Postprint: Effects of Soy Isoflavones on Egg Production and Reproductive Performance in Broiler Breeders

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Abstract

This experiment aimed to explore the effects of daidzein supplementation on egg production and reproductive performance in broiler breeder hens. A total of 240 S2 line broiler breeder hens at 43 weeks of age with similar physiological condition (body weight and laying rate) were randomly divided into 4 groups with 6 replicates per group and 10 hens per replicate: one group served as the control group and was fed a basal diet without daidzein, while the remaining three groups were fed the basal diet supplemented with 5, 10, and 20 mg/kg daidzein, respectively. Additionally, 20 robust S2 line roosters were selected for semen collection, and pooled semen was used for artificial insemination of the experimental hens. The experimental period lasted for 15 weeks. The results showed that, compared with the control group: 1) daidzein supplementation had no significant effect on body weight gain, feed intake, or mortality rate of S2 line hens ($P>0.05$); 2) daidzein supplementation significantly improved the laying rate ($P<0.05$), with the 10 mg/kg group showing the best performance among the three treatment groups, increasing the laying rate by 4.1% ($P<0.05$) and daily egg production by 3.5% ($P<0.05$). The feed-to-egg ratio was reduced by 8.0% and 11.2% in the 5 and 10 mg/kg groups, respectively ($P<0.05$); 3) the 10 mg/kg group increased the fertilization rate, hatchability, and healthy chick rate by 13.1%, 20.5%, and 5.8%, respectively ($P<0.05$). In conclusion, dietary supplementation with daidzein can significantly affect egg production and reproductive performance in broiler breeder hens, with the 10 mg/kg group demonstrating the best overall effect.

Full Text

Effects of Daidzein on Laying and Reproductive Performance of Broiler Breeders

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Abstract: This experiment investigated the effects of dietary daidzein supplementation on the laying and reproductive performance of broiler breeders. A total of 240 43-week-old S2 broiler breeder hens with similar body condition (body weight and laying rate) were randomly divided into 4 groups with 6 replicates per group and 10 hens per replicate. One group served as the control and was fed a basal diet without daidzein, while the remaining three groups received the basal diet supplemented with 5, 10, or 20 mg/kg daidzein, respectively. Twenty healthy S2 roosters were selected for semen collection, and mixed semen was used for artificial insemination of the hens in all four groups. The experimental period lasted for 15 weeks. The results showed that, compared with the control group: (1) daidzein supplementation had no significant effects on body weight gain, feed intake, or mortality of S2 hens ($P>0.05$); (2) daidzein supplementation significantly improved laying rate ($P<0.05$), with the 10 mg/kg group showing the best performance among the three treatment groups, increasing laying rate by 4.1% ($P<0.05$) and daily egg mass by 3.5% ($P<0.05$), while the feed-to-egg ratio decreased by 8.0% and 11.2% in the 5 and 10 mg/kg groups, respectively ($P<0.05$); (3) the 10 mg/kg group increased fertility rate, hatchability, and healthy chick rate by 13.1%, 20.5%, and 5.8%, respectively ($P<0.05$). These findings indicate that dietary daidzein supplementation can significantly affect the laying and reproductive performance of broiler breeders, with 10 mg/kg daidzein showing the optimal overall effect.

Key words: daidzein; broiler breeders; laying performance; reproductive performance

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Introduction

Daidzein is an isoflavone phytoestrogen widely found in natural plants, and its effects on the laying and reproductive performance of livestock and poultry have long attracted research attention. Studies by Leopold et al. [1] and Setchell et al. [2] have shown that the effects of phytoestrogens are related to endogenous estrogen levels in the body and vary under different physiological conditions. When endogenous estrogen levels are low, daidzein binds to estro-

gen receptors and exerts estrogen-like effects, participating in the regulation of various reproductive hormones and thereby improving reproductive capacity. In recent years, concerns have intensified regarding broiler breeders that suffer from severe declines in laying and reproductive performance due to excessive feed intake and strong fat deposition capacity leading to overweight. Previous studies on the effects of daidzein on laying and reproductive performance in poultry have mainly focused on laying hens [3-4]. However, due to differences in primary purpose and metabolic processes between laying hens and broiler breeders, systematic research is still lacking on whether daidzein supplementation in broiler breeder diets can improve laying and reproductive performance as it does in laying hens. This experiment was designed to investigate the effects of different doses of daidzein on the laying and reproductive performance of S2 broiler breeder hens, aiming to improve feed utilization, enhance laying and reproductive performance, and promote the healthy, rapid, and sustainable development of China' s broiler breeder industry.

Materials and Methods

1.1 Experimental Animals and Materials

This experiment utilized the S2 broiler breeder line developed by the Jiangsu Poultry Science Institute. This line was bred over more than twenty years using the dw dwarf gene and is characterized by partridge feathers, yellow shanks, compact body size, early maturity, high egg production, high qualified egg rate, and savings in feed and housing space. Daidzein was provided by Sichuan Guanghan Biochemical Products Co., Ltd.

At 43 weeks of age, 240 S2 broiler breeder hens with body weights around 1,640 g and laying rates of approximately 80% were selected and divided into 4 groups with 6 replicates per group and 10 hens per replicate. One group served as the control and was fed a basal diet without daidzein, while the remaining three groups were experimental groups that received the basal diet supplemented with 5, 10, or 20 mg/kg daidzein, respectively. At 43 weeks of age, 20 healthy S2 roosters were selected for semen collection, and mixed semen was used for artificial insemination of the hens in all four groups. The entire experimental period lasted for 15 weeks. The composition and nutrient levels of the basal diet are shown in Table 1 .

1.3 Feeding Management and Measurement of Experimental Indices

All experimental hens were housed under the same conditions in cages with ad libitum access to feed and water. Eggs were collected daily, and the number of eggs, egg weight, and number of unqualified eggs (sand-shell eggs, soft-shell eggs, double-yolk eggs, misshapen eggs, and broken eggs) were recorded by replicate. Feed consumption and mortality were recorded weekly by replicate. At the

end of the experiment, 2,500 qualified eggs from each group were selected for incubation. Eggs were candled to calculate fertility rate, and after hatching, the hatchability of fertile eggs and healthy chick rate were calculated.

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

1.4 Data Processing and Statistical Analysis

Data were analyzed using SPSS 16.0 software with one-way ANOVA. Results are expressed as "mean ± standard deviation" (mean±SD), and LSD multiple comparisons were performed.

Results

2.1 Effects of Daidzein on Performance of S2 Broiler Breeders

As shown in Table 2 , daidzein supplementation had no significant effects on body weight gain, mortality, feed intake, or feed-to-gain ratio of S2 broiler breeders ($P>0.05$).

Table 2 Effects of daidzein on performance of S2 broiler breeders

2.2 Effects of Daidzein on Laying Performance of S2 Broiler Breeders

As shown in Table 3 , compared with the control group, the laying rates of experimental groups 1, 2, and 3 increased by 2.3%, 4.1%, and 2.7%, respectively ($P<0.05$). There was no significant difference in laying rate between groups 2 and 3 ($P>0.05$), but both were significantly higher than group 1 ($P<0.05$).

Daily egg mass, which comprehensively considers both laying rate and egg weight, better reflects the laying performance of poultry. Compared with the control group, daily egg mass in groups 2 and 3 increased by 3.5% and 3.2%, respectively ($P<0.05$). The feed-to-egg ratio decreased by 8.0% and 11.2% in groups 1 and 2, respectively, compared with the control group ($P<0.05$), while no significant change was observed in group 3 ($P>0.05$). These results suggest that daidzein can improve the laying performance of S2 broiler breeders, with the most pronounced effects observed at the supplementation level of 10 mg/kg.

Table 3 Effects of daidzein on laying performance of S2 broiler breeders

2.3 Effects of Daidzein on Reproductive Performance of S2 Broiler Breeders

As shown in Table 4 , compared with the control group, fertility rate increased by 11.8% and 13.1% in groups 1 and 2, respectively ($P<0.05$), and hatchability increased by 18.3% and 20.5%, respectively ($P<0.05$). No significant changes in fertility rate or hatchability were observed in group 3 ($P>0.05$).

Compared with the control group, embryonic death rate decreased by 32.4%, 36.7%, and 31.8% in groups 1, 2, and 3, respectively ($P<0.05$). The healthy chick rate in group 2 increased by 5.8% ($P<0.05$), while no significant changes were observed in groups 1 and 3 ($P>0.05$).

Table 4 Effects of daidzein on reproductive performance of S2 broiler breeders

Discussion

3.1 Effects of Daidzein on Performance of S2 Broiler Breeders

Animal studies have reported that appropriate dietary supplementation of daidzein can significantly affect feeding behavior and accelerate production, with extensive research conducted in poultry. Meng et al. [5] found that intravenous injection of daidzein before feeding significantly increased feed intake, feeding time, and feeding frequency in laying hens. Gu et al. [6] reported that supplementation of 10, 50, and 100 mg/kg daidzein in the basal diet of late-laying hens significantly improved laying performance without significantly affecting feed intake. These contrasting results suggest that the method of administration, dosage, and chicken breed may differently influence feed intake responses to daidzein. The present study is consistent with the findings of Gu et al. [6], demonstrating that daidzein supplementation did not significantly alter production performance or feed intake in broiler breeders.

3.2 Effects of Daidzein on Laying Performance of S2 Broiler Breeders

Egg production is a complex physiological process regulated by the neuroendocrine system in poultry, and hormone levels in the body significantly influence laying performance. Reports have shown that daidzein supplementation induces notable changes in hormone levels in laying hens, which affect laying performance by altering nutrient metabolic pathways. Liu et al. [7] found that dietary supplementation of 3 mg/kg daidzein increased laying rate and egg weight in 330-day-old Roman laying hens. Ke et al. [8] reported that adding 3 mg/kg daidzein to the diet of 7-month-old quails increased laying rate by 6.7%, decreased feed-to-egg ratio by 5.0%, and elevated serum triiodothyronine (T3) levels by 23.5% compared with the control group. Zhou [9] fed late-laying Shaoxing ducks with basal diets supplemented with 3 or 5 mg/kg daidzein and observed laying rate increases of 57.00% and 13.33%, daily egg mass increases of 13.13% and 16.61%, and feed-to-egg ratio decreases of 9.40% and 11.41%, respectively. These studies indicate that daidzein can improve laying performance in poultry with dose-dependent effects. Regarding the underlying mechanisms, Ni et al. [10] demonstrated that daidzein supplementation significantly decreased mRNA expression of growth hormone receptor and insulin-like growth factor-1 receptor in the uterus of the oviduct, which regulates oviduct size in Isa laying hens, resulting in increased oviduct weight. Liu et al. [11] showed that

daidzein upregulated mRNA expression of follicle-stimulating hormone estrogen α-receptor, promoting rapid development of large white follicles and small yellow follicles. The present study is consistent with these findings and further demonstrates that 10 mg/kg daidzein supplementation yielded optimal laying performance. The mechanism may involve daidzein-mediated regulation of gene expression in the ovary and oviduct of broiler breeders.

3.3 Effects of Daidzein on Reproductive Performance of S2 Broiler Breeders

Studies have reported that the key factor influencing reproductive performance after daidzein supplementation in livestock and poultry is the endogenous estrogen level, with different doses of daidzein exerting antagonistic or promotional effects on the development of reproductive organs such as the ovary and oviduct [12]. Huang et al. [13] demonstrated that dietary supplementation of 3 or 6 mg/kg daidzein significantly improved fertility and hatchability in laying hens. Zhang et al. [14] found that while 6 mg/kg daidzein significantly increased laying rate in Muscovy ducks, it significantly decreased fertility and hatchability. In contrast, 12 mg/kg daidzein significantly increased laying rate and average egg weight but significantly decreased qualified egg rate, fertility, and hatchability. The authors verified that higher residual daidzein levels in duck eggs from the 6 and 12 mg/kg groups competitively bound to estrogen receptors in duck embryos, adversely affecting embryonic development. Zhao et al. [15] reported that appropriate daidzein supplementation (6 mg/kg) significantly elevated serum T3 and thyroxine (T4) levels in a dose-dependent manner and improved reproductive performance by modulating the hypothalamic-pituitary-gonadal axis, whereas daidzein exceeding the permissible dose significantly decreased reproductive performance. The present study found that the 10 mg/kg group exhibited significantly higher fertility, hatchability, and healthy chick rates, along with significantly lower embryonic death rate, compared with the 20 mg/kg group. These findings are consistent with previous research and may be explained by the relatively lower estrogen levels in S2 broiler breeders compared with typical laying hens, allowing 10 mg/kg daidzein to bind and act as an estrogen agonist that positively regulates the hypothalamic-pituitary-gonadal axis to improve reproductive performance. In contrast, supplementation with 20 mg/kg daidzein exceeded the permissible dose, ultimately exerting negative effects on reproductive performance.

Conclusions

Dietary supplementation with different doses of daidzein had no significant effects on body weight gain, feed intake, or mortality of broiler breeders.

Dietary daidzein supplementation can improve laying performance (laying rate and daily egg mass) and reproductive performance (fertility rate, hatchability, and healthy chick rate) of broiler breeders, with 10 mg/kg daidzein showing the

optimal effect, while excessive supplementation tends to decrease both laying and reproductive performance.

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