ and Hall, JA (2016). Rumen microorganisms decrease bioavailability of inorganic selenium supplements. *Biol. Trace Elem. Res.*, 171: 338-343. <https://doi.org/10.1007/s12011-015-0560-8>.
- Gong, J and Xiao, M (2018). Effect of organic selenium supplementation on selenium status, oxidative stress, and antioxidant status in selenium-adequate dairy cows during the periparturient period. *Biol. Trace Elem. Res.*, 186: 430-440. <https://doi.org/10.1007/s12011-018-1323-0>.
- Grossi, S; Rossi, L; De Marco, M and Sgoifo Rossi, CA (2021). The effect of different sources of selenium supplementation on the meat quality traits of young charolaise bulls during the finishing phase. *Antioxidants*, 10: 596. <https://doi.org/10.3390/antiox10040596>.
- Hachemi, MA; Cardoso, D; De Marco, M; Geraert, PA and Briens, M (2023a). Inorganic and organic selenium speciation of seleno-yeasts used as feed additives: New insights from elemental selenium determination. *Biol. Trace Elem. Res.*, 201: 5839-5847.
- Hachemi, MA; Sexton, JR; Briens, M and Whitehouse, NL (2023b). Efficacy of feeding hydroxy-selenomethionine on plasma and milk selenium in mid-lactation dairy cows. *J. Dairy Sci.*, 106: 2374-2385. <https://doi.org/10.3168/jds.2022-22323>.
- Hall, JA; Vorachek, WR; Stewart, WC; Gorman, ME; Mosher, WD; Pirelli, GJ and Bobe, G (2013). Selenium supplementation restores innate and humoral immune responses in footrot-affected sheep. *PLoS One*, 8: e82572. <https://doi.org/10.1371/journal.pone.0082572>.
- Honikel, KO (1998). Reference methods for the assessment of physical characteristics of meat. *Meat Sci.*, 49: 447-457. [https://doi.org/10.1016/S0309-1740\(98\)00034-5](https://doi.org/10.1016/S0309-1740(98)00034-5).
- Hosnedlova, B; Kepinska, M; Skalickova, S; Fernandez, C; Ruttkay-Nedecky, B; Malevu, TD; Sochor, J; Baron, M; Melcova, M; Zidkova, J and Kizek, R (2017). A summary of new findings on the biological effects of selenium in selected animal species—A critical review. *Int. J. Mol. Sci.*, 18: 2209. <https://doi.org/10.3390/ijms18102209>.
- Huang, Q; Wang, S; Yang, X; Han, X; Liu, Y; Khan, NA and Tan, Z (2023). Effects of organic and inorganic selenium on selenium bioavailability, growth performance, antioxidant status and meat quality of a local beef cattle in China. *Front. Vet. Sci.*, 10: 1171751. <https://doi.org/10.3389/fvets.2023.1171751>.
- IOM (2000). Dietary reference intakes for vitamin C, vitamin E, selenium, and carotenoids. Washington D.C. USA, National Academy Press. PP: 284-319. <https://doi.org/10.17226/9810>.
- Issakowicz, J; Bueno, MS; Sampaio, ACK and Duarte, KMR (2013). Effect of concentrate level and live yeast (*Saccharomyces cerevisiae*) supplementation on Texel lamb performance and carcass characteristics. *Livest. Sci.*, 155: 44-52. <https://doi.org/10.1016/j.livsci.2013.04.001>.
- Jlali, M; Briens, M; Rouffineau, F; Geraert, PA and Mercier, Y (2014). Evaluation of the efficacy of 2-hydroxy-4-methylselenobutanoic acid on growth performance and tissue selenium retention in growing pigs. *J. Anim. Sci.*, 92: 182-188. <https://doi.org/10.2527/jas.2013-6783>.
- Jlali, M; Briens, M; Rouffineau, F; Mercierand, F; Geraert, PA and Mercier, Y (2013). Effect of 2-hydroxy-4-methylselenobutanoic acid as a dietary selenium supplement to improve the selenium concentration of table eggs. *J. Anim.*, 91: 1745-1752. <https://doi.org/10.2527/jas.2012-5825>.
- Juniper, DT; Phipps, RH and Bertin, G (2011). Effect of dietary supplementation with selenium-enriched yeast or sodium selenite on selenium tissue distribution and meat quality in commercial-line turkeys. *Animal*, 5: 1751-1760. <https://doi.org/10.1017/S1751731111000796>.
- Juszczuk-Kubiak, E; Bujko, K; Cymer, M; Wicińska, K; Gabryszuk, M and Pierzchała, M (2016). Effect of inorganic dietary selenium supplementation on selenoprotein and lipid metabolism gene expression patterns in liver and loin muscle of growing lambs. *Biol. Trace Elem. Res.*, 172: 336-345. <https://doi.org/10.1007/s12011-015-0592-0>.
- Kieliszek, M and Sandoval, SNS (2023). The importance of selenium in food enrichment processes. A comprehensive review. *J. Trace Elem. Med. Biol.*, 79: 127260. <https://doi.org/10.1016/j.jtemb.2023.127260>.
- Kirchgessner, M and Kellner, RJ (1981). Estimation of the energy value of green forage and roughage by the cellulase method. *Landwirtsch. Forsch.*, 34: 276-281 (in German).
- Kumar, N; Garg, AK; Dass, RS; Chaturvedi, VK; Mudgal, V and Varshney, VP (2009). Selenium supplementation influences growth performance, antioxidant status and immune response in lambs. *Anim. Feed Sci. Technol.*, 153: 77-87. <https://doi.org/10.1016/j.anifeedsci.2009.06.007>.
- Li, B; Li, X; Cheng, L; Li, J; Liu, Q; Duan, G; Yan, Y; Xu, Y; Zhao, J; Wang, B and Zhang, C (2025). Impact of dietary selenium supplementation on growth performance, rumen fermentation, antioxidant profiles, and meat quality in lambs on a high-concentrate diet. *Anim. Feed Sci. Technol.*, 333: 116614. <https://doi.org/10.1016/j.anifeedsci.2025.116614>.
- Li, JL and Sunde, RA (2016). Selenoprotein transcript level and enzyme activity as biomarkers for selenium status and selenium requirements of chickens (*Gallus gallus*). *PLoS One*, 11: e0152392. <https://doi.org/10.1371/journal.pone.0152392>.
- Li, Y; Zhang, W; Zhou, H; Zhu, J and Pan, C (2022). Effects of hydroxyselenomethionine with symmetrical and chelated chemical structure on lactation performances, antioxidant status and immunities, selenium transfer efficiencies for early-lactating dairy cows. *Symmetry*, 14: 916. <https://doi.org/10.3390/sym14050916>.
- Mariezcurrrena-Berasain, MD; Mariezcurrrena-Berasain, MA; Lugo, J; Libien-Jiménez, Y; Pinzon-Martinez, DL; Salem, AZM and García-Fabila, M (2022). Effects of dietary supplementation with organic selenium-enriched yeast on growth performance, carcass characteristics, and meat quality of finishing lambs. *Trop. Anim. Health Prod.*, 54: 49. <https://doi.org/10.1007/s11250-021-02992-w>.
- NRC (2007). *Nutrient requirements of small ruminants: Sheep, goats, cervids, and new world camelids*. 1st Edn., Washington D.C. USA, The National Academies Press. PP: 1-362. <https://doi.org/10.17226/11654>.
- Otto, G; Roehle, R; Looft, H; Thielking, L; Knap, PW; Rothschild, MF; Plastow, GS and Kalm, E (2007). Associations of DNA markers with meat quality traits in pigs with emphasis on drip loss. *Meat Sci.*, 75: 185-195. <https://doi.org/10.1016/j.meatsci.2006.03.022>.
- Paiva, FA; Netto, AS; Corrêa, LB; Silva, TH; Guimarães, ICSB; Del Claro, GR; Cunha, JA and Zanetti, MA (2019). Organic selenium supplementation increases muscle selenium content in growing lambs compared to inorganic source. *Small Rumin. Res.*, 175: 57-64. <https://doi.org/10.1016/j.smallrumres.2019.04.008>.
- Papinaho, PA; Ruusunen, MH; Suuronen, T and Fletcher, DL (1996). Relationship between muscle biochemical and meat quality properties of early deboned broiler breasts. *J.*

- Appl. Poult. Res., 5: 126-133. <https://doi.org/10.1093/japr/5.2.126>.
- Pecoraro, BM; Leal, DF; Frias-De-Diego, A; Browning, M; Odle, J and Crisci, E** (2022). The health benefits of selenium in food animals: a review. *J. Anim. Sci. Biotechnol.*, 13: 58. <https://doi.org/10.1186/s40104-022-00706-2>.
- Rasmussen, AJ and Andersson, M** (1996). New method for determination of drip loss in pork muscles. In: *Proceedings of the 42nd International Congress of Meat Science and Technology*. Lillehammer, Norway. PP: 286-287.
- Rayman, MP** (2008). Food-chain selenium and human health. *Br. J. Nutr.*, 100: 254-268. <https://doi.org/10.1017/S0007114508939830>.
- Salles, MSV; Zanetti, MA; Junior, LCR; Salles, FA; Azzolini, AECS; Soares, EM; Faccioli, LH and Valim, YML** (2014). Performance and immune response of suckling calves fed organic selenium. *Anim. Feed Sci. Technol.*, 188: 28-35. <https://doi.org/10.1016/j.anifeedsci.2013.11.008>.
- Sazili, AQ; Parr, T; Sensky, PL; Jones, SW; Bardsley, RG and Buttery, PJ** (2005). The relationship between slow and fast myosin heavy chain content, calpastatin and meat tenderness in different ovine skeletal muscles. *Meat Sci.*, 69: 17-25. <https://doi.org/10.1016/j.meatsci.2004.06.021>.
- Shi, L; Xun, W; Yue, W; Zhang, C; Ren, Y; Liu, Q; Wang, Q and Shi, L** (2011). Effect of elemental nano-selenium on feed digestibility, rumen fermentation, and purine derivatives in sheep. *Anim. Feed Sci. Technol.*, 163: 136-142. <https://doi.org/10.1016/j.anifeedsci.2010.10.016>.
- Sun, LL; Gao, ST; Wang, K; Xu, JC; Sanz-Fernández, MV; Baumgard, LH and Bu, DP** (2019). Effects of source on bioavailability of selenium, antioxidant status, and performance in lactating dairy cows during oxidative stress-inducing conditions. *J. Dairy Sci.*, 102: 311-319. <https://doi.org/10.3168/jds.2018-14974>.
- Sun, P; Wang, J; Liu, W; Bu, DP; Liu, SJ and Zhang, KZ** (2017). Hydroxy-selenomethionine: A novel organic selenium source that improves antioxidant status and selenium concentrations in milk and plasma of mid-lactation dairy cows. *J. Dairy Sci.*, 100: 9602-9610. <https://doi.org/10.3168/jds.2017-12610>.
- Sun, H; Zhao, L; Xu, ZJ; De Marco, M; Briens, M; Yan, XH and Sun, LH** (2021). Hydroxy-selenomethionine improves the selenium status and helps to maintain broiler performances under a high stocking density and heat stress conditions through a better redox and immune response. *Antioxidants*. 10: 1542. <https://doi.org/10.3390/antiox10101542>.
- Surai, PF; Kochish, II; Fisinin, VI and Velichko, OA** (2018). Selenium in poultry nutrition: from selenite to organic selenium sources. *J. Poult. Sci.*, 55: 79-93. <https://doi.org/10.2141/jpsa.0170132>.
- Tang, JY; He, Z; Liu, YG; Jia, G; Liu, GM; Chen, XL; Tian, G; Cai, JY; Kang, B and Zhao, H** (2021). Effect of supplementing hydroxy selenomethionine on meat quality of yellow feather broiler. *Poult. Sci.*, 100: 101389. <https://doi.org/10.1016/j.psj.2021.101389>.
- Tian, XZ; Li, JX; Luo, QY; Wang, X; Xiao, MM; Zhou, D; Lu, Q and Chen, X** (2022). Effect of supplementation with selenium-yeast on muscle antioxidant activity, meat quality, fatty acids and amino acids in goats. *Front. Vet. Sci.*, 8: 813672. <https://doi.org/10.3389/fvets.2021.813672>.
- Vacchina, V; Foix, D; Menta, M; Martinez, H and Séby, F** (2021). Optimization of elemental selenium (Se(0)) determination in yeasts by anion-exchange HPLC-ICP-MS. *Anal. Bioanal. Chem.*, 413: 1809-1816. <https://doi.org/10.1007/s00216-020-03129-y>.
- Van Soest, PJ; Robertson, JB and Lewis, BA** (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *J. Dairy Sci.*, 74: 3583-3597. [https://doi.org/10.3168/jds.S0022-0302\(91\)78551-2](https://doi.org/10.3168/jds.S0022-0302(91)78551-2).
- Vieira, SL; Teixeira, VQ; Simões, CT; Soster, P; Kindlein, L and Stefanello, C** (2022). Broiler meat production as affected by dietary supplemental hydroxy-selenomethionine. *Livest. Sci.*, 259: 104912. <https://doi.org/10.1016/j.livsci.2022.104912>.
- Vignola, G; Lambertini, L; Mazzone, G; Giammarco, M; Tassinari, M; Martelli, G and Bertin, G** (2009). Effects of selenium source and level of supplementation on the performance and meat quality of lambs. *Meat Sci.*, 81: 678-685. <https://doi.org/10.1016/j.meatsci.2008.11.009>.
- Wahyono, T; Wahyuningsih, R; Setiawan, AI; Pratiwi, D; Kurniawan, T; Hariyadi, S; Sholikin, MM; Jayanegara, A; Triyannanto, E and Febrisiantosa, A** (2023). Effect of dietary selenium supplementation (organic and inorganic) on carcass characteristics and meat quality of ruminants: a meta-analysis. *J. Anim. Feed Sci.*, 32: 127-137. <https://doi.org/10.22358/jafs/157555/2023>.
- Weiss, WP** (2003). Selenium nutrition of dairy cows: comparing responses to organic and inorganic selenium forms. In: Lyons, TP and Jacques, KA (Eds.), *Nutritional biotechnology in the feed and food industries. Proceedings of Alltech's 19th Annual Symposium*. Nottingham, UK, Nottingham University Press. PP: 333-343.
- Zhang, F; Li, X and Wei, Y** (2023). Selenium and selenoproteins in health. *Biomolecules*. 13: 799. <https://doi.org/10.3390/biom13050799>.
- Zhao, L; Sun, LH; Huang, JQ; Briens, M; Qi, DS; Xu, SW and Lei, XG** (2017). A novel organic selenium compound and regulation of selenium speciation, selenogenome and selenoproteins in broiler chicks. *J. Nutr.*, 147: 789-797. <https://doi.org/10.3945/jn.116.247338>.