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Effects of Selenium Yeast and Sodium Selenite on Serum Antioxidant Capacity and Dynamic Changes of Egg Selenium Retention in Linwu Ducks (Postprint)

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Abstract

The present study aimed to investigate the effects of selenium yeast and sodium selenite on serum antioxidant capacity, egg quality, and dynamic changes in egg selenium retention in Linwu ducks. A total of 240 healthy 29-week-old Linwu ducks with similar laying rates were randomly allocated into 3 groups with 5 replicates per group and 16 ducks per replicate. The control group was fed a basal diet (without exogenous selenium supplementation, containing 0.183 mg/kg selenium); the experimental groups were fed the basal diet supplemented with 0.3 mg/kg sodium selenite or selenium yeast, respectively. After 42 days of feeding, exogenous selenium supplementation was withdrawn and all ducks were fed the basal diet for an additional 10 days. The results showed: 1) Compared with the control group, dietary supplementation with sodium selenite or selenium yeast had no significant effect on production performance or egg quality of Linwu ducks ($P>0.05$). Dietary supplementation with 0.3 mg/kg sodium selenite or selenium yeast extremely significantly increased serum selenium content ($P<0.01$) and significantly increased serum glutathione peroxidase activity ($P<0.05$). Dietary supplementation with 0.3 mg/kg selenium yeast significantly decreased serum malondialdehyde content ($P<0.05$). 2) Compared with the control group, dietary supplementation with sodium selenite or selenium yeast extremely significantly increased egg selenium content ($P<0.01$). Within 5 days after withdrawal of supplementation, egg selenium content in the experimental groups remained extremely significantly higher than that in the control group ($P<0.01$). On days 7 and 8 after withdrawal, egg selenium content in the selenium yeast group was extremely significantly higher than that in the sodium selenite and control groups ($P<0.01$). On days 9 and 10 after withdrawal, egg selenium content in the experimental groups decreased to the same level as the

control group (P>0.05). In conclusion, dietary supplementation with sodium selenite or selenium yeast had no significant effect on production performance or egg quality in Linwu ducks, but could improve serum antioxidant capacity and increase selenium content in serum and eggs. Compared with sodium selenite, dietary supplementation with selenium yeast could prolong the retention time of selenium in eggs.

Full Text

Effects of Sodium Selenite and Selenium Yeast on Serum Antioxidant Capacity and Dynamic Changes of Egg Selenium Retention in Linwu Ducks

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Abstract

This experiment was conducted to investigate the effects of sodium selenite and selenium yeast on serum antioxidant capacity, egg quality, and the dynamic changes of egg selenium retention in Linwu ducks. Two hundred and forty healthy 29-week-old Linwu ducks with similar laying rates were randomly allocated into three groups, each consisting of five replicates with sixteen ducks per replicate. The control group was fed a basal diet without supplemental selenium (containing 0.183 mg/kg selenium), while the experimental groups received the basal diet supplemented with 0.3 mg/kg selenium from either sodium selenite or selenium yeast. After 42 days of feeding, the supplemental selenium sources were withdrawn, and all groups were fed the basal diet for an additional 10 days.

The results showed that: (1) Compared with the control group, dietary supplementation with sodium selenite or selenium yeast had no significant effect on production performance or egg quality of Linwu ducks (P>0.05). However, supplementation with 0.3 mg/kg selenium from either source significantly increased serum selenium content (P<0.01) and glutathione peroxidase activity (P<0.05). Additionally, supplementation with 0.3 mg/kg selenium from yeast significantly decreased serum malondialdehyde content (P<0.05). (2) Dietary supplementation with sodium selenite or selenium yeast significantly increased egg selenium content compared with the control group (P<0.01). Within five days after withdrawal of supplementation, egg selenium content in both experimental groups

remained significantly higher than that in the control group (P<0.01). On days 7 and 8 post-withdrawal, the selenium yeast group exhibited significantly higher egg selenium content than both the sodium selenite and control groups (P<0.01). By days 9 and 10 after withdrawal, egg selenium content in all groups had declined to levels comparable to the control group (P>0.05).

In conclusion, dietary supplementation with sodium selenite or selenium yeast did not significantly affect the production performance or egg quality of Linwu ducks, but improved serum antioxidant capacity and increased selenium content in both serum and eggs. Compared with sodium selenite, selenium yeast supplementation prolonged the retention duration of selenium in eggs.

Keywords: selenium; sodium selenite; selenium yeast; antioxidant capacity; egg; Linwu duck

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Selenium is an essential trace element for humans and animals, serving as a necessary component of important selenoproteins and antioxidant enzymes. It functions to scavenge reactive oxygen species in the body and provides biological benefits including antioxidant activity, anti-stress effects, and immune enhancement [1-3]. Selenium exhibits dual effects, as its toxic dose is very close to its nutritional requirement, and different forms and sources of selenium show significant differences in biological utilization and function [2-3]. Therefore, investigating appropriate dosages and forms of selenium intake and studying its transformation and enrichment in livestock products are crucial for the scientific and safe use of selenium and for guiding the production of selenium-enriched animal products.

Currently, two main selenium sources are used in livestock diets: inorganic selenium (selenate or selenite) and organic selenium (selenium yeast or selenomethionine preparations) [4]. Organic selenium is generally considered superior to inorganic selenium in improving antioxidant capacity in poultry [5-6] and has beneficial effects on reproductive performance in breeding birds [4, 7]. Sun et al. [8] reported that selenium yeast and nano-selenium were effective in improving antioxidant capacity in laying hens, with selenium yeast being more effective in increasing egg selenium content. Lu et al. [9] also demonstrated that selenium from selenium yeast transferred to eggs more rapidly and efficiently than sodium selenite. The appropriate selenium supplementation level in poultry diets ranges from 0.1 to 0.4 mg/kg, with 0.4 mg/kg (as nano-selenium) recommended for laying pigeons [10], 0.28-0.35 mg/kg for geese [6], 0.2 mg/kg (as nano-selenium) for quail during late laying period [11], and 0.10-0.30 mg/kg (as selenium yeast) for laying hens [12]. Additionally, Yan et al. [13] found that dietary supplementation with 0.250 mg/kg selenium and 200 mg/kg vitamin E improved production performance and egg quality in Cherry Valley breeding ducks.

Previous studies have primarily focused on egg quality and selenium content under continuous supplementation, while the dynamic changes of egg selenium

deposition after withdrawal of supplementation and the effects of different selenium sources on selenium retention duration remain unreported. Furthermore, research on selenium supplementation in laying ducks, particularly Linwu ducks, is limited. Therefore, this study utilized peak-laying Linwu ducks to evaluate the effects of sodium selenite and selenium yeast on production performance, egg quality, serum antioxidant capacity, and the dynamic changes of egg selenium retention after withdrawal of supplemental selenium, aiming to explore the deposition and retention patterns of different selenium sources in duck eggs.

1. Materials and Methods

1.1 Experimental Materials Selenium yeast containing 2,000 mg/kg selenium and feed-grade sodium selenite containing 1% selenium were used in this study.

1.2 Experimental Design and Diets Two hundred and forty healthy Linwu ducks at 29 weeks of age during peak production, with similar laying rates, were randomly divided into three groups with five replicates each and sixteen ducks per replicate. The experiment lasted 52 days, with different diets fed during days 1-42, followed by the basal diet for all groups during days 43-52. The control group received a basal diet without supplemental selenium (analyzed selenium content of 0.183 mg/kg), while the experimental groups received the basal diet supplemented with 0.3 mg/kg selenium from either sodium selenite or selenium yeast. The composition and nutrient levels of the basal diet are presented in Table 1 .

1.3 Management The experiment was conducted at the Waterfowl Research Farm of Hunan Institute of Animal Science and Veterinary Medicine. Ducks were housed individually in double-layer metal cages with ad libitum access to feed and water. Conventional management practices were followed throughout the trial.

1.4 Measurements

1.4.1 Production Performance During the experimental period, daily records were maintained for each replicate, including total egg number, total egg weight, feed intake, and number of defective eggs (soft-shelled, cracked, misshapen, or rough-shelled). Average egg weight, daily egg mass, laying rate, qualified egg rate, average daily feed intake, and feed-to-egg ratio were calculated for each group.

1.4.2 Egg Quality On day 42, fifteen eggs per group (three per replicate) with weights close to the average were selected for quality analysis within 24 hours. Measurements included yolk ratio, albumen ratio, shell thickness (using a shell thickness gauge), egg shape index (measured with vernier calipers), yolk

color (using a yolk color fan), and albumen height (using an albumen height gauge). Haugh units were calculated using the formula: HU = 100 × log(H - 1.7W^0.37 + 7.57), where H represents albumen height (mm) and W represents egg weight (g).

1.4.3 Serum Antioxidant Capacity On day 42, two ducks per replicate with similar body weights were selected after a 12-hour fast. Blood samples (5 mL) were collected from the wing vein, allowed to clot for 30 minutes, and then centrifuged at 3,000 rpm for 15 minutes to separate serum. Serum glutathione peroxidase (GSH-Px) activity, superoxide dismutase (SOD) activity, glutathione (GSH) content, and malondialdehyde (MDA) content were measured using colorimetric methods with assay kits purchased from Nanjing Jiancheng Bioengineering Institute. Serum selenium content was determined by hydride generation atomic fluorescence spectrometry (according to GB/T 13883-2008).

1.4.4 Egg Selenium Content Determination On days 28, 35, and 42 of the experiment, and on days 1-10 after withdrawal of supplemental selenium, fifteen eggs per group (three per replicate) with weights close to the average were collected for selenium content analysis using hydride generation atomic fluorescence spectrometry.

1.5 Statistical Analysis Data were analyzed using one-way ANOVA with SPSS 18.0 software, followed by Duncan' s multiple comparison test. Results are expressed as mean ± standard deviation (SD). Differences were considered significant at $P<0.05$ and highly significant at $P<0.01$.

2. Results

2.1 Effects of Different Selenium Sources on Production Performance and Egg Quality As shown in Table 2 , dietary supplementation with 0.3 mg/kg sodium selenite or selenium yeast had no significant effects on average daily feed intake, laying rate, average egg weight, or feed-to-egg ratio in peak-laying Linwu ducks ($P>0.05$).

Table 3 demonstrates that dietary supplementation with 0.3 mg/kg sodium selenite or selenium yeast did not significantly affect egg quality parameters including egg shape index, shell thickness, albumen height, yolk ratio, shell weight percentage, Haugh unit, or yolk color ($P>0.05$).

2.2 Effects of Different Selenium Sources on Serum Antioxidant Capacity Table 4 shows that after 42 days of supplementation with 0.3 mg/kg sodium selenite or selenium yeast, serum selenium content in peak-laying Linwu ducks increased to 0.15 and 0.14 mg/kg, respectively, both significantly higher than the control group ($P<0.01$). Serum GSH-Px activity increased to 468.29 and 469.11 U/mL, respectively, significantly higher than the control group

(P<0.05). The selenium yeast group exhibited the lowest serum MDA content at 4.46 nmol/mL, significantly lower than both the control and sodium selenite groups (P<0.05).

2.3 Effects of Different Selenium Sources on Egg Selenium Content Table 5 reveals that dietary supplementation with sodium selenite or selenium yeast significantly increased egg selenium content compared with the control group (P<0.01). Within five days after withdrawal of supplementation (days 43-47), egg selenium content in both experimental groups remained significantly higher than the control group (P<0.01). On day 6 post-withdrawal (day 48), the sodium selenite group showed no significant difference from the control group (P>0.05), while the selenium yeast group maintained significantly higher egg selenium content than both the control (P<0.01) and sodium selenite groups (P<0.05). On days 7 and 8 post-withdrawal (days 49 and 50), the selenium yeast group exhibited significantly higher egg selenium content than both the sodium selenite and control groups (P<0.01). By days 9 and 10 after withdrawal (days 51 and 52), egg selenium content in all groups had decreased to comparable levels with no significant differences (P>0.05).

3. Discussion

3.1 Effects of Different Selenium Sources on Production Performance and Egg Quality Research findings on the effects of dietary selenium sources on poultry production performance have been inconsistent. Hu et al. [14] reported that dietary supplementation with selenium-enriched alfalfa significantly improved laying rate and daily egg mass in Roman hens, while selenium yeast significantly increased laying rate. Laika and Jahanian [15] also found that dietary supplementation with zinc-selenium methionine complex significantly improved performance in Leghorn hens. Conversely, Chantiratikul et al. [16] observed that selenium-enriched kale as a dietary selenium source had no significant effect on feed intake or production performance in laying hens. Sun et al. [8] and Zduńczyk et al. [17] similarly reported that selenium supplementation did not significantly affect laying hen performance. These discrepancies may be attributed to differences in poultry breed, production stage, basal dietary selenium content, and selenium source type. The current study found that supplementation with 0.3 mg/kg sodium selenite or selenium yeast had no significant effect on production performance in peak-laying Linwu ducks.

The present study also found that dietary supplementation with 0.3 mg/kg sodium selenite or selenium yeast had no significant effect on egg quality parameters such as Haugh unit in Linwu ducks, which is consistent with the findings of Yan et al. [13] in Cherry Valley breeding ducks. This may be related to the strong regulatory capacity of immune and antioxidant functions in peak-laying ducks. Payne et al. [18] suggested that dietary selenium yeast could slow the decline in Haugh unit and extend egg shelf life. Qu et al. [11] also demonstrated that dietary supplementation with nano-selenium and selenium

yeast significantly delayed the decrease in Haugh unit during quail egg storage. However, as the current study did not investigate egg quality during storage, we cannot conclude that dietary supplementation with 0.3 mg/kg sodium selenite or selenium yeast has no effect on egg quality during storage.

3.2 Effects of Different Selenium Sources on Serum Antioxidant Capacity After absorption in the duodenum, selenium enters the bloodstream and binds with α-globulin and β-globulin for transport to various tissues [19]. Selenium is an essential component of GSH-Px, thioredoxin reductase, and selenoprotein P, through which it regulates antioxidant capacity [20-21]. Recent research has revealed significant differences in absorption and transport mechanisms between organic and inorganic selenium, with organic selenium demonstrating higher absorption efficiency, biological safety, and antioxidant enhancement than inorganic selenium [4]. Sun et al. [8] reported that compared with sodium selenite and selenomethionine, dietary supplementation with selenium yeast and nano-selenium was more effective in increasing plasma GSH-Px activity and total antioxidant capacity (T-AOC) in laying hens. Zhang et al. [22] found that compared with sodium selenite, dietary selenomethionine supplementation in 39-week-old Lingnan Yellow broiler breeders significantly increased GSH-Px activity in serum and breast muscle of offspring, serum GSH content, and pancreatic T-AOC. Qu et al. [11] demonstrated that both selenium yeast and nano-selenium significantly increased serum GSH-Px activity, total superoxide dismutase (T-SOD) activity, and T-AOC while significantly decreasing MDA content, with nano-selenium showing superior antioxidant effects compared to selenium yeast. The current results align with previous findings, indicating that dietary supplementation with 0.3 mg/kg selenium significantly increased serum selenium content and GSH-Px activity in Linwu ducks, while selenium yeast supplementation significantly decreased serum MDA content.

3.3 Effects of Different Selenium Sources on Egg Selenium Content Previous studies have shown that egg selenium content increases with dietary selenium level [10], with organic selenium demonstrating superior deposition efficiency compared to inorganic selenium [23-24]. Delezie et al. [25] found that dietary selenium supplementation levels were reflected in egg selenium content, with the highest content observed in eggs from hens supplemented with 0.5 mg/kg selenium, followed by 0.3 mg/kg, and the lowest with 0.1 mg/kg. Among selenium sources, selenomethionine showed the most pronounced dose-response, followed by selenium yeast, with sodium selenite showing the weakest response. Jing et al. [23] reported that organic selenium (selenium yeast and selenomethionine) significantly increased egg selenium content more effectively than inorganic sources, with higher supplementation levels resulting in greater egg selenium content. Lu et al. [9] and Cai et al. [12] demonstrated that selenium from selenium yeast transferred to eggs more rapidly and efficiently than sodium selenite, with egg selenium content increasing with longer supplementation duration. These studies focused on the effects of continuous selenium

supplementation on selenium enrichment patterns, while the impact of selenium withdrawal after continuous supplementation on egg selenium retention remains unreported.

The current study confirmed that dietary selenium supplementation significantly increased and maintained egg selenium content at relatively stable levels, consistent with previous research. Additionally, we found that after 42 days of continuous supplementation, egg selenium content remained higher than the control group for five days post-withdrawal. Following withdrawal, egg selenium content in the sodium selenite group decreased to control levels after 7 days, while the selenium yeast group maintained elevated levels for 9-10 days. Thus, selenium yeast prolonged selenium retention in duck eggs by 2-3 days compared with sodium selenite. These results demonstrate that 42 days of dietary selenium supplementation extended selenium retention in eggs after withdrawal, with selenium yeast attenuating the decline in egg selenium content more effectively than sodium selenite. This may be because dietary selenium supplementation increased selenium content in duck serum, liver, and muscle [26], and after withdrawal, selenium stored in these tissues gradually mobilized and enriched in eggs, prolonging retention. The specific mechanisms warrant further investigation.

Conclusions

1. Dietary supplementation with 0.3 mg/kg selenium from either selenium yeast or sodium selenite had no significant effect on production performance or egg quality in peak-laying Linwu ducks.
2. Dietary selenium supplementation significantly increased selenium content and antioxidant capacity in serum, as well as selenium content in duck eggs.
3. Dietary selenium supplementation extended selenium retention in eggs after withdrawal, with selenium yeast demonstrating a longer retention effect than sodium selenite.

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