

## Effects of Nutritional Level and Selenium Yeast on Growth Performance, Nutrient Apparent Digestibility, and Serum Antioxidant Indices in Yantai Black Pigs (Postprint)

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### Abstract

This experiment was conducted to investigate the effects of nutritional level and yeast selenium on growth performance, nutrient apparent digestibility, and serum antioxidant indices in Yantai black pigs. Forty-eight Yantai black pigs with good health status and a body weight of  $(70.30 \pm 1.30)$  kg were randomly allocated to 4 groups with 4 replicates per group and 3 pigs per replicate. Group I was fed a low-nutrition-level diet (digestible energy 11.19 MJ/kg, crude protein 12.28%), Group II was fed a low-nutrition-level diet supplemented with 0.5 mg/kg yeast selenium, Group III was fed a high-nutrition-level diet (digestible energy 13.11 MJ/kg, crude protein 14.73%), and Group IV was fed a high-nutrition-level diet supplemented with 0.5 mg/kg yeast selenium. The preliminary period lasted 7 days, and the formal experimental period lasted 105 days. The results showed that: 1) The average daily gain (ADG) of Groups III and IV was significantly higher than that of Groups I and II ( $P < 0.01$ ), the average daily feed intake (ADFI) of Group IV was significantly higher than that of Groups I and II ( $P < 0.01$ ), and the feed-to-gain ratio (F/G) of Group IV was reduced by 4.60% and 5.74% compared with Groups I and II, respectively ( $P < 0.01$ ). 2) The apparent digestibility of crude protein in Group IV was increased by 2.73% and 3.17% compared with Groups I and II, respectively ( $P < 0.01$ ), and increased by 0.82% compared with Group III ( $P > 0.05$ ). 3) The activities of serum superoxide dismutase (SOD), glutathione peroxidase (GSH-Px), and total antioxidant capacity (T-AOC) in Groups II and IV were significantly higher than those in Groups I and III ( $P < 0.01$ ), while serum malondialdehyde (MDA) content was significantly lower than that in Groups I and III ( $P < 0.01$ ). 4) No interaction effect between yeast selenium and nutritional level was observed for growth performance, nutrient apparent digestibility, or serum antioxidant indices ( $P > 0.05$ ). These results indicate that under the experimental conditions,

nutritional level had a significant effect on growth performance and apparent digestibility of crude protein in Yantai black pigs, and yeast selenium significantly improved the antioxidant capacity of Yantai black pigs.

## Full Text

### Effects of Nutrient Level and Yeast Selenium on Growth Performance, Nutrient Apparent Digestibility and Serum Antioxidant Indexes of Yantai Black Pigs

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#### Abstract

This experiment aimed to investigate the effects of nutrient level and yeast selenium on growth performance, nutrient apparent digestibility, and serum antioxidant indexes of Yantai black pigs. Forty-eight healthy Yantai black pigs with a body weight of  $(70.30 \pm 1.30)$  kg were randomly allocated into four groups, with four replicates per group and three pigs per replicate. Group I was fed a low-nutrient-level diet (digestible energy: 11.19 MJ/kg, crude protein: 12.28%), Group II was fed the low-nutrient-level diet supplemented with 0.5 mg/kg yeast selenium, Group III was fed a high-nutrient-level diet (digestible energy: 13.11 MJ/kg, crude protein: 14.73%), and Group IV was fed the high-nutrient-level diet supplemented with 0.5 mg/kg yeast selenium. The pre-experimental period lasted 7 days, followed by a 105-day formal experimental period.

The results showed: 1) The average daily gain (ADG) of Groups III and IV was significantly higher than that of Groups I and II ( $P < 0.01$ ). The average daily feed intake (ADFI) of Group IV was significantly higher than that of Groups I and II ( $P < 0.01$ ). The feed-to-gain ratio (F/G) of Group IV decreased by 4.60% and 5.74% compared with Groups I and II, respectively ( $P < 0.01$ ). 2) The crude protein apparent digestibility of Group IV increased by 2.73% and 3.17% compared with Groups I and II, respectively ( $P < 0.01$ ), and was 0.82% higher than that of Group III ( $P > 0.05$ ). 3) Serum superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) activities, and total antioxidant capacity (T-AOC) in Groups II and IV were significantly higher than those in Groups I and III ( $P < 0.01$ ), while serum malondialdehyde (MDA) content was significantly lower than that in Groups I and III ( $P < 0.01$ ). 4) No interaction effects between yeast selenium and nutrient level were observed on growth performance, nutrient apparent digestibility, or serum antioxidant indexes ( $P > 0.05$ ). In conclusion, under the experimental conditions, nutrient level significantly affected

the growth performance and crude protein apparent digestibility of Yantai black pigs, while yeast selenium significantly improved their antioxidant capacity.

**Keywords:** Yantai black pigs; nutrient level; yeast selenium; growth performance; serum antioxidant indexes

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## Introduction

Dietary nutrient levels play a crucial role in pig production. Energy and protein in diets not only support maintenance and growth but also directly determine the rate of fat and protein deposition in animals. Feeding diets with different nutrient levels significantly influences pig growth rate, feed-to-gain ratio (F/G), and feeding efficiency. Yeast selenium, as a novel feed additive, has attracted increasing attention. Lü et al. [1] demonstrated that high-nutrient-level diets outperformed medium- and low-nutrient-level diets in ADG and F/G. In 1973, Rotruck et al. [2] discovered that selenium is an essential component of glutathione peroxidase (GSH-Px), and the World Health Organization (WHO) declared selenium an essential trace element for human and animal life activities in the same year. Research indicates that GSH-Px activity changes with selenium concentration, though this change lags behind selenium level variations. When selenium is deficient, GSH-Px activity decreases, failing to adequately catalyze peroxides and leading to accumulation of lipid free radicals and peroxides, which causes peroxidative damage to cell membranes [3]. Selenium functions not only as a component of antioxidant enzyme systems but also by directly scavenging blood free radicals to protect against free radical damage [4]. Wang et al. [5] reported that selenomethionine improved weight gain in commercial pigs. Dietary nutrient levels represent an important prerequisite in pig production, significantly influencing productivity improvements. Yeast selenium is a new selenium supplement with better bioavailability than traditional inorganic selenium sources. This experiment aimed to study the effects of nutrient level and yeast selenium on growth performance, nutrient apparent digestibility, and serum antioxidant indexes of Yantai black pigs, providing theoretical reference for their feeding management.

## Materials and Methods

### 1.1 Experimental Design

The experiment was conducted at the Yantai Black Pig Conservation Farm in Weihai City. Forty-eight healthy Yantai black pigs with body weight of  $(70.30 \pm 1.30)$  kg (half male and half female) were selected. A  $2 \times 2$  factorial design was employed, with pigs randomly divided into four groups, each containing four replicates of three pigs per pen. Group I received a low-nutrient-level diet (digestible energy: 11.19 MJ/kg, crude protein: 12.28%), Group II received the low-nutrient-level diet supplemented with 0.5 mg/kg yeast selenium, Group III

received a high-nutrient-level diet (digestible energy: 13.11 MJ/kg, crude protein: 14.73%), and Group IV received the high-nutrient-level diet supplemented with 0.5 mg/kg yeast selenium. The pre-experimental period lasted 7 days, followed by a 105-day formal experimental period.

## 1.2 Experimental Diets

The experimental diets were corn-miscellaneous meal type, formulated according to the Chinese “Feeding Standards for Swine” (2004). While maintaining a constant energy-to-protein ratio and other nutrient levels, the low-nutrient-level diet had 15% lower energy content than the high-nutrient-level diet. Yeast selenium was purchased from Zhuhai Wanfukang Biotechnology Co., Ltd., with a selenium content of 2,000 mg/kg. The composition and nutrient levels of experimental diets are presented in .

## 1.3 Management Practices

Pigs were fed powdered diets ad libitum with free access to water. Before the experiment, routine disinfection, deworming, and vaccination procedures were performed according to farm protocols. Pens were cleaned daily, and pig health status was monitored regularly.

## 1.4 Measurement Indicators

**1.4.1 Growth Performance** Individual body weight was measured in the morning after overnight fasting at the beginning and end of the experiment to calculate ADG. Daily feed consumption was recorded per replicate (pen) to determine ADFI, F/G, average daily crude protein intake, and average daily energy intake.

**1.4.2 Nutrient Apparent Digestibility** The apparent digestibility of nutrients in each diet was determined using the internal indicator method with acid-insoluble ash (AIA) as the indicator (hydrochloric acid concentration: 3 mol/L). During the final 10 days of the experiment, fresh fecal samples were collected continuously for three days at irregular intervals each day. Fresh feces from each replicate were mixed thoroughly, and 5 mL of 10% sulfuric acid was added per 100 g sample for nitrogen fixation. Samples were dried at 60-65°C to prepare air-dried samples, then equilibrated at room temperature for 24 hours before weighing, recording, grinding, and storage in sample bags. Dry matter (DM), crude protein (CP), calcium (Ca), and phosphorus (P) contents in diets and feces were determined according to the “National Standards of the People’s Republic of China” (GB/T 6432-1994, GB/T 6433-1994, GB/T 6436-2002, GB/T 6437-2002). The apparent digestibility of a nutrient (%) was calculated as:  $100 - (\text{indicator content in diet} / \text{indicator content in feces}) \times (\text{nutrient content in feces} / \text{nutrient content in diet}) \times 100$ .

**1.4.3 Serum Antioxidant Indexes** Serum antioxidant indexes [GSH-Px activity, superoxide dismutase (SOD) activity, malondialdehyde (MDA) content, and total antioxidant capacity (T-AOC)] were measured using assay kits from Nanjing Jiancheng Bioengineering Institute. Whole blood samples were kept at room temperature for 1-2 hours without anticoagulant. After blood coagulation, samples were centrifuged at 3,000-4,000 r/min for 10 minutes at room temperature. The supernatant was collected in 1.5 mL centrifuge tubes and stored at 2-8°C for same-day analysis using a 752 UV-Vis spectrophotometer, centrifuge, and constant temperature water bath.

### 1.5 Statistical Analysis

Data were preprocessed using Excel 2010. General linear model (GLM) in SPSS 17.0 was used for variance analysis of nutrient level, yeast selenium, and their interaction effects, followed by Duncan's multiple comparison tests.  $P < 0.05$  indicated significant difference,  $P < 0.01$  indicated highly significant difference, and  $0.05 < P < 0.10$  indicated a trend.

## Results

### 2.1 Effects of Nutrient Level and Yeast Selenium on Growth Performance of Yantai Black Pigs

The effects of nutrient level and yeast selenium on growth performance are shown in . For ADG, yeast selenium showed a trend to increase ADG ( $P = 0.07$ ). Groups III and IV had significantly higher ADG than Groups I and II ( $P < 0.01$ ). Group IV exhibited the highest ADG, increasing by 17.20% and 15.20% compared with Groups I and II ( $P < 0.01$ ), respectively, and by 5.24% compared with Group III ( $P < 0.05$ ). Group III increased ADG by 11.20% and 9.47% compared with Groups I and II ( $P < 0.01$ ), respectively. No interaction effect was observed between yeast selenium and nutrient level ( $P > 0.05$ ). For F/G, Group IV showed the lowest value, decreasing by 4.60%, 5.74%, and 1.99% compared with Groups I, II, and III ( $P < 0.01$ ,  $P < 0.01$ ,  $P > 0.05$ ), respectively. Group III decreased F/G by 2.66% and 3.83% compared with Groups I and II ( $P < 0.05$ ), respectively. For ADFI, yeast selenium had no significant effect ( $P > 0.05$ ). Group IV increased ADFI by 12.03% and 9.01% compared with Groups I and II ( $P < 0.01$ ), respectively, and by 3.84% compared with Group III ( $P > 0.05$ ). No interaction effect was detected between yeast selenium and nutrient level ( $P > 0.05$ ). Average daily crude protein intake and average daily energy intake followed similar patterns to ADFI, with no interaction between yeast selenium and nutrient level ( $P > 0.05$ ).

### 2.2 Effects of Nutrient Level and Yeast Selenium on Nutrient Apparent Digestibility of Yantai Black Pigs

The effects on nutrient apparent digestibility are presented in . For dry matter apparent digestibility, neither nutrient level nor yeast selenium had significant effects ( $P > 0.05$ ), and no interaction was observed ( $P > 0.05$ ). For crude protein

apparent digestibility, yeast selenium had no significant effect ( $P>0.05$ ), while nutrient level showed a highly significant effect ( $P<0.01$ ). Group IV exhibited the highest crude protein apparent digestibility, increasing by 2.73% and 3.17% compared with Groups I and II ( $P<0.01$ ), respectively, and by 0.82% compared with Group III ( $P>0.05$ ). No interaction effect was detected ( $P>0.05$ ). For calcium and phosphorus apparent digestibility, neither nutrient level nor yeast selenium had significant effects ( $P>0.05$ ), though yeast selenium showed trends to improve calcium and phosphorus digestibility ( $P=0.09$  and  $P=0.07$ , respectively). No interaction effect was observed ( $P>0.05$ ).

### 2.3 Effects of Nutrient Level and Yeast Selenium on Serum Antioxidant Indexes of Yantai Black Pigs

The effects on serum antioxidant indexes are shown in . For serum SOD activity, yeast selenium had a highly significant effect ( $P<0.01$ ), while nutrient level showed no significant effect ( $P>0.05$ ). Group IV increased serum SOD activity by 13.13% and 10.50% compared with Groups I and III ( $P<0.01$ ), respectively, and by 2.37% compared with Group II ( $P>0.05$ ). No interaction effect was detected ( $P>0.05$ ). For serum GSH-Px activity, yeast selenium had a highly significant effect ( $P<0.01$ ), while nutrient level showed a trend ( $P=0.06$ ). Group IV increased serum GSH-Px activity by 23.27% and 18.69% compared with Groups I and III ( $P<0.01$ ), respectively, and by 3.83% compared with Group II ( $P>0.05$ ). No interaction effect was observed ( $P>0.05$ ). For serum MDA content, yeast selenium had a highly significant effect ( $P<0.01$ ), while nutrient level showed a trend ( $P=0.06$ ). Group I had the highest serum MDA content, exceeding Groups II, III, and IV by 18.22% ( $P<0.01$ ), 3.83% ( $P>0.05$ ), and 25.68% ( $P<0.01$ ), respectively. No interaction effect was detected ( $P>0.05$ ). For serum T-AOC, yeast selenium had a highly significant effect ( $P<0.01$ ) and nutrient level had a significant effect ( $P<0.05$ ). Group IV increased serum T-AOC by 26.33%, 5.09%, and 16.14% compared with Groups I, II, and III ( $P<0.01$ ,  $P>0.05$ ,  $P<0.01$ ), respectively. No interaction effect was observed ( $P>0.05$ ).

## Discussion

### 3.1 Effects of Nutrient Level and Yeast Selenium on Growth Performance of Yantai Black Pigs

Dietary nutrient level is a critical factor in pig nutrition. Appropriate nutrient levels enhance growth rate and feed conversion efficiency while fully expressing animal genetic potential. Chiba et al. [6] reported that dietary nutrient levels affect feed intake in growing pigs fed ad libitum. Low-nutrient-level diets typically contain higher crude fiber with poorer palatability, reducing feed intake. Lower energy content in these diets results in reduced energy intake and consequently decreased growth performance [7]. Research on Tianjin white pigs (20-60 kg) demonstrated that high-energy-high-protein and high-energy-low-protein diets achieved the highest feed conversion efficiency, significantly outperforming

low-energy-low-protein diets. High-energy diets showed significantly better feed conversion than low-energy diets, and high-protein diets significantly increased ADG compared with low-protein diets [8]. Overall, high-nutrient-level diets generally exhibit better palatability, improving ADFI, ADG, and feed conversion, thereby enhancing growth performance. These findings align with our results showing that high nutrient levels significantly improved growth performance, increased ADG and ADFI, and decreased F/G in Yantai black pigs, consistent with Zhao et al. [9]. Regarding selenium, Lin [10] reported that 0.5 mg/kg nano-selenium significantly increased ADG and decreased F/G in finishing pigs compared with sodium selenite groups and control. Similarly, 0.5 mg/kg yeast selenium and nano-selenium significantly improved ADG and reduced F/G in newborn piglets, weaned piglets, and growing-finishing pigs. In our experiment, yeast selenium supplementation increased ADG in Yantai black pigs and showed a trend to increase ADFI, though not significantly, with no interaction between nutrient level and yeast selenium. However, some studies found no significant effects of different selenium sources on growth performance in growing-finishing pigs, though trends for improved ADFI and ADG and reduced F/G were observed [11]. These differing conclusions may result from variations in animal breeds, individual differences, and experimental duration.

### **3.2 Effects of Nutrient Level and Yeast Selenium on Nutrient Apparent Digestibility of Yantai Black Pigs**

Previous research demonstrated that nutrient levels significantly affect apparent digestibility in growing-finishing pigs, with high-nutrient-level groups showing the highest digestibility, significantly exceeding medium- and low-nutrient-level groups. Crude protein apparent digestibility was significantly higher in high-nutrient-level groups than in medium-nutrient-level groups, and calcium and phosphorus apparent digestibility were significantly higher than in medium- and low-nutrient-level groups [12-13]. He et al. [14] reported that dietary energy level significantly affected apparent digestibility of dry matter, crude protein, phosphorus, and crude fat, while different crude protein levels significantly influenced crude protein and crude fat apparent digestibility. In our experiment, high nutrient levels significantly improved crude protein apparent digestibility and feed utilization, while showing no significant effects on dry matter, calcium, or phosphorus apparent digestibility, possibly due to animal breed differences and experimental duration variations. Selenium also influences nutrient apparent digestibility, improving dry matter and nitrogen digestibility [15]. Zhang et al. [16] found that 0.45 mg/kg yeast selenium in dairy cow diets significantly improved apparent digestibility of organic matter, acid detergent fiber, neutral detergent fiber, calcium, and phosphorus, and significantly increased crude protein apparent digestibility. In our study, nutrient level showed no significant effects on dry matter, calcium, or phosphorus apparent digestibility, but high nutrient levels significantly improved crude protein apparent digestibility. The overall main effect of yeast selenium was not significant, though supplementation tended to improve calcium and phosphorus apparent digestibility without sig-

nificant differences, and no interaction with nutrient level was observed. These results are similar to Zhang [17], who found that replacing sodium selenite with yeast selenium slightly but non-significantly improved crude fat and organic matter digestibility in dairy cows.

### 3.3 Effects of Nutrient Level and Yeast Selenium on Serum Antioxidant Indexes of Yantai Black Pigs

Serum SOD, GSH-Px, MDA, and T-AOC are important indicators reflecting animal antioxidant capacity [18]. Selenium is an essential component of GSH-Px, which participates in peroxidation reactions by catalyzing reduced glutathione (GSH) to eliminate oxidative substances and hydroxyl radicals generated during cellular metabolism, while promoting hydrogen peroxide decomposition and reducing peroxidative damage to cell membranes by unsaturated fatty acids. Selenium deficiency reduces GSH-Px synthesis and decreases antioxidant capacity [19-20]. SOD is a crucial antioxidant enzyme widely distributed in animals and plants, representing an important substance for free radical scavenging *in vivo*. MDA is the end product of lipid peroxidation, and its production exacerbates membrane damage, making serum MDA content a commonly used indicator in aging and stress resistance physiology research.

Mahan et al. [21] demonstrated that selenium-enriched yeast supplementation in piglet diets more significantly increased GSH-Px activity compared with sodium selenite. Jia [22] and Gao et al. [23] reported that dietary yeast selenium increased serum GSH-Px activity and significantly decreased serum MDA content in pigs. Our results showed that 0.5 mg/kg yeast selenium supplementation had highly significant effects on all antioxidant indexes, significantly increasing serum SOD and GSH-Px activities and T-AOC while significantly decreasing serum MDA content in Yantai black pigs, consistent with Jia [22]. Nutrient level showed no significant effects on serum SOD, GSH-Px activity, or T-AOC, but exhibited trends to increase GSH-Px activity and decrease MDA content, similar to Chen [24]. However, our experiment demonstrated that nutrient level significantly improved serum T-AOC in Yantai black pigs, contributing to enhanced antioxidant capacity.

## Conclusion

1. Nutrient level significantly affected growth performance and crude protein apparent digestibility, and showed certain influences on serum antioxidant indexes of Yantai black pigs.
2. Yeast selenium exhibited a trend to increase average daily feed intake and significantly improved serum antioxidant indexes in Yantai black pigs.
3. No interaction effects were observed between nutrient level and yeast selenium on growth performance, nutrient apparent digestibility, or serum antioxidant indexes of Yantai black pigs.

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