Effects of Dietary Arginine Level on Reproductive Performance of Yellow-Feathered Broiler Breeders During Peak Laying Period: Postprint

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Abstract

This experiment aimed to investigate the effects of different dietary arginine levels on the reproductive performance of yellow-feathered broiler breeder chickens. A total of 780 yellow-feathered broiler breeder chickens at 36 weeks of age were selected and randomly allocated to 5 groups using a single-factor experimental design (dietary arginine levels of 0.65%, 0.80%, 0.95%, 1.10%, and 1.25%), with 6 replicates per group and 26 birds per replicate. The experiment consisted of a 2-week pre-trial period during which the diet of Group 1 was fed, followed by a 10-week formal trial period. The results showed that dietary supplementation with different arginine levels had no significant effect on egg production rate, average egg weight, or feed-to-egg ratio throughout the entire experimental period ($P>0.05$). The 1.10% arginine group exhibited the highest egg production rate, with an improving trend compared to the 0.65% and 1.25% arginine groups ($P<0.10$). The 1.25% arginine group had the lowest average egg weight, showing a decreasing trend compared with the other four groups ($P<0.10$). Dietary supplementation with different arginine levels significantly affected eggshell strength, eggshell thickness, yolk ratio, protein content, as well as malondialdehyde content and reduced glutathione/oxidized glutathione ratio in breeder chicken plasma ($P<0.05$). Dietary arginine level had no significant effect on fertilization rate, hatchability, healthy chick rate, or average healthy chick hatching weight ($P>0.05$). These results indicate that moderate arginine supplementation can improve egg production rate of yellow-feathered broiler breeder chickens to a certain extent, and enhance eggshell strength and antioxidant capacity of breeder chickens. Based on multiple indicators from this experiment, the recommended dietary arginine level for fast-growing yellow-feathered broiler breeder chickens during the peak egg production period is 1.10%.

Full Text

Effects of Dietary Arginine Levels on Reproductive Performance of Chinese Yellow-Feather Broiler Breeders during Peak Laying

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Abstract

This trial was conducted to investigate the effects of different dietary arginine levels on reproductive performance of Chinese yellow-feather broiler breeders. Seven hundred and eighty 36-week-old Chinese yellow-feather broiler breeders were randomly assigned to 5 groups according to a single-factor randomized design. Each group contained 6 replicates with 26 birds per replicate. The dietary arginine levels were 0.65%, 0.80%, 0.95%, 1.10% and 1.25%, respectively. A 2-week pre-trial was conducted during which all birds were fed the diet containing 0.65% arginine, followed by a 10-week formal trial. The results demonstrated that dietary arginine supplementation had no significant effects on laying rate, average egg weight, or feed-to-egg ratio across the entire experimental period ($P>0.05$). The 1.10% arginine group achieved the highest laying rate, which showed an increasing trend compared with the 0.65% and 1.25% arginine groups ($P<0.10$). The 1.25% arginine group had the lowest average egg weight, which tended to decrease compared with the other four groups ($P<0.10$). Dietary arginine levels significantly affected eggshell strength, eggshell thickness, yolk percentage, protein content, plasma malondialdehyde content, and the reduced glutathione/oxidized glutathione ratio ($P<0.05$). However, dietary arginine levels had no significant effects on fertility rate, hatchability, salable chick rate, or average salable chick birth weight ($P>0.05$). In conclusion, appropriate arginine supplementation can improve the laying rate of Chinese yellow-feather broiler breeders to some extent, and enhance eggshell strength and antioxidant capacity. Based on comprehensive evaluation of multiple indices, the recommended dietary arginine level for fast-growing Chinese yellow-feather broiler breeders during peak laying period is 1.10%.

Keywords: Chinese yellow-feather broiler breeders; laying period; arginine; reproductive performance; egg quality

Introduction

Arginine is an important functional amino acid that plays multiple physiological roles in animals [1-2]. For chickens, arginine is an essential amino acid due to their limited capacity for endogenous synthesis [3]. Recent studies have shown that arginine can improve reproductive performance in animals [4-6] and promote luteinizing hormone release to induce ovulation in females. Arginine also exhibits beneficial effects on growth and sexual maturation of pullets [7]. Najib et al. [8] found that increasing dietary arginine level to 1.5% improved laying performance and feed conversion ratio in laying hens. Lmgs et al. [9] reported that dietary arginine supplementation increased laying rate and egg weight in broiler breeders without significantly affecting hatchability. Duan et al. [10] suggested that the arginine requirement for broiler breeders during late laying period was 1.36%. Currently, research on arginine in chickens is limited, and studies on broiler breeders are even scarcer. The existing research on arginine nutrition in broiler breeders has focused on white-feathered strains. In China, yellow-feathered broilers account for half of the market share [11-12], yet nutritional research on Chinese yellow-feather broiler breeders lags behind. In recent years, our research group has been dedicated to studying the nutritional requirements of Chinese yellow-feather broiler breeders, having investigated requirements for protein and energy [13], calcium [14], phosphorus [15], zinc [16], lysine [17], methionine [18], isoleucine [19], and vitamin A [20] during the laying period. Therefore, this study was conducted to investigate arginine requirements during the laying period of Chinese yellow-feather broiler breeders. This research aims to fill the gap in arginine nutrition studies for this breed, improve the nutritional research framework, and enhance laying rate and reproductive performance given the current suboptimal production levels, thereby providing scientific basis for formulating nutritional standards.

Materials and Methods

1.1 Experimental Design This experiment employed a single-factor randomized design. Seven hundred and eighty healthy 36-week-old fast-growing Lingnan yellow-feather broiler breeder hens (without white feather lineage, medium body size, reaching 5% laying rate at 24 weeks, body weight approximately 2.3 kg, with 175-185 eggs and 145-155 salable chicks per housed hen by 66 weeks) with uniform genetic background were selected as experimental birds. Based on consistent body weight and laying rate, they were randomly divided into 5 groups with 6 replicates per group. Each replicate consisted of 13 cages with 2 birds per cage.

1.2 Experimental Diets A corn-corn gluten meal basal diet was formulated (soybean meal was replaced by feed-grade corn gluten meal with 63.5% crude protein as the protein source due to its high arginine content). Nutrient levels were primarily based on the Chinese Yellow-Feathered Chicken Nutrition Requirements Standard (2004) [21] and previous research results from the Institute of Animal Science, Guangdong Academy of Agricultural Sciences. Diet composition and nutrient levels were calculated according to the Chinese Feed Composition and Nutritional Value Table [21] (Table 1). Different arginine levels (0.65%, 0.80%, 0.95%, 1.10% and 1.25%) were achieved by adding varying proportions of L-arginine hydrochloride (Ningbo Daxie Development Zone Hyde Amino Acid Industry Co., Ltd.).

1.3 Management The trial was conducted at the experimental farm of the Institute of Animal Science, Guangdong Academy of Agricultural Sciences. Broiler breeders were housed in 3-tier step cages with restricted feeding. Birds were fed 125 g per bird once daily at 09:00 and provided water ad libitum via nipple drinkers. During the trial, lighting was maintained at a constant 16 h per day with natural ventilation. Temperature and humidity in the hen house were recorded daily at 08:00, 14:00 and 20:00. During the last 2 weeks of the trial, artificial insemination was performed at 16:00 every 2 days with 30 L per bird. Other management practices followed conventional feeding and immunization procedures. Before the formal trial, all birds were fed the diet of Group 1 for 2 weeks to stabilize laying performance, followed by a 10-week formal trial period.

1.4 Measurements

1.4.1 Production Performance Eggs were collected once daily at 15:00. The number of eggs and unqualified eggs (including cracked, soft-shelled, double-yolk and misshapen eggs) were recorded for each replicate. Total egg weight was measured to calculate laying rate, average egg weight, total feed consumption, feed-to-egg ratio and unqualified egg rate using the following formulas:

Laying rate (%) = (Total number of eggs / Accumulated bird-days) × 100
Average egg weight (g) = Total egg weight / Total number of eggs
Feed-to-egg ratio = Total feed consumption / Total egg weight
Cracked egg rate (%) = (Number of cracked eggs / Number of eggs) × 100
Unqualified egg rate (%) = (Number of unqualified eggs / Number of eggs) × 100

1.4.2 Hatching Performance During the last week of the trial, 50 qualified hatching eggs were selected from each replicate, marked and incubated. Fertility rate, hatchability, salable chick rate and average salable chick birth weight were determined:

Fertility rate (%) = [(Number of incubated eggs - Number of infertile eggs) / Number of incubated eggs] × 100
Hatchability (%) = [Number of hatched chicks / (Number of incubated eggs - Number of infertile eggs)] × 100
Salable chick rate (%) = (Number of salable chicks / Number of hatched chicks) × 100

Average salable chick birth weight (g) = Total weight of salable chicks / Number of salable chicks

1.4.3 Egg Quality At the end of the trial, 2 qualified hatching eggs were randomly selected from each replicate and measured within 48 h for egg weight, egg shape index, eggshell strength, eggshell thickness, yolk weight, and protein and fat content. Egg shape index = transverse diameter / longitudinal diameter. Eggshell thickness was measured at three points (blunt end, middle, and pointed end) after removing the shell membrane using a micrometer, and the average value was calculated. Eggshell strength was measured using an eggshell force gauge (Model SN:EF04512011, ORKA Food Technology, Japan). After shell removal, eggs were freeze-dried into whole egg powder. Protein content was determined by the Kjeldahl method and fat content by Soxhlet extraction, with results calculated on a dry matter basis.

1.4.4 Plasma Biochemical Indices At the end of the trial, after weighing, 2 birds close to the average body weight were selected from each replicate. Blood (5 mL) was collected from the wing vein and centrifuged at 3,000 r/min for 15 min to separate plasma. Plasma uric acid, malondialdehyde (MDA), reduced glutathione (GSH), oxidized glutathione (GSSG), total superoxide dismutase (T-SOD) and nitric oxide synthase (NOS) were determined using assay kits from Nanjing Jiancheng Bioengineering Institute following the manufacturer' s instructions. The GSH/GSSG ratio was calculated from measured values.

1.4.5 Slaughter Traits and Reproduction-Related Indices After blood collection, broiler breeders were slaughtered. After feather removal, carcass weight was recorded and the comb was excised and weighed. The abdominal cavity was opened to excise the ovary and oviduct, which were weighed separately. Oviduct length was measured and the number of dominant follicles (>8 mm diameter) was recorded. Organ weights were divided by carcass weight to calculate comb index, ovary index and oviduct index.

1.5 Statistical Analysis All data were analyzed using the GLM procedure of SAS 8.1 software. Duncan' s multiple comparison was performed when significant differences were detected. Data not normally distributed were transformed before statistical analysis. Significance level was set at $P<0.05$, with $P<0.10$ considered as a tendency. Results were expressed as means ± standard error (mean±SE).

Results

2.1 Effects of Dietary Arginine Levels on Production Performance As shown in Table 2 , dietary arginine levels had no significant effects on laying rate, average egg weight, feed-to-egg ratio or qualified egg rate ($P>0.05$). The 1.10% arginine group achieved the highest laying rate, which was 3.65% and

3.97% higher than the 0.65% and 1.25% arginine groups, respectively (P<0.10). The 1.25% arginine group had the lowest average egg weight, which was 1.97% lower than the 0.80% arginine group (P<0.10) and tended to decrease compared with the 0.65%, 0.95% and 1.10% arginine groups (P<0.10). The 1.10% arginine group had the lowest feed-to-egg ratio, which was 4.03% and 3.20% lower than the 1.25% and 0.65% arginine groups, respectively (P<0.10). The qualified egg rate in the 0.80% arginine group was 1.1 percentage points higher than that in the 1.25% arginine group (P<0.10). Overall, the 1.10% arginine group showed optimal production performance.

2.2 Effects of Dietary Arginine Levels on Egg Quality As shown in Table 3 , dietary arginine levels tended to affect egg shape index (P<0.10). The 1.10% arginine group had the highest egg shape index, which was 2.34% higher than the 0.95% arginine group (P<0.10). Eggshell strength in the 1.10% arginine group was the highest and significantly greater than that in the 0.65%, 0.80% and 0.95% arginine groups (P<0.05). Both the 0.95% and 1.25% arginine groups had significantly higher eggshell strength than the 0.65% and 0.80% arginine groups (P<0.05). The 0.65% arginine group had significantly lower eggshell thickness than the other four groups (P<0.05). Yolk percentage was highest in the 0.95% arginine group, significantly higher than in the 0.65%, 0.80% and 1.10% arginine groups (P<0.05). The 0.65%, 1.10% and 1.25% arginine groups also had significantly higher yolk percentage than the 0.80% arginine group (P<0.05). Protein content in the 0.95% arginine group was significantly higher than in the other four groups (P<0.05). No significant differences in fat content were observed among groups (P>0.05).

2.3 Effects of Dietary Arginine Levels on Plasma Biochemical Indices As shown in Table 4 , dietary arginine levels had no significant effect on plasma uric acid content (P>0.05), though the 1.25% arginine group tended to have lower uric acid than the 0.65% arginine group (P<0.10). The 1.25% arginine group had significantly higher plasma MDA content than the other four groups (P<0.05). Plasma T-SOD activity in the 1.25% arginine group tended to be higher than in the 0.95% arginine group (P<0.10). No significant differences in plasma NOS activity were observed among groups (P>0.05). The GSH/GSSG ratio in the 0.95% arginine group was significantly higher than in the other four groups (P<0.05), and the 1.25% arginine group was also significantly higher than the 1.10% arginine group (P<0.05).

2.4 Effects of Dietary Arginine Levels on Other Reproduction-Related Traits As shown in Table 5 , dietary arginine levels had no significant effect on ovary index (P>0.05). Both the 1.10% and 1.25% arginine groups had significantly higher comb index than the other three groups (P<0.05). Dietary arginine levels had no significant effects on oviduct length or oviduct index (P>0.05). No significant effects were observed on dominant follicle number, fertility rate or hatchability (P>0.05).

2.5 Effects of Dietary Arginine Levels on Hatching Performance As shown in Table 6 , dietary arginine levels had no significant effects on fertility rate, hatchability, salable chick rate or average salable chick birth weight (P>0.05). The chick birth weight/incubated egg weight ratio in the 1.25% arginine group was significantly higher than in the 0.65% and 0.80% arginine groups (P<0.05).

Discussion

3.1 Effects of Dietary Arginine Levels on Production Performance For broiler breeders, production performance is part of reproductive performance. This study found that dietary arginine could improve laying rate to some extent, although the overall effect was not significant, while excessive arginine supplementation tended to decrease laying rate. These results are both consistent and inconsistent with previous reports. Lmgs et al. [9] increased dietary arginine level from 0.943% to 1.543% with 0.15% increments and found that laying rate first increased then decreased, showing a significant quadratic correlation with arginine level. Another study reported that compared with 0.89% arginine, 1.49% arginine increased laying rate by 2.25 percentage points (not significant), while 2.49% arginine significantly decreased laying rate by 7.57 percentage points compared with 1.49% arginine [8]. Other research has reported significant linear and quadratic effects of arginine level on laying rate in broiler breeders [10]. The improvement in laying performance may be attributed to arginine stimulating increased secretion of luteinizing hormone, which directly acts on ovaries and follicles [22]. High-dose arginine may affect laying performance because arginine metabolism and catabolism require substantial energy, particularly in avian species that excrete uric acid [23]. This study found that high-dose arginine supplementation significantly decreased average egg weight, which contradicts the report by Lmgs et al. [9] that egg weight increased linearly with arginine level. Excessive arginine supplementation (>2.00%) has been shown to decrease feed intake and affect performance in laying hens [8]. In this study, dietary arginine levels were all below 1.25%, and all birds consumed the entire daily ration of 125 g due to restricted feeding. Therefore, production performance in this study was not affected by feed intake. Although fast-growing Chinese yellow-feather broiler breeders require restricted feeding to prevent excessive fatness, the differences in laying rate and egg weight did not affect statistical analysis of the feed-to-egg ratio. The results clearly showed that excessive arginine supplementation increased feed-to-egg ratio and decreased feed conversion efficiency.

3.2 Effects of Dietary Arginine Levels on Egg Quality Few studies have reported on the effects of arginine on egg quality and composition. Yang [24] indicated that qualified hatching eggs should be oval-shaped with an egg shape index of 1.33-1.38, with 1.35 being optimal. In this study, the egg shape index of fast-growing Chinese yellow-feather broiler breeders was relatively low, with only the 1.10% arginine group approaching the recommended value. Although no significant effect on qualified egg rate was observed, arginine improved eggshell strength and thickness, possibly because arginine promotes synthesis of ovocleidin-17, a shell matrix-specific protein in avian species that contains abundant arginine residues and regulates mineral deposition in eggshells [25]. Mou et al. [26] found that moderate arginine supplementation increased crude protein content in egg yolk, consistent with this study' s finding that the 0.95% arginine group had the highest protein content in whole egg powder. Mou et al. [25] also reported that arginine supplementation decreased fat content in egg yolk, though this study found no significant effect on fat content in whole egg powder. Egg quality measurements may be substantially affected by random egg selection, and multiple measurements should be integrated for comprehensive analysis to ensure accuracy.

3.3 Effects of Dietary Arginine Levels on Plasma Biochemical Indices
In avian species, arginine participates in protein synthesis as an amino acid and is catabolized through the ornithine cycle to produce ammonia, which is then converted to purine and finally excreted as uric acid [27]. This study found that high-dose arginine supplementation decreased plasma uric acid content, consistent with previous reports [3,28], possibly because high dietary arginine increased uric acid excretion in feces, thereby decreasing blood uric acid levels. Multiple studies have reported antioxidant functions of arginine [29-31]. This study found that dietary arginine improved total antioxidant status mainly by decreasing plasma GSSG content and increasing the GSH/GSSG ratio. However, high-dose arginine significantly increased plasma MDA content. Other studies have reported that arginine supplementation had no significant effect on antioxidant indices in blood of diabetic patients [32].

3.4 Effects of Dietary Arginine Levels on Other Reproduction-Related Traits Studies in sows have clearly demonstrated that arginine can improve reproductive performance [2,6,33]. Basiouni et al. [34] found that hens fed 2.05% arginine had heavier F1 follicles than those fed 1.54% arginine. This study found no significant effect of dietary arginine on dominant follicle number in fast-growing Chinese yellow-feather broiler breeders. Fertility and hatchability were also unaffected by dietary arginine level, consistent with the findings of Lmgs et al. [9]. Both excessively large and small egg weights can affect hatchability and chick quality. Generally, hatching eggs for layer breeds should weigh 50-60 g, while those for broiler breeds should weigh 52-68 g [24]. In this study, selected hatching eggs weighed 52-65 g. Although the highest arginine dose group had relatively lower laying rate and egg weight, resulting in numerically lower selected hatching egg weight, this group produced the heaviest chicks at hatching. While neither difference was significant, the chick birth weight/incubated egg weight ratio was significantly higher than in the two low-dose arginine groups, indicating that arginine improved hatching conversion efficiency to some extent. This suggests that arginine supplementation could be increased during the fertilization period to improve hatching conversion efficiency, though no related studies have been reported.

Conclusion

1. Dietary arginine levels of 0.80%-1.10% tended to improve laying rate and decrease feed-to-egg ratio in fast-growing Chinese yellow-feather broiler breeder hens. Excessive arginine supplementation tended to decrease laying rate and egg weight while increasing feed-to-egg ratio and unqualified egg rate.
2. Dietary arginine levels of 1.10%-1.25% significantly increased eggshell strength.
3. Dietary arginine can improve antioxidant capacity, but excessive arginine supplementation may cause oxidative stress.
4. The recommended dietary arginine level for fast-growing Chinese yellow-feather broiler breeders during peak laying period is 1.10%.

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