K-STATE Research and Extension

SWINE DAY 2021

KANSAS STATE UNIVERSITY SWINE INDUSTRY DAY 2021

Evaluation of Selenium Source on Nursery Pig Growth Performance, Serum and Tissue Selenium Concentrations, and Serum Antioxidant Status[1]

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Summary

A total of 3,888 pigs (337 × 1050, PIC; initially 13.1 ± 0.10 lb) were used in a 42-d trial. At the time of placement, pens of pigs were weighed and allotted to 1 of 3 dietary treatments in a randomized complete block design with blocking structure including sow farm origin, date of entry into the facility, and average pen body weight. A total of 144 pens were used with 72 double-sided 5-hole stainless steel fence line feeders, with feeder serving as the experimental unit. For each feeder, 1 pen contained 27 gilts and 1 pen contained 27 barrows. There were 24 replicates per dietary treatment. Diets were fed in three phases and all contained 0.3 ppm added selenium. A common phase 1 diet contained added selenium from sodium selenite and was fed in pelleted form to all pigs for approximately 7 d. Three selenium sources [sodium selenite; selenium yeast; and hydroxy-selenomethionine (OH-SeMet)] were used to formulate 3 experimental diets in meal form for phase 2 and phase 3. From d 0 to 7, there was marginally significant evidence ($P = 0.097$) of a difference in ADFI, although no significant pairwise differences were observed ($P > 0.05$). There were no additional differences in growth performance between treatments during the d 0 to 7 period. Clinical disease attributed to *Streptococcus suis* was observed within the trial, and water soluble antimicrobial therapy was administered to all treatment groups. From d 7 to 42, pigs fed OH-SeMet tended to have decreased ADG ($P < 0.10$) and had increased ($P < 0.05$) serum and tissue selenium concentration compared to other treatments. There was marginally significant evidence of a source × day interaction for T-AOC where the numerical increase over time was less for the OH-SeMet compared to sodium selenite or selenium yeast treatments. There was no difference ($P > 0.05$) in antioxidant status as measured by serum GSH-Px or TBARS assay between treatments. In summary, compared to sodium selenite and selenium yeast, OH-SeMet had greater bioavailability as indicated by increased serum and tissue selenium concentration; however, antioxidant status was similar

[1] The authors appreciate Hord Family Farms (Bucyrus, OH), and Adisseo France SAS (Antony, France) for their support of this research project.

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between treatments, and OH-SeMet tended to reduce growth performance compared with pigs fed sodium selenite.

Introduction

Selenium is an essential mineral that functions as a cofactor for several enzymes (e.g., glutathione peroxidase and thioredoxin reductase) that protect cells from oxidative damage from stress.[4,5] It is also an important component of several selenoproteins that are important for all stages of animal production. Selenium deficiency may result in sudden death, pale muscle, liver necrosis, mulberry heart, and damage to lungs and gastrointestinal tissues.[5] Therefore, selenium supplementation is important for animal production, especially in regions that use feed ingredients grown in low selenium soils. There are several selenium sources in either inorganic (sodium selenite) or organic forms [selenium yeast and hydroxy-selenomethionine (OH-SeMet)]; however, the differences between these products when fed to nursery pigs is not clear. Therefore, the objective of this study was to determine the effect of selenium source (sodium selenite, selenium yeast, and OH-SeMet) on growth performance, serum and tissue selenium concentrations, and serum antioxidant status of nursery pigs.

Materials and Methods

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this study. Experiments were conducted at a commercial research facility located in north central Ohio (Bucyrus, OH).

Animals and diets

Weaned pigs (approximately 21 days of age) originating from three sow farms were loaded into the research facility over a 5-day period. Sows were fed diets containing 0.3 ppm of added selenium with minimum of 50% from yeast-derived organic selenium and the remainder from sodium selenite. At the time of weaning, a total of 3,888 pigs (337 × 1050, PIC, Hendersonville, TN; initially 13.1 ± 0.10 lb BW) were placed in the research barn with 27 pigs per pen (7.5 × 8.9 ft). A total of 144 pens were used with 72 double-sided 5-hole stainless steel fence line feeders each feeding 2 adjacent pens with feeder serving as the experimental unit. For each feeder, 1 pen contained 27 gilts and 1 pen contained 27 barrows. Each pen also contained a cup-waterer to provide *ad libitum* access to feed and water. At the time of placement in the nursery facility, pens of pigs were weighed and allotted to 1 of 3 dietary treatments in a randomized complete block design with blocking structure including sow farm origin, date of entry into the facility, and average pen BW. There were 24 replicates (feeders) per dietary treatment.

Samples of corn, soybean meal, and enzymatically-treated soybean meal (HP300, Hamlet Protein Inc., Findlay, OH) were collected and analyzed for Se concentration at Michigan State University Veterinary Diagnostic Laboratory (MSU VDL, East Lansing, MI) prior to initiation of the study. The trace mineral premix used in the diets did not contain selenium (SEM Minerals, L.P., Quincy, IL). Diets were fed in three phases and all contained 0.3 ppm added selenium (Table 1). Phase 1 common diet was

[4] Reese, D. E. and G. M. Hill. 2009. Trace minerals and vitamins for swine diets. In: National swine nutrition guide.

[5] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. doi: 10.17226/13298.

formulated with added selenium from sodium selenite, manufactured and pelleted at Premier Feeds, LLC (Urbana, OH), and was fed to all pigs from weaning (13.1 lb) to approximately 15 lb BW with a feed budget of 1.5 lb/pig. Three selenium sources [sodium selenite; selenium yeast; and hydroxy-selenomethionine (OH-SeMet)] were used to formulate 3 experimental diets for phase 2 and 3, and were manufactured at the Hord Elevator (Bucyrus, OH). Phase 2 and 3 diets were fed in meal form with a feed budget of 25.5 and 32 lb/pig, respectively. All diets met the NRC[5] vitamin and mineral requirement estimates.

Feed samples were collected from at least 6 feeders per treatment per phase, pooled, and subsampled for selenium concentration (MSU VDL) and crude protein (Kansas State University Swine Nutrition Laboratory, Manhattan, KS). The feed selenium assay was based on an Agilent Technologies Inc. (Santa Clara, CA) method using an inductively coupled plasma mass spectrometer (ICP/MS). Selenium concentration was calibrated using a 6-point linear curve of the analyte-internal standard response ratio. Standards were from Inorganic Ventures (Christiansburg, VA). A National Institute of Standards and Technology (NIST; Gaithersburg, MD) typical diet standard was used as a control.

There was an outbreak of *Streptococcus suis* in the research barn during the phase 2 period for approximately 7 d. Amoxicillin (250 mg/5 mL; NDC 0781-6041-55; Sandoz, Princeton, NJ) was administered through the water to all pens.

Data and sample collection

Feed additions to each individual feeder were made and recorded by an electronic feeding system (Dry Exact; Big Dutchman, Inc., Holland, MI). Pens of pigs were weighed by pen and feed disappearance was calculated every 7 d until the conclusion of the trial to calculate ADG, ADFI, pen average BW, and feed efficiency. Feed disappearance was measured by using a volumetric regression equation, which estimates quantity of feed remaining in the feeder subtracted by the quantity of feed added to the feeder.

Serum samples were collected from 1 median-weight barrow of each experimental unit on d 0, 21, and 42 of the experiment. The same pig per experimental unit was marked with a high visibility, numbered ear tag on d 0 and used in all subsequent serum collections. Serum samples of two pigs were unable to be collected due to removal, therefore replacement barrows from the same pen were randomly selected and used for further sampling. Whole blood samples were allowed to clot for 30 min, centrifuged at 1,500 × g for 15 min, and the resulting serum supernatants were divided into 7 polypropylene tubes as aliquots, and transferred and stored at -112°F. Day 0 serum samples were collected when all pigs were still on the phase 1 common diet. Serum selenium concentration was analyzed on d 0, 21, and 42 samples at the MSU VDL. The serum selenium assay used a similar method as the feed selenium analysis, but with in-house serum pools as the controls. Serum glutathione peroxidase (GSH-Px), total antioxidant capacity (T-AOC), and ghiobarbituric acid reactive substances (TBARS) were evaluated on d 21 and 42 samples at the Kansas State University Swine Nutrition Laboratory. For serum GSH-Px, assay kits were purchased from Cayman Chemical Company (Ann Arbor, MI; # 703102) and samples were run in triplicate in 96-well microplates with intra-assay CV of ≤ 5.0%. For serum T-AOC, assay kits were purchased from Cell Biolabs, Inc. (OxiSelec, San Diego, CA; # STA-360) and samples were run in duplicate in 96-well microplates with intra-assay CV of ≤ 5.0%. For TBARS, assay was a modifi-

cation of the methods of Yagi (1998),[6] and Aguilar Diaz De Leon and Borges (2020)[7] and samples were run in triplicate in 96-well microplates with intra-assay CV of ≤ 5.0%. Malondialdehyde bis (MDA bis) standard curve was prepared freshly for each 96-well micro titer plate with a range of 1.56 to 100 μM MDA. A total of 100 μL of each standard or undiluted serum sample was added in each test tube, and then 200 μL of 10% TCA (trichloroacetic acid) solution was added for MDA extraction. The solution was then mixed with 1.0 mL of TBA/sodium acetate and incubated in a boiling water bath (203°F) for 60 min. After incubation, test tubes were placed in an ice bath for 15 min and then centrifuged at 1500 × g for 10 min at 4°C. Immediately after centrifugation, 150 μL of supernatant was aliquoted from each tube and placed into a separate well of a 96-well micro titer plate. The absorbances were read at 532 nm with a spectrophotometer. The average absorbance reading of the blank samples was subtracted from all other absorbance readings. Standard curve was created by plotting the blank-subtracted absorbance readings and the known concentrations of each standard. Sample data points were then fitted using the equation of the linear regression line obtained from the standard curve to calculate sample concentrations.

The same 72 barrows used for serum collection were euthanized on d 42 of the experiment for the collection of muscle and liver tissue. Muscle samples were collected from the loin at the 10th rib. Liver samples were collected from the right median lobe adjacent to the gallbladder. Following collection, fresh tissue samples were stored on ice and transported to the MSU VDL for analysis of tissue selenium concentration. The tissue selenium analysis used a similar method as the feed selenium analysis, but with NIST bovine liver and muscle standards as controls.

Statistical analysis

Data were analyzed as a randomized complete block design for one-way ANOVA using the lmer function from the lme4 package for growth performance, percentage of injectable treatments, selenium concentration, and antioxidant status, and the glmer function (binominal distribution) from the lme4 package for percentage of removal and mortality in R program (R Core Team, 2019).[8] Feeder (2 pens of pigs) was considered the experimental unit. Initial pen average BW, sow farm origin, and date of entry into the facility were used as blocking factors. Treatment was used as the fixed effect. For d 7 to 42 growth performance, d 0 to 7 ADFI was used as a covariate. For serum selenium concentration, d 0 selenium concentration was used as a covariate for d 21 and 42 serum selenium concentrations, which were analyzed as repeated measurements. For the serum GSH-Px, T-AOC, and TBARS assay, micro titer plate was used as a random effect, and serum samples were balanced for block when placed on microplates. For the serum GSH-Px assay, 3 subsamples per sample were used to plot a regression line over time for the activity of GSH-Px of each sample as one value. For the serum T-AOC assay, each sample was tested as duplicates and analyzed as repeated measurement. For the serum TBARS assay, each sample was tested as triplicates and analyzed as repeated

[6] Yagi K. Simple assay for the level of total lipid peroxides in serum or plasma. Methods Mol Biol. 1998. 108:101-6. doi: 10.1385/0-89603-472-0:101.

[7] Aguilar Diaz De Leon, J., Borges, C. R. 2020. Evaluation of oxidative stress in biological samples using the thiobarbituric acid reactive substances assay. J. Vis. Exp. (159), e61122, doi:10.3791/61122.

[8] R Core Team. 2019. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria. https://www.R-project.org/.

measurement. Tukey adjustment was used for multiple comparisons. All results were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

Growth performance

From d 0 to 7, there was no evidence of difference ($P > 0.05$) in d 0 BW, d 7 BW, ADG, and F/G between treatments (Table 2). However, despite the common diet, there was marginally significant evidence of a difference ($P = 0.097$) in ADFI from d 0 to 7, with the OH-SeMet having a numerically lower ADFI compared to the other treatment groups. Therefore, d 0 to 7 ADFI was used as a covariate for growth performance in subsequent periods and overall growth performance. From d 7 to 21, pigs fed OH-SeMet had decreased ($P < 0.05$) ADFI and consequently a lower ADG compared to the other two treatments. There was no evidence of difference ($P > 0.05$) in F/G between treatments. From d 21 to 42, there was no evidence of difference ($P > 0.05$) in any growth criteria between the three treatments. From d 7 to 42, pigs fed OH-SeMet tended to have decreased ADG ($P < 0.10$) compared to pigs fed sodium selenite. From d 0 to 42 (overall period), pigs fed OH-SeMet tended to have decreased ADFI ($P < 0.10$) compared to pigs fed sodium selenite. However, for the same period, there was no evidence of difference ($P > 0.05$) in ADG, F/G, d 42 BW, percentage of injections, removal, and mortality between treatments.

Serum and tissue selenium concentration

Serum selenium on d 0 was used as a covariate for analysis of concentrations on d 21 and 42. There was a tendency ($P = 0.072$) of source × day interaction. Pigs fed OH-SeMet had a greater increase in serum Se from d 21 to 42 compared to pigs fed sodium selenite or selenium yeast. On d 21, pigs fed OH-SeMet had increased ($P < 0.05$) serum selenium concentration compared to pigs fed selenium yeast. On d 42, despite a lower ADFI, pigs fed OH-SeMet had increased ($P < 0.05$) serum, muscle, and liver selenium concentration compared to all other treatments.

Antioxidant status

There was a marginally significant increase in GSH-Px ($P = 0.074$) over time; however, no source × day interaction or main effect of source was observed ($P > 0.10$). There was a source × day interaction ($P = 0.027$) on serum T-AOC where although no significant means separation was present, pigs fed OH-SeMet had a smaller numerical increase in serum T-AOC from d 21 to 42 compared to pigs fed sodium selenite or selenium yeast. Additionally, there was a marginally significant increase in T-AOC over time ($P = 0.089$). There was no evidence of a source × day, source, or day effect for TBARS ($P > 0.10$).

In summary, compared to sodium selenite and selenium yeast, pigs fed OH-SeMet had greater bioavailability as indicated by increased serum and tissue selenium concentration. However, antioxidant status was similar between treatments and OH-SeMet showed a lower ADFI and consequently a lower ADG in the early phase compared with pigs fed sodium selenite. When the overall trial period is considered, no selenium source effect on ADG, F/G, and d 42 BW was detected between treatments. In this experiment, which used a common pelleted starter diet based on a feed budget, there was a marginally significant difference observed in ADFI from d 0 to 7, which approximately

corresponds with the feeding duration of the common diet. Subsequently, there was a health challenge with *S. suis* which required administration of water soluble antimicrobials across all treatment groups. This observed reduction in ADFI is not consistent with previous research with OH-SeMet; therefore, additional research is needed to characterize the results further under commercial conditions.

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Table 1. Diet composition, (as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3
Ingredients, %			
Corn	35.00	60.64	62.90
Soybean meal (46.5% CP)	21.90	30.27	31.34
Dried whey	25.00	---	---
Soft red wheat	5.00	---	---
Enzymatically treated soybean meal[2]	5.00	2.50	---
Corn oil	3.50	1.50	1.50
Calcium carbonate	0.83	1.10	1.05
Monocalcium phosphate	0.90	1.10	0.95
Sodium chloride	0.35	0.50	0.35
L-Lys-HCl	0.50	0.50	0.45
DL-Met	0.33	0.28	0.21
Thr source[3]	0.26	0.33	0.28
L-Trp	0.08	0.06	0.05
L-Val	0.21	0.15	0.10
Phytase[4]	0.05	0.10	0.10
Choline chloride	0.04	---	---
Vitamin premix[5]	0.05	0.05	0.05
Sodium metabisulfite	0.50	0.50	0.50
Zinc oxide	0.38	0.26	---
Copper sulfate	---	0.03	0.03
Trace mineral premix[6]	0.10	0.10	0.10
Selenium source[7]	0.05	0.05	0.05
Total	100.00	100.00	100.00

continued

Table 1. Diet composition, (as-fed basis)[1]

Item	Phase 1	Phase 2	Phase 3
Calculated analysis			
SID AA, %			
Lys	1.42	1.38	1.30
Ile:Lys	55	56	57
Leu:Lys	105	113	117
Met:Lys	42	40	38
Met and Cys:Lys	62	61	59
Thr:Lys	66	65	65
Trp:Lys	21.8	20.7	20.2
Val:Lys	72	71	69
His:Lys	32	36	37
Net energy, kcal/lb	1,192	1,120	1,128
CP, %	20.6	21.9	21.0
Ca, %	0.74	0.75	0.70
STTD P, %	0.59	0.50	0.47

[1]Corn, soybean meal, HP300 (Hamlet Protein Inc., Findlay, OH), sodium selenite, selenium yeast, and hydroxy-selenomethionine (OH-SeMet) were analyzed for selenium concentration prior to the study at Michigan State University Veterinary Diagnostic Laboratory (East Lansing, MI). Analyzed selenium concentration: corn (0.06 ppm), soybean meal (0.275 ppm), HP300 (0.321 ppm), sodium selenite (640.1 ppm), selenium yeast (648.8 ppm), and OH-SeMet (657.8 ppm). Basal selenium concentration was calculated based on ingredient sample analysis prior to the study for corn, soybean meal, and HP300 at the MSU VDL, and selenium concentration for dried whey and wheat were from NRC (2012). The basal selenium concentration for phase 1, 2, and 3 were 0.141, 0.128, and 0.124 ppm respectively. All diets had 0.3 ppm added selenium from either selenium sources. (National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. doi: 10.17226/13298.)

[2]HP300 (Hamlet Protein Inc., Findlay, OH) is an enzyme-treated soybean meal.

[3]L-Threonine was used in phase 1 diet, and Thr pro Biomass (CJ Bio America, Fort Dodge, IA) was used in phase 2 and 3 diets.

[4]Quantum Blue 5G (AB Vista, Plantation, FL) was used in phase 1 diet and provided 1,986 FTU per lb of diet with an expected STTD P release of 0.13%. Quantum Blue 2G was used in phase 2 and 3 diets, and provided 908 FTU per lb of diet with an expected STTD P release of 0.14%.

[5]Vitamin premix (Hord Family Farms, Bucyrus, OH) provided per lb of diet: 2,500 IU vitamin A; 750 IU vitamin D; 30 IU vitamin E; 1.5 mg vitamin K; 0.015 mg vitamin B_{12}; 11.25 mg niacin; 12.5 mg pantothenic acid; 3.75 mg riboflavin; 0.1 mg biotin; 1.0 mg folic acid; and 0.45 mg pyridoxine.

[6]Trace mineral premix (SEM Minerals, L.P., Quincy, IL) didn't contain selenium and provided per lb of diet: 73.03 mg Zn, 60.78 mg Fe, 19.05 mg Mn, 6.35 mg Cu, 0.30 mg Cl, and 4.08 µg Cr.

[7]Sodium selenite was used in phase 1 diet as the added selenium source. Sodium selenite, selenium yeast, and OH-SeMet were used as the added selenium source in phase 2 and 3 diets as 3 dietary treatments. Feed samples were collected from at least 6 feeders per treatment per phase, pooled, and subsampled for selenium concentration (MSU VDL) and crude protein (Kansas State University Swine Nutrition Laboratory, Manhattan, KS). Phase 1 diet had 18.6% CP and 0.514 ppm Se. Phase 2 diets had 19.9, 20.5, and 20.5% CP, and 0.552, 0.588, and 0.616 ppm Se for diets with sodium selenite, selenium yeast, and OH-SeMet, respectively. Phase 3 diets had 19.0, 19.8, and 19.0% CP, and 0.414, 0.548, and 0.549 ppm Se for diets with sodium selenite, selenium yeast, and OH-SeMet, respectively.

Table 2. Evaluation of selenium source on nursery pig growth performance[1,2]

	Sodium selenite	Selenium yeast	OH-SeMet	SEM	*P* =
d 0 to 7 (pre-trial)[3]					
d 0 BW, lb	13.1	13.1	13.1	0.10	0.979
d 7 BW, lb	14.6	14.6	14.6	0.18	0.485
ADG, lb	0.21	0.21	0.21	0.014	0.367
ADFI, lb	0.24	0.23	0.22	0.008	0.097
F/G	1.17	1.15	1.15	0.047	0.792
d 7 to 21					
d 21 BW, lb	28.1	28.1	27.8	≤ 0.15	0.121
ADG, lb	0.96[a]	0.95[a]	0.93[b]	≤ 0.007	0.003
ADFI, lb	1.08[a]	1.08[a]	1.06[b]	≤ 0.007	0.015
F/G	1.13	1.13	1.13	≤ 0.006	0.557
d 21 to 42					
d 42 BW, lb	59.3	58.9	58.8	≤ 0.24	0.312
ADG, lb	1.48	1.46	1.47	≤ 0.010	0.328
ADFI, lb	2.11	2.07	2.08	≤ 0.017	0.176
F/G	1.42	1.42	1.42	≤ 0.006	0.367
d 7 to 42					
ADG, lb	1.27[x]	1.26[xy]	1.25[y]	≤ 0.007	0.066
ADFI, lb	1.70	1.67	1.67	≤ 0.011	0.100
F/G	1.33	1.33	1.33	≤ 0.004	0.566
d 0 to 42					
ADG, lb	1.09	1.08	1.07	≤ 0.006	0.110
ADFI, lb	1.45[x]	1.43[xy]	1.42[y]	≤ 0.009	0.090
F/G	1.33	1.32	1.33	≤ 0.004	0.449
Treatments, %[4]	10.0	9.6	11.6	1.45	0.424
Removal, %[5]	2.60	2.60	2.90	≤ 0.516	0.145
Mortality, %[6]	0.39	0.46	0.54	≤ 0.204	0.166
Removal with mortality, %[7]	3.11	3.19	3.57	≤ 0.538	0.244

[1]A total of 3,888 pigs (initially 13.1 ± 0.10 lb) were used with 54 pigs per replicate and 24 replicates per treatment. All pigs were fed 1.5 lb per pig of the phase 1 common starter pellet that contained 0.3 ppm of added selenium from sodium selenite for approximately 7 d. Phase 2 and phase 3 treatment diets were fed after pigs finished the phase 1 feed budget. All treatment diets provided 0.3 ppm added selenium.

[2]BW = body weight. ADG = average daily gain. ADFI = average daily feed intake. F/G = feed-to-gain ratio.

[3]Day 0 to 7 ADFI was used as a covariate for growth performance in subsequent periods and overall growth performance.

[4]The number of injectable treatments given when pigs were on treatment diets divided by the number of pigs on d 0.

[5]The number of pigs removed based on body condition, lameness, and health status when they were on treatment diets divided by the number of pigs on d 0.

[6]The number of pigs found dead when they were on treatment diets divided by the number of pigs on d 0.

[7]The number of pigs removed or dead when they were on treatment diets divided by the number of pigs on d 0.

[a,b] Means within a row with different superscripts differ ($P \leq 0.05$).

[x,y] Means within a row with different superscripts differ ($0.05 < P \leq 0.10$).

Table 3. Evaluation of selenium source on nursery pig serum and tissue selenium concentrations and serum antioxidant status[1]

					P =		
	Sodium selenite	Selenium yeast	OH-SeMet	SEM	Source × day	Source	Day
Serum selenium, ng/mL[2]					0.072	0.002	< 0.0001
d 21	130.9[cd]	121.8[d]	138.8[c]	≤ 3.72			
d 42	183.7[b]	183.8[b]	204.6[a]	≤ 3.72			
Liver selenium, µg/g					---	< 0.0001	---
d 42	1.97[b]	1.99[b]	2.45[a]	0.049			
Muscle selenium, µg/g					---	< 0.0001	---
d 42	0.81[b]	0.87[b]	1.42[a]	0.024			
Serum GSH-Px, nmol/min/mL[3]					0.710	0.971	0.074
d 21	868.9	888.1	880.6	≤ 128.51			
d 42	1,268.2	1,210.2	1,238.9	≤ 128.51			
Serum T-AOC, CRE[4]					0.027	0.306	0.089
d 21	359.0	388.9	384.6	≤ 22.93			
d 42	439.7	469.7	416.8	≤ 22.93			
TBARS, µM MDA[5]					0.262	0.177	0.781
d 21	5.92	5.25	6.34	0.97			
d 42	5.52	4.28	4.58	0.97			

[1]A total of 3,888 pigs (initially 13.1 ± 0.10 lb) were used with 54 pigs per replicate and 24 replicates per treatment. All pigs were fed 1.5 lb per pig of the phase 1 common starter pellet that contained 0.3 ppm of added selenium from sodium selenite for approximately 7 d. Phase 2 and phase 3 treatment diets were fed after pigs finished the phase 1 feed budget. All treatment diets provided 0.3 ppm added selenium. Selenium concentration for serum, liver, and muscle was analyzed at the Michigan State University Veterinary Diagnostic Laboratory.

[2]Day 0 serum samples were collected when all pigs were fed the phase 1 common diet and averaged 125 ng/mL across all treatments. Day 0 serum selenium concentration was only used as a covariate for statistical analysis of d 21 and 42 serum selenium concentration as repeated measurement.

[3]GSH-Px = Glutathione peroxidase. One unit is defined as the amount of enzyme that causes the oxidation of 1.0 nmol of NADPH to $NADP^+$ per minute at 77°F.

[4]T-AOC = Total antioxidant capacity. CRE = µM Copper Reducing Equivalents.

[5]Thiobarbituric acid reactive substances. µM of MDA (malondialdehyde) equivalent.

[a,b,c,d] Means within a response with different superscripts differ ($P \leq 0.05$).