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Effects of Dietary Supplementation with Selenium and Vitamin E on Growth Performance, Nutrient Apparent Digestibility and Blood Parameters in Female Sika Deer (*Cervus nippon*)

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Abstract

To evaluate the effects of selenium (Se) and vitamin E (Vit E) on female sika deer. This study was conducted using a 3 × 2 + 1 factorial experiment. Depending on treatment design, the deer were fed with the basal diet supplemented with 0.2, 0.3, and 0.4 mg of selenium as well as 100 and 200 IU of vitamin E per kg of dry matter (DM). Accordingly, six groups named G1 to G6 are involved in this study. In addition, group G0 was available in the study, in which the deer were fed with only basal diet. The results show that the final body weight (BW), average daily gain (ADG), and apparent digestibility of crude protein, ether extract, and neutral detergent fiber of the deer in G1 to G6 increased as the selenium level increased from 0.2 to 0.3 mg per kg of DM ($P < 0.05$). Higher IgG content of the deer was observed with the intake of selenium and vitamin E ($P < 0.05$). The total content of protein of the deer in G3 was higher than that in G0 ($P < 0.05$), and the activity of glutathione peroxidase increased following the increase in the supplementation levels of selenium and vitamin E ($P < 0.05$). Furthermore, selenium had significant effects on the concentration of T4 and T3 ($P < 0.05$). The optimum levels of selenium and vitamin E for 1-year-old female sika deer were 0.3 mg and 100 IU per kg of dietary DM, respectively.

Keywords Trace minerals · Selenium · Vitamin E · Metabolism · Requirement

Introduction

Micro mineral supplements in animal diet meeting requirements are crucial for the growth and immune system development of animals. They interact with toxic metals at several points in the body: absorption and excretion of toxic metals; transport of metals in the body; binding to target proteins; metabolism and sequestration of toxic metals; and oxidative stress [1]. They also function as prosthetic groups in active sites or as co-enzymes for indispensable metalloenzymes. Selenium (Se) is an essential trace element and a key component of important enzymes such as the glutathione peroxidase (GSH-P*x*) and iodothyronine deiodinase [2]. According to relevant studies [3, 4], dietary requirements for selenium are definite for domestic ruminants including cattle, sheep, and goats, and the analysis of selenium in diet helps in the diagnosis and prevention of deficiencies.

Vitamin E is an effective antioxidant in the biological membranes and can protect cellular structures against damage from oxygen free radicals and reactive products of lipid peroxidation [5]. It is considered the first line of defense against lipid peroxidation [6]. One of the benefits of vitamin E is that it can improve the liver and kidney functions, as shown by oxidative stress biomarkers induced by organ phosphorus insecticide diazinon [7].

The significance of low intake of selenium for the health of wild cervids remains undetermined, and only a few reports of nutritional deficiencies have been published [8, 9]. It is proved that low intake of selenium will cause nutritional deficiencies and diseases in domestic cattle. However, further research is required to determine whether the low intake of selenium is also critical for wild cervids. Previous research or references are known to be available only for red deer (*Cervus elaphus*) and reindeer (*Rangifer tarandus*) [10–12], and little work has been conducted for the effects of seleni-

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um and vitamin E on sika deer (*Cervus nippon*). This study is designed to evaluate the effectiveness of dietary selenium and vitamin E supplementation on the growth performance, nutrient digestibility and biochemical blood parameters of domestic female sika deer.

Material and Methods

Animals, Diets, and Experimental Design

This study was conducted by employing a 3 × 2 + 1 factorial experiment, in which 56 1-year-old female sika deer with average body weight of 40.3 ± 2.38 kg were selected. Prior to the experiment, basal diet (without additional supplementation of selenium and vitamin E) was gradually introduced to the experimental animals during the 14-day adaptation period. After this period, the animals were randomly divided into seven groups with equal mean body weights ($P > 0.05$). The groups were named G0, G1, G2, G3, G4, G5, and G6, in which different experimental diet was given to each group (7 deer/diet). The factors of the experiment were selenium (in the form of sodium selenite) and vitamin E. Three levels of selenium and two levels of vitamin E were adopted in the seven groups as follows: group 1 (G0): basal diet containing 0.05 mg of selenium per kg of DM, without additional supplementation of selenium or vitamin E; group 2 (G1): basal diet supplemented with 0.2 mg of selenium and 100 IU of vitamin E per kg of DM; group 3 (G2): basal diet supplemented with 0.2 mg of selenium and 200 IU of vitamin E per kg of DM; group 4 (G3): basal diet supplemented with 0.3 mg of selenium and 100 IU of vitamin E per kg of DM; group 5 (G4): basal diet supplemented with 0.3 mg of selenium and 200 IU of vitamin E per kg of DM; group 6 (G5): basal diet supplemented with 0.4 mg of selenium/kg and 100 IU of vitamin E per kg of DM; group 7 (G6): basal diet supplemented with 0.4 mg of selenium and 200 IU of vitamin E per kg of DM. All the supplements were added by the manufacturer during the feed pelleting process. The composition of the basal diet is listed in Table 1. The amounts of selenium and vitamin E supplements of the diets in the seven groups are presented in Table 2.

Management and Measurement

The deer were kept in 10-m × 20-m pens for feeding in groups and managed in a unified way. They were provided with ample clean and fresh drinking water at all times. Diets were offered to the deer as total mixed rations twice daily at 06:00 and 16:00, respectively. Digestion trial was carried out from June 18 to June 24.

Table 1 Nutritive composition and content of basal diet

Parameter	Content
Composition (%)	
Corn flour	22
Soybean meal	12
Lucerne	50
Distillers dried grains with soluble (DDGS)	4
Corn germ meal	5.5
Molasses	5
NaCl	0.5
Additives[a]	1
Total	100
Measured nutrient concentration (dry matter)	
GE (MJ/kg)	15.03
Crude protein (CP, %)	16.49
Neutral detergent fiber (NDF, %)	47.96
Ether extract (EE, %)	1.76
Acid detergent fiber (ADF, %)	23.95
Ca (%)	1.22
P (%)	1.14
Se (mg/kg)	0.05
Vitamin E (IU/kg)	3.15

[a] Contained the following premix per kg: Mg, 76 mg; Cu, 36 mg; Zn, 43 mg; Fe, 53 mg; vitamin A, 2484 IU; vitamin D_3, 496.8 IU; vitamin K_3, 0.23 mg; vitamin B_1, 10.092 mg; vitamin B_2, 0.69 mg; vitamin B_{12}, 1.38 mg; folic acid, 0.023 mg; nicotinic acid, 1.62 mg; calcium pantothenate, 1.15 mg; $CaHPO_4$, 5.17 g; $CaCO_3$, 4.57 g

Growth Trial

The growth trial lasted for 70 days according to a randomized design, during which feed intake was recorded daily, and the feed efficiency and the average daily gain (ADG) were calculated. The animals were weighed twice in a week after overnight fasting, and mean body weights were used to determine ADG.

Table 2 Experimental design

Group	Se supplemental level (mg/kg)	Vitamin E supplemental level (IU/kg)
G0	0.0	0
G1	0.2	100
G2	0.2	200
G3	0.3	100
G4	0.3	200
G5	0.4	100
G6	0.4	200

Collection of Blood Samples

Blood samples of the deer were collected through jugular vein puncture in the morning (before watering and feeding) 30 days after the start of the experiment. The deer were anaesthetized with xylazine hydrochloride (from Qing Dao Hanhe Animal and Plant Medicine Co., Ltd.) at a dosage of 0.5~3.0 mg per kg of body mass with a blow-gun-dart syringe. Then, each deer was treated with an intravenous injection of tolazoline hydrochloride (Sigma-Aldrich, St. Louis, MO, USA) for recovery from the xylazine hydrochloride followed by 2 mL penicillin as prophylactic after sampling. The blood was collected into tubes, and heparin sodium was applied to prevent the blood from clotting. Then plasma was obtained after centrifuging for 10 min at 3000 r/min. After that, it was stored in 2-mL plastic vials at – 20 °C for further analysis.

Feces Sampling

On the 37th day of the experiment, four deer were selected from each group and 28 deer in total were housed individually in metabolic cages, which allowed separation of urine and feces in order to determine nutrient digestibility. The digestive experiment lasted for 6 days, and the excretions were collected daily. Then, the feed were sampled for further analysis. The fecal output was collected and weighed, and 10% of it was kept for subsequent analysis. For the purpose of chemical analysis described below, the fecal material was successively dried at 60 °C, ground to pass a 1-mm mesh, and preserved in airtight bottles. The feeds and refusals were processed similarly prior to chemical analysis.

Chemical Analysis

Dry matter (DM), crude protein (CP), ether extract (EE), acid detergent fiber (ADF), neutral detergent fiber (NDF), P, Ca, and ash insoluble in hydrochloric acid (HCl) in the diets and feces were analyzed according to AOAC (2005).

Blood biochemical parameters including glutamic-pyruvic transaminase (GPT) and glutamic-oxaloacetic transaminase (GOT), total protein (TP), albumin (ALB), triiodothyronine (T3), thyroxin (T4), and glutathione peroxidase (GSH-P*x*) were measured with diagnostic kits. In addition, GPT was measured by Rye's method; GOT was measured by microplate method; TP, ALB, and GSH-P*x* were measured by colorimetry; T3 and T4 were measured by chemical fluorescence method.

Statistical Analysis

The data were presented as mean ± SD. Analysis of variance and comparison of significance were carried out by Duncan's multiple range tests from SAS (SAS Institute, Cary, NC, USA, 2008). The data were analyzed by means of repeated measures with a model containing selenium levels, vitamin E levels, and selenium levels × vitamin E levels. The differences among treatments were considered statistically significant with $P < 0.05$.

Results

Growth Performance

For all the deer in the seven groups, final BW and ADG increased with increase in selenium level in the diet ($P < 0.05$); the maximal growth and the highest ADG were shown in G3 group (Table 3). There were no vitamin E or selenium × vitamin E interactions related to the growth performance that was analyzed.

Intake and Digestibility of Nutrients

The effects of the levels of selenium and vitamin E in the diets on intake and apparent digestibility of nutrients are shown in Tables 4 and 5. From Table 4, we can see that there is no difference in nutrient intake ($P > 0.05$). It can also be seen that there are no differences in apparent digestibility of DM, NDF, Ca, and P among the seven groups ($P > 0.05$). Apparent digestibility of CP, EE, and NDF increased with increase in selenium level ($P < 0.05$). However, no vitamin E or selenium × vitamin E interaction was found ($P > 0.05$) (Table 4).

Hematological Biochemical Parameters

There were no differences in IgA during the whole experiment. Higher content of IgG was observed with the supplementation of selenium and vitamin E ($P < 0.05$). The content of IgM was affected by selenium levels ($P < 0.05$) as indicated in Table 6. The effects of the levels of selenium and vitamin E in diets on blood profiles are shown in Table 7. It can also be noted that there were no differences in ALB, GOT, and GPT among the seven treatments ($P > 0.05$). Furthermore, the TP concentration of the deer in G3 was greater than that in G0 ($P < 0.05$) and the activity of GSH-P*x* increased with increase in vitamin E level ($P < 0.05$). It can, therefore, be concluded that the level of selenium has significant effects on the concentration of T4 and T3 ($P < 0.05$) while there is no indication of selenium × vitamin E interactions ($P > 0.10$).

Discussion

Effects on Growth

As an essential element for animal growth, selenium plays an important biological role. It is an important auxiliary factor of 5′-deiodinase, a key enzyme used to synthesize triiodothyronine

Table 3 Parameters of growth performance

Item	Initial BW (kg)	Final BW (kg)	ADG (g/d)	DM intake (kg/d)
G0	38.88 ± 2.08	45.93 ± 1.96	147.58 ± 5.27^{b}	1.438 ± 0.210
G1	40.08 ± 1.26	50.70 ± 2.47	177.09 ± 5.87^{ab}	1.528 ± 0.254
G2	41.25 ± 1.28	52.62 ± 2.06	148.29 ± 6.02^{b}	1.502 ± 0.305
G3	43.75 ± 0.96	54.59 ± 1.88	180.63 ± 6.12^{a}	1.489 ± 0.428
G4	42.96 ± 0.73	51.57 ± 2.12	164.00 ± 5.87^{ab}	1.460 ± 0.327
G5	41.25 ± 1.54	48.13 ± 1.96	154.63 ± 8.69^{b}	1.537 ± 0.378
G6	39.16 ± 2.01	49.70 ± 1.06	172.17 ± 7.66^{ab}	1.521 ± 0.401
Se levels				
Se1	41.47 ± 1.88	50.66 ± 0.87^{b}	158.69 ± 5.69^{b}	1.482 ± 0.432
Se2	43.34 ± 1.24	53.08 ± 1.26^{a}	168.31 ± 6.82^{a}	1.494 ± 0.362
Se3	41.19 ± 1.36	50.41 ± 2.05^{b}	160.40 ± 9.69^{b}	1.502 ± 0.371
Vit E levels				
Vit E1	41.69 ± 0.97	51.14 ± 1.33	157.45 ± 10.01	1.452
Vit E2	41.07 ± 0.69	52.29 ± 1.38	160.15 ± 10.29	1.501
P value				
Se	0.354	0.032	0.027	0.120
Vit E	0.769	0.596	0.925	0.325
Se × Vit E	0.808	0.361	0.036	0.078

[a,b] Values within a row with different superscripts differ significantly ($P < 0.05$)

(T3) in animals. Triiodothyronine is a significant hormone that regulates animal growth by controlling the body's energy and protein anabolism. Selenium deficiency will cause the reduction of T3 synthesis and growth inhibition [13]. In addition, through interaction with glutathione peroxidase, selenium can prevent the lipid structure of animal cell membranes from being destroyed by oxidative damage that affects the growth. According to previous studies, livestock diets supplemented with selenium at different levels have different effects on body weight gain and feed utilization [14, 15]. The main findings of this study indicate that selenium supplements at a level of 0.3 mg per kg of DM have beneficial effects on final BW and average daily gain (ADG) in female sika deer. According to this study, the selenium level in diets significantly affects final BW and ADG. However, Vignola et al. [16] found that selenium as a dietary supplement had no significant effects on ADI, ADG, or feed/gain of lambs when the selenium level in the basal diet was 0.13 mg per kg of DM. Johansson et al. [17] and Skrivanova et al. [18] reported similar results in lambs and beef cattle. Supplement of selenium influences the growth rates of lambs [19]. Therefore, selenium as a supplementation has no significant effects on growth unless the basal diet lacks selenium. The results of this study show that the selenium level in the basal diet (0.05 mg/kg) fails to meet the growth requirements of 1-year-old female sika deer, and higher ADG can be achieved when the dietary selenium is supplemented at a level of 0.3 mg/kg.

Effects on Apparent Digestibility

There are no public data about the effects of selenium and vitamin E on the digestibility or absorption of nutrients in sika deer. According to this study, the digestibility of crude protein, ether extract, and NDF was affected by the selenium level in the diets. The results of the study may suggest that the activity and number of cellulolytic bacteria can be promoted by selenium. According to previous studies, similar results were observed. Shi et al. [20] found that digestibility of DM, organic matter (OM), CP, ether extract (EE), aNDF, and ADF in total tract of sheep improved as a result of intake of nano-selenium ($P < 0.01$). Wang et al. [21] found that a linear ($P < 0.01$) and quadratic ($P < 0.01$) increase in digestibility of aNDF occurred among dairy cows as a result of intake of selenium at the levels of 0.15, 0.3, and 0.45 mg per kg of DM. However, Serra et al. [22] reported that the supplementation of 0.2 mg of selenium per kg of DM (in the forms of Na_2SeO_3 and Na_2SeO_4, per kg DM) had no effect on digestibility of NDF in sheep. The dif-

Table 4 Parameters of nutrient intake

Item	DM (kg/day)	CP (g/day)	EE (g/day)	ADF (g/day)	NDF (g/day)	Ca (g/day)	P (g/day)
G0	2.16 ± 0.12	356.18 ± 18.22	38.02 ± 5.12	517.32 ± 30.15	1035.94 ± 50.20	26.35 ± 3.81	24.62 ± 2.36
G1	2.25 ± 0.23	371.03 ± 20.30	39.60 ± 4.87	538.88 ± 32.24	1079.10 ± 55.21	27.45 ± 2.57	25.65 ± 3.01
G2	2.34 ± 0.16	385.87 ± 40.56	41.20 ± 3.59	560.43 ± 33.57	1122.26 ± 51.27	28.55 ± 2.61	26.68 ± 2.88
G3	2.41 ± 0.31	397.41 ± 25.31	42.42 ± 4.51	577.20 ± 28.17	1155.84 ± 49.53	29.40 ± 2.15	27.47 ± 2.57
G4	2.40 ± 0.28	395.76 ± 22.87	42.24 ± 5.12	574.80 ± 37.52	1181.04 ± 39.25	29.28 ± 2.33	27.36 ± 2.54
G5	2.51 ± 0.37	398.47 ± 30.16	45.23 ± 4.79	582.12 ± 40.21	1192.83 ± 30.23	30.62 ± 2.56	28.61 ± 1.85
G6	2.47 ± 0.40	400.25 ± 37.55	43.47 ± 5.01	591.57 ± 30.17	1184.61 ± 35.21	30.13 ± 3.02	28.16 ± 3.07
Se levels							
Se1	2.30 ± 0.32	378.45 ± 33.21	40.40 ± 3.56	544.37 ± 32.57	1092.55 ± 30.16	28.00 ± 2.06	26.17 ± 2.17
Se2	2.40 ± 0.54	396.58 ± 35.54	42.33 ± 2.87	575.26 ± 33.87	1169.30 ± 42.17	29.34 ± 2.21	27.42 ± 2.52
Se3	2.52 ± 0.33	399.38 ± 29.12	44.35 ± 3.60	585.26 ± 36.62	1188.26 ± 38.58	30.37 ± 2.33	28.38 ± 2.32
Vit E levels							
VE1	2.41 ± 0.38	388.97 ± 33.17	41.52 ± 3.15	562.37 ± 32.15	1168.75 ± 39.57	28.76 ± 2.54	27.24 ± 1.96
VE2	2.40 ± 0.41	393.96 ± 32.52	42.07 ± 2.95	576.35 ± 35.16	1159.30 ± 36.87	29.03 ± 2.65	27.40 ± 2.83
P value							
Se	0.130	0.061	0.123	0.235	0.201	0.401	0.235
Vit E	0.521	0.185	0.286	0.587	0.324	0.114	0.307
Se × Vit E	0.320	0.197	0.437	0.321	0.396	0.158	0.287

[a,b] Values within a row with different superscripts differ significantly ($P < 0.05$)

ference could be caused by the different metabolic style between inorganic selenium and nano-selenium in rumen. In addition, the numbers and activity of proteolytic enzymes decrease in the pancreas of chicks [23, 24] and in rats [25], resulting in selenium deficiency. The results of this study suggest that the functions of selenium maintaining the production of proteolytic digestive enzymes and the activity of protein decomposing bacteria can be improved by selenium.

Table 5 Parameters of nutrient digestibility (%)

Item	DM	CP	EE	ADF	NDF	Ca	P
G0	55.32 ± 2.12	61.78 ± 2.58^{b}	48.12 ± b3.06	42.06 ± 2.87	49.02 ± 3.05^{b}	46.78 ± 2.96	52.08 ± 1.97
G1	56.45 ± 1.87	63.42 ± 2.81^{b}	50.30 ± 2.05^{b}	43.65 ± 1.81	52.31 ± 2.05^{b}	47.06 ± 3.05	53.45 ± 3.18
G2	59.48 ± 2.96	64.66 ± 3.06^{b}	55.81 ± 3.05^{b}	45.78 ± 1.56	55.05 ± 2.38^{b}	48.25 ± 2.18	52.38 ± 2.76
G3	63.18 ± 3.69	69.31 ± 4.15^{a}	59.05 ± 2.87^{a}	46.03 ± 2.36	59.64 ± 3.52^{a}	47.98 ± 1.26	54.21 ± 3.02
G4	62.44 ± 2.82	67.25 ± 2.36^{ab}	60.11 ± 3.11^{a}	44.38 ± 3.45	60.12 ± 4.50^{a}	46.31 ± 2.14	55.22 ± 2.54
G5	60.02 ± 4.05	63.02 ± 2.12^{b}	58.70 ± 2.66^{a}	45.65 ± 5.88	58.87 ± 1.58^{a}	45.86 ± 2.88	54.02 ± 3.65
G6	61.35 ± 3.01	62.78 ± 2.02^{b}	54.02 ± 1.12^{b}	42.36 ± 2.16	54.36 ± 2.67^{ab}	46.08 ± 3.05	53.64 ± 4.21
Se levels							
Se1	57.96 ± 3.61	64.04 ± 3.11^{a}	53.06 ± 3.00^{a}	44.72 ± 4.12	53.68 ± 3.05^{a}	47.65 ± 1.25	52.92 ± 3.55
Se2	62.81 ± 2.54	68.28 ± 3.54^{b}	59.58 ± 2.51^{b}	45.21 ± 3.87	59.88 ± 2.87^{b}	47.15 ± 1.87	54.72 ± 3.62
Se3	60.68 ± 3.12	62.90 ± 2.88^{ab}	56.36 ± 3.11^{ab}	44.00 ± 3.96	56.62 ± 3.56^{ab}	45.97 ± 1.96	53.83 ± 2.97
Vit E levels							
VE1	59.88 ± 2.87	65.25 ± 2.71	56.02 ± 2.01	45.11 ± 3.06	56.94 ± 3.48	46.97 ± 2.54	53.89 ± 2.82
VE2	61.09 ± 2.14	64.89 ± 3.05	56.65 ± 3.56	44.17 ± 4.15	56.51 ± 4.82	46.88 ± 2.65	53.75 ± 2.91
P value							
Se	0.135	0.041	0.020	0.582	0.031	0.510	0.541
Vit E	0.432	0.385	0.187	0.473	0.431	0.876	0.651
Se × Vit E	0.132	0.221	0.325	0.456	0.387	0.654	0.788

[a,b] Values within a row with different superscripts differ significantly ($P < 0.05$)

Table 6 Effects of Se and Vit E levels on plasma immunity

Item	IgA ug/mL	IgM ug/mL	IgG ug/mL
G0	132.05 ± 6.05	324.52 ± 6.82^{b}	932.15 ± 15.12^{b}
G1	135.78 ± 5.62	352.41 ± 6.87^{ab}	987.25 ± 12.88^{a}
G2	142.25 ± 7.45	362.15 ± 6.52^{ab}	992.35 ± 11.65^{a}
G3	138.32 ± 6.43	378.76 ± 4.25^{a}	1023.56 ± 13.57^{a}
G4	146.87 ± 9.05	372.57 ± 6.21^{a}	1043.18 ± 14.56^{a}
G5	143.79 ± 7.21	358.24 ± 7.89^{ab}	1005.24 ± 10.71^{a}
G6	139.89 ± 6.58	364.33 ± 9.16^{ab}	1012.68 ± 25.12^{a}
Se levels			
Se1	136.54 ± 6.35	360.18 ± 5.88^{a}	990.38 ± 19.36^{b}
Se2	140.65 ± 3.89	376.54 ± 3.96^{b}	1041.35 ± 17.85^{a}
Se3	141.38 ± 4.57	361.66 ± 7.54^{a}	1010.24 ± 14.32^{b}
Vit E levels			
Vit E1	139.52 ± 5.97	360.15 ± 12.56	1025.32 ± 21.25^{a}
Vit E2	136.77 ± 5.42	362.18 ± 13.45	998.24 ± 22.87^{b}
P value			
Se	0.778	0.038	0.028
Vit E	0.214	0.616	0.021
Se × Vit E	0.856	0.772	0.611

[a,b] Values within a row with different superscripts differ significantly ($P < 0.05$)

Effects on Hematological Biochemical Parameters

The results of this study indicate that diets have no effects on the level of IgA. In contrast, it was reported that vitamin E could increase IgG and IgM, and Se could improve the immunity and synthesis of IgA and IgG of broiler chickens [26]. The significant increase in IgG and IgM ($P < 0.05$) in treated sika deer is consistent with the finding of Balicka-Ramsisz et al. [27] which stated that blood metabolites of sheep increased due to selenium administration. This may be due to the increase in protein anabolism and the decrease in protein catabolism. In addition, the increase in the other 183 blood metabolites could be ascribed to the improvement of feed efficiency, which is due to the supplementation of vitamin E and selenium and by means of the overall increase in animal health and/or reproductive performance. The activity of GSH-P*x* improves with increase in the levels of selenium and vitamin E since selenium is the component of GSH-P*x* and selenium and vitamin E are complementary in biological oxidation resistance. This result is consistent with the finding of Zhang et al. [28]. Furthermore, selenium has a close relationship with iodine enzymes I, II and III, which maintain a dynamic balance of the metabolism of thyroid hormone. Therefore, this study indicates that selenium level has significant effects on the concentration of T4 and T3.

Conclusion

An appropriate amount of selenium and vitamin E dietary supplements can improve the rate of body weight gain, feed conversion rate, and antioxidant capacity of 1-year-old female sika deer. For 1-year-old female sika

Table 7 Effects of Se and Vit E levels on blood profiles

Item	TP (g/L)	ALB (g/L)	GOT (U/L)	GPT (U/L)	GSH-P*x* (U/L)	T4 (ng/mL)	T3 (ng/mL)
G0	58.93 ± 5.01^{b}	20.93 ± 2.19	55.15 ± 3.06	61.85 ± 3.08	110.32 ± 5.62^{b}	115.35 ± 6.86^{b}	1.82 ± 0.24^{a}
G1	60.38 ± 4.21^{ab}	20.35 ± 2.62	65.55 ± 3.96	57.88 ± 3.07	131.18 ± 6.21^{ab}	105.42 ± 8.55^{a}	2.04 ± 0.33^{ab}
G2	62.60 ± 4.38^{ab}	22.93 ± 2.06	56.18 ± 5.13	61.15 ± 2.96	132.25 ± 4.97^{ab}	106.12 ± 7.32^{a}	2.82 ± 0.21^{b}
G3	63.63 ± 3.21^{a}	23.60 ± 3.18	73.00 ± 2.86	74.18 ± 2.51	156.52 ± 10.15^{a}	104.08 ± 8.15^{a}	2.45 ± 0.41^{b}
G4	60.30 ± 2.59^{ab}	21.55 ± 1.95	60.88 ± 1.57	62.60 ± 3.11	132.75 ± 8.96^{ab}	106.23 ± 6.46^{a}	1.96 ± 0.17^{ab}
G5	62.80 ± 3.62^{ab}	24.60 ± 2.11	58.28 ± 3.52	67.25 ± 2.15	141.40 ± 7.46^{ab}	102.05 ± 9.03^{a}	1.87 ± 0.15^{a}
G6	62.08 ± 2.15^{ab}	21.60 ± 1.08	55.75 ± 2.88	55.10 ± 4.67	155.14 ± 5.88^{a}	103.08 ± 7.18^{a}	1.99 ± 0.20^{ab}
Se levels							
Se1	61.49 ± 1.56	20.85 ± 1.96	60.86 ± 2.56	59.51 ± 5.88	131.28 ± 6.91^{a}	105.77 ± 8.15^{a}	2.43 ± 0.31^{a}
Se2	61.96 ± 2.35	22.39 ± 2.38	66.94 ± 3.62	68.39 ± 6.96	144.24 ± 6.58^{b}	105.16 ± 7.33^{ab}	2.21 ± 0.30^{ab}
Se3	62.44 ± 1.97	23.33 ± 1.54	57.01 ± 4.75	61.18 ± 5.75	148.30 ± 5.96^{b}	102.57 ± 4.96^{b}	1.93 ± 0.29^{b}
Vit E levels							
Vit E1	62.27 ± 2.82	21.63 ± 1.02	65.61 ± 5.11	66.43 ± 4.23	142.33 ± 10.31^{a}	103.85 ± 5.88	2.12 ± 0.17
Vit E2	61.66 ± 3.06	22.42 ± 2.42	57.60 ± 2.19	59.62 ± 4.31	135.66 ± 11.58^{b}	105.14 ± 6.79	2.56 ± 0.15
P value							
Se	0.767	0.801	0.048	0.039	0.041	0. 011	0.046
Vit E	0.572	0.756	0.170	0.246	0.025	0.309	0.471
Se × Vit E	0.128	0.120	0.775	0.469	0.325	0.408	0.326

[a,b] Values within a row with different superscripts differ significantly ($P < 0.05$)

deer, the optimum levels of selenium and vitamin E are 0.3 mg and 100 IU per kg of dietary DM, respectively.

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Compliance with Ethical Standards This study was conducted according to the guidelines of the Declaration of Helsinki (2008), and all procedures involving animals were approved by the animal welfare committee of the Institute of Special Animals and Plant Science, Chinese Academy of Agricultural Science (Jilin, Jilin Province, China) from May 12, 2015 to July 22, 2015(Protocol no. 2015ISAP0620).

Conflict of Interest The authors declare that they have no conflict of interest.

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