# Effects of Selenium Yeast and Nano-Selenium on Growth Performance, Trace Element Content in Meat, and Serum Antioxidant Indices of Squabs in the Late Finishing Stage: Postprint

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**Date:** 2017-10-10T00:00:00+00:00

## Abstract

This experiment was conducted to investigate the effects of selenium yeast and nano-selenium on growth performance, trace element content in meat, and serum antioxidant indices of late-fattening squabs. Two hundred ten healthy 21-day-old American King pigeons were randomly allocated into 7 groups with 3 replicates per group and 10 pigeons per replicate. A 2 (selenium source) × 4 (level) factorial randomized experimental design was employed, with dietary selenium sources being selenium yeast and nano-selenium, and selenium supplementation levels of 0 (control, basal diet containing 0.08 mg/kg selenium), 0.1, 0.3, and 0.5 mg/kg (as selenium). The preliminary period was 3 days, and the formal experimental period was 7 days. The results showed: 1) No significant differences were found in average daily feed intake, average daily gain, or feed-to-gain ratio among all groups (P>0.05). 2) The selenium content in meat of all selenium-supplemented groups was significantly higher than that of the control group (P<0.05), increasing with selenium supplementation level, with a significant interaction between selenium source and level (P<0.05). Compared with the control group, the selenium content in meat increased by 28.72%, 62.09%, and 106.05% in the selenium yeast groups at 0.1, 0.3, and 0.5 mg/kg selenium, respectively, and by 19.83%, 26.12%, and 45.65% in the nano-selenium groups at 0.1, 0.3, and 0.5 mg/kg selenium, respectively (P<0.05), with the selenium yeast groups having significantly higher selenium content than the nano-selenium groups (P<0.05). 3) Compared with the control group, the serum total superoxide dismutase, glutathione peroxidase, and catalase activities, and total antioxidant capacity were significantly increased (P<0.05), while serum malondialdehyde content was significantly decreased (P<0.05) in the 0.3 and 0.5 mg/kg selenium yeast and nano-selenium groups; compared with the control and 0.1 mg/kg groups, the catalase activity and total antioxidant capacity were significantly increased (P<0.05), while malondialdehyde content was significantly decreased (P<0.05) in the 0.3 and 0.5 mg/kg groups. In conclusion, dietary supplementation with selenium yeast and nano-selenium can significantly enhance serum antioxidant capacity and significantly increase selenium content in pigeon meat.

## Full Text

### Effects of Selenium Yeast and Nano-Selenium on Growth Performance, Meat Trace Element Contents and Serum Antioxidant Indices of Squabs in Latter Finishing Period

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**Abstract:** This experiment was conducted to investigate the effects of selenium yeast (SY) and nano-selenium (NS) on growth performance, meat trace element contents, and serum antioxidant indices of squabs during the latter finishing period. A total of 210 healthy 21-day-old American King pigeons were randomly allocated into 7 groups with 3 replicates per group and 10 squabs per replicate. A 2×4 factorial randomized design was employed, with two selenium sources (SY and NS) and four supplementation levels [0 (control, basal diet containing 0.08 mg/kg Se), 0.1, 0.3, and 0.5 mg/kg (as Se)]. The pretrial period lasted 3 days, followed by a 7-day formal trial. The results showed: 1) No significant differences were observed in average daily feed intake, average daily gain, or feed-to-gain ratio among all groups (P>0.05). 2) All selenium-supplemented groups exhibited significantly higher selenium content in meat compared to the control group (P<0.05), with levels increasing as selenium supplementation increased; a significant interaction existed between selenium source and supplementation level (P<0.05). Compared with the control, selenium content in meat increased by 28.72%, 62.09%, and 106.05% in the 0.1, 0.3, and 0.5 mg/kg SY groups, respectively, and by 19.83%, 26.12%, and 45.65% in the corresponding NS groups (P<0.05). Moreover, the SY group showed significantly higher meat selenium content than the NS group (P<0.05). 3) Compared with the control, the 0.3 and 0.5 mg/kg SY and NS groups showed significantly elevated serum total superoxide dismutase, glutathione peroxidase, and catalase activities, as well as total antioxidant capacity (P<0.05), while serum malondialdehyde content was significantly reduced (P<0.05). Compared with both the control and 0.1 mg/kg groups, the 0.3 and 0.5 mg/kg groups exhibited significantly higher catalase activity and total antioxidant capacity (P<0.05) and significantly lower malondialdehyde content (P<0.05). In conclusion, dietary supplementation with either

SY or NS can significantly enhance serum antioxidant capacity and increase selenium deposition in squab meat.

**Keywords:** squab; selenium yeast; nano-selenium; growth performance; trace elements; antioxidant

Selenium is an essential trace element for human and animal growth and development, playing multiple roles in enhancing antioxidant capacity, improving immune function, delaying aging, resisting stress, and promoting growth. Selenium supplementation can not only improve animal production performance but also produce selenium-enriched livestock products, thereby increasing economic benefits. Recent research on selenium supplementation in livestock and poultry has demonstrated that organic selenium offers higher bioavailability and biological safety compared to inorganic selenium. Selenium yeast (SY) is produced through selenium enrichment in the cellular protein structure of growing yeast, while nano-selenium (NS) is a nanoparticle of elemental selenium with a protein core, red elemental selenium membrane, and protein dispersant, typically with particle sizes under 80 nm. Both SY and NS represent high-quality organic selenium sources currently under development, characterized by high absorption rates, low toxicity, and environmental friendliness, making them promising replacements for inorganic selenium. As safe and efficient organic selenium sources, both have considerable advantages as feed additives. To date, research on their application has focused primarily on pigs, chickens, and geese, with few reports in meat pigeon production. Some studies suggest that NS exhibits superior absorption and deposition in the body compared to SY, but comparative studies of their effects in squab production remain unreported. Therefore, this experiment supplemented squab diets with different levels of SY and NS to investigate their effects on growth performance, meat trace element contents, and serum antioxidant indices during the latter finishing period, providing a theoretical basis for research and application of efficient selenium sources and reference for safe selenium supplementation and selenium-enriched squab meat production.

### 1.1 Experimental Design and Management

This trial employed a 2×4 factorial randomized design. Two hundred ten 21-day-old healthy American King pigeons were randomly divided into 7 groups with 3 replicates each containing 10 squabs. The two dietary selenium sources were SY and NS, with supplementation levels of 0 (control, basal diet containing 0.08 mg/kg selenium), 0.1, 0.3, and 0.5 mg/kg (as selenium). The pretrial lasted 3 days, during which all groups were fed the basal diet. Daily observations were made and groups adjusted to ensure no significant differences in feed consumption or body weight among groups. The formal trial lasted 7 days (squabs are typically marketed around 30 days of age), with each group receiving their respective experimental diets according to the design. The basal diet was formulated according to NRC (1994) poultry nutrient requirements, with composition and nutrient levels shown in Table 1 .

The experiment was conducted in a double-row pigeon house with single-box cages. Experimental squabs were housed in three tiers (upper, middle, lower) with 10 squabs per cage, each cage representing one replicate. Squabs had ad libitum access to feed (dry mash) provided five times daily to stimulate intake and water via cup drinkers. The pigeon house was cleaned daily, feeders and drinkers washed once daily, and the house sprayed and disinfected twice weekly.

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

| Ingredients | Content | Nutrient levels[2] | Content |
|---|---|---|---|
| Corn | – | Metabolizable energy, ME/(MJ/kg) | – |
| Pea | – | Crude protein, CP | – |
| Wheat | – | Lysine, Lys | – |
| Limestone | – | Methionine, Met | – |
| Yeast powder | – | Calcium, Ca | – |
| CaHPO | – | Available phosphorus, AP | – |
| NaCl | – | Selenium, Se/(mg/kg) | 0.08 |
| Premix[1] | – | | |
| Total | 100.00 | | |

[1]The premix provided the following per kg of diet: VA 3,000 IU, VD  6,400 IU, VC 0.24 mg, VK 0.2 mg, VB  0.8 mg, VB  3.2 mg, VB  22 mg, VB  20 mg, biotin 80  g, nicotinic acid 4 mg, folic acid 2 mg, Mg 100 mg, Cu 50 mg, Zn 40 mg, Mn 100 mg, I 0.50 mg.
[2]Selenium was a measured value, while other nutrient levels were calculated values.

### 1.2 Experimental Materials

The organic selenium sources used were SY (active selenium content 2‰) and NS (active selenium content 1‰, spherical uniform distribution without agglomeration, average particle size 50-100 nm as observed by transmission electron microscopy), both commercially available products. The measured selenium contents in diets containing 0.1, 0.3, and 0.5 mg/kg selenium from SY and NS were 0.185, 0.375, 0.596, 0.187, 0.378, and 0.598 mg/kg, respectively.

### 1.3 Measurement Indicators and Methods

#### 1.3.1 Growth Performance

At the end of the pretrial and formal trial periods, squabs in each replicate were weighed individually. Daily feed intake and mortality were recorded for each group (by replicate) to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G) during the statistical period.

#### 1.3.2 Trace Element Content

At the end of the trial, three squabs were randomly selected from each replicate, deprived of feed (with water) for 12 hours, then slaughtered and dissected to collect breast muscle samples, which were stored at -20°C for trace element analysis. Iron, zinc, and selenium contents in meat were determined by flame atomic absorption spectrometry according to GB/T 5009.90-2003, GB/T 9695.20-2008, and GB/T 13883-2008. Muscle samples were pretreated using wet digestion. Standard solutions were prepared and measured using a flame atomic absorption instrument (SP-AA3800) to generate standard curves before trace element determination.

#### 1.3.3 Antioxidant Indices

At the end of the trial, 3 mL of blood was collected from the wing vein of three randomly selected squabs per replicate. After tilting the collection tubes and allowing 30 minutes for clotting, samples were centrifuged at 3,500 r/min for 10 minutes. The supernatant (0.5-1.0 mL) was transferred to 0.5 mL centrifuge tubes, labeled with group and date, and stored at -20°C for serum antioxidant analysis. Serum glutathione peroxidase (GSH-Px), total superoxide dismutase (T-SOD), and catalase (CAT) activities, as well as total antioxidant capacity (T-AOC) and malondialdehyde (MDA) content, were measured using a microplate reader (Multiskan GO, Thermo Fisher Scientific, USA) and assay kits from Nanjing Jiancheng Bioengineering Institute.

### 1.4 Data Processing and Analysis

All data were analyzed using SAS 9.2 statistical software and expressed as “means”and “pooled standard error (SE).”The GLM model was used to test main effects of selenium source and level and their interaction. Multiple comparisons for significant differences ($P<0.05$) were performed using the LSD method.

## 2.1 Effects of SY and NS on Growth Performance of Squabs

As shown in Table 2 , dietary SY and NS had no significant effects on average daily feed intake, average daily gain, or feed-to-gain ratio of squabs ($P>0.05$).

**Table 2 Effects of SY and NS on growth performance of squabs**

| Se source | Supplemental level (mg/kg) | ADFI (g) | ADG (g) | F/G |
|---|---|---|---|---|
| Control | 0 | – | – | – |
| SY | 0.1 | – | – | – |
| SY | 0.3 | – | – | – |
| SY | 0.5 | – | – | – |
| NS | 0.1 | – | – | – |

| Se source | Supplemental level (mg/kg) | ADFI (g) | ADG (g) | F/G |
|---|---|---|---|---|
| NS | 0.3 | – | – | – |
| NS | 0.5 | – | – | – |
| Pooled SE | | – | – | – |
| P-value | | | | |
| Se source | | >0.05 | >0.05 | >0.05 |
| Se level | | >0.05 | >0.05 | >0.05 |
| Se source × Se level | | >0.05 | >0.05 | >0.05 |

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

## 2.2 Effects of SY and NS on Trace Element Contents in Meat of Squabs

As shown in Table 3 , dietary selenium source had no significant effect on iron or zinc content in squab meat (P>0.05). Both SY and NS groups showed significantly higher selenium content in meat compared to the control group (P<0.05), with levels increasing as selenium supplementation increased; a significant interaction existed between selenium source and supplementation level (P<0.05). Selenium content in meat increased by 28.72%, 62.09%, and 106.05% in the 0.1, 0.3, and 0.5 mg/kg SY groups, respectively, and by 19.83%, 26.12%, and 45.65% in the corresponding NS groups. Between the two selenium sources, the SY group exhibited significantly higher selenium content in meat than the NS group (P<0.05), with a 26.86% increase.

**Table 3 Effects of SY and NS on trace element contents in meat of squabs**

| Se source | Supplemental level (mg/kg) | Se ( g/kg) | Fe (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|
| Control | 0 | 165.4e | – | – |
| SY | 0.1 | 212.9cd | – | – |
| SY | 0.3 | 268.1b | – | – |
| SY | 0.5 | 340.8a | – | – |
| NS | 0.1 | 198.2d | – | – |
| NS | 0.3 | 240.9bc | – | – |
| NS | 0.5 | 273.9a | – | – |
| Pooled SE | | 215.9b | – | – |
| P-value | | <0.001 | >0.05 | >0.05 |
| Se source | | <0.001 | | |
| Se level | | <0.001 | | |

| Se source | Supplemental level (mg/kg) | Se ( g/kg) | Fe (mg/kg) | Zn (mg/kg) |
|---|---|---|---|---|
| Se source × Se level | | <0.001 | | |

## 2.3 Effects of SY and NS on Serum Antioxidant Indices of Squabs

As shown in Table 4 , all selenium-supplemented groups exhibited significantly higher serum GSH-Px activity compared to the control group (P<0.05). The 0.3 and 0.5 mg/kg SY and NS groups showed significantly increased serum T-AOC and CAT activity (P<0.05) and significantly reduced serum MDA content (P<0.05). Except for the 0.1 mg/kg SY group, all other selenium-supplemented groups demonstrated significantly elevated serum T-SOD activity (P<0.05). Serum GSH-Px and T-SOD activities increased significantly with increasing selenium supplementation levels (P<0.05). Compared with both the control and 0.1 mg/kg groups, the 0.3 and 0.5 mg/kg groups showed significantly higher CAT activity and T-AOC (P<0.05) and significantly lower MDA content (P<0.05). Between selenium sources, the SY group exhibited significantly higher serum GSH-Px activity than the NS group (P<0.05), while the NS group showed significantly higher T-SOD activity and T-AOC than the SY group (P<0.05).

**Table 4 Effects of SY and NS on serum antioxidant indices of squabs**

| Se source | Supplemental level (mg/kg) | GSH-Px (mU/mL) | T-AOC (U/mL) | T-SOD (U/mL) | CAT (U/mL) | MDA (mmol/L) |
|---|---|---|---|---|---|---|
| Control | 0 | 609.76e | 6.75d | 52.00d | 7.48a | 2.58c |
| SY | 0.1 | 714.58cd | 7.56cd | 54.60d | 7.10a | 3.00c |
| SY | 0.3 | 738.90abc | 9.18c | 61.27c | 6.03bc | 4.96b |
| SY | 0.5 | 768.56a | 11.02b | 67.20ab | 5.70cd | 4.54b |
| NS | 0.1 | 677.96d | 8.14cd | 60.84c | 7.36a | 2.98c |
| NS | 0.3 | 720.65bcd | 9.19c | 63.00bc | 6.46b | 4.37b |
| NS | 0.5 | 759.76ab | 12.93a | 69.87a | 5.21d | 6.00a |
| Pooled SE | | 740.68a | 9.25b | 61.03b | 7.23a | 4.67a |
| P-value | | 719.46b | 10.08a | 64.57a | 6.24b | 5.45c |
| Se source | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| Se level | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

| Se source | Supplemental level (mg/kg) | GSH-Px (mU/mL) | T-AOC (U/mL) | T-SOD (U/mL) | CAT (U/mL) | MDA (mmol/L) |
|---|---|---|---|---|---|---|
| Se source × Se level | | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |

### 3.1 Effects of SY and NS on Growth Performance of Squabs

Currently, research on different selenium sources in squabs is limited. This trial demonstrated that supplementation with 0.1-0.5 mg/kg selenium from either SY or NS had no significant effect on growth performance of squabs during the latter finishing period, with no significant differences between selenium sources. These findings are consistent with Wang et al. in geese supplemented with 0.3 mg/kg selenium and Zhang et al. in pigs receiving 0.3-0.8 mg/kg selenium from SY or NS. However, Qu et al. reported that both SY and NS significantly improved laying performance in quails, with NS showing superior effects. Upton et al. and Luo et al. found that SY significantly improved feed conversion ratio and reduced feed-to-gain ratio in Arbor Acres broilers and Cherry Valley ducks, respectively. Wang et al. observed that NS significantly increased daily gain and feed consumption in broilers, with 0.15-1.20 mg/kg NS significantly reducing feed-to-gain ratio. In contrast, Xia et al. reported that 0.1-0.3 mg/kg NS had no significant effect on growth performance in Lingnan yellow broilers. These varying results may be attributed to differences in animal species and breeds, selenium absorption, transport and utilization, as well as differences in selenium products, supplementation levels, experimental conditions, and trial duration. In conclusion, SY and NS can improve livestock and poultry production performance to some extent, with no significant differences between the two sources.

### 3.2 Effects of SY and NS on Trace Element Contents in Squab Meat

Selenium-enriched meat serves as an important medium for selenium supplementation. Current research on selenium-enriched poultry meat development has focused primarily on chicken. Tian et al. and Kou et al. reported that 0.3 mg/kg SY significantly increased selenium content in chicken meat. Zhou et al. and Xu et al. demonstrated that dietary supplementation with 0.3 mg/kg and 0.1-1.0 mg/kg NS, respectively, significantly increased selenium content in broiler tissues and improved meat quality, with selenium content increasing as supplementation levels increased. This trial found that dietary supplementation with 0.1-0.5 mg/kg selenium from either SY or NS significantly increased selenium content in squab breast muscle, with levels increasing as supplementation increased, consistent with previous studies. Organic selenium, being similar to sulfur-containing amino acids, can substitute for sulfur-containing amino acids during protein synthesis, thereby increasing total selenium storage in the body.

In contrast, most inorganic selenium is excreted through the kidneys during metabolism, with only a small amount incorporated into body proteins, resulting in poorer tissue deposition than organic selenium. Both NS and SY are high-quality organic selenium sources currently under development. No previous studies have compared their deposition effects in pigeon meat. Qu et al. reported that NS showed better deposition in quail eggs than SY, while Sun et al. found that SY had higher deposition efficiency in eggs of pre-laying Hy-Line hens than NS. This trial also demonstrated that SY resulted in higher selenium deposition in squab breast muscle than NS. These discrepancies may be due to differences in trace element deposition capacity among poultry types with different purposes and species, as well as variations in trial duration, nutritional levels, and management. This trial also found that SY or NS supplementation had no significant effect on iron or zinc content in squab muscle, suggesting these selenium sources do not significantly affect iron and zinc deposition.

### 3.3 Effects of SY and NS on Serum Antioxidant Indices of Squabs

The body' s antioxidant system comprises enzymatic and non-enzymatic components, with selenium playing a crucial role in the enzymatic antioxidant system through selenoproteins and selenium-containing nucleic acids. This trial demonstrated that dietary SY and NS supplementation significantly improved antioxidant enzyme activities, consistent with findings from Qu et al., Jing et al., and Wang. Malondialdehyde is the end product of lipid peroxidation triggered by free radicals, and its content reflects the degree of lipid peroxidation and indirectly indicates antioxidant capacity. This trial showed that 0.3 and 0.5 mg/kg selenium from both SY and NS significantly reduced MDA content, with no significant difference between the two sources, aligning with Wang et al.' s findings in geese. However, Sun et al. reported that 0.3 mg/kg of both selenium sources did not significantly reduce plasma MDA content in laying hens. These divergent results may stem from differences in experimental animals, selenium active components, feeding conditions, and physiological status. Total antioxidant capacity is a comprehensive indicator of antioxidant capability, and dietary SY and NS supplementation can significantly increase plasma T-AOC. In this trial, both selenium sources significantly increased serum T-AOC in squabs, with the NS group showing significantly higher levels than the SY group, consistent with Sun et al.' s results. As an organic selenium source, SY can more easily enter the body to exert its effects, while NS not only has an efficient absorption pathway but can also directly scavenge free radicals. Whether NS demonstrates superior antioxidant effects compared to SY requires further investigation.

**Conclusions:**

1. Dietary supplementation with SY or NS had no significant effect on growth performance of squabs during the latter finishing period.
2. Selenium content in squab meat increased with dietary selenium supplementation level, with SY showing superior deposition efficiency to NS and a significant interaction between selenium source and supplementa-

tion level.

3. Supplementation with 0.3 and 0.5 mg/kg selenium from either SY or NS significantly enhanced the body’ s antioxidant capacity.
4. For production of selenium-enriched squab meat, supplementation with 0.5 mg/kg selenium from SY is recommended during the latter finishing period.

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