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Evaluation of dietary selenium sources and levels on growth performance, carcass characteristics, selenium concentrations, and blood biochemistry of growing-finishing pigs

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Abstract

Selenium (Se) is an essential trace mineral that plays an important role in physiological and biochemical responses by regulating the antioxidant system. Dietary Se is provided as a nutritional supplement to livestock diets in inorganic (ISe) or organic (OSe) form and has different bioavailability to animals. However, the comparison of the effects of dietary Se in different forms and levels of bioavailability are still limited. Therefore, this study was conducted to evaluate the effects of dietary Se sources and levels on growth performance, carcass characteristics, proximate composition of pork loin, Se concentrations, and blood biochemistry of growing-finishing pigs. In a randomized complete block design (block = initial body weight and sex), 160 pigs (28.17 ± 3.03 kg of body weight) were allotted to five dietary treatments (4 pigs/pen; 8 replicates/treatment) and fed for 14 weeks. Dietary treatments were 1) a non-Se-fortified diet based on corn and soybean meal provided as control (CON), 2) CON + 0.3 ppm ISe (ISe3), 3) CON + 0.5 ppm ISe (ISe5), 4) CON + 0.3 ppm OSe (OSe3), and 5) CON + 0.5 ppm OSe (OSe5). Data and sample collections were conducted at the specific time points during the study. Pigs fed dietary OSe tended to have an increased ($p < 0.10$) gain to feed ratio in the grower phase compared with those fed dietary ISe. In addition, dietary OSe increased ($p < 0.05$) hot carcass weight compared with dietary ISe. In contrast, dietary ISe increased ($p < 0.05$) crude protein content of pork loin compared with dietary OSe. Se concentrations in the kidney and pork loin were higher when the dietary Se source was OSe ($p < 0.05$) and increased with increasing dietary Se level ($p < 0.05$). In the finisher phase, serum total protein, calcium, inorganic phosphorus, magnesium, and creatinine

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Availability of data and material
Upon reasonable request, the datasets of this study can be available from the corresponding author.

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Ethics approval and consent to participate
The experimental protocol for this study was reviewed and approved by the Institutional Animal Care and Use Committee of Chungnam National University, Daejeon, South Korea (approval #: 202006A-CNU-090).

concentrations increased with increasing dietary Se level ($p < 0.05$). In conclusion, our study verified that dietary ISe and OSe each affected crude protein content of pork loin and tissue Se concentrations, respectively. Furthermore, blood biochemistry was modulated by prolonged intake with increased levels of dietary Se, regardless of the Se source.

Keywords: Blood biochemistry, Carcass characteristics, Growing-finishing pigs, Selenium, Selenium concentration

INTRODUCTION

The goal of the swine industry is to produce high-quality pork. In addition, consumers have recently become more interested in pork produced from healthy pigs, and the quality of the feed consumed by pigs has naturally become more important. From a nutritional perspective, pork quality can be improved by appropriately applying vitamins, minerals, and fatty acids to feed [1]. Among them, dietary selenium (Se), an essential trace mineral, is a major component of selenoproteins (SeP), which play a crucial role in biological functions of the body related to its antioxidation, thyroid hormones metabolism, and reproductive and muscle function [2,3]. SePs are distributed to various tissues and have diverse cellular functions: antioxidation (glutathione peroxidase [GPX]) and redox regulation (thioredoxin reductase [TRXR]) against reactive oxygen species (ROS), and thyroid hormone (deiodinase) [2,4]. These characteristics of dietary Se plays an important role in improving the meat quality, growth, and health of pigs [5–9], but Se deficiency or toxicity can lead to problems [10–13].

The dietary Se used in livestock feed is classified into inorganic Se (ISe) and organic Se (OSe). Because the bioavailability of dietary Se varies depending on the sources as well as levels, the biological results in animal trials also differ [5–9,14]. In particular, the main excretion route differs depending on the Se source, and the Se retention varies as well as total amount of excreted Se [13]. Thus, we hypothesized that the addition of dietary Se from different sources and levels in feed could affect blood biochemistry due to differences in the tissue bioavailability. This is because nutritional factors influence the physiological changes of animals, which are also reflected in blood parameters [15,16]. This study aimed to evaluate the effects of different dietary Se sources and levels on growth performance, carcass characteristics, proximate composition of pork loin, Se concentrations, and blood biochemistry of growing-finishing pigs.

MATERIALS AND METHODS

Animal ethics

The experimental protocol for this study was reviewed and approved by the Institutional Animal Care and Use Committee of Chungnam National University, Daejeon, Korea (approval #: 202006A-CNU-090).

Experimental animals, design, and diets

A total of 160 pigs ([Landrace × Yorkshire] × Duroc; initial average body weight [BW] = 28.17 ± 3.03 kg) were assigned to one of five dietary treatments (4 pigs/pen; 8 replicates/treatment) in a randomized complete block design (block = initial BW and sex). Dietary treatments were 1) a non-Se-fortified diet based on corn and soybean meal (CON), 2) CON + 0.3 ppm ISe (ISe3), 3) CON + 0.5 ppm ISe (ISe5), 4) CON + 0.3 ppm OSe (OSe3), and 5) CON + 0.5 ppm OSe (OSe5). The experimental diet was formulated according to the nutritional requirements of growing

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and finishing pigs, except for Se [17] (Table 1). This study was conducted on two phase feeding programs, with the grower phase from experimental day 1 to 49 and the finisher phase from experimental day 50 to 98. The ISe and OSe products (sodium selenite, 1,000 ppm; Se-yeast, 1,000 ppm, Sel-plex, respectively) were obtained from commercial suppliers (Daone Chemical, Siheung, Korea; Alltech Korea, Seoul, Korea, respectively). Diets were provided in mash form, and pigs had *ad libitum* access to the feed and water throughout the study. All pigs were housed in same sized pen where ambient temperature, humidity, and lighting program were automatically controlled.

Data and sample collection

BW of individual pigs and feed residuals in the feeder after supply were weighed and recorded on a pen basis at the end of each phase to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio ([G:F], feed efficiency). Blood samples were randomly collected from six pigs per dietary treatment via the jugular vein of pigs using 10 mL serum tubes (BD Vacutainer Systems, Franklin Lakes, NJ, USA) at the end of each phase. The collected blood samples were centrifuged at 3,000 × g for 15 minutes at 4℃ to obtain serum samples and stored at -80℃ for further blood analyses. On the last day of the study, one pig per pen with a BW similar to market weight was individually weighed, recorded, and transferred to a commercial slaughterhouse (FarmStory Hannaeng LPC, Seoul, Korea). The day before slaughter, pigs had completely restricted

Table 1. Composition of experimental diets for growing-finishing pigs (as-fed basis)

Item	Grower (day 1 to 49)	Finisher (day 50 to 98)
Ingredient (%)		
Corn	81.04	90.38
Soybean meal (44%)	15.02	6.71
Tallow	0.61	0.11
Mono-dicalcium phosphate	1.34	1.05
Limestone	0.79	0.64
Salt	0.30	0.30
Vitamin-mineral premix[1)]	0.20	0.20
L-Lysine-HCl	0.45	0.41
DL-Methionine	0.05	0.02
L-Threonine	0.15	0.13
L-Tryptophan	0.05	0.05
Total	100.00	100.00
Calculated energy and nutrient contents		
Metabolizable energy (kcal/kg)	3,365	3,353
Crude protein (%)	13.98	11.24
Crude fat (%)	3.67	3.51
Calcium (%)	0.64	0.50
Phosphorus (%)	0.57	0.48
Lysine (%)	0.89	0.66
Methionine (%)	0.25	0.19
Threonine (%)	0.64	0.36
Tryptophan (%)	0.18	0.47

[1)]Provided per kilogram of diet: vitamin A, 12,000 IU; vitamin D3, 2,500 IU; vitamin E, 30 IU; vitamin K3, 3mg; D-pantothenic acid, 15 mg; nicotinic acid, 40 mg; choline, 400 mg; and vitamin B12, 12 μg; Fe, 90 mg from iron sulfate; Cu, 8.8 mg from copper sulfate; Zn, 100 mg from zinc oxide; Mn, 54 mg from manganese oxide; I, 0.35 mg from potassium iodide.

access to feed for 12 hours, but had been allowed access to water. The slaughter process and carcass characteristics evaluation were conducted according to the conventional procedures of the Korea Institute for Animal Products Quality Evaluation. After dividing the carcass into two parts, the liver and kidney were collected before the evisceration process. Pork loins (longissimus muscles) were collected from near the 10th ribs on the right side of the carcass for further analysis. The collected tissue and loin samples were stored at −20℃ until Se concentration analysis. Carcass characteristics were evaluated using hot carcass weight, and backfat thickness.

Blood biochemistry and growth hormone analysis

The serum samples were analyzed for total protein, calcium, inorganic phosphorus, magnesium, total cholesterol, triglyceride, glucose, albumin, creatinine, blood urea nitrogen (BUN), aspartate aminotransferase, and alanine aminotransferase using a clinical auto analyzer (Toshiba Acute Biochemical Analyzer-TBA-40FR, Toshiba Medical Instruments, Tokyo, Japan) with specific kits (Wako Pure Chemical Industries, Osaka, Japan) [18]. The other serum samples were analyzed for porcine insulin-like growth factor-1 (IGF-1) using enzyme-linked immunosorbent assay kit (MyBioSource, San Diego, CA, USA) according to the provided manufacturer's instructions. The concentration of serum IGF-1 was determined using a microplate reader (Epoch microplate spectrophotometer, BioTek Instruments, Winooski, VT, USA).

Chemical analyses

The proximate composition of the pork loin was evaluated based on moisture, crude protein, crude fat, and ash contents according to the Association of Official Analytical Chemists (AOAC) method [19]. To determine Se concentration in the diets, liver, kidney, pork loin, and serum, the samples were digested in a digestion block (N-biotek, South Korea), acted with 2,3-diaminonaphthalene solution, and analyzed with a fluorescence spectrometer (RF-6000, Shimadzu, Kyoto, Japan) using the fluorometric method [20], as reported in the AOAC (method 996.16) [19].

Statistical analyses

Data were analyzed using the MIXED procedure of SAS (SAS Institute, Cary, NC, USA) in a randomized complete block design (block = initial BW and sex) with the pen as the experimental unit. Statistical models for growth performance, carcass characteristics, proximate composition of pork loin, Se concentrations, and blood biochemistry included dietary treatments as main effect and blocks as random effects. Contrast statements were applied to determine the dietary Se effects (source, level, and source × level interaction). Statistical significance and tendency among dietary treatments were considered at $p < 0.05$ and $0.05 \leq p < 0.10$, respectively.

RESULTS AND DISCUSSION

Growth performance

There were no clinical lesions and/or signs of disease associated with Se deficiency or toxicity in all pigs fed the dietary treatments throughout the study. According to the National Research Council, the requirement of dietary Se for pig is 0.15 to 0.30 ppm [17], and the Food and Drug Administration suggests that the dietary Se content in swine feed should not exceed 0.30 ppm [21]. In this study, analyzed dietary Se content in the dietary treatments were as follows: 0.081 (CON), 0.464 (ISe3), 0.623 (ISe5), 0.458 (OSe3), and 0.628 ppm (OSe5). The effects of dietary Se sources and levels on the growth performance of growing-finishing pigs are shown in Table 2. Pigs fed OSe tended to have increase ($p < 0.10$) G:F in the grower phase compared with those fed ISe. However,

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Table 2. Effects of dietary selenium sources and levels on growth performance of growing-finishing pigs[1)]

Item[2)]	Dietary treatments					SEM	*p*-value			
	CON	ISe3	ISe5	OSe3	OSe5		Diet	Source	Level	Source × Level
Grower (day 1 to 49)										
Initial BW (kg)	28.90	28.95	28.86	28.76	28.75	1.26	0.999	0.907	0.968	0.979
Final BW (kg)	66.65	67.81	68.77	67.96	68.37	2.73	0.986	0.963	0.803	0.921
ADG (kg/d)	0.772	0.789	0.813	0.802	0.808	0.036	0.933	0.916	0.692	0.806
ADFI (kg/d)	1.708	1.942	1.946	1.863	1.821	0.092	0.354	0.274	0.840	0.807
G:F (kg/kg)	0.453	0.410	0.418	0.435	0.444	0.013	0.125	0.055	0.496	0.958
Finisher (day 50 to 98)										
Initial BW (kg)	66.65	67.81	68.77	67.96	68.37	2.73	0.986	0.963	0.803	0.921
Final BW (kg)	112.27	114.67	115.96	114.95	114.30	3.65	0.967	0.853	0.931	0.792
ADG (kg/d)	0.971	0.997	1.004	1.004	0.977	0.040	0.962	0.814	0.807	0.675
ADFI (kg/d)	2.344	2.456	2.784	2.638	2.450	0.217	0.629	0.728	0.749	0.241
G:F (kg/kg)	0.447	0.435	0.364	0.391	0.484	0.059	0.632	0.521	0.859	0.172
Overall (day 1 to 98)										
Initial BW (kg)	28.90	28.95	28.86	28.76	28.75	1.26	0.999	0.907	0.968	0.979
Final BW (kg)	112.27	114.67	115.96	114.95	114.30	3.65	0.967	0.853	0.931	0.792
ADG (kg/d)	0.869	0.891	0.906	0.900	0.891	0.029	0.912	0.904	0.910	0.678
ADFI (kg/d)	2.016	2.209	2.349	2.196	2.132	0.104	0.266	0.276	0.717	0.334
G:F (kg/kg)	0.437	0.407	0.387	0.415	0.435	0.024	0.548	0.242	0.992	0.406

[1)]Each value is the mean of 8 replicates (4 pigs/pen).

[2)]CON, a non-selenium-fortified diet based on corn and soybean meal; ISe3, CON + 0.3 ppm inorganic selenium; ISe5, CON + 0.5 ppm inorganic selenium; OSe3, CON + 0.3 organic selenium; OSe5, CON + 0.5 ppm organic selenium; Diet, all dietary treatments; Source, inorganic or organic; Level, 0.3 or 0.5 ppm; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G:F, gain to feed ratio.

there were no differences in the growth performance during the finisher and overall phase among dietary treatments. Most previous studies have shown that different sources and levels of dietary Se did not affect the growth performance of pigs [6,13,22,23]. However, some previous studies have reported that dietary OSe improved the growth performance of pigs compared with dietary ISe or non-Se-fortified diet [8,14,24]. Although the results of improved G:F in the OSe group compared with the ISe group cannot be easily explained, the antioxidant capacity of dietary Se [2,3] or its interaction with reproductive hormones [2,24,25] is assumed to be direct or indirect effects due to the higher bioavailability of dietary OSe than dietary ISe.

Carcass characteristics and proximate composition of pork loin

Pigs fed ISe had higher ($p < 0.05$) hot carcass weight in finisher phase than those fed OSe (Table 3). However, there were no differences in dressing percentage, and backfat thickness among dietary treatments. Hot carcass weight is the weight at which the head and internal organs are removed after slaughter and before chilling and is used to evaluate meat quantity rather than meat quality. There may be an error in that high live weight is proportional to high carcass weight, but this is not simple. Therefore, the dressing percentage, expressed as a ratio of live weight, and backfat thickness are considered in the production of high-quality livestock products. In a previous study, hot carcass weight was positively correlated with fat and muscle thickness, as well as negatively correlated with lean yield [26]. Although the increased hot carcass weight did not lead to an increase in backfat thickness in our study, the increased hot carcass weight in the ISe group may be related to bone and/or skeletal muscle development. This is because the bone and muscle are the main tissues

Table 3. Effects of dietary selenium sources and levels on carcass characteristics of finishing pigs[1)]

Item[2)]	Dietary treatments					SEM	*p*-value			
	CON	ISe3	ISe5	OSe3	OSe5		Diet	Source	Level	Source × Level
Hot carcass weight (kg)	88.16	88.68	86.80	85.80	85.97	0.89	0.104	0.045	0.346	0.260
Dressing percentage (%)	77.23	77.27	77.28	77.16	77.33	0.06	0.346	0.638	0.141	0.182
Backfat thickness (mm)	21.83	21.18	20.45	20.97	21.74	1.06	0.881	0.612	0.985	0.483

[1)]Each value is the mean of 8 replicates (1 pig/pen).

[2)]CON, a non-selenium-fortified diet based on corn and soybean meal; ISe3, CON + 0.3 ppm inorganic selenium; ISe5, CON + 0.5 ppm inorganic selenium; OSe3, CON + 0.3 organic selenium; OSe5, CON + 0.5 ppm organic selenium; Diet, all dietary treatments; Source, inorganic or organic; Level, 0.3 or 0.5 ppm; Dressing percentage = (hot carcass weight / final body weight) × 100.

in the body that retain Se [3,27]. In addition, adequate dietary Se plays an important role in the proliferation and differentiation of bone cells via the regulation of ROS [28]. Se deficiency can be associated with muscular dystrophy because it induces oxidative stress through decreased expression of SeP genes such as GPX and TRXR [29]. However, dietary Se has been reported to prevent white muscle disease caused by Se deficiency in pigs [30]. Moreover, in a previous *in vitro* study, it was reported that among different Se sources, sodium selenite reduced intracellular ROS levels in myocytes [31]. Taken together, different dietary Se sources may have differences in bioavailability and cellular metabolism depending on the body tissues.

As shown in Table 4, the crude protein content of pork loin was different among dietary treatments ($p < 0.05$). Additionally, dietary ISe increased ($p < 0.05$) the crude protein content of pork loin compared with dietary OSe. The crude ash of pork loin was decreased ($p < 0.05$) as Se level increased from 0.3 ppm to 0.5 ppm. The interaction between dietary Se source and level was observed on moisture ($p < 0.05$), crude protein ($p < 0.10$), and crude fat contents ($p < 0.05$) of pork loin. In a previous study, dietary ISe had higher moisture content and lower crude protein and fat contents in pork loin than dietary OSe [8]. However, a previous study reported that dietary Se did not affect the crude protein and crude fat contents of pork loin, regardless of Se source [7]. Meat quality should be considered through indicators such as water holding capacity (WHC), color, and pH because proximate composition has limitations in evaluating meat quality. Previous studies have consistently shown that dietary Se was more effective than non-Se, especially dietary OSe than Ise, in reducing drip, pressing, or cooking loss of meat [5–8,22]. Interestingly, dietary Se did not affect meat color and/or pH, regardless of Se source or even level. The effect of dietary Se on the WHC of meat could be related to the upregulation of muscular SeP W, which has antioxidant properties [6,32,33]. However, dietary ISe resulted in a higher drip loss as well as paler-colored muscle than dietary OSe [5]. Although our study only analyzed the proximate composition of pork loin, based

Table 4. Effects of dietary selenium sources and levels on proximate composition of pork loin of finishing pigs[1)]

Item[2)]	Dietary treatments					SEM	*p*-value			
	CON	ISe3	ISe5	OSe3	OSe5		Diet	Source	Level	Source × Level
Moisture (%)	73.07	75.53	73.42	72.63	76.71	1.43	0.246	0.892	0.500	0.047
Crude protein (%)	21.54	20.28	22.49	20.06	19.33	0.71	0.045	0.030	0.313	0.056
Crude fat (%)	2.43	2.12	3.08	2.96	2.52	0.32	0.237	0.664	0.430	0.043
Ash (%)	0.69	1.08	0.74	0.99	0.81	0.10	0.065	0.924	0.020	0.418

[1)]Each value is the mean of 4 replicates (1 pig/pen).

[2)]CON, a non-selenium-fortified diet based on corn and soybean meal; ISe3, CON + 0.3 ppm inorganic selenium; ISe5, CON + 0.5 ppm inorganic selenium; OSe3, CON + 0.3 organic selenium; OSe5, CON + 0.5 ppm organic selenium; Diet, all dietary treatments; Source, inorganic or organic; Level, 0.3 or 0.5 ppm.

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on previous studies, dietary ISe may reduce meat quality than dietary OSe. In addition, because the crude protein content of pork loin had a negative correlation with cooking loss [34], meat quality evaluation should be supported by additional research.

Selenium concentrations

As expected, dietary Se had higher ($p < 0.05$) Se concentration in the liver, kidney, pork loin, and serum than non-Se-fortified diet (Table 5). In addition, pigs fed dietary OSe or high level of Se had higher Se concentration in the liver ($p < 0.10$ and $p < 0.05$, respectively) and kidney ($p < 0.05$ and $p < 0.05$, respectively) than those fed dietary ISe or low level of Se, and both results showed an interaction ($p < 0.05$) between source and level. Furthermore, dietary OSe or 0.5 ppm Se had higher ($p < 0.05$ and $p < 0.05$, respectively) pork loin Se concentration than dietary ISe or 0.3 ppm Se. However, the differences in the source and level on pork loin did not show any interactions. Pigs fed high level of Se tended to have higher ($p < 0.10$) serum Se concentration than those fed low level of Se. Dietary Se is absorbed in the small intestine, transported to the liver through the bloodstream, and then distributed to other tissues through the bloodstream after SeP production and metabolism in the liver [21,35]. Therefore, the liver is the main organ responsible for regulating Se metabolism in the body. In addition, the liver mirrors the degree of intestinal absorption [36]. The kidney plays a major role in the utilization of Se to protect the cellular membranes involved in performing their function as well as the excretion of Se [14,37]. Consistent with our study, the previous studies also showed that the Se level in the kidney of pigs was higher than that in the liver or pork loin [5,12,14,23]. Moreover, the Se concentrations in the liver, kidney, and pork loin were higher in dietary OSe than the ISe [12,14,23]. These results indicate that the OSe is more effective than the ISe for absorbing Se from the small intestine and retaining the levels for Se metabolic utilization in the body. Se level in tissues reflects long-term status of animals, while Se level in blood along with urine reflects the short-term status of Se intake [13,37]. Unlike Se concentrations in tissues, this study showed that Se concentration in serum differed only at the Se level, regardless of the Se source. Interestingly, some previous studies have reported that the effects of Se source on serum Se concentration were reduced in the finishing period, but not in the growing period [14,23]. Moreover, serum Se concentration was high when dietary ISe was added at a low level (i.e. 0.5 mg/kg), whereas when dietary OSe was added, serum Se concentration also increased with increasing Se level [5]. These results suggest that there are differences in the concentrations of Se retained in the blood of pigs at different growth stages depending on the source as well as the level of Se. Furthermore, based on the reference values of Se levels in blood for Se deficiency or toxicity [24], our result supported that the pigs were neither deficient nor in toxicity condition and that it was not associated with health problems during the study. However, the blood Se level in the CON group

Table 5. Effects of dietary selenium sources and levels on selenium concentrations of finishing pigs[1)]

Item[2)]	Dietary treatments					SEM	*p*-value			
	CON	ISe3	ISe5	OSe3	OSe5		Diet	Source	Level	Source × Level
Liver (ppm)	0.240	0.384	0.579	0.275	0.650	0.016	< 0.001	0.079	< 0.001	0.030
Kidney (ppm)	1.050	1.893	2.016	2.090	2.373	0.036	< 0.001	< 0.001	< 0.001	0.043
Pork loin (ppm)	0.070	0.123	0.129	0.131	0.162	0.007	< 0.001	0.013	0.020	0.107
Serum (ppm)	0.062	0.154	0.170	0.151	0.165	0.007	< 0.001	0.624	0.052	0.888

[1)]Each value is the mean of 4 replicates (1 pig/pen).

[2)]CON, a non-selenium-fortified diet based on corn and soybean meal; ISe3, CON + 0.3 ppm inorganic selenium; ISe5, CON + 0.5 ppm inorganic selenium; OSe3, CON + 0.3 organic selenium; OSe5, CON + 0.5 ppm organic selenium; Diet, all dietary treatments; Source, inorganic or organic; Level, 0.3 or 0.5 ppm.

was at the marginal level, indicating that the addition of dietary Se to feed should be considered.

Blood biochemistry

In the grower phase, pigs fed dietary OSe tended to have higher ($p < 0.10$) serum BUN concentration than those fed dietary ISe (Table 6). However, there were no differences in other biochemical indices among dietary treatments. On the other hand, high level of dietary Se had lower concentrations of serum total protein ($p < 0.05$), calcium ($p < 0.05$), inorganic phosphorus ($p < 0.05$), magnesium ($p < 0.05$), total cholesterol ($p < 0.10$), albumin ($p < 0.10$), and creatinine ($p < 0.05$) in the finisher phase than low level of dietary Se. BUN is a useful predictor of protein status in animals because it is related to nitrogen utilization efficiency [38]. In addition, blood BUN has been reported to be negatively correlated with feed efficiency and lean growth in pigs [39]. However, in the current study, dietary OSe supplementation resulted in higher blood BUN during the grower

Table 6. Effects of dietary selenium sources and levels on blood biochemistry of growing-finishing pigs[1)]

Item[2)]	Dietary treatments					SEM	*p*-value			
	CON	ISe3	ISe5	OSe3	OSe5		Diet	Source	Level	Source × Level
Grower (day 49)										
Total protein (g/dL)	7.06	6.38	6.15	6.80	7.18	0.44	0.446	0.123	0.868	0.509
Calcium (mg/dL)	11.51	9.57	9.69	10.28	10.84	0.77	0.391	0.247	0.666	0.779
Inorganic phosphorus (mg/dL)	11.51	9.84	9.59	10.21	10.90	0.82	0.470	0.318	0.793	0.575
Magnesium (mg/dL)	2.84	2.33	2.29	2.50	2.65	0.18	0.228	0.160	0.761	0.613
Total cholesterol (mg/dL)	94.88	78.63	80.50	91.75	95.38	9.01	0.544	0.141	0.764	0.924
Triglyceride (mg/dL)	56.63	32.63	45.50	68.00	45.63	10.59	0.231	0.114	0.660	0.117
Glucose (mg/dL)	76.50	55.50	58.50	59.00	56.50	12.26	0.736	0.952	0.984	0.826
Albumin (g/dL)	3.86	3.54	3.36	3.51	3.76	0.23	0.564	0.429	0.873	0.372
Creatinine (mg/dL)	1.45	1.34	1.16	1.28	1.35	0.10	0.408	0.551	0.633	0.242
BUN (mg/dL)	10.58	9.00	7.86	10.08	10.32	1.01	0.331	0.099	0.662	0.504
AST (IU/L)	49.00	44.25	43.25	50.13	50.00	10.27	0.979	0.548	0.957	0.967
ALT (IU/L)	68.75	47.63	43.50	61.25	48.38	10.33	0.410	0.385	0.423	0.678
IGF-1 (pg/mL)	118.56	141.54	124.70	126.54	147.93	21.69	0.858	0.852	0.918	0.392
Finisher (day 98)										
Total protein (g/dL)	6.56	6.50	5.41	6.51	5.58	0.37	0.098	0.815	0.015	0.841
Calcium (mg/dL)	9.74	9.36	7.70	9.11	8.11	0.47	0.036	0.864	0.012	0.490
Inorganic phosphorus (mg/dL)	8.21	7.88	6.45	7.70	6.84	0.35	0.014	0.767	0.005	0.436
Magnesium (mg/dL)	1.89	1.83	1.53	1.88	1.55	0.10	0.043	0.714	0.007	0.903
Total cholesterol (mg/dL)	89.88	88.50	81.38	93.63	77.50	6.15	0.374	0.920	0.078	0.476
Triglyceride (mg/dL)	49.13	32.63	32.50	52.75	32.00	6.76	0.106	0.167	0.143	0.148
Glucose (mg/dL)	77.75	74.75	73.75	80.00	75.50	6.98	0.969	0.624	0.699	0.806
Albumin (g/dL)	3.79	3.91	3.34	3.59	3.29	0.23	0.263	0.419	0.072	0.552
Creatinine (mg/dL)	1.31	1.38	1.04	1.24	1.01	0.10	0.091	0.447	0.016	0.597
BUN (mg/dL)	9.49	7.95	7.30	8.06	7.35	0.87	0.417	0.926	0.443	0.972
AST (IU/L)	28.88	24.75	21.00	29.38	22.13	3.55	0.368	0.430	0.142	0.629
ALT (IU/L)	40.00	44.88	41.25	47.38	40.38	5.55	0.850	0.886	0.354	0.765
IGF-1 (pg/mL)	120.48	148.39	132.36	129.12	137.73	18.08	0.854	0.706	0.840	0.506

[1)]Each value is the mean of 4 replicates (1 pig/pen).

[2)]CON, a non-selenium-fortified diet based on corn and soybean meal; ISe3, CON + 0.3 ppm inorganic selenium; ISe5, CON + 0.5 ppm inorganic selenium; OSe3, CON + 0.3 organic selenium; OSe5, CON + 0.5 ppm organic selenium; Diet, all dietary treatments; Source, inorganic or organic; Level, 0.3 or 0.5 ppm; BUN, blood urea nitrogen; AST, aspartate aminotransferase; ALT, alanine aminotransferase; IGF-1, insulin-like growth factor-1.

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phase than dietary ISe, which is expected to result in low protein and amino acids utilization, but in fact resulted in high feed efficiency in growing pigs. When considering the protein metabolism, previous results of dietary Se on crude protein digestibility or nitrogen retention have been inconsistent [14,23], but our results indicated that dietary OSe may have a negative effect on protein synthesis in the grower phase. Blood creatinine level, along with BUN, is related to the health of the liver and kidney, which are the main organs involved in amino acids deamination and urea synthesis. Additionally, phospholipid hydroperoxide GPX, one of the SeP, is known to inhibit lipid peroxidation due to its ability to reduce lipid and cholesterol peroxides [4,40], and its regulations by dietary Se were confirmed [24,29]. Our results indicated that increasing dietary Se level affected not only Se concentration in the liver and kidney, but also the nutritional metabolism of the organs that play an important role in Se metabolism and excretion. In addition, because blood values reflect the nutritional, physiological, and health status of animals [15,16], blood metabolic changes caused by dietary Se supplementation appear to have affected blood total protein and albumin, which are components of blood proteins. Furthermore, blood biochemistry results may be related to previous study showing that different source and level of dietary Se influence the retention and excretion of macro-minerals such as calcium, phosphorous, and magnesium [13].

CONCLUSION

The addition of dietary OSe and ISe to the grower-finisher diet improved the crude protein content of pork loin and tissue Se concentrations, respectively. In addition, dietary Se level modulated blood biochemistry of finishing pigs by prolonged intake, regardless of the Se source. Based on the results of the present study showing different physiological performance depending on the dietary Se sources and levels, further studies are needed to evaluate the effects of different levels of mixed Se sources on growth and health of growing-finishing pigs.

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