

Effects of Dietary Glycine Nano-Selenium Supplementation on Antioxidant Capacity and Selenium Content in Serum, Tissues and Organs of Finishing Pigs

Authors: Dai Wuzhou, Hu Xiaolong, Yunlin Zheng, Hong Zuopeng

Date: 2018-12-24T00:00:00+00:00

Abstract

This study aimed to investigate the effects of dietary supplementation with glycine nano-selenium on antioxidant capacity and selenium content in serum, tissues, and organs of finishing pigs. One hundred sixty Duroc × Landrace × Yorkshire crossbred finishing pigs with an approximate body weight of 70 kg were randomly allocated into 4 groups, with 4 replicates per group and 10 pigs per replicate. The control group was fed a basal diet, while the experimental groups were fed test diets supplemented with 0.1, 0.3, and 0.5 mg/kg (as selenium) of glycine nano-selenium, respectively. The experiment consisted of a 5-day preliminary period and a 60-day formal experimental period. The results showed: 1) The 0.1 mg/kg glycine nano-selenium group exhibited significantly higher glutathione peroxidase activity in liver, kidney, pancreas, and heart, as well as serum total antioxidant capacity and superoxide dismutase activity, compared with the control group ($P < 0.05$). 2) Compared with the control group, dietary supplementation of 0.3 and 0.5 mg/kg glycine nano-selenium extremely significantly increased glutathione peroxidase activity in serum, muscle, liver, kidney, pancreas, and heart ($P < 0.01$), while simultaneously extremely significantly decreasing malondialdehyde content in serum, muscle, liver, kidney, pancreas, and heart ($P < 0.01$); furthermore, dietary supplementation of 0.3 mg/kg glycine nano-selenium also extremely significantly increased superoxide dismutase and catalase activities in the liver ($P < 0.01$); dietary supplementation of 0.5 mg/kg glycine nano-selenium also extremely significantly increased total antioxidant capacity and superoxide dismutase activity in the pancreas and heart ($P < 0.01$). 3) The 0.1, 0.3, and 0.5 mg/kg glycine nano-selenium groups showed extremely significantly higher selenium content in serum, muscle, liver, kidney, pancreas, and heart of finishing pigs compared with the control group ($P < 0.01$). In conclusion, dietary supplementation of glycine nano-selenium can enhance

the antioxidant capacity and selenium content in serum, tissues, and organs of finishing pigs, with the best effect observed at the supplementation level of 0.5 mg/kg.

Full Text

Effects of Glycine Nanoselenium Supplementation on Antioxidant Capacity and Selenium Content in Serum, Tissues and Organs of Finishing Pigs

DAI Wuzhou¹, HU Xiaolong¹, ZHENG Yunlin¹, HONG Zuopeng²

¹College of Animal Science and Technology, Jiangxi Agricultural University, Nanchang 330045, China;

²Zhejiang Weifeng Bio-Technology Co., Ltd., Jiande 311600, China

Abstract

This experiment was conducted to investigate the effects of dietary glycine nanoselenium supplementation on antioxidant capacity and selenium content in serum, tissues and organs of finishing pigs. One hundred and sixty Duroc × Landrace × Yorkshire crossbred finishing pigs with an average body weight of approximately 70 kg were randomly allocated into four groups, with four replicates per group and ten pigs per replicate. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 0.1, 0.3, or 0.5 mg/kg of glycine nanoselenium (expressed as selenium). The experiment consisted of a 5-day preliminary period followed by a 60-day formal trial period. The results demonstrated: (1) The 0.1 mg/kg glycine nanoselenium group exhibited significantly higher glutathione peroxidase activity in liver, kidney, pancreas and heart, as well as enhanced total antioxidant capacity and superoxide dismutase activity in serum compared to the control group ($P < 0.05$). (2) Compared with the control group, dietary supplementation with 0.3 and 0.5 mg/kg glycine nanoselenium significantly increased glutathione peroxidase activity in serum, muscle, liver, kidney, pancreas and heart ($P < 0.01$), while concurrently decreasing malondialdehyde content in these same tissues ($P < 0.01$). Additionally, 0.3 mg/kg supplementation significantly elevated superoxide dismutase and catalase activities in liver ($P < 0.01$), whereas 0.5 mg/kg supplementation significantly increased total antioxidant capacity and superoxide dismutase activity in pancreas and heart ($P < 0.01$). (3) Selenium concentrations in serum, muscle, liver, kidney, pancreas and heart were significantly higher in all glycine nanoselenium-supplemented groups compared to the control group ($P < 0.01$). These findings indicate that dietary glycine nanoselenium supplementation can enhance antioxidant capacity and selenium content in serum, tissues and organs of finishing pigs, with the optimal supplementation level being 0.5 mg/kg.

Keywords: finishing pigs; glycine nanoselenium; antioxidant capacity; glutathione peroxidase

Introduction

Selenium (Se) is an essential trace element for both humans and animals, playing critical roles in maintaining redox homeostasis, protecting immune function, improving reproductive performance, and preventing cancer. Selenium deficiency can lead to various pathological conditions, including impaired mobility, unsteady standing, and white muscle disease in piglets, as well as exudative diathesis and white muscle disease in chickens. Selenium exerts its antioxidant function through selenoproteins that act on antioxidant enzymes, with glutathione peroxidase (GSH-Px) being the most important antioxidant enzyme in animal bodies. Through interaction with selenoproteins, GSH-Px specifically catalyzes the reduction of glutathione and eliminates toxic peroxides, thereby protecting cells, tissues and organs from oxidative damage. However, selenium also exhibits toxicity at high concentrations, making the development of low-toxicity, high-efficiency selenium sources and determination of optimal supplementation levels a persistent research focus in animal nutrition.

Nanoselenium is a nano-scale elemental selenium with particle size generally not exceeding 100 nm. Compared with inorganic selenium, nanoselenium offers advantages including higher biological activity, lower toxicity, improved absorption and utilization, and better deposition efficiency, suggesting its potential to replace inorganic selenium in feed applications. Previous research has demonstrated that nanoselenium supplementation in finishing pigs yields superior effects on antioxidant function and selenium deposition compared to organic and inorganic selenium sources. Studies have confirmed the positive effects of nanoselenium on growth performance, muscle quality, selenium content, immune function, thyroid function, and antioxidant indices in piglets and finishing pigs. Glycine nanoselenium (G-SeNPs) is a novel selenium source using glycine as a nanoselenium modification carrier, characterized by stable physicochemical properties, good flowability, and absence of agglomeration. However, research on its effects on antioxidant capacity and tissue selenium content in finishing pigs remains limited. Therefore, this study utilized Duroc × Landrace × Yorkshire finishing pigs to investigate the effects of different glycine nanoselenium supplementation levels on antioxidant capacity and selenium content in serum and tissues, providing theoretical guidance for future widespread application of glycine nanoselenium in finishing pig diets.

Materials and Methods

1.1 Experimental Materials and Basal Diet

Glycine nanoselenium (feed grade) with an average particle size of 60 nm was provided by Zhejiang Jiande Weifeng Feed Co., Ltd., containing 1% selenium. Glycine nanoselenium is a composite with glycine as the modifier and dispersant and nanoselenium as the coating, appearing as a reddish-brown powder with no odor but a characteristic sweet taste of glycine, and is hygroscopic and water-soluble. When used as a feed additive, glycine nanoselenium exists as solid

particles; upon dissolution in water, glycine completely dissolves and elemental selenium returns to nano-scale, forming spherical suspensions in solution.

The basal diet was a corn-soybean meal-based powder formulated according to NRC (2012) standards. The composition and nutrient levels of the basal diet are presented in Table 1 .

Table 1 Composition and nutrient levels of the basal diet (air-dry basis)

Item	Content
Ingredients	
Corn	
Soybean meal	
Wheat bran	
Premix ¹	
Total	
Nutrient levels	
Metabolizable energy (MJ/kg) ²	
Crude protein	
Available phosphorus	
Methionine	
Lysine	
Selenium (mg/kg)	

¹The premix provided the following per kg of diet: VA 1,625 IU, VD 400 IU, VE 7.5 IU, VK 0.5 mg, VB 0.75 mg, VB 1 mg, VB 0.5 mg, VB 5 g, pantothenic acid 3 mg, nicotinamide 5 mg, biotin 25 g, folic acid 0.25 mg, Fe 120 mg, Zn 103.5 mg, Mn 41.34 mg, I 0.5 mg, Co 0.2 mg.

²Metabolizable energy was a calculated value; others were measured values.

1.2 Experimental Design

One hundred and sixty Duroc × Landrace × Yorkshire crossbred finishing pigs with an average body weight of approximately 70 kg were randomly divided into four groups with four replicates per group and ten pigs per replicate, with equal numbers of barrows and gilts in each replicate. Group 1 served as the control group receiving the basal diet without any selenium source, while the remaining three groups received the basal diet supplemented with 0.1, 0.3, or 0.5 mg/kg glycine nanoselenium (expressed as selenium). The trial was conducted at Zhengxin Animal Husbandry Co., Ltd. in Huzhou City, Zhejiang Province from September to November 2015. The experiment included a 5-day preliminary period followed by a 60-day formal trial period.

1.3 Sample Collection

Feed was withheld for 24 hours before the end of the trial, though water was provided ad libitum. Based on similar body weight principles, two pigs (one barrow and one gilt) were selected from each replicate, totaling 32 pigs. Blood samples were collected via anterior vena cava puncture, allowed to clot for 30 minutes at 37°C, then centrifuged at 3,000 rpm for 10 minutes. Serum was aspirated into 1.5 mL centrifuge tubes and stored at -70°C until analysis.

Following blood collection, pigs were slaughtered to obtain muscle, liver, heart, kidney, and pancreas samples. Muscle samples (approximately 100 g) were collected from the left carcass at the last rib. Liver samples (approximately 20 g) were taken from the middle of hepatic lobules. Kidney samples (approximately 20 g) were collected from the left kidney. Heart and pancreas samples (each approximately 20 g) were also obtained. All tissue samples were wrapped in aluminum foil, snap-frozen in liquid nitrogen, and subsequently transferred to -70°C storage until analysis.

1.4 Analytical Methods

1.4.1 Determination of Antioxidant Indices in Serum and Tissues

Total antioxidant capacity (T-AOC) and activities of glutathione peroxidase (GSH-Px), superoxide dismutase (SOD), catalase (CAT), and malondialdehyde (MDA) content in serum and tissues were determined strictly according to kit instructions (Nanjing Jiancheng Bioengineering Institute) using a SpectraMax MS microplate reader or UV-2000 UV-Vis spectrophotometer.

1.4.2 Determination of Selenium Content in Serum One hundred microliters of serum sample were placed in a glass test tube, mixed with 1 mL each of 50% (v/v) hydrochloric acid solution and mixed acid solution (5% thiourea + 5% ascorbic acid), and reacted for 15 minutes before being diluted to volume with ultrapure water. Selenium content was measured using an AFS-3100 dual-channel atomic fluorescence spectrophotometer (Hangzhou Demao Technology Co., Ltd.).

1.4.3 Determination of Selenium Content in Tissues After blotting dry, 0.2 g of tissue sample was weighed into a microwave digestion vessel, mixed with 1 mL H₂O, sealed, and digested until a colorless transparent solution was obtained. The solution was then evaporated for approximately 30 minutes, diluted to volume with ultrapure water, and mixed. Two milliliters of this solution were transferred to a test tube, mixed with 1 mL each of 50% (v/v) hydrochloric acid and mixed acid solution (5% thiourea + 5% ascorbic acid), reacted for 15 minutes, diluted to volume with ultrapure water, and analyzed using an AFS-3100 dual-channel atomic fluorescence spectrophotometer (Hangzhou Demao Technology Co., Ltd.).

1.5 Statistical Analysis

All measured indices were expressed as mean values without considering gender differences, with each group serving as a statistical unit (n=4). One-way ANOVA was used to compare the effects of different nanoselenium supplementation levels on various parameters, with LSD post-hoc test for multiple comparisons. All analyses were performed using SPSS 20.0 (IBM). Significance level was set at $P < 0.05$ and highly significant level at $P < 0.01$.

Results

2.1 Serum Antioxidant Indices

As shown in Table 2, dietary glycine nanoselenium supplementation exerted highly significant effects on serum T-AOC, GSH-Px, SOD and CAT activities, and MDA content in finishing pigs ($P < 0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg glycine nanoselenium increased serum T-AOC by 7.07% ($P < 0.05$), 16.03% ($P < 0.01$), and 20.25% ($P < 0.01$), respectively. Supplementation with 0.3 and 0.5 mg/kg significantly elevated serum GSH-Px activity by 15.02% ($P < 0.01$) and 15.39% ($P < 0.01$), SOD activity by 7.89% ($P < 0.01$) and 12.93% ($P < 0.01$), and CAT activity by 23.24% ($P < 0.01$) and 25.04% ($P < 0.01$), respectively, while decreasing serum MDA content by 9.06% ($P < 0.01$) and 16.37% ($P < 0.01$). Linear analysis revealed that serum T-AOC and activities of GSH-Px, SOD, and CAT were positively correlated with glycine nanoselenium supplementation level ($P < 0.01$), whereas serum MDA content was negatively correlated ($P < 0.01$).

Table 2 Effects of G-SeNPs supplementation on antioxidant indices in serum of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P-value	Linear effect	Quadratic effect
T-AOC (U/mL)	1.54Aa	1.65Ab	1.79Bc	1.85Bc	<0.001	<0.001	
GSH-Px (U/mL)	663.81Aa	691.58Aa	763.54Bb	765.99Bb	<0.001	<0.001	
SOD (U/mL)	125.23Aa	131.58ABa	135.11BCb	141.41Cc	<0.001	<0.001	
CAT (U/mL)	3.95Aa	4.15Aa	4.87Bb	4.94Bb	<0.001	<0.001	
MDA (nmol/mL)	5.93Aa	5.60ABa	5.39BCb	4.96Cc	<0.001	<0.001	

In the same row, values with no letter or the same letter superscripts indicate

no significant difference ($P>0.05$), different lowercase letters indicate significant difference ($P<0.05$), and different uppercase letters indicate highly significant difference ($P<0.01$). The same applies below.

2.2 Muscle Antioxidant Indices

As shown in Table 3, dietary glycine nanoselenium supplementation significantly affected muscle GSH-Px and SOD activities and MDA content ($P<0.01$). Compared with the control group, supplementation with 0.3 and 0.5 mg/kg glycine nanoselenium increased muscle GSH-Px activity by 13.35% ($P<0.01$) and 15.33% ($P<0.01$), and SOD activity by 8.97% ($P<0.05$) and 12.9% ($P<0.05$), respectively, while decreasing muscle MDA content by 40.75% ($P<0.01$) and 38.49% ($P<0.01$). Linear analysis indicated that muscle GSH-Px and SOD activities were positively correlated with glycine nanoselenium supplementation level ($P<0.01$), whereas muscle MDA content was negatively correlated ($P<0.01$).

Table 3 Effects of G-SeNPs supplementation on antioxidant indices in muscle of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P- value	Linear effect	Quadratic effect
T-AOC (U/mg prot)	106.92Aa	111.53ABa	121.19Bb	123.31Bb	<0.001		
GSH-Px (U/mg prot)	87.38Aa	91.18ABa	95.22ABb	98.66Bc	<0.001		
SOD (U/mg prot)	0.80Aa	0.62Aa	0.47Bb	0.43Cc	<0.001	<0.001	
MDA (nmol/mg prot)							

2.3 Liver Antioxidant Indices

As shown in Table 4, dietary glycine nanoselenium supplementation significantly influenced liver GSH-Px, SOD, and CAT activities, as well as MDA content ($P<0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg increased liver GSH-Px activity by 8.51% ($P<0.01$),

22.10% ($P < 0.01$), and 29.38% ($P < 0.01$), respectively, and decreased liver MDA content by 7.49% ($P < 0.01$), 14.15% ($P < 0.01$), and 15.36% ($P < 0.01$), respectively. Supplementation with 0.3 mg/kg increased liver SOD activity by 5.35% ($P < 0.01$), while 0.5 mg/kg supplementation increased liver CAT activity by 15.57% ($P < 0.05$). Linear analysis revealed that liver GSH-Px, SOD, and CAT activities were positively correlated with glycine nanoselenium supplementation level ($P < 0.01$), whereas liver MDA content was negatively correlated ($P < 0.01$).

Table 4 Effects of G-SeNPs supplementation on antioxidant indices in liver of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P-value	Linear effect	Quadratic effect
T-AOC (U/mg prot)	1.03a	1.06b	1.11ab	1.13b			
GSH-Px (U/mg prot)	116.91Aa	126.86Bb	142.74Cc	151.26Dd	<0.001	<0.001	
SOD (U/mg prot)	296.69Aa	299.23ABa	312.55Bb	309.09ABb	<0.001		
CAT (U/mg prot)	66.49Aa	68.84ABa	72.52BCb	76.84Cb	<0.001	<0.001	
MDA (nmol/mg prot)	4.14Aa	3.83Bb	3.56BCc	3.51Cc	<0.001	<0.001	

2.4 Kidney Antioxidant Indices

As shown in Table 5, dietary glycine nanoselenium supplementation significantly affected kidney T-AOC, GSH-Px activity, and MDA content ($P < 0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg increased kidney GSH-Px activity by 5.34% ($P < 0.05$), 12.47% ($P < 0.01$), and 16.98% ($P < 0.01$), respectively. Supplementation with 0.3 and 0.5 mg/kg increased kidney T-AOC by 10.16% ($P < 0.01$) and 11.32% ($P < 0.01$), SOD activity by 3.95% ($P < 0.05$) and 4.59% ($P < 0.05$), respectively, while decreasing kidney MDA content by 8.91% ($P < 0.01$) and 10.04% ($P < 0.01$), respectively. Supplementation with 0.5 mg/kg increased kidney CAT activity by 8.80% ($P < 0.05$). Linear analysis indicated that kidney T-AOC and GSH-Px activity were positively correlated with glycine nanoselenium supplementation level ($P < 0.01$), whereas kidney MDA content was negatively correlated ($P < 0.01$).

Table 5 Effects of G-SeNPs supplementation on antioxidant indices in kidney of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P- value	Linear effect	Quadratic effect
T-AOC (U/mg prot)	0.43Aa	0.45ABab	0.48Bbc	0.48Bc	<0.001		
GSH-Px (U/mg prot)	338.59Aa	356.68Ab	380.82Bc	396.09Bc	<0.001	<0.001	
SOD (U/mg prot)	468.61a	477.20ab	487.10b	490.14b	<0.001		
CAT (U/mg prot)	56.87a	58.31ab	59.89ab	61.87b	<0.001		
MDA (nmol/mg prot)	1.77Aa	1.70ABab	1.62Bb	1.60Bb	<0.001		

2.5 Pancreas Antioxidant Indices

As shown in Table 6, dietary glycine nanoselenium supplementation significantly influenced pancreas T-AOC, GSH-Px activity, CAT activity, and MDA content ($P < 0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg increased pancreas T-AOC by 13.70% ($P < 0.01$), 15.25% ($P < 0.01$), and 18.86% ($P < 0.01$), respectively, and increased pancreas GSH-Px activity by 6.79% ($P < 0.05$), 13.84% ($P < 0.01$), and 23.01% ($P < 0.01$), respectively. Supplementation with 0.3 and 0.5 mg/kg increased pancreas CAT activity by 10.52% ($P < 0.01$) and 10.98% ($P < 0.01$), respectively, while decreasing pancreas MDA content by 13.68% ($P < 0.01$) and 18.87% ($P < 0.01$), respectively. Linear analysis revealed that pancreas T-AOC, GSH-Px activity, and CAT activity were positively correlated with glycine nanoselenium supplementation level ($P < 0.01$), whereas pancreas MDA content was negatively correlated ($P < 0.01$).

Table 6 Effects of G-SeNPs supplementation on antioxidant indices in pancreas of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P- value	Linear effect	Quadratic effect
T- AOC (U/mg prot)	0.39Aa	0.44Bb	0.45Bbc	0.46Bc	<0.001	<0.001	
GSH- Px (U/mg prot)	175.06Aa	186.94AB	199.28Bc	215.33Cd	<0.001	<0.001	
SOD (U/mg prot)							
CAT (U/mg prot)	4.12Aa	4.30ABa	4.55Bb	4.57Bb	<0.001		
MDA (nmol/mg prot)	0.42Aa	0.39ABab	0.37BCb	0.34Cc	<0.001	<0.001	

2.6 Heart Antioxidant Indices

As shown in Table 7, dietary glycine nanoselenium supplementation significantly affected heart T-AOC, GSH-Px activity, SOD activity, CAT activity, and MDA content ($P < 0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg increased heart T-AOC by 5.48% ($P < 0.05$), 6.62% ($P < 0.01$), and 10.73% ($P < 0.01$), respectively; increased heart GSH-Px activity by 12.17% ($P < 0.01$), 39.77% ($P < 0.01$), and 49.49% ($P < 0.01$), respectively; increased heart CAT activity by 7.59% ($P < 0.01$), 10.09% ($P < 0.01$), and 18.05% ($P < 0.01$), respectively; and decreased heart MDA content by 15.34% ($P < 0.01$), 28.01% ($P < 0.01$), and 45.82% ($P < 0.01$), respectively. Supplementation with 0.3 and 0.5 mg/kg increased heart SOD activity by 7.54% ($P < 0.05$) and 11.62% ($P < 0.01$), respectively. Linear analysis revealed that heart T-AOC, GSH-Px activity, SOD activity, and CAT activity were positively correlated with glycine nanoselenium supplementation level ($P < 0.01$), whereas heart MDA content was negatively correlated ($P < 0.01$).

Table 7 Effects of G-SeNPs supplementation on antioxidant indices in heart of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P- value	Linear effect	Quadratic effect
T- AOC (U/mg prot)	0.44Aa	0.46ABb	0.47Bbc	0.49Bc	<0.001		
GSH- Px (U/mg prot)	134.72Aa	151.11Bb	188.29Cc	201.38Cd	<0.001	<0.001	
SOD (U/mg prot)	189.42Aa	196.40Aa	203.71ABb	211.42Bc	<0.001		
CAT (U/mg prot)	5.04Aa	5.42Bb	5.54Bb	5.95Cc	<0.001	<0.001	
MDA (nmol/mg prot)	1.90Aa	1.61Bb	1.37Cc	1.03Dd	<0.001	<0.001	

2.7 Selenium Content in Serum and Tissues

As shown in Table 8, dietary glycine nanoselenium supplementation significantly affected selenium content in serum and tissues ($P < 0.01$). Compared with the control group, supplementation with 0.1, 0.3, and 0.5 mg/kg increased serum selenium content by 79.23% ($P < 0.01$), 169.97% ($P < 0.01$), and 210.97% ($P < 0.01$), respectively; increased muscle selenium content by 3.30% ($P < 0.05$), 5.61% ($P < 0.01$), and 16.50% ($P < 0.01$), respectively; increased heart selenium content by 6.92% ($P < 0.01$), 22.68% ($P < 0.01$), and 36.69% ($P < 0.01$), respectively; increased liver selenium content by 15.31% ($P < 0.01$), 31.82% ($P < 0.01$), and 46.62% ($P < 0.01$), respectively; increased pancreas selenium content by 9.27% ($P < 0.01$), 15.23% ($P < 0.01$), and 24.69% ($P < 0.01$), respectively; and increased kidney selenium content by 18.8% ($P < 0.01$), 31.35% ($P < 0.01$), and 37.4% ($P < 0.01$), respectively. Highly significant differences in selenium content among different supplementation levels were observed in serum and all organs (heart, liver, pancreas, kidney) ($P < 0.01$). Linear analysis demonstrated that selenium content in serum and tissues was positively correlated with glycine nanoselenium supplementation level ($P < 0.01$).

Table 8 Effects of G-SeNPs supplementation on selenium content in serum, tissues and organs of finishing pigs (n=4)

Item	0 mg/kg	0.1 mg/kg	0.3 mg/kg	0.5 mg/kg	P- value	Linear effect	Quadratic effect
Serum (g/mL)	0.0939Aa	0.1683Bb	0.2535Cc	0.2920Dd	<0.001	<0.001	
Muscle	0.0303Aa	0.0313AB	0.0320Bb	0.0353Cc	<0.001	<0.001	
Heart	0.1142Aa	0.1221Bb	0.1401Cc	0.1561Dd	<0.001	<0.001	
Liver	0.1169Aa	0.1348Bb	0.1541Cc	0.1714Dd	<0.001	<0.001	
Pancreas	0.3151Aa	0.3443Bb	0.3631Cc	0.3929Dd	<0.001	<0.001	
Kidney	0.5760Aa	0.6843Bb	0.7566Cc	0.7914Dd	<0.001	<0.001	

Discussion

3.1 Effects of Glycine Nanoselenium on Serum Antioxidant Capacity in Finishing Pigs

Free radicals are continuously produced in animal bodies, with oxygen radicals being particularly active and abundant. Under normal conditions, oxygen radicals do not cause harm, but excessive oxygen radicals can damage cells through lipid peroxidation, affecting normal physiological functions, disrupting homeostasis, and compromising animal health. Animals possess endogenous antioxidant defense systems comprising enzymatic and non-enzymatic components. Enzymatic components primarily include SOD, CAT, and GSH-Px, while non-enzymatic components mainly consist of vitamins C, A, and E. The activity levels of these enzymatic antioxidants indirectly reflect the overall antioxidant capacity of the organism. This study demonstrated that dietary glycine nanoselenium supplementation significantly increased serum antioxidant capacity in finishing pigs in a dose-dependent linear manner, with the most pronounced effects observed at 0.5 mg/kg supplementation.

3.2 Effects of Glycine Nanoselenium on Muscle Antioxidant Capacity in Finishing Pigs

Through long-term genetic selection, swine production performance and lean meat percentage have improved substantially, yet the frequent occurrence of poor-quality meat causes significant economic losses. Pork quality is influenced by multiple intrinsic and extrinsic factors, including genetics, nutrition, transportation, and slaughter methods, with lipid peroxidation being a critical factor affecting meat quality. Research indicates that unsaturated fatty acids on muscle cell membranes are highly susceptible to oxidation by oxygen radicals, which disrupts cell membrane integrity, increases myoglobin loss, and consequently reduces meat quality. Studies in broilers have shown that dietary supplementation with 0.3 mg/kg selenium yeast significantly increases muscle SOD activity and decreases muscle MDA content. Similarly, supplementation with 0.3 mg/kg selenium yeast in growing-finishing pigs has been reported to enhance muscle SOD and GSH-Px activities while reducing MDA content. The present study demon-

strated that glycine nanoselenium supplementation increased muscle CAT, GSH-Px, and SOD activities and T-AOC while decreasing MDA content, indicating that glycine nanoselenium enhances muscle antioxidant capacity and may help prevent rapid deterioration of meat quality.

3.3 Effects of Glycine Nanoselenium on Organ Antioxidant Capacity in Finishing Pigs

Selenium is an essential trace element that scavenges excess free radicals, thereby enhancing antioxidant capacity, preventing cellular and tissue damage from lipid peroxidation, and maintaining animal health. The liver and kidney are not only vital detoxification organs but also primary sites for selenium metabolism. As an essential component of the antioxidant enzyme GSH-Px, dietary selenium content significantly influences antioxidant enzyme activity in tissues. Studies have shown that selenium-deficient diets decrease endogenous antioxidant enzyme activity, compromising overall antioxidant capacity. Research in rats has demonstrated that dietary supplementation with 0.2 mg/kg nanoselenium increases SOD, GSH-Px, and CAT activities in liver, kidney, and heart while reducing MDA content. The current study found that all three glycine nanoselenium supplementation levels increased SOD, GSH-Px, CAT activities, and T-AOC in heart, kidney, liver, and pancreas to varying degrees, while decreasing MDA content in these organs. These results collectively demonstrate that dietary glycine nanoselenium supplementation improves antioxidant capacity in various organs of finishing pigs, with the most effective level being 0.5 mg/kg.

3.4 Effects of Nanoselenium on Selenium Content in Finishing Pigs

After absorption and metabolism, selenium is widely distributed throughout various tissues. Within safe supplementation ranges, excess selenium is excreted through urine and other pathways. Tissue selenium content depends on the selenium source, supplementation level, and animal species. Studies in broilers have shown that supplementation with selenomethionine, selenium yeast, or inorganic selenium significantly increases selenium content in liver, kidney, breast muscle, and plasma compared to control groups, with selenomethionine showing superior effects to selenium yeast, and inorganic selenium being the least effective. The highest supplementation level of 0.7 mg/kg yielded the best results. Research in goats from selenium-enriched areas has demonstrated significantly higher selenium content in heart, liver, spleen, and serum compared to goats from normal selenium areas. In the present study, different levels of nanoselenium supplementation significantly increased selenium content in serum and all tissues of finishing pigs, with content increasing linearly as supplementation level increased. According to Ministry of Agriculture Announcement No. 1224, the maximum limit for selenium feed additives in complete feed or total mixed rations is 0.5 mg/kg. To avoid exceeding this limit, the highest supplementation level in this study was set at 0.5 mg/kg, which resulted in the highest selenium content in finishing pigs.

Conclusion

Dietary glycine nanoselenium supplementation enhances antioxidant capacity and increases selenium content in serum and tissues of finishing pigs. Based on comprehensive evaluation, the optimal supplementation level is 0.5 mg/kg.

References

- [1] HATFIELD D L, TSUJI P A, CARLSON B A, et al. Selenium and seleno-cysteine: roles in cancer, health, and development[J]. Trends in Biochemical Sciences, 2014, 39(3): 112-120.
- [2] SHINI S, SULTAN A, BRYDEN W L. Selenium biochemistry and bioavailability: implications for animal agriculture[J]. Agriculture, 2015, 5(4): 1277-1288.
- [3] EL DEMERDASH F M, NASR H M. Antioxidant effect selenium on lipid peroxidation, hyperlipidemia biochemical parameters exposed diazinon[J]. Journal of Trace Elements in Medicine and Biology, 2014, 28(1): 89-93.
- [4] HABIBIAN M, GHAZI S, MOEINI M M, et al. Effects of dietary selenium and vitamin E on immune response and biological blood parameters of broilers reared under thermoneutral or heat stress conditions[J]. International Journal of Biometeorology, 2014, 58(5): 741-752.
- [5] SURAI P F, FISININ V I. Selenium in pig nutrition and reproduction: boars and semen quality-a review[J]. Asian-Australasian Journal of Animal Sciences, 2015, 28(5): 730-746.
- [6] VINCETI M, FILIPPINI T, CILLONI S, et al. The epidemiology of selenium and human cancer[J]. Advances in Cancer Research, 2017, 136: 1-48, doi:10.1016/bs.acr.2017.07.001.
- [7] COLLINS D E, EATON K A, HOENERHOFF M J. Spontaneous dilated cardiomyopathy and right-sided heart failure as a differential diagnosis for Hepatosis dietetica in a production pig[J]. Comparative Medicine, 2015, 65(4): 327-332.
- [8] YAO H D, ZHAO W C, ZHAO X, et al. Selenium deficiency mainly influences the gene expressions of antioxidative selenoproteins in chicken muscles[J]. Biological Trace Element Research, 2014, 161(3): 318-327.
- [9] BERMINGHAM E N, HESKETH J E, SINCLAIR B R, et al. Selenium-enriched foods are more effective at increasing glutathione peroxidase (GPx) activity compared with selenomethionine: a meta-analysis[J]. Nutrients, 2014, 6(10): 4002-4031.
- [10] WANG Xuedong, DAI Jinjun, LI Biao. Characteristics of selenium yeast and its application in pig production[J]. Swine Production, 2009(5): 6-8.
- [11] WANG Liang, SHAN Anshan. Research progress of nanoselenium in animal nutrition[J]. China Animal Husbandry & Veterinary Medicine, 2011, 38(4): 38-42.
- [12] ZHANG Yishan, BIAN Lianquan, YOU Siqin. Effects of three selenium sources on tissue selenium deposition and antioxidant capacity in growing-finishing pigs[J]. Feed Industry, 2008, 29(1): 18-20.

- [13] XIA Meisheng, HU Caihong, WANG Xuhui, et al. Effects of nanoselenium on growth and antioxidant capacity in piglets[J]. Chinese Journal of Animal Science, 2006, 42(3): 28-30.
- [14] HU Caihong, WANG Xuhui, ZHANG Saijun, et al. Effects of nanoselenium on growth and immunity in weaned piglets[J]. Bulletin of Science and Technology, 2007, 23(2): 215-218, 224.
- [15] CHEN Guiying, YUE Binghui. Effect of nanoselenium on growth performance of weaned piglets[J]. Shanghai Journal of Animal Husbandry and Veterinary Medicine, 2008(6): 73-74.
- [16] LIN Changguang, LIN Jinyu, LIU Dongxia, et al. Effects of different selenium sources on growth performance, serum antioxidant capacity and plasma selenium content in weaned piglets[J]. Acta Veterinaria et Zootechnica Sinica, 2013, 44(11): 1790-1796.
- [17] XIA Meisheng, ZHANG Hongmei, HU Caihong. Effect of nanoselenium on muscle quality of finishing pigs[J]. Journal of Zhejiang University (Agriculture and Life Sciences), 2005, 31(3): 263-268.
- [18] LIN Changguang, ZHENG Jingui, LIN Jinyu, et al. Effects of different selenium sources and levels on growth performance, immune function and thyroid hormone levels in weaned piglets[J]. China Feed, 2013(21): 20-24, 26.
- [19] LIU Zhaohong, YUE Binghui. Toxic effects of oxygen free radicals on animal bodies[J]. Shanghai Journal of Animal Husbandry and Veterinary Medicine, 2005(3): 57.
- [20] LI Shaohua, LIU Dajian, GUO Xiaofeng, et al. Effect of dietary vitamin E supplementation on pork quality in finishing pigs[J]. Swine Production, 2002(3): 18-19.
- [21] LI Qingping, QIAO Xiuhong, WANG Xiangdong. Effect of dietary vitamin E supplementation on pork quality[J]. Chinese Journal of Animal Science, 2003, 39(5): 34-35.
- [22] KOU Qing, LIANG Mijuan, TAO Liangliang. Effect of selenium yeast on tissue selenium content and antioxidant capacity in broilers[J]. Cereal & Feed Industry, 2012, 12(1): 48-50.
- [23] HE Hongchao, LI Biao. Effects of selenium yeast on selenium content, antioxidant capacity and meat quality in pigs[J]. Feed Research, 2011(4): 50-51, 55.
- [24] VENARDOS K, HARRISON G, HEADRICK J, et al. Effects of dietary selenium on glutathione peroxidase and thioredoxin reductase activity and recovery from cardiac ischemia-reperfusion[J]. Journal of Trace Elements in Medicine and Biology, 2005, 18(1): 81-88.
- [25] HE Yudan. Effects of nanoselenium on antioxidant capacity, reproductive function and toxicity mechanism in male SD rats[D]. PhD Dissertation. Hangzhou: Zhejiang University, 2014: 60-65.
- [26] GUO Junrui. Evaluation of efficacy and safety of organic selenium in broiler diets[D]. Master's Thesis. Beijing: Chinese Academy of Agricultural Sciences, 2014: 23-38.
- [27] ZHANG Lei, ZHOU Zhanqin, FU Mingzhe, et al. Selenium deposition in tissues of goats from selenium-enriched areas and its effect on PHGPx

expression[J]. Journal of Northwest A&F University (Natural Science Edition), 2014, 42(11): 1-7.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv –Machine translation. Verify with original.