Effects of Glucose Oxidase on Growth Performance, Serum Biochemical Indices, Antioxidant Function, and Nutrient Digestibility in Weaned Piglets (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary supplementation with different levels of glucose oxidase (GOD) on growth performance, serum biochemical indices, antioxidant function, and nutrient digestibility in weaned piglets. One hundred fifty 28-day-old weaned piglets [average body weight (8.41$±$0.06) kg] were selected and randomly divided into 5 groups with 3 replicates per group and 10 piglets per replicate, with a 1:1 ratio of males to females. The control group was fed a basal diet, while experimental groups I to IV were fed test diets supplemented with 120, 180, 240, and 300 U/kg glucose oxidase in the basal diet, respectively. The experimental period lasted 30 days. The results showed: 1) Compared with the control group, glucose oxidase supplementation had no significant effect on final body weight, average daily gain (ADG), average daily feed intake (ADFI), or feed-to-gain ratio (F/G) of piglets ($P > 0.05$), while the diarrhea rate in experimental group II was significantly reduced ($P < 0.05$). 2) Serum albumin (ALB) content in piglets of experimental group IV was significantly higher than that of the control group ($P < 0.05$), and serum urea nitrogen (UN) content in experimental groups III and IV was significantly higher than that of the control group ($P < 0.05$). 3) Serum superoxide dismutase (SOD) activity in experimental group II was significantly higher than that in experimental groups III and IV ($P < 0.05$), and serum malondialdehyde (MDA) content in experimental groups II and III was significantly lower than that in the control group and experimental group IV ($P < 0.05$). 4) Dry matter digestibility in piglets of experimental group II was significantly higher than that of the control group and experimental group I ($P < 0.05$), crude protein digestibility in piglets of experimental groups I, II, and III was significantly higher than that of the control group ($P < 0.05$), and

gross energy digestibility in piglets of experimental groups II and III was significantly higher than that of the control group ($P < 0.05$). In conclusion, dietary supplementation with glucose oxidase in weaned piglets can improve serum antioxidant function, reduce diarrhea rate, promote the metabolism and digestion/absorption of proteins, carbohydrates, and lipids in the body, thereby enhancing production performance, with a recommended supplementation level of 180 U/kg.

Full Text

Effects of Glucose Oxidase on Growth Performance, Serum Biochemical Parameters, Antioxidant Function, and Nutrient Digestibility in Weaned Piglets

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Abstract: This experiment investigated the effects of dietary supplementation with different levels of glucose oxidase (GOD) on growth performance, serum biochemical parameters, antioxidant function, and nutrient digestibility in weaned piglets. One hundred fifty 28-day-old weaned piglets [average body weight (8.41$±$0.06) kg] were randomly allocated to five groups with three replicates per group and ten piglets per replicate (half male and half female). The control group received a basal diet, while experimental groups I–IV received the basal diet supplemented with 120, 180, 240, and 300 U/kg GOD, respectively. The trial lasted 30 days.

The results showed that: (1) Compared with the control group, GOD supplementation did not significantly affect final body weight, average daily gain (ADG), average daily feed intake (ADFI), or feed-to-gain ratio (F/G) ($P > 0.05$), but the diarrhea rate in group II was significantly reduced ($P < 0.05$). (2) Serum albumin (ALB) content in group IV was significantly higher than in the control group ($P < 0.05$), and serum urea nitrogen (UN) content in groups III and IV was significantly higher than in the control group ($P < 0.05$). (3) Serum superoxide dismutase (SOD) activity in group II was significantly higher than in groups III and IV ($P < 0.05$), while serum malondialdehyde (MDA) content in groups II and III was significantly lower than in the control group and group IV ($P < 0.05$). (4) Dry matter digestibility in group II was significantly higher than in the control group and group I ($P < 0.05$). Crude protein digestibility in groups I, II, and III was significantly higher than in the control group ($P < 0.05$). Gross energy digestibility in groups II and III was significantly higher than in the con-

trol group ($P < 0.05$). In conclusion, dietary GOD supplementation improved serum antioxidant function, reduced diarrhea rate, and enhanced metabolism and absorption of protein, carbohydrate, and lipid in weaned piglets, thereby improving their overall performance. The recommended supplementation level is 180 U/kg.

Keywords: glucose oxidase; weaned piglet; growth performance; serum biochemical index; antioxidant function; nutrient digestibility

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The intestinal morphology of weaned piglets is underdeveloped, with limited secretion of digestive enzymes, resulting in low nutrient digestibility and poor resistance to infection. These animals are highly susceptible to foodborne pathogens, exhibiting elevated rates of diarrhea and mortality. Current production practices primarily rely on dietary antibiotics or high-dose zinc oxide to prevent post-weaning growth depression and reduce diarrhea and mortality. However, antibiotic use leads to drug residues and increased antimicrobial resistance, while excessive zinc oxide supplementation can damage the piglet digestive tract, impair subsequent growth, and cause severe environmental pollution. Glucose oxidase (GOD) is an oxidoreductase that catalyzes glucose oxidation to produce gluconic acid and hydrogen peroxide. Gluconic acid helps regulate gastrointestinal pH, inhibiting harmful bacteria while promoting beneficial microbial proliferation, and hydrogen peroxide also exhibits bactericidal effects. Recognized as a novel feed additive by the Ministry of Agriculture in 1999, GOD is increasingly used in animal nutrition. Previous research demonstrates that dietary GOD supplementation reduces pathogen infection risk and improves growth performance and health status in piglets. This study investigated the effects of GOD supplementation in diets for 28-day-old weaned piglets to determine optimal dosage and provide theoretical basis and technical parameters for its application in swine production.

1.1 Glucose Oxidase

The GOD used in this experiment was a powdered solid product provided by Jinan Nornoon Biological Engineering Co. Ltd.

1.2 Experimental Animals and Design

The trial was conducted at Sunlight Agricultural Development Co. Ltd. in Shaoyang, Hunan Province. One hundred fifty 28-day-old weaned piglets with identical genetic background and normal development were selected (half male and half female). Using a single-factor experimental design, piglets were randomly divided into five groups with three replicates per group and ten piglets per replicate. The control group received the basal diet, while experimental groups I–IV received the basal diet supplemented with 120, 180, 240, and 300 U/kg GOD, respectively. The experimental period lasted 30 days.

1.3 Basal Diet Composition and Nutrient Levels

The basal diet was formulated according to NRC (2012) nutrient requirements for swine, using corn and soybean meal as primary ingredients. The composition and nutrient levels are presented in Table 1 .

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

Ingredients	Content	Nutrient Levels[2]	Content
Corn		ME (Mcal/kg)	
Extruded corn		Crude protein	
Soybean meal		Crude fat	
Broken rice		Crude fiber	
Fermented soybean meal		Calcium	
Fish meal (imported)		Non-phytate phosphorus	
Soybean oil		Salt (NaCl)	
Premix[1]		Lysine	
Whey powder		Methionine	
Rice gluten meal		Methionine + Cysteine	
Total		Threonine	
		Tryptophan	

[1]The premix provided the following per kg of diet: Cu 15 mg, Zn 104 mg, Fe 100 mg, Mn 19 mg, VA 10,000 IU, VD 1,000 IU, VE 40 IU, VK 2.5 mg, VB_5 70 mg, D-pantothenic acid 16 mg, riboflavin 5 mg, folic acid 2 mg, niacin 25 mg, thiamine 1.6 mg, VB_6 1.8 mg, biotin 0.20 mg, VB_{12} 0.025 mg, GOD 1,200 U/g.

[2]Nutrient levels were calculated values.

1.4 Feeding Management

Experimental piglets were housed in nursery facilities with plastic slatted flooring, ten piglets per pen (half male and half female). They were fed pelleted diets ad libitum with free access to water (measured but not restricted). Barn temperature, humidity, and all experimental data were recorded. Routine immunization and management protocols were followed.

1.5.1 Growth Performance Indices

Piglets were weighed after fasting at the beginning and end of the experiment. Daily feed consumption per pen, mortality, and body weight of deceased piglets were recorded to calculate ADG, ADFI, and F/G. Fecal consistency and diarrhea incidence were observed twice daily (morning and afternoon). Diarrhea rate was calculated as: Diarrhea rate (%) = 100 × [diarrhea incidents / (total piglets × experimental days)].

1.5.2 Serum Biochemical and Antioxidant Indices

On day 30, one piglet per replicate (three per group) with body weight close to the group average was selected for blood collection via anterior vena cava using vacuum serum tubes (10 mL per piglet). Serum was harvested after centrifugation at 3,000 r/min for 5 minutes and stored at -20°C for analysis. Serum total protein (TP), albumin (ALB), urea nitrogen (UN), glucose (GLU), and total cholesterol (TC) were measured using an automatic biochemical analyzer (Mindray BS-408). Serum superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) activities, and malondialdehyde (MDA) content were determined using ELISA kits purchased from Nanjing Jiancheng Bioengineering Institute.

1.5.3 Nutrient Digestibility

Fecal collection method was used to determine nutrient utilization efficiency. During the final 3 days of the experiment, feces were collected per replicate in plastic bags. Sample preservation and analysis methods followed reference [8]. Dry matter (DM), crude protein (CP), and gross energy (GE) in diets and feces were determined. Acid-insoluble ash content was measured according to GB/T 23742-2009/ISO 5985:2002. Apparent nutrient digestibility was calculated as: Apparent digestibility (%) = 100 - [(nutrient content in feces × acid-insoluble ash in diet) / (nutrient content in diet × acid-insoluble ash in feces)] × 100.

1.6 Data Processing and Statistical Analysis

Data were analyzed using one-way ANOVA in SPSS 21.0. Significance was declared at $P < 0.05$, and Duncan' s multiple comparison test was used for post-hoc analysis. Results are expressed as means and standard errors.

2.1 Effects of Glucose Oxidase on Growth Performance of Weaned Piglets

As shown in Table 2 , GOD supplementation did not significantly affect final body weight, ADG, ADFI, or F/G compared with the control group ($P > 0.05$). However, the diarrhea rate in group II was significantly lower than in the control group ($P < 0.05$), with no significant differences among other groups ($P > 0.05$).

Table 2 Effects of GOD on growth performance of weaned piglets

Items	Control group	Test group	Test group	Test group	Test group	P-value
Initial weight (kg)						
Final weight (kg)						

Items	Control group	Test group	Test group	Test group	Test group	P-value
ADG (g)						
ADFI (g)						
F/G						
Diarrhea rate (%)	4.83[a]	0.94[a]	0.55	0.72[a]	1.00[a]	

In the same row, values with the same or no letter superscripts indicate no significant difference ($P > 0.05$), while different letter superscripts indicate significant difference ($P < 0.05$). The same applies below.

2.2 Effects of Glucose Oxidase on Serum Biochemical Parameters of Weaned Piglets

Table 3 shows that serum TP, globulin (GLB), GLU, and TC contents were higher in experimental groups than in the control group, but differences were not significant ($P > 0.05$). Serum ALB content in group IV was significantly higher than in the control group ($P < 0.05$), with no significant differences among other experimental groups ($P > 0.05$). Serum UN content in groups III and IV was significantly higher than in the control group ($P < 0.05$), with no significant differences among other groups ($P > 0.05$).

Table 3 Effects of GOD on serum biochemical parameters of weaned piglets

Items	Control group	Test group	Test group	Test group	Test group	P-value
TP (g/L)						
ALB (g/L)	29.33	36.50[a]	31.50[a]	31.27[a]	38.13[a]	
GLB (g/L)	2.85	3.42[a]	3.72[a]	4.69[a]	4.58[a]	
A/G						
UN (mmol/L)						
GLU (mmol/L)						
TC (mmol/L)						

2.3 Effects of Glucose Oxidase on Serum Antioxidant Function of Weaned Piglets

As presented in Table 4 , serum SOD activity in group II was significantly higher than in groups III and IV ($P < 0.05$), but did not differ significantly from the control group or group I ($P > 0.05$). Serum GSH-Px activity was highest in group II, though no significant differences were observed among groups ($P > 0.05$). Serum MDA content was lower in all experimental groups compared with the control group, being significantly lower in groups II and III ($P < 0.05$), but not significantly different from groups I and IV ($P > 0.05$).

Table 4 Effects of GOD on serum antioxidant indexes of weaned piglets

Items	Control group	Test group	Test group	Test group	Test group	P-value
SOD (U/mL)	144.14[a]	124.86[a]	153.91[a]	110.26	92.04	
GSH-Px (U/L)	9.83	7.66[a]	5.86	6.59	9.21	
MDA (nmol/mL)						

2.4 Effects of Glucose Oxidase on Nutrient Digestibility of Weaned Piglets

Table 5 indicates that dry matter digestibility in group II was significantly higher than in the control group and group I ($P < 0.05$). Crude protein digestibility in groups I, II, and III was significantly higher than in the control group ($P < 0.05$). Gross energy digestibility in groups II and III was significantly higher than in the control group ($P < 0.05$).

Table 5 Effects of GOD on nutrient digestibility of weaned piglets, %

Items	Control group	Test group	Test group	Test group	Test group	P-value
DM digestibility	85.45	85.36	86.96[a]	86.76[a]	85.87[a]	
CP digestibility	85.36	86.16[a]	87.34[a]	86.35[a]	85.98[a]	

Items	Control group	Test group	Test group	Test group	Test group	P-value
GE digestibility	85.20	85.64[a]	86.23[a]	85.98[a]	85.58[a]	

3.1 Effects of Glucose Oxidase on Growth Performance of Weaned Piglets

Glucose oxidase reduces gastrointestinal pH, effectively inhibiting pathogenic bacteria while promoting beneficial microbial growth, thereby enhancing immunity, improving intestinal microflora balance, maintaining intestinal morphology, and promoting animal growth. Numerous studies have reported that GOD supplementation significantly increases ADG and reduces F/G and diarrhea rates in weaned piglets. In the current study, while GOD supplementation did not significantly affect final body weight, ADG, ADFI, or F/G, it showed a tendency to improve final body weight and ADG and significantly reduced diarrhea rate, consistent with previous research. These findings demonstrate that dietary GOD supplementation effectively improves ADG, reduces F/G, promotes growth, and decreases diarrhea incidence in piglets.

3.2 Effects of Glucose Oxidase on Serum Biochemical Parameters of Weaned Piglets

Serum TP, ALB, and GLB contents reflect protein absorption and metabolism, while the albumin/globulin ratio (A/G) indicates animal health status. Elevated TP and ALB levels suggest enhanced metabolic activity. Serum GLU participates in carbohydrate metabolism, with higher levels within the normal range indicating improved glycogen synthesis. TC content reflects lipid metabolism status, potentially increasing when fat catabolism is elevated. Serum UN content negatively correlates with protein synthesis and amino acid balance but positively correlates with protein catabolism. Previous studies found no significant differences in serum GLU, ALB, GLB, TP, or A/G between control and GOD-supplemented piglets, suggesting GOD maintains good health status without significantly affecting glucose conversion and absorption. Other research reported that GOD reduces serum urea nitrogen, increases nitrogen retention, and improves protein synthesis efficiency. Our results showed that GOD supplementation increased serum ALB, GLB, GLU, and TC contents to varying degrees, significantly elevating ALB and UN levels while maintaining all parameters within normal physiological ranges, consistent with previous findings. Elevated serum TP and ALB can enhance energy mobilization and humoral immune function, indicating that GOD supplementation improves protein, carbohydrate, and lipid metabolism and enhances piglet growth performance and immunity.

3.3 Effects of Glucose Oxidase on Serum Antioxidant Function of Weaned Piglets

Endogenous enzymatic antioxidants SOD and GSH-Px constitute the primary antioxidant defense system. Total antioxidant capacity represents overall enzymatic and non-enzymatic antioxidant levels, while MDA, a lipid peroxidation metabolite, indirectly reflects cellular damage from oxygen free radicals. When free radicals increase, the endogenous antioxidant system is activated to prevent oxidative damage. Previous research demonstrated that GOD increased serum SOD activity and reduced MDA content in broilers, exhibiting antioxidant and anti-stress effects. Our study found that dietary GOD supplementation significantly increased serum SOD activity and improved GSH-Px activity, with groups III and IV showing significantly reduced serum MDA content compared with the control. These results indicate that under stress conditions, piglets can mobilize endogenous enzymatic antioxidant defenses, and GOD supplementation alleviates stress effects, reduces free radical production, effectively inhibits MDA formation, minimizes tissue damage, and enhances antioxidant function, consistent with previous studies.

3.4 Effects of Glucose Oxidase on Nutrient Digestibility of Weaned Piglets

Apparent nutrient digestibility is a crucial indicator of feed nutritional value, influenced by feed properties, processing methods, animal species and age, and analytical techniques. Glucose oxidase functions as an acidifier in the gastrointestinal tract, activating pepsin and accelerating crude protein digestion. Previous studies reported that GOD supplementation significantly improved dry matter and crude protein digestibility in piglets. Our findings showed that 180 U/kg GOD supplementation significantly enhanced digestibility of dry matter, crude protein, and gross energy, consistent with literature reports and demonstrating that dietary GOD improves nutrient absorption and growth performance in piglets.

Dietary glucose oxidase supplementation improves antioxidant function, enhances immunity, reduces diarrhea rate, and promotes nutrient digestion and absorption in weaned piglets, thereby improving growth performance. GOD can be promoted as a substitute for zinc oxide in production, with a recommended supplementation level of 180 U/kg.

References

[1] Zhang ZS, Dou BT, Bai YL, et al. Hazards and countermeasures of excessive antibiotic feed additives in livestock production [J]. Shaanxi Agricultural Sciences, 2012, 58(3): 127-128.

[2] Wang YD, Li KH, Luo CH, et al. Drawbacks and countermeasures of high-dose zinc application in weaned piglet diets [J]. Guangdong Feed, 2013, 22(1): 35-36.

[3] Zhao HQ, Zhao GX, Zhang XY, et al. Research progress on glucose oxidase and its application in animal husbandry [J]. Henan Animal Husbandry and Veterinary Medicine, 2007, 28(9): 11-12.

[4] Fan YW, Wu XY. Application research of glucose oxidase [J]. Feed Industry, 2007, 28(20): 15-16.

[5] Yang JX, Zhang RF, Ma QG, et al. Effects of glucose oxidase on growth performance and intestinal health of weaned piglets [J]. China Animal Husbandry and Veterinary Medicine, 2011, 38(6): 18-21.

[6] Yang JX, Zhang RF, Zhang JZ, et al. Effects of glucose oxidase on gastrointestinal microflora and blood biochemical indices in piglets [J]. Animal Husbandry and Veterinary Medicine, 2011, 43(6): 53-56.

[7] Yin J, Mei NA. Effects of dietary glucose oxidase on growth performance of broiler piglets [J]. Contemporary Animal Husbandry, 2012(2): 35-36.

[8] Zhang LY. Feed Analysis and Feed Quality Detection Technology [M]. 3rd ed. Beijing: China Agricultural Science and Technology Press, 2007.

[9] Zhao XF, Zhang HF. Functions of glucose oxidase and its application in animal husbandry [J]. Guangdong Feed, 2007, 16(1): 34-35.

[10] Bankar SB, Bule MV, Singhal RS, et al. Glucose oxidase—An overview [J]. Biotechnology Advances, 2009, 27(4): 489-501.

[11] Xiao J. Effects of glucose oxidase on production performance and intestinal morphology of piglets [D]. Master' s thesis. Changsha: Hunan Agricultural University, 2014.

[12] Chen C. Effects of glucose oxidase on piglet growth and diarrhea and its substitution for high-dose zinc oxide [D]. Master' s thesis. Changsha: Hunan Agricultural University, 2014.

[13] Zhang HY, Cheng ZJ, Chen YQ, et al. Effects of glucose oxidase on growth performance of weaned piglets [J]. Feed Industry, 2014, 35(10): 14-16.

[14] Tian DX, Zhang YK, Tian QC. Trial on prevention of early weaning diarrhea in piglets by adding glucose oxidase and phytohemagglutinin to diets [J]. Animal Husbandry and Feed Science, 2012, 33(10): 92-94.

[15] Cao YH, Li ZJ, Dai ZM, et al. Effects of liquid feed on serum biochemical indices in ultra-early weaned piglets [J]. Feed Industry, 2006, 27(7): 32-35.

[16] Tang HO, Gao XH, Li XJ, et al. Effects of glucose oxidase on growth performance, fecal microflora, and serum indices of piglets [J]. Chinese Journal of Animal Nutrition, 2014, 26(12): 3781-3786.

[17] Tang HO, Gao XH, Yao B, et al. Effects of glucose oxidase on growth performance, serum indices, and slaughter performance of meat ducks and its efficacy in alleviating aflatoxin B1 toxicity [J]. Chinese Journal of Animal Nutrition, 2015, 27(8): 2361-2367.

[18] Li H, Yang MM, Qu Q, et al. Effects of green tea polyphenols on blood biochemical parameters and antioxidant capacity in heat-stressed broilers [J]. Chinese Journal of Veterinary Science, 2016, 36(5): 801-803, 813.

[19] Li YB, Zhang YD, Liu MR. Study on effects of ozone disinfection on animal blood biochemistry [C]//Proceedings of the Beijing-Tianjin-Hebei Animal Husbandry and Veterinary Science and Technology Innovation Exchange Conference and New Ideas, New Views, New Methods Forum. Baoding: Chinese Association of Animal Science and Veterinary Medicine, 2008.

[20] Tancin V, Broucek JJ, Harcek L, et al. Different nutrition of calves in relation to thyroid hormone levels and biochemical indexes [J]. Zivocisna Vyroba, 1994, 39(11): 961-971.

[21] Sigh R, Cresswell P. Defective cross-presentation of viral antigens in GILT-Free mice [J]. Science, 2010, 328(5984): 1394-1398.

[22] Song HB. Nutritional regulation effects and mechanisms of glucose oxidase on broiler growth [D]. Master' s thesis. Baoding: Hebei Agricultural University, 2008.

[23] Chen QH, Chen FM, Xiao J, et al. Effects of glucose oxidase on growth performance, nutrient digestibility, intestinal microflora, and morphology of piglets [J]. Chinese Journal of Animal Nutrition, 2015, 27(10): 3218-3224.

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