Effects of Different Dietary Selenium Sources and Supplementation Levels in Breeder Hens on Growth Performance, Meat Quality, Selenium Deposition, and Antioxidant Function of Offspring Broilers (Postprint)

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Abstract

This experiment aimed to investigate the effects of different selenium sources and supplementation levels in broiler breeder diets on growth performance, meat quality, selenium deposition, and antioxidant function of offspring broilers. A total of 540 healthy 48-week-old Lingnan Yellow broiler breeder hens were randomly divided into 6 groups with 3 replicates per group and 30 hens per replicate. The experiment adopted a 3 (selenium source) × 2 (level) two-factor randomized design. Dietary selenium sources were sodium selenite (SS), selenium yeast (SY), and selenomethionine (SM), with selenium supplementation levels of 0.15 and 0.30 mg/kg (as selenium). The pre-trial period lasted 4 weeks, and the formal trial period lasted 8 weeks. The results showed: 1) Compared with the SS group, the SM group significantly reduced the feed conversion ratio of offspring broilers at 1–21 days of age ($P<0.05$); the SM and SY groups significantly increased selenium content in liver, kidney, and muscle, as well as kidney catalase (CAT) activity, and significantly decreased liver malondialdehyde (MDA) content in 1-day-old offspring broilers ($P<0.05$). Compared with the SY group, the SM group significantly increased the pH of breast muscle at 16 h postmortem and selenium content in kidney and muscle of offspring broilers ($P<0.05$). 2) The 0.30 mg/kg group showed significantly higher selenium content in liver, kidney, and muscle of offspring broilers compared with the 0.15 mg/kg group ($P<0.05$). Compared with the 0.30 mg/kg group, the 0.15 mg/kg group significantly increased Hunter a value and pH of breast muscle at 8 h postmortem ($P<0.05$), and significantly decreased drip loss of breast muscle at 24 and 48 h postmortem in offspring broilers ($P<0.05$), significantly increased liver glutathione peroxidase, total superoxide dismutase (T-SOD) activity, and total antioxidant capacity (T-AOC), as well as kidney T-SOD, CAT activity, and

T-AOC in 1-day-old offspring broilers (P<0.05), and significantly decreased kidney MDA content in 1-day-old offspring broilers (P<0.05). It can be concluded that under the conditions of this experiment, supplementation of 0.15 mg/kg SM in broiler breeder diets yielded the best results.

Full Text

Effects of Dietary Different Selenium Sources and Supplemental Levels of Broiler Breeders on Growth Performance, Meat Quality, Selenium Retention, and Antioxidant Function of Offspring Broilers

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Abstract: This experiment was conducted to investigate the effects of different selenium sources and supplemental levels in broiler breeder diets on the growth performance, meat quality, selenium retention, and antioxidant function of offspring broilers. A total of 540 healthy Lingnan Yellow broiler breeders at 48 weeks of age were randomly assigned to 6 groups with 3 replicates per group and 30 birds per replicate. A 3 (selenium source) × 2 (level) factorial randomized design was employed, with dietary selenium sources being sodium selenite (SS), selenium-enriched yeast (SY), and selenomethionine (SM), and selenium supplemental levels being 0.15 and 0.30 mg/kg (as Se). The pre-test period lasted 4 weeks, followed by an 8-week formal test period. The results showed: 1) Compared with the SS group, the SM group significantly reduced the feed-to-gain ratio of offspring broilers aged 1–21 days (P<0.05). The SM and SY groups significantly increased selenium content in the liver, kidney, and muscle, as well as kidney catalase (CAT) activity, and significantly decreased liver malondialdehyde (MDA) content in 1-day-old offspring broilers (P<0.05). Compared with the SY group, the SM group significantly increased breast muscle pH at 16 h postmortem and selenium content in the kidney and muscle of offspring broilers (P<0.05). 2) The 0.30 mg/kg group showed significantly higher selenium content in the liver, kidney, and muscle of 1-day-old offspring broilers compared with the 0.15 mg/kg group (P<0.05). Compared with the 0.30 mg/kg group, the 0.15 mg/kg group significantly increased breast muscle Hunter a* value and pH at 8 h postmortem, significantly reduced breast muscle drip loss at 24 and 48 h, significantly increased liver glutathione peroxidase (GSH-Px) activity, total superoxide dismutase (T-SOD) activity, and total antioxidant capacity (T-AOC), as well as kidney T-SOD activity, CAT activity, and T-AOC in 1-day-old offspring broilers (P<0.05), and significantly decreased kidney MDA content in 1-day-old offspring broilers (P<0.05). These results suggest that under the conditions of this experiment, supplementation of broiler breeder diets with 0.15 mg/kg SM yielded the best outcomes.

Keywords: selenium source; selenium level; maternal effect; broiler breeders

Maternal effect refers to the phenomenon where an organism' s phenotype is determined not only by its genotype and environment but also by the influence of the female parent [1]. Since all nutrients required for offspring development are transmitted from the mother through the placenta, milk, and egg, maternal nutrition is crucial for offspring development, production performance, and health. Rehfeldt et al. [2] reported that nutrients in the egg determine avian growth and development, and these nutrients are influenced by the nutritional status of the hen.

Selenium is an essential trace element for humans and livestock that promotes animal growth and enhances antioxidant capacity [3-4]. Two categories of selenium sources are added to diets: inorganic and organic selenium. Compared with inorganic selenium, organic selenium exhibits stronger biological activity, higher absorption rates, and lower environmental pollution [5-6]. In poultry, selenium from the hen' s diet is transferred to the offspring through the egg [7]. Pappas et al. [8] found that the effect of maternal selenium on offspring broilers could persist until 4 weeks post-hatch. To investigate the effects of different types and supplemental levels of maternal selenium on the growth performance, meat quality, selenium retention, and antioxidant function of offspring broilers, this experiment used selenium-enriched yeast (SY) and selenomethionine (SM) as organic selenium sources, with inorganic sodium selenite (SS) as the control, at two selenium levels of 0.15 and 0.30 mg/kg, aiming to elucidate the maternal nutritional effects of selenium.

1.1 Experimental Materials

SS (purity 99%) and SM (purity 99%) were purchased from Sigma Company, while SY was provided by Alltech Company.

1.2 Experimental Diets

Broiler breeders and their offspring were fed mash and pelleted diets, respectively. Except for selenium, all nutrient levels met the NRC (1994) recommended standards. The composition and nutrient levels of the basal diets for breeders and offspring are shown in Table 1 and Table 2 , respectively. During the pre-test period, breeders were fed a basal diet without selenium supplementation (measured selenium content of 0.04 mg/kg). During the experimental period, offspring broilers were fed commercial compound feed with a measured selenium content (as SS) of 0.15 mg/kg.

1.3 Experimental Design and Management

This experiment employed a 3 (selenium source) × 2 (level) factorial randomized design. A total of 540 healthy Lingnan Yellow broiler breeders at 48 weeks of age were randomly assigned to 6 groups with 3 replicates per group and 30 birds per replicate. Dietary selenium sources were SS, SY, and SM, with supplemental levels of 0.15 and 0.30 mg/kg (as Se). Breeders were housed in 3-tier stacked

cages with 2 birds per cage. The pre-test period lasted 4 weeks, followed by an 8-week formal test period. Artificial insemination was performed once weekly using the same semen source for all groups. During the final week, hatching eggs were collected and stored separately by group and replicate before incubation.

After hatching, 60 newly hatched chicks were randomly selected from each replicate for rearing. All offspring broilers were fed the same diet across three stages: 1–21 days, 22–42 days, and 43–56 days of age.

Throughout the experimental period, both breeders and offspring broilers had ad libitum access to feed and water, received conventional management, and were vaccinated according to standard protocols.

1.4 Sample Collection

After hatching, 5 newly hatched chicks were randomly selected from each replicate, dissected, and their liver, kidney, and left breast muscle were collected and stored at -80 °C.

At the conclusion of the offspring broiler rearing trial (56 days of age), 4 birds from each replicate were randomly selected, fasted for 12 h, slaughtered, and sampled.

1.5 Measurements

1.5.1 Growth Performance of Offspring Broilers During the rearing period, feed weight, residual feed weight, mortality count, and weight of dead birds were accurately recorded for each replicate. All birds were weighed at 21 and 56 days of age to determine feed consumption, body weight gain, feed-to-gain ratio, and mortality rate for each replicate.

1.5.2 Carcass Composition of 56-Day-Old Offspring Broilers Carcass composition was analyzed according to the poultry slaughter measurement standards specified by the National Livestock and Poultry Breed Committee. Live weight was recorded after 12 h of feed withdrawal. Carcass weight was measured after bleeding and feather removal. Semi-eviscerated weight was obtained by removing the trachea, esophagus, crop, intestines, spleen, pancreas, gallbladder, and reproductive organs from the carcass. Eviscerated weight was obtained by removing the heart, liver, proventriculus, gizzard, fat, head, and feet from the semi-eviscerated carcass. The following formulas were used:

- Dressing percentage (%) = (carcass weight/live weight) × 100
- Semi-eviscerated percentage (%) = (semi-eviscerated weight/live weight) × 100
- Eviscerated percentage (%) = (eviscerated weight/live weight) × 100
- Abdominal fat percentage (%) = (abdominal fat weight/live weight) × 100

1.5.3 Drip Loss of Breast Muscle in 56-Day-Old Offspring Broilers After slaughter, the middle portion of the left breast muscle was excised and trimmed into a 5 cm × 2 cm × 1 cm (length × width × height) block. Surface moisture was absorbed with filter paper, and the sample was weighed (W_0). The meat sample was then suspended by fixing one end with wire, with muscle fibers oriented vertically downward, placed in an inflated sample bag without contacting the bag walls, sealed, and stored at 4 °C. Sample weight was measured at 24 and 48 h postmortem (W_1), and drip loss was calculated using the following formula [9]:

Drip loss (%) = $[(W_0 - W_1)/W_0] \times 100$

1.5.4 Breast Muscle Color in 56-Day-Old Offspring Broilers At an ambient temperature of 25 °C, the Hunter a* value of breast muscle was measured at 8 and 16 h postmortem using an SP60 Series meat colorimeter [10]. Three different locations on each sample surface were measured and averaged.

1.5.5 Breast Muscle pH in 56-Day-Old Offspring Broilers The pH of the left pectoralis minor muscle was measured using a calibrated Delta-320 pH meter.

1.5.6 Selenium Content in Liver, Kidney, and Breast Muscle of 1-Day-Old Offspring Broilers Tissue selenium content was determined using an AF-610A atomic fluorescence spectrometer. Approximately 0.2 g of sample was weighed into a microwave digestion vessel, 1 mL H_2O_2 was added, and the vessel was sealed and digested for approximately 7 min until the solution became colorless and transparent. After cooling, the solution was diluted to 10 mL with ultrapure water. Then, 2 mL of the digestate was transferred to a 10 mL test tube, mixed with 1 mL of 50% (V/V) hydrochloric acid solution and 1 mL of a mixed solution containing 5% thiourea and 5% ascorbic acid, reacted for 15 min, diluted with ultrapure water, mixed, and analyzed. Ultrapure water and selenium standard reference material [Pig Liver Composition Analysis Standard Material (GBW08551), National Food Inspection Institute] were used as blank and positive controls, respectively.

1.5.7 Antioxidant Function of 1-Day-Old Offspring Broilers Glutathione peroxidase (GSH-Px) activity, total superoxide dismutase (T-SOD) activity, catalase (CAT) activity, total antioxidant capacity (T-AOC), malondialdehyde (MDA) content, and tissue protein content were measured using assay kits from Nanjing Jiancheng Bioengineering Institute according to the manufacturer' s instructions.

1.6 Statistical Analysis

All data were analyzed using SPSS 16.0 statistical software and expressed as "mean ± standard deviation." A GLM model was used to test the main ef-

fects of selenium source and supplemental level and their interaction. Multiple comparisons were performed using the LSD method for data with significant differences ($P<0.05$).

2.1 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Growth Performance of Offspring Broilers

As shown in Table 3 and Table 4 , compared with the SS group, the SM group significantly reduced the feed-to-gain ratio of offspring broilers aged 1–21 days ($P<0.05$). Different selenium sources and supplemental levels in broiler breeder diets had no significant effects on growth performance of offspring broilers aged 22–56 days ($P>0.05$).

2.2 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Carcass Composition and Meat Quality of 56-Day-Old Offspring Broilers

As shown in Table 5 , Table 6 , and Table 7 , different selenium sources and levels in broiler breeder diets had no significant effects on any carcass composition parameters of 56-day-old offspring broilers ($P>0.05$). Compared with the SS and SY groups, the SM group significantly increased breast muscle pH at 16 h postmortem in 56-day-old offspring broilers ($P<0.05$). Compared with the 0.30 mg/kg group, the 0.15 mg/kg group significantly increased breast muscle Hunter a* value and pH at 8 h postmortem ($P<0.05$) and significantly reduced breast muscle drip loss at 24 and 48 h postmortem ($P<0.05$).

2.3 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Tissue Selenium Retention of 1-Day-Old Offspring Broilers

As shown in Table 8 , compared with the SS group, the SM and SY groups significantly increased selenium content in the liver, kidney, and muscle of 1-day-old offspring broilers ($P<0.05$). Compared with the SY group, the SM group significantly increased selenium content in the kidney and muscle of 1-day-old offspring broilers ($P<0.05$). The 0.30 mg/kg group showed significantly higher selenium content in the liver, kidney, and muscle of 1-day-old offspring broilers compared with the 0.15 mg/kg group ($P<0.05$).

2.4 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Antioxidant Function of 1-Day-Old Offspring Broilers

As shown in Table 9 and Table 10 , compared with the SS group, the SM and SY groups significantly increased kidney CAT activity ($P<0.05$) and significantly

decreased liver MDA content in 1-day-old offspring broilers ($P<0.05$). Compared with the 0.30 mg/kg group, the 0.15 mg/kg group significantly increased liver GSH-Px activity, T-SOD activity, and T-AOC, as well as kidney T-SOD activity, CAT activity, and T-AOC in 1-day-old offspring broilers ($P<0.05$), and significantly decreased kidney MDA content in 1-day-old offspring broilers ($P<0.05$).

3.1 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Growth Performance and Meat Quality of Offspring Broilers

Although genetic selection primarily determines the transmission of parental genes to offspring, accumulating evidence demonstrates that maternal nutritional effects significantly influence offspring broilers. Cantor et al. [11] found that feeding selenium-supplemented diets to hens improved growth performance of offspring broilers at 14 days of age. Guo et al. [12] reported that maternal organic selenium significantly increased body length and weight of offspring chicks compared with inorganic selenium. The present results showed that SM, compared with SS and SY, significantly increased body weight and reduced feed-to-gain ratio of offspring broilers at 21 days of age, though different forms of maternal selenium had no significant effects on growth performance at 56 days of age. The likely reason is that maternal selenium acts directly on chicks during early nutritional programming, while its direct effects gradually diminish during the later growth period as offspring broilers consume substantial amounts of selenium-containing commercial feed, resulting in relatively minor impacts.

The results also indicated that 0.15 mg/kg selenium, compared with 0.30 mg/kg, significantly increased breast muscle Hunter a* value and pH at 8 h postmortem and reduced drip loss. This may be because excessive selenium content has certain adverse effects on the organism, though the specific mechanism requires further investigation.

3.2 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Tissue Selenium Retention of 1-Day-Old Offspring Broilers

Selenium can be transferred from the hen to the egg, subsequently affecting selenium content in embryonic and 1-day-old offspring broiler tissues; therefore, selenium content in the maternal diet is critical for offspring development [11]. Selenium levels exhibit tissue-specific distribution, with selenium from blood primarily stored in the liver and kidney, and only small amounts accumulating in muscle, bone, and brain [13]. Invernizzi et al. [14] found in laying hens that SY significantly increased selenium content in breast muscle and liver compared with the basal diet, and organic selenium significantly increased selenium deposition in tissues of 1-day-old offspring broilers compared with inorganic selenium. The present results showed that SM and SY groups, compared with the

SS group, significantly increased selenium content in the liver, kidney, and muscle of 1-day-old offspring broilers. The 0.30 mg/kg group showed significantly higher selenium content in these tissues than the 0.15 mg/kg group, consistent with the findings of Pappas et al. [8]. Additionally, the SM group significantly increased selenium content in the kidney and muscle of 1-day-old offspring broilers compared with the SY group. The probable reason is that SY, as a fermentation product, exists primarily as protein-bound selenium in yeast and requires cell wall disruption and protein degradation before absorption, whereas SM exists as a free amino acid that can be directly absorbed by the intestine.

3.3 Effects of Different Selenium Sources and Supplemental Levels in Broiler Breeder Diets on Antioxidant Function of 1-Day-Old Offspring Broilers

Selenium is an important dietary antioxidant. Selenium deficiency reduces selenoenzyme activity, impairs free radical scavenging, and consequently causes biological membrane damage and dysfunction in detoxification and immune functions, leading to various diseases. Selenium in newly hatched chicks is obtained from the mother through the egg. Surai et al. [15] found that selenium supplementation in broiler breeder diets increased liver selenium content and GSH-Px activity in 1-day-old offspring broilers, enhancing antioxidant function, and this maternal effect persisted for 5–10 days post-hatch. Pappas et al. [8] demonstrated that hen selenium nutrition could influence offspring broilers up to 4 weeks of age. The present results showed that organic selenium sources (SM and SY) in broiler breeder diets, compared with inorganic selenium (SS), significantly increased kidney CAT activity and decreased liver MDA content in 1-day-old offspring broilers. CAT is an important antioxidant enzyme that effectively decomposes hydrogen peroxide (H_2O_2) and scavenges oxygen free radicals, thereby improving antioxidant capacity.

This study also found that in 1-day-old offspring broilers, dietary supplementation with 0.15 mg/kg selenium was more effective than 0.30 mg/kg in increasing tissue T-SOD activity and T-AOC, consistent with the findings of Wilaison et al. [16]. Wilaison et al. [17] supplemented quail breeder diets with 0, 0.25, 0.50, and 1.00 mg/kg selenium and found that GSH-Px mRNA expression was highest in the 0.25 mg/kg group, while expression decreased in the 0.50–1.00 mg/kg groups. This suggests that excessive selenium content may have toxic side effects on embryonic and 1-day-old offspring broiler development.

- For selenium retention: SM > SY > SS, and 0.30 mg/kg level > 0.15 mg/kg level.
- For antioxidant function: Both organic selenium sources were superior to SS, but SM and SY showed similar effects.
- For improving offspring broiler growth performance: SM significantly improved feed-to-gain ratio at 21 days compared with SS, while other indices showed no significant differences among groups.

- Under the conditions of this experiment, 0.15 mg/kg SM in broiler breeder diets demonstrated better maternal nutritional effects.

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