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Selenium Supplementation Tended to Increase Digestibility and Milk Fat Content in Dairy Goats: A Meta-Analysis

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ABSTRACT

A meta-analysis was conducted to determine the effects of selenium supplementation on milk production, milk composition, and nutrient digestibility in dairy goats. A database was constructed based on relevant published papers. Related studies that met the criteria were sourced from PubMed, Scopus, and Google Scholar. After the identification of studies through the SYRCLE method, the final dataset consisted of 15 studies and 188 treatments. The data were analyzed using R version 4.3.3 (2024-02-29 ucrt) "Angel Food Cake", which utilizes packages such as lme4, lmerTest, and caret. The results showed that increasing concentrations of selenium tended to increase the digestibility of dry matter (DM), organic matter (OM), crude protein (CP), ether extract (EE), and total digestible nutrients (TDN) (p<0.05). Additionally, the results indicated a significant improvement on the milk fat content (p<0.05). In conclusion, selenium supplementation until 0.2 mg/kg significantly increase digestibility and milk fat content in dairy goats.

Keywords: dairy goat; digestibility; meta-analysis; selenium

INTRODUCTION

Selenium (Se) is a trace mineral and a micronutrient that is only required in small amounts and cannot be synthesized by the livestock body (Gu & Gao, 2022). Selenium (Se) is a crucial micronutrient for high-producing animals, including dairy and pregnant animals, due to its role in several vital biological functions, such as antioxidant protection, health and productivity, optimization of reproductive success, support and longevity, and performance improvement (Gu & Gao, 2022). In pregnant animals, Se is vital in the proper fetal development and dam health, contributing to better reproductive performance and reduced incidence of placenta retention (Gu & Gao, 2022). Se deficiency in high-producing animals can occur for several reasons, such as dietary imbalance and high production demands. High-producing animals have elevated nutritional requirements. If these conditions are not met, deficiencies can occur even if the general Se levels in the diet are adequate for less productive animals (Vona *et al.*, 2021).

There are two forms of selenium commonly used in the livestock industry, namely nonorganic selenium (sodium selenite and sodium selenate) and organic selenium (Se-Yeast, selenomethionine, and selenocysteine) (Arshad *et al.*, 2020). The effects of selenium, both organic and non-organic, have been inconsistent in the literature. Barcelos *et al.* (2022) reported that goats given selenium as a feed supplement did not exhibit significant differences in milk production, milk composition, or the selenium concentration in milk. Rashnoo *et al.* (2020) reported a significant difference in the effect of selenium supplementation on milk production, milk composition, and the selenium concentration in goat milk. To address this inconsistency, there is a method called meta-analysis. Meta-analysis is the statistical analysis of a large collection of analysis results from previous studies to integrate findings (Adli *et al.*, 2023). To estimate the effect of size from multiple studies, a meta-analysis was performed to address the inconsistency of findings from multiple experiments at a particular level of generality (Adli *et al.*, 2024). Therefore, this study aimed to provide more reliable conclusions about the effect of supplementation on the milk yield, milk composition, and nutrient digestibility of dairy goats.

MATERIALS AND METHODS

Eligibility Criteria, Search Strategy, and Data Extraction

The literature gathered during the search phase will be further refined using the criteria detailed in Figure 1. These criteria include both inclusion and exclusion factors based on the population, intervention, comparison, and outcome (PICO) framework according to the methods of Adli *et al*. (2024). The population refers to the number of goats used in the experiment. The

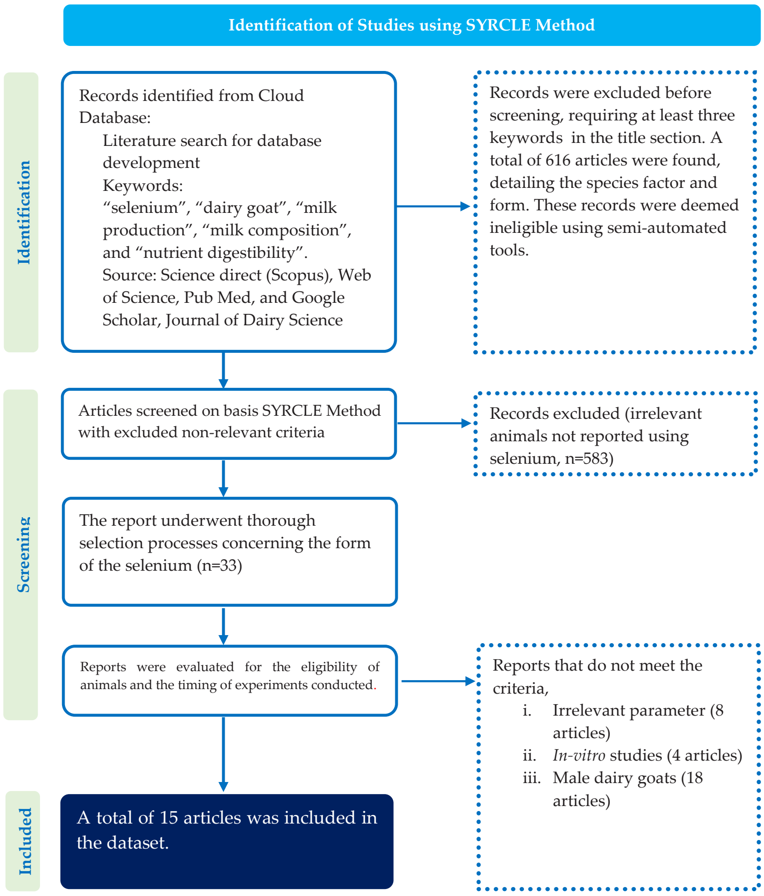

Figure 1. Diagram flow for study selection in meta-analysis study

intervention denotes the different amounts of selenium administered. The comparison involved the use of a nonselenium control group. The outcome consists of the observed parameters.

Each section of the title, abstract, methods, and results will be evaluated against these specific criteria. The search results, in *.ris file format, were imported into Mendeley Desktop v1.19.8. The application automatically identified duplicate data, which were then manually verified. Once it was confirmed that the articles were identical, they were merged. The initial relevance assessment of the articles included in this meta-analysis was conducted using the titles and abstracts. If an article met the criteria outlined in the previously provided PICO framework, it proceeded to the next step of the overall selection process for the article content.

A dataset was constructed from published literature reporting the use of selenium as a feed supplement in dairy goats, covering publications from 2005 to 2023. Literature searches were conducted on PubMed (https://pubmed.ncbi.nlm.nih.gov/), Scopus (https://www.sciencedirect.com/), and Google Scholar (https://scholar.google.com/) using the keywords 'selenium', 'dairy goat', 'milk production', 'milk composition', and 'nutrient digestibility', respectively. The literature collected was from 01/01/2005 to 31/12/2023.

The criteria for articles included in the database were as follows: 1) the article was published between 2005 and 2023, 2) the treatment included the dose of selenium used, 3) the article reported the use of selenium in dairy goats, excluding other animals, 4) the dairy goats were adult females, 5) selenium was administered by mixing it into the feed, and 6) the parameters included milk production, milk composition (fat, protein, lactose, total solids, and selenium concentration), and nutrient digestibility (dry matter, crude protein, ether extract, and total digestible nutrients).

For articles meeting these criteria, data were tabulated in Excel, including the author, year of publication, breed of goat used, lactation phase of the goat, type and amount of selenium used, and the values for each parameter. All the data were converted into similar units of measurement to facilitate direct analysis of specific parameters. The final database comprised 15 articles with a total of 188 treatment units. Figure 1 provides details of the study selection process used in this meta-analysis, and Table 1 presents a summary of the completed dataset.

Publication Bias, Grey Literature, and Quality Assessments

The limitations of the study also referred to as the inherent risks of bias in the overall research, were scrutinized using the Cochrane Collaboration assessment method (Budiarto *et al.*, 2024). Grey literature management, including theses and conference proceedings not reported in English, was excluded. Grey literature was considered only if it originated from experimental research and journals indexed with digital object identifiers (DOIs) and written in English. A total of 15 selected studies were utilized in this investigation to evaluate individual biases (see Figure 2). This evaluation involved assessing various criteria, such as the differing levels and forms of selenium administered to the dairy goats (D1); identifying deviations in the levels and forms of selenium interventions on the dairy goats (D2); observing the presence of missing data and parameters in the experimental outcomes (D3); examining how each researcher assessed the validity of the levels and forms of selenium on the dairy goats (D4); and considering the researchers' subjectivity in reporting the results of selenium concentration (D5). This assessment was conducted by three independent researchers. Each criterion was evaluated hierarchically, with a score of 3 assigned for "low risk," a score of 2 for "some concerns," and a score of 1 for "high risk." These scores were then used to determine the overall risk of bias for each study. The individual assessments for each criterion were summa-

Table 1. Studies selected for inclusion in the meta-analysis

No	References	Source of selenium	Periods	Level (mg/day)	Strain of dairy goat
1	Barcelos *et al*. (2022)	Se yeast	L	0-6.97	Saanen
2	Zhang *et al*. (2017)	Se enriched yeast and sodium selenite	L	0-1.12	Guanzhong
3	Mitsiopoulou *et al*. (2021)	N/A	L	0-0.12	Alpine X Local breed
4	Pechova *et al*. (2008)	Sodium selenite and LPC	L	0-0.45	N/A
5	Taheri *et al*. (2016)	Sodium selenite and selenomethionine	L	0-0.3	Iranian native
6	Rashnoo *et al*. (2020)	N/A	P	0-0.25	N/A
7	Kachuee *et al*. (2014)	Sodium selenite and selenomethionine	L	0-0.3	Merghoz
8	El-Nahrawy *et al*. (2022)	Sodium selenite and se yeast	L	0-0.45	Zaraibi
9	Petrera *et al*. (2009)	Sodium selenite and se yeast	L	0-0.26	Saanen
10	Gafaar *et al*. (2022)	Sodium selenite and se yeast	L	0-0.43	Zaraibi
11	Vasconcelos *et al*. (2023)	Se yeast	L	0-40	Saanen X Toggenburg
12	Kachuee *et al*. (2019)	Sodium selenite and selenomethionine	L	0-0.6	Khalkhali
13	Tozzi *et al*. (2016)	Sodium selenite and se yeast	L	0-0.2	Alpine
14	Misurova *et al*. (2009)	Sodium selenite and LPC	P	0-0.28	White shorthair
15	Horky *et al*. (2017)	N/A	L	0-0.99	White shorthair

Note: LPC= lactate protein complex, L= Lactating period, P= Pregnant, N/A = not available.

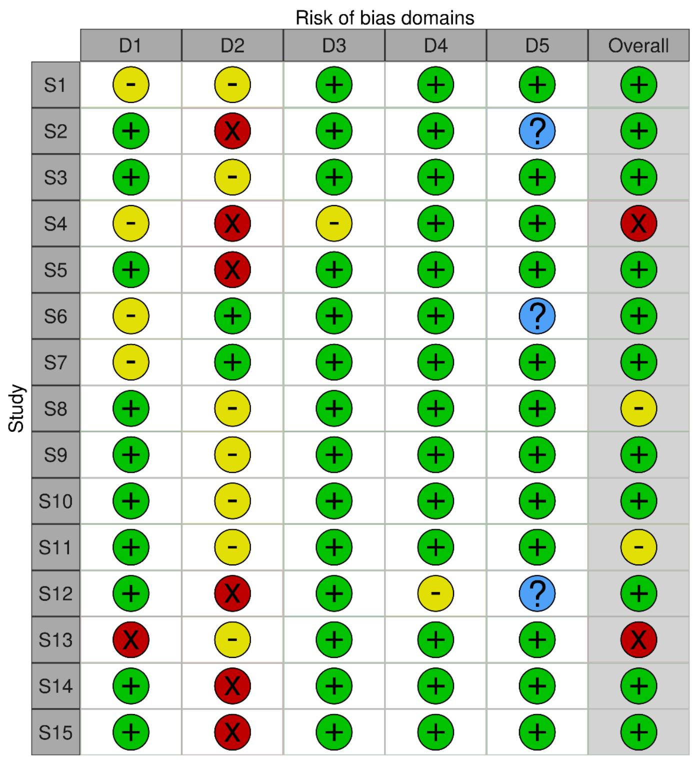

Figure 2. Individual plot from the pool of 15 studies. D1= first domain, bias arising from the randomization on process; D2= second domain, bias due to deviations from intended intervention; D3= third domain, bias due to missing outcome data; D4= fourth domain, bias in measurement of the outcome; D5= fifth domain, bias in selection of the reported result. Judgement: X= High; -= Some concerns; += Low; ?= No information.

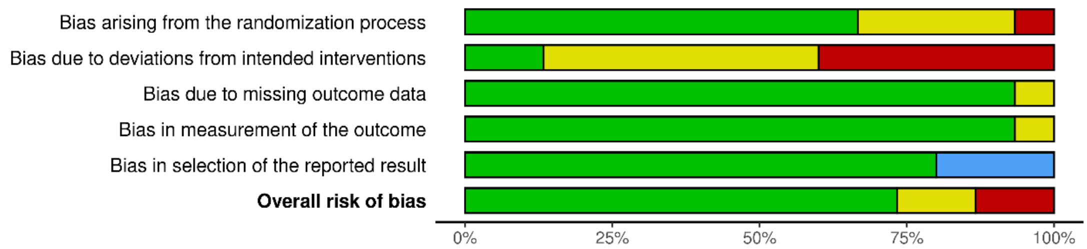

Figure 3. Summary of risk of bias (ROB) from 15 studies. = Low risk; = Some concerns; = High risk; = No information.

rized in a table and entered into the Robvis (Risk-of-Bias VISualization) website to generate traffic light plots and weighted bar plots. The summary of the risk of bias is illustrated in Figures 2 and 3.

Data Coding and Statistical Analysis

All analyses of the datasets that met the inclusion criteria were conducted using R version 4.3.3 (2024-02-29 ucrt) "Angel Food Cake", which was computed with the xlsx; ggplot; and tidyverse packages. Two analyses were conducted: qualitative analysis and quantitative analysis. In the field of nutrition, most of the dependent variables that were included in the meta-analysis were continuous (continuous predictor variables), so a linear mixed model was used with the following formula (Sauvant *et al.*, 2008):

$$Y_{ijk}= \mu + S_i + \tau_j + S\tau_{ij} + \beta_1X_{ij} + b_iX_{ij} + \beta_2X^2_{ij} + b_iX^2_{ij} + e_{ijk} \quad (1)$$

Y_{ijk} represents the dependent variable, μ represents the overall mean value (intercept value), S_i denotes the random effect of the *i*th study, assumed to be ~ N_{iid} (0, σ_S^2), τ_j represents the fixed effect of the j^{th} of τ factors, and $S\tau_{ij}$ represents the random interaction effect between the *i*th and *j*th dosage of the τ factor, also assumed to follow a normal distribution with mean 0 and variance $\sigma_{S\tau}^2$. β_1 represents the overall value of the linear regression coefficient for Y in relation to X, serving as a fixed effect or slope; β_2 denotes the general coefficient of the quadratic regression for Y concerning X, functioning as a fixed effect or slope, and X_{ij} and X^2_{ij} represent the continuous values of the predictor variable in both linear and quadratic forms, respectively. b_i represents the random effect specific to each study on the regression coefficient of Y with respect to X, assumed to be ~ N_{iid} (0, σ_b^2). Finally, e_{ijk} represents the residual value arising from unpredictable error.

The validation test was carried out utilizing the root mean square error (RMSE) and coefficient of determination (R^2) as metrics. The following equation represents the RMSE and R^2.

$$RMSE = \sqrt{\frac{\sum(O-P)^2}{NDP}} \quad (2)$$

$$R^2 = \frac{(\sigma^2{}_f + \sum(\sigma^2{}_l))}{(\sigma^2{}_f + \sum(\sigma^2{}_l) + \sigma^2{}_e + \sigma^2{}_d)} \quad (3)$$

In this scenario, 0 represents the actual value, P represents the estimated value, NDP denotes the number of data points, σ^2_f represents the variant of a fixed factor, $\sum(\sigma^2_l)$ is the sum of component variances, σ^2_e signifies the variance attributed to predictor dispersion, and σ^2_d characterizes the specific distribution of the variance.

Additionally, a categorical meta-analysis was conducted to compare the varying effects of SE on the parameters of interest. In this model, the types of SE were designated as fixed effects, while the different experiments within studies were coded as random effects using the following statistical model:

$$Y_{ij}= \mu + s\tau_{ij} + \beta_a + (\beta_a \times \beta_b)_{ij} + s\beta_{ij} + e_{ij} \quad (3)$$

where Y_{ij} represents the estimated means of Y, μ represents the overall mean, s_i represents the random effect of different experiments, β_j represents the fixed effect of the treatment group, $\beta_a \times \beta_b$ represent the interaction effect between the treatment group and covariate, $s\tau_{ij}$ represents random interaction between the *i* experiment and the *j* treatment group, and e_{ij} represents residual error ~ N (0, σ^2). Tukey-Kramer's test was used to separate the least square means of the categorical variables.

RESULTS

The findings of linear mixed models investigating the relationship between inclusion levels and various outcomes are detailed in Table 2. An increase in Se supplementation up to 0.1% demonstrated a significant quadratic relationship ($p=0.05$; $R^2=0.221$) with fat composition in milk, although the magnitude of effects varied depending on the strain, as indicated by the significant interaction effects ($p<0.05$) between inclusion levels and phase. Se supplementation had no significant impact ($p>0.05$) on dry matter intake, milk yield, protein, lactose, total solids, or the selenium nutrient content in dairy goats. There was no interaction effect between inclusion level and the form of Se. Se supplementation markedly enhanced dry matter digestibility (DMD) ($p=0.05$; $R^2=0.01$), organic matter digestibility (OMD) ($p=0.05$; $R^2=0.008$), crude protein digestibility ($p=0.05$; $R^2=0.01$), ether extract ($p=0.05$; $R^2=0.123$), and total digestible nutrients ($p=0.05$; $R^2=0.45$) in curvilinear patterns. After further post hoc analysis of the nutrient digestibility of the ether extract, it was found that selenomethionine was the best source of selenium (Table 2). Moreover, glutathione peroxidase (GSH-Px) activity exhibited a curvilinear pattern ($p<0.001$; $R^2= 0.44$) (Table 3). Among the different forms, the lactate protein complex demonstrated superior performance compared to the others.

Linear regression of the correlation between the selenium level and milk production. Milk yield= 1.59

Table 2. Interaction effect of different sources of selenium on milk production, milk composition, and nutrient digestibility in dairy goats

No	Response variables	N	CON vs TRT						SEM	p value	Interaction effects
			Control	Sodium selenite	Se yeast	SEY	Seleno methionine	LPC			TRT × forms
	Milk composition										
1	Milk yield, L / day	34	1.50	1.67	1.84	2.86	1.18	N/A	1.33	0.29	0.43
2	Fat, %	25	3.50	3.59	3.43	3.55	N/A	2.96	1.13	0.39	0.56
3	Protein, %	25	3.24	3.28	4.26	3.12	N/A	2.71	0.50	0.73	0.32
4	Lactose, %	17	4.31	4.42	10.40	N/A	N/A	4.87	1.77	0.24	0.31
5	Total solid, %	20	11.77	11.83	33.39	13.35	N/A	11.63	1.02	0.45	0.76
6	Selenium, %	22	18.83	37.71	70.24	14.35	N/A	79.00	1.81	0.21	0.87
	Nutrient digestibility										
7	DM, %	9	66.33	69.61	70.24	N/A	72.56	N/A	4.99	0.11	0.21
8	OM, %	9	67.73	70.89	70.83	N/A	74.05	N/A	5.01	0.11	0.34
9	CP, %	9	61.46	65.40	66.69	N/A	66.97	N/A	4.77	0.06	0.33
10	EE, %	9	75.93[a]	79.69[ab]	11.38[ab]	N/A	89.87[b]	N/A	15.58	0.05*	<0.001
11	TDN, %	9	63.60	66.54	65.29	N/A	72.22	N/A	4.48	0.13	0.34
	Feed intake										
12	DMI, (g/head/day)	9	1423.00	1586.23	1484.00	1253.22	1456.25	N/A	3.23	0.33	0.67
	Antioxidant										
13	GSH-Px (μkat/L)	18	325.77[a]	972.72[b]	170.29[ab]	782.2[ab]	N/A	904.2[ab]	0.41	<0.001	0.32

Note: CON= control, DM= dry matter, DMI= dry matter intake, CP= crude protein, EE= Ether extract, g= gram, GSH-Px= glutathione peroxidase, L = litre, LPC= lactate protein complex, OM= Organic matter, N= number of data points, N/A= not available, Se= selenium, SEY= selenium enriched yeast; TDN= total digestible nutrient; TRT= treatments, μg= microgram, μkat=mikrokatal. *= significant ($p<0.05$), [a,b]The values with different superscripts indicate a significant difference.

Table 3. Regression linear model of the effect of the selenium concentration on milk production, milk composition, and nutrient digestibility dairy goats

No	Response variables	Model	Unit	N	Parameter estimates				Model statistics				p value	
					Intercept	SE intercept	Slope	SE slope	RMSE	AIC	R^2	L/Q	SE × strain	SE × form
	Nutrient composition													
1	Milk yield	L	L/day	34	1.59	0.29	0.001	0.008	1.71	61.47	0.121	0.87	0.34	0.23
2	Fat	L	%	25	3.54	0.21	2.11	0.07	1.23	33.42	0.505	0.028		0.43
		Q					-0.02	0.007	1.22	34.85	0.221	0.05*	0.05	0.57
3	Protein	L	%	25	3.25	0.11	-0.004	0.006	1.39	24.26	0.011	0.53	0.426	0.31
4	Lactose	L	%	17	4.38	0.08	-0.008	0.005	1.08	16.81	0.002	0.16	0.923	0.85
5	Total solid	L	%	20	11.67	0.68	-0.03	0.01	1.11	61.63	0.014	0.12	0.974	0.73
6	Selenium	L	μg/L	22	30.79	7.79	0.10	0.60	1.29	202.19	0.021	0.87	0.43	0.21
	Nutrient digestibility													
7	DMD		%	9	66.69	1.39	8.75	3.01	0.82	39.23	0.011	0.05*	0.87	0.56
8	OMD	L	%	9	68.04	1.52	7.13	0.003	1.24	23.45	0.030	0.021	0.23	0.67
		Q					8.15	2.64	0.84	38.55	0.008	0.05*	0.45	0.76
9	CPD	L	%	9	61.89	1.11	8.24	0.007	1.11	23.44	0.004	0.23	0.23	0.83
		Q					10.12	3.41	0.98	38.52	0.014	0.05*	0.67	0.81
10	EE	L	%	9	76.24	4.06	8.76	0.23	1.01	21.22	0.002	0.21	0.34	0.78
		Q					10.68	3.28	0.93	45.00	0.123	0.05*	0.76	0.21
11	TDN	L	%	9	63.88	2.63	6.76	2.11	1.12	56.22	0.450	0.43	0.56	0.32
		Q					7.77	2.67	0.84	41.13	0.452	0.05*	0.23	0.33
	Feed intake													
12	DMI	L	g/head/ day	9	1413.00	3.45	4.56	0.03	1.22	4.33	0.54	0.43	0.34	0.23
13	GSH-Px	L	(μkat/L)	18	329.44	133.83	1224.0	231.00	0.11	0.86	0.44	<0.001	0.05	0.32

Note: AIC= akaike information criterion, DMD= dry matter digestibility, DMI= dry matter intake, CPD= crude protein digestibility, EE= ether extract, g= gram, GSH-Px= glutathione peroxidase, L= linear, TDN= total digestible nutrients, N= number of observations, OM= organic matter digestibility,Q= quadratic, RMSE= root mean squares error, SE= standard error, SE × strain= p-value of interaction effect between SE levels and strain of dairy goats, SE × form= p-value of interaction effect between SE levels and form of selenium in the dairy goats, μg= microgram, μkat=mikrokatal. *= significant ($p<0.05$).

+ 0.001x; n= 34; p-value=0.087 (Figure 4); selenium= 30.79 + 0.1x; n= 22; p-value=0.87 (Figure 5). Moreover, linear regression revealed a correlation between the selenium level and milk composition. Milk fat= 3.54 – 0.02x; n= 25; p-value= 0.05; Milk protein= 3.25 – 0.004x; n= 25; p-value= 0.53; milk lactose= 4.38 – 0,008x; n= 17; p-value= 0.16; total solid= 11.67 – 0.03x; n= 20; p-value= 0.12 (Figure 6). DMD= 66.69 + 8.75x; n= 9; p-value= 0.05; OMD= 68.04 + 8.15x; n= 9; p-value= 0.05; CP= 61.89 + 10.12x; n= 9; p-value= 0.05; EE= 76.24 + 10.68x; n= 9;

p-value= 0.05; TDN= 63.88 + 7.77x; n= 9; p-value= 0.05 (Figure 7).

DISCUSSION

A potential limitation of this meta-analysis is the variability across the included studies regarding study duration, goat breeds, and environmental conditions. For instance, the studies utilized different strains of dairy goats, including Saanen, Guanzhong, Alpine X Local, and Iranian native breeds, which may respond differently to selenium supplementation. Additionally, there are variations in selenium sources and supplementation levels, ranging from 0 to 40 mg/day, as well as differences in periods of goat reproductive stages (lactating or pregnant). This meta-analysis revealed that

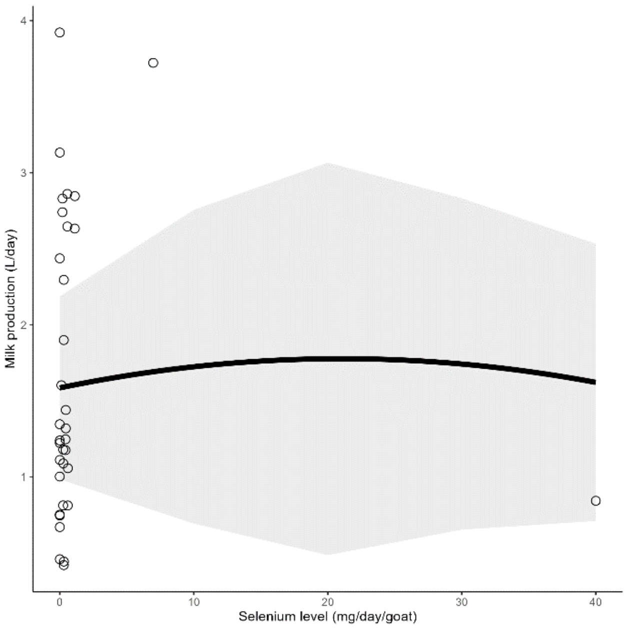

Figure 4. Linear regression of the correlation between the selenium level and milk production. Milk production= 1.59 + 0.001x. , ○ (black circles) indicates differences among the 15 studies.

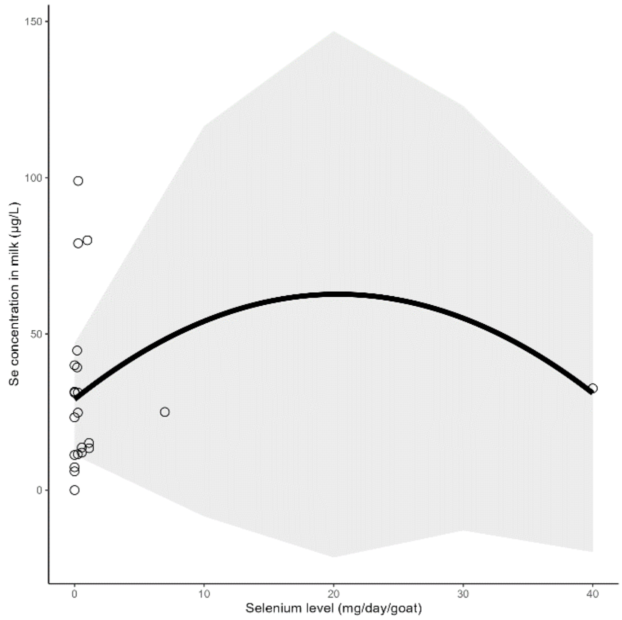

Figure 5. Linear regression of the correlation between the selenium concentration and the Se concentration in milk. Se concentration= 30.79 + 0.1x, ○ (black circles) indicates differences among the 15 studies.

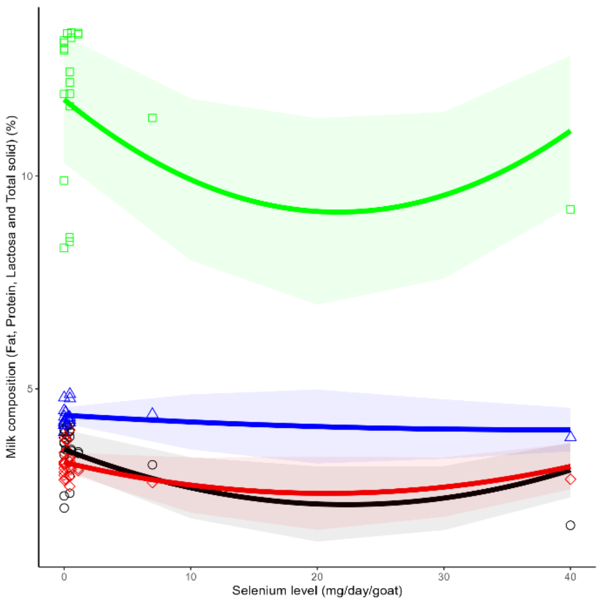

Figure 6. Linear regression of the correlation between the selenium level and milk composition. Milk fat= 3.54 – 0.02x; Milk protein= 3.25 – 0.004x; Milk lactose= 4.38 – 0.008x; Total solid= 11.67 – 0.03x (Color; ○ Black= milk fat; ○ red= milk protein; △ blue= milk lactose; □ green= total solid). The differing shapes align with this line.

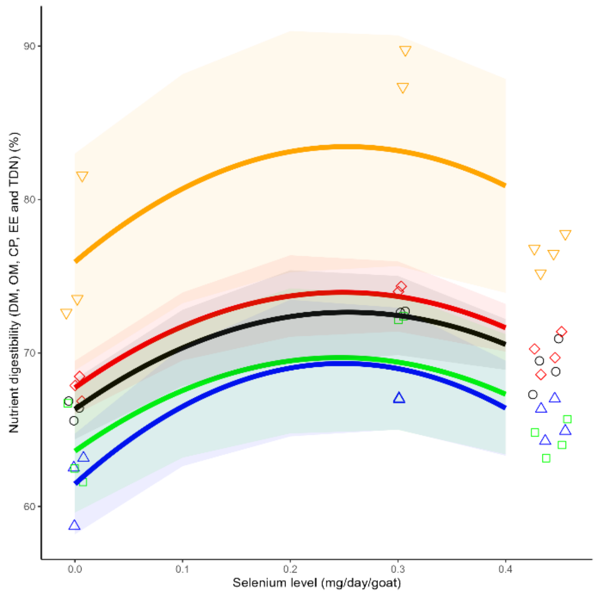

Figure 7. Linear regression of the correlation between the selenium level and nutrient digestibility. DM= 66.69 + 8.75x; OM= 68.04 + 8.15x; CP= 61.89 + 10.12x; EE= 76.24 + 10.68x; TDN= 63.88 + 7.77x (Color; ○ black= dry matter (DM); □ red= organic matter (OM); △ blue= crude protein (CP); △ orange= ether extract; □ green= total digestible nutrient (TDN). The differing shapes align with this line.

selenium supplementation through feed can improve feed digestibility (DM, OM, CP, EE, and TDN) in dairy goats. Taheri *et al*. (2016) reported that selenium supplementation in the form of selenomethionine and sodium selenite at 0.3 mg/day/head increased feed digestibility (DM, OM, CP, EE, and TDN) in Iranian native goats. One of the selenium sources used is Se yeast, which is made from *Saccharomyces cerevisiae*. Ly *et al*. (2017) reported that adding Saccharomyces cerevisiae to feed can increase palatability and nutrient digestibility. The effect of the feed conversion ratio was reflected in nutrient digestibility (Sjofjan *et al.,* 2021). The increase in feed digestibility after selenium supplementation may be due to rumen microbes incorporating Se to form proteins and cell wall components, which protect them from oxidative damage to cell membranes. This phenomenon may alter the composition of the rumen microbiota and modulate rumen fermentation patterns (Hendawy *et al.,* 2022). Selenium supplementation modulates the rumen microbiome, which includes an increase in total bacteria, total anaerobic fungi, total protozoa, *Butyrivibrio fibrisolvens*, *Fibrobacter succinogenes*, *Ruminococcus albus*, and *Ruminococcus flavefaciens,* and a decrease in the relative abundance of the rumen *Prevotella ruminicola* (Zhang *et al.,* 2020).

Recently, a number of published reports have provided strong evidence explaining the role of selenium in dairy animals, including dairy goats. For example, a study by Zhang *et al*. (2017) reported that there was a significant increase in milk production and the Se concentration in Guanzhong goat milk compared to those in the control treatment after supplementation with Se enriched yeast and sodium selenite. Gafaar *et al*. (2022) reported an increase in milk production and feed digestibility in Zairabi goats supplemented with sodium selenite and Se yeast. Selenium supplementation can lead to changes in the fatty acid profile of milk by leveraging its antioxidant properties, influencing enzyme activities related to lipid metabolism, modulating hormonal functions, supporting overall health, and impacting the rumen microbiota. These combined effects help reduce the proportion of saturated fatty acids and increase the levels of unsaturated fats in milk. These fatty acids have been reported to have important health benefits, including anticarcinogenic, antiatherogenic, and antidiabetic effects (Netto *et al.,* 2022). Moreover, there is no significant difference in influence between the other variables. Even so, the levels of lactose, protein, and total milk solids in several journals are taken according to standards. According to Dharmawan *et al*. (2019), milk protein content ranges from 2.31% to 3.87% on average. The stable ingredient in milk that determines milk volume is lactose. Although the potential for Se supplementation to negatively impact the fatty acid profile of goat milk should be carefully considered, Se supplementation should not be avoided. The overall benefits to animal health, milk yield, and productivity often outweigh the risks when Se is supplemented appropriately. A balanced and well-monitored approach can help ensure that the advantages of Se are realized without compromising the health benefits of goat milk.

There was a significant increase in the milk Se concentration after selenium supplementation. Another study also revealed that the use of different forms of sodium selenite with selenium yeast (SY) in dairy cattle diets more than doubled the Se concentrations in organic milk (Han *et al.,* 2021). The selenium content in milk is important because of its role in supporting growth, immune function, reproductive organs, thyroid and muscle function, and antioxidant effects (Toth *et al.,* 2022). Organic Se, due to its higher bioavailability and better integration with biological systems, generally has a more positive effect on nutrient digestibility than does inorganic Se. This difference highlights the importance of considering the form of Se used in supplementation to maximize its benefits on animal health and productivity (Toth *et al.,* 2022). Being more compatible with inorganic Se, in biological systems, organic Se might have fewer antagonistic interactions with other nutrients, thereby supporting better overall digestion and nutrient absorption (Han *et al.,* 2021).

Selenomethionine is concluded to be the best source of selenium. Organic selenium, such as selenomethionine (SeMet), is easier to digest in animals than inorganic forms such as sodium selenite or selenate. Research has shown that organic selenium is more efficiently assimilated and utilized by animals, leading to better selenium and antioxidant status (Geraert *et al.,* 2017; Surai *et al.,* 2019). Organic selenium, specifically SeMet, can be metabolized as an amino acid, allowing it to be readily incorporated into functional selenoproteins in the body (Shini *et al.,* 2015). Research has shown that organic forms of selenium, such as selenized yeasts and chelates of selenomethionine, are more bioavailable than inorganic forms, such as sodium selenite (Huang *et al.,* 2023). Inorganic selenium needs to be converted into organic forms before it can be utilized by the body. The digestion of inorganic selenium involves complex chemical pathways, such as dissolving inorganic selenium in an ether-based solvent and reacting it with low-molecular-weight amino acids to generate organic selenium (Muhammad *et al.,* 2021).

The positive effect of selenium supplementation on dairy goat productivity may be because it can improve antioxidant status in livestock, which can indirectly affect livestock productivity. This is evidenced by the increase in antioxidant enzymes such as glutathione peroxidase after selenium supplementation. These enzymes can protect against oxidative stress and improve overall animal health (Juniper *et al.,* 2019). Selenium deficiency prevents many diseases, the most critical of which are retained placenta and mastitis in dairy cows. Additionally, regulating GSHPx activity, reduces the risk of oxidative stress and metabolic disorders, to which dairy cows, especially high-producing cows, are susceptible (Pilarczyk *et al.,* 2012). The highest GSH-Px activity was observed in the first stage of lactation, which may indicate greater oxidative stress during this period than during to the other stages (Pilarczyk *et al.,* 2012).

The practical implications of this meta-analysis offer valuable recommendations for dairy goat farmers and nutritionists concerning selenium supplementation.

Selenomethionine, in particular, provides superior bioavailability and greater benefits for improving goat health and milk production. Farmers can adjust selenium supplementation according to the specific breed and reproductive stage of their goats. By incorporating these findings into farm management practices, farmers may enhance herd health, improve milk quality, and boost overall productivity.

CONCLUSION

According to a meta-analysis, selenium supplementation through feed can reduce the milk fat content. Selenium supplementation was also effective at increasing feed digestibility (DM, OM, CP, EE, and TDN) in dairy goats. However, selenium supplementation through feed did not affect milk production, protein content, lactose content, total solids, or the Se concentration in milk. The best selenium obtained was selenomethionine.

CONFLICT OF INTEREST

We certify that there are no conflicts of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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REFERENCES

Adli, D. N., O. Sjofjan, M. M. Sholikin, C. Hidayat, D. T. Utama, A. Jayanegara, M. H. Natsir, Y. F. Nuningtyas, M. Pramujo, & P. S. Puspita. 2023. The effects of lactic acid bacteria and yeast as probiotics on the performance, blood parameters, nutrient digestibility, and carcase quality of rabbits: A meta-analysis. Ital. J. Anim. Sci. 22:157-168. https://doi.org/10.1080/1828051X.2023.2172467

Adli, D. N., S. Sugiharto, A. Irawan, Y. A. Tribudi, S. Wibowo, A. F. M. Azmi, O. Sjofjan, A. Jayanegara, H. Tistiana, T. Wahyono, S. Aditya, M. M. Sholikin, & S. Sadarman. 2024. The effects of herbal plant extract on the growth performance, blood parameters, nutrient digestibility and carcase quality of rabbits: A meta-analysis. Heliyon 10:e25724. https://doi.org/10.1016/j.heliyon.2024.e25724

Arshad, M. A., H. M. Ebeid, & F. Hassan. 2020. Revisiting the effects of different dietary sources of selenium on the health and performance of dairy animals: A review. Biol. Trace Ele. Res. 199:3319–3337. https://doi.org/10.1007/s12011-020-02480-6

Barcelos, B. V. Gomes, A. M. C.Vidal. J. E. F. Junior, M. L. G. M. L. de Araujo, H. D. R. Alba, & A. S. Netto. 2022. Effect of selenium and vitamin E supplementation on the metabolic status of dairy goats and respective goat kids in the peripartum period. Trop. Anim. Health Prod. 54:36. https://doi.org/10.1007/s11250-021-03034-1

Budiarto, R., S. Mubarok, M. M. Sholikin, D. N. Sari, A. Khalisha, S. L. Sari, B. P. N. Rahmat, T. Ujilestari, & D. N. Adli. 2024. Vitamin C variation in citrus in response to genotypes, storage temperatures, and storage times: A systematic review and meta-analysis. Heliyon 10:1-17. https://doi.org/10.1016/j.heliyon.2024.e29125

Dharmawan, R., P. Surjowardojo, & T. E. Susilorini. 2019. Effect of steaming up by gliricidia sepium to dairy goats in late gestation on milk yield and composition during the early lactation. Int. Res. J. Adv. Eng. Sci. 4:290-293.

El-Nahrawy, M. M., M. E. El-Gendy, K. F. El-Riedy, M. A. E. Zommara, & M. A. Ghanimah. 2022. Effect of inorganic and organic selenium on performance of dairy Zaraibi goats and their suckling kids. Report Opinion 14:29-39.

Gafaar, H. M., M. El-Nahrawy, M. E. El-Gendy, K. F. E. El-Riedy, M. A. E. Zommara, R. A. E. Mesbah, & M. A. Ghanimah. 2022. Nutritional effect of different forms of selenium additive on productive performance of dairy Zaraibi goats and their suckling kids. Adv. J. Agr. Res. 9:276-283.

Geraert, P., M. Briens, & Y. G. Liu. 2017. Comparing organic selenium sources. AFMA Matrix. 26:37-39.

Gurevitch, J., J. Koricheva, S. Nakagawa, & G. Stewart. 2018. Meta-analysis and the science of research synthesis. Nature 555:175-182. https://doi.org/10.1038/nature25753

Gu, X. & C. Gao. 2022. New horizons for selenium in animal nutrition and functional foods. Anim. Nutr. 11:80-86. https://doi.org/10.1016/j.aninu.2022.06.013

Han, L., K. Pang, T. Fu, C. J. C. Philips, & T. Gao. 2021. Nano-selenium Supplementation Increases Selenoprotein (Sel) gene expression profiles and milk selenium concentration in lactating dairy cows. Biol. Trace Ele. Res. 199:113-119. https://doi.org/10.1007/s12011-020-02139-2

Hendawy, A. O., S. Sugimura, K. Sato, M. M. Mansour, A. H. A. El-Aziz, H. Samir, M. A. Islam, A. B. M. R. Bostami, A. S. Mandour, A. Elfadadny, R. F. Ragab, H. A. Abdelmageed, & A. M. Ali. 2022. Selenium supplementation on rumen microbiota, rumen fermentation, and apparent nutrient digestibility of ruminant animals: A review. Fermentation 8:4. https://doi.org/10.3390/fermentation8010004

Hesnedlova, B., M. Kepinska, S. Skalickova, C. Fernandez, B. Ruttkay-Nedecky, T. D. Malevu, J. Sochor, M. Baron, M. Melcova, J. Zidkova, & R. Kizek. 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

Horky, P., P. Nevrkla, & J. Skladanka. 2017. Selenium in goat nutrition. Acta Universitatis Agriculturae Silviculturae Mendelianae Brunensis 65:1499-1503. https://doi.org/10.11118/actaun201765051499

Huang, Q., S. Wang, X. Yang, X. Han, Y. Liu, N. A. Khan, & Z. Tan. 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. 20:1171751. https://doi.org/10.3389/fvets.2023.1171751

Ianni, A., F. Bennato, C. Martino, D. Innosa, L. Grotta, & G. Martino. 2019. Effects of selenium supplementation on chemical composition and aromatic profiles of cow milk and its derived cheese. J. Dairy Sci. 102:6853-6862. https://doi.org/10.3168/jds.2019-16382

Juniper, D. T., C. Rymer, & M. Briens. 2019. Bioefficacy of hydroxy-selenomethionine as a selenium supplement in pregnant dairy heifers and on the selenium status of their calves. J. Dairy Sci. 102:7000-7010. https://doi.org/10.3168/jds.2018-16065

Kachuee, R., H. Abdi, Benemar, Y. Mansoori, & J. Seifdavati. 2019. The effect of nano-selenium, seleno-methionine and sodium selenite on milk production, selenium and IgG levels of Khalkhali goats and their kids. J. Anim. Sci. Res. 29:57-71.

Kachuee, R., M. Moeini, & M. Souri. 2014. Effects of organic and inorganic selenium supplementation during late pregnancy on colostrum and serum Se status, performance and passive immunity in Merghoz goats. Anim. Prod. Sci. 54:1016-1022. https://doi.org/10.1071/AN13150

Ly, J., O. Sjofjan, I. H. Djunaidi, & S. Suyadi. 2017. Effect of Supplementing *Saccharomyces cerevisiae* into low quality local-based feeds on performance and nutrient digestibility of late starter local pigs. J. Agr. Sci. Tech. 7:345-349. https://doi.org/10.17265/2161-6256/2017.05.006

Misurova, L., L. Pavlata, A. Pechova, & R. Dvorak. 2009. Effect of a long-term peroral supplementation with sodium selenite and selenium lactate-protein complex on selenium status in goats and their kids. Vet. Med. 54:324-332. https://doi.org/10.17221/107/2009-VETMED

Mitsiopoulou, C., C. Karaiskou, M. Simoni, F. Righi, A. C. Pappas, K. Sotirakoglou, & E. Tsiploka. 2021. Influence of dietary sesame meal, vitamin E and selenium supplementation on milk production, composition, and fatty acid profile in dairy goats. Livest. Sci. 244:104336. https://doi.org/10.1016/j.livsci.2020.104336

Muhammad, A. I., D. A. Mohamed, L. T. Chwen, H. Akit, & A. A. Samsudin. 2021. Effect of selenium sources on laying performance, egg quality characteristics, intestinal morphology, microbial population and digesta volatile fatty acids in laying hens. Animals 11:1681. https://doi.org/10.3390/ani11061681

Netto, A. S. T. H. Silva, M. M. Martins, A. M. C. Vidal, M. S. V. Salles, L. C. R. Junior, & M. A. Zanetti. 2022. Inclusion of sunflower oil, organic selenium, and vitamin E on milk production and composition, and blood parameters of lactating cows. Animals 12:1968. https://doi.org/10.3390/ani12151968

Pechova, A., B. Janstova, L. Misurova, M. Drackova, L. Vorlova, & L. Pavlata. 2008. Impact of supplementation of various selenium forms in goats on quality and composition of milk, cheese and yoghurt. Acta Veterinaria BRNO 77:407-414. https://doi.org/10.2754/avb200877030407

Petrera, F., L. Calamari, & G. Bertin. 2009. Effect of either sodium selenite or Se–yeast supplementation on selenium status and milk characteristics in dairy goats. Small Rum. Res. 82:130-138. https://doi.org/10.1016/j.smallrumres.2009.02.008

Pilarczyk, B., D. Jankowiak, A. Tomza-Marciniak, R. Pilarczyk, P. Sablik, R. Drozd, & M. Skólmowska. 2012. Selenium concentration and glutathione peroxidase (GSH-Px) activity in serum of cows at different stages of lactation. Biol. Trace Elem. Res. 147:91-96. https://doi.org/10.1007/s12011-011-9271-y

Rashnoo, M., Z. Rahmati, A. Azarfar, & A. Fadayifar. 2020. The effects of maternal supplementation of selenium and iodine via slow-release blouses in late pregnancy on milk production of goats and performance of their kids. Ital. J. Anim. Sci. 19:502-513. https://doi.org/10.1080/1828051X.2020.1761269

Sauvant, D., P. Schmidely, J. J. Daudin, & N. R. St-Pierre. 2008. Meta-analyses of experimental data in animal nutrition. Animal 2:1203-1214. https://doi.org/10.1017/S1751731108002280

Sjofjan, O., D. N. Adli, M. H. Natsir, Y. F. Nuningtyas, T. S. Wardani, I. Sholichatunnisa, S. N. Ulpah, & O. Firmansyah. 2021. Effect of dietary modified-banana-tuber meal substituting dietary corn on growth performance, carcass trait and dietary-nutrients digestibility of coloured-feather hybrid duck. Jurnal Ilmu Ternak dan Veteriner 26:39-48. https://doi.org/10.14334/jitv.v26i1.2686

Shini, S., A. Sultan, & W. L. Bryden. 2015. Selenium biochemistry and bioavailability: Implications for animal agriculture. Agriculture 5:1277–1288. https://doi.org/10.3390/agriculture5041277

Surai, P. F., I. I. Kochish, V. I. Fisinin, & D. T. Juniper. 2019. Revisiting oxidative stress and the use of organic selenium in dairy cow nutrition. Animals 9:462. https://doi.org/10.3390/ani9070462

Taheri, Z., S. Karimi, H. Mehrban, & A. Moharrery. 2016. Supplementation of different selenium sources during early lactation of native goats and their effects on nutrient digestibility, nitrogen and energy status. J. Appl. Anim. Res. 46:64–68. https://doi.org/10.1080/09712119.2016.1259625

Tozzi, B., G. B. Liponi, B. Turchi, L. Casini, F. Fratini, S. Minieri, E. Incerti, & D. Gatta. 2016. Fortification of dairy goats' products with various selenium sources. Large Anim. Rev. 22:257-263.

Vasconcelos, A. M., T. P. Martins, V. Souza, J. M. Bonfim, R. C. F. F. Pompeu, D. A. E. Facanha, P. L. Pereira, J. Ferreira, & R. M. F. Silveira. 2023. Effect of a 60-day organic selenium-supplemented diet on the decrease of somatic cell counts in goat milk. Trop. Anim. Prod. 55:113. https://doi.org/10.1007/s11250-023-03526-2

Vona, R., L. Pallotta, M. Cappelletti, C. Severi, & P. Matarrese. 2021. The impact of oxidative stress in human pathology: Focus on gastrointestinal disorders. Antioxidants 10:201. https://doi.org/10.3390/antiox10020201

Zhang, L., X. R. Liu, J. Z. Liu, X. P. An, Z. Q. Zhou, B. Y. Cao, & Y. X. Song. 2017. Supplemented organic and inorganic selenium affects milk performance and selenium concentration in milk and tissues in the Guanzhong dairy goat. Biol. Trace Elem. Res. 83:254-260. https://doi.org/10.1007/s12011-017-1112-1

Zhang, Z. D., C. Wang, H. S. Du, Q. Liu, G. Guo, W. J. Huo, J. Zhang, Y. L. Zhang, C. X. Pei, & S. L. Zhang. 2020. Effects of sodium selenite and coated sodium selenite on lactation performance, total tract nutrient digestion and rumen fermentation in Holstein dairy cows. Animal 14:2091-2099. https://doi.org/10.1017/S1751731120000804