Effects of Dietary Crude Protein Level on Reproductive Performance of Jining Bairi Chickens and Organ Indices and Serum Biochemical Indices of Newborn Chicks (Postprint)

Authors: Yin Ruoxin, Zhang Shuai, Zhang Qian, Shi Tianhong, Cao Bingjian, Hu Xiyi, Ding Xiangwen, Su Pengcheng, Song Zhigang

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Abstract

This experiment aimed to investigate the effects of dietary crude protein level on the reproductive performance of Jining Bairi chickens and the organ indices and serum biochemical indices of newly hatched chicks, in order to determine the dietary crude protein requirement for Jining Bairi chickens aged 41–48 weeks. A single-factor completely randomized experimental design was adopted. A total of 525 healthy Jining Bairi laying breeder chickens at 40 weeks of age with similar body weight and no significant difference in laying rate ($P > 0.05$) were selected and randomly divided into 5 treatments, with 5 replicates per treatment and 21 chickens per replicate. Each treatment was fed experimental diets with crude protein levels of 13%, 14%, 15%, 16%, and 17%, respectively. The pre-experimental period was 7 days, and the experimental period was 56 days. The results showed that: 1) Dietary crude protein level highly significantly affected the average daily crude protein intake ($P < 0.01$), which increased significantly with increasing dietary crude protein level. 2) Dietary crude protein level significantly or highly significantly affected the total number of eggs laid, the number of qualified hatching eggs, and the number of hatched chicks ($P < 0.05$ or $P < 0.01$). 3) For newly hatched chicks from eggs incubated at 44 weeks of age, the dietary crude protein level of breeder chickens only significantly affected the heart index ($P < 0.05$); for newly hatched chicks from eggs incubated at 48 weeks of age, the dietary crude protein level of breeder chickens significantly affected the small intestine index ($P < 0.05$) and highly significantly affected the liver index and serum uric acid content ($P < 0.01$). Based on the comprehensive results of the experiment, the appropriate dietary crude protein level to meet the optimal reproductive performance of Jining Bairi breeder chickens aged 41–48 weeks was 14.81%.

Full Text

Effects of Dietary Crude Protein Level on Reproductive Performance and Organ Indexes and Serum Biochemical Parameters for Newborn Chicks of Jining Bairi Chickens

YIN Ruoxin[1],[2], ZHANG Shuai[2], ZHANG Qian[3], SHI Tianhong[1], CAO Bingjian[2], HU Xiyi[2], DING Xiangwen[2], SU Pengcheng[2], SONG Zhigang[2]*

[1]Poultry Institute, Shandong Academy of Agricultural Sciences, Jinan 250023, China
[2]College of Animal Science and Technology, Shandong Agricultural University, Tai' an 271018, China
[3]Huangdao Entry-Exit Inspection and Quarantine Bureau, Qingdao 266555, China

Abstract: This experiment investigated the effects of dietary crude protein level on reproductive performance, organ indexes, and serum biochemical parameters in newborn chicks of Jining Bairi chickens to determine the optimal dietary crude protein requirement for breeder hens aged 41–48 weeks. A single-factor completely randomized design was employed, utilizing 525 healthy 40-week-old Jining Bairi breeder hens with similar body weight and laying rate ($P > 0.05$). The hens were randomly divided into five treatment groups, each consisting of five replicates of 21 birds. Each group received experimental diets containing 13%, 14%, 15%, 16%, or 17% crude protein. The pre-trial period lasted 7 days, followed by a 56-day experimental period. The results demonstrated: (1) dietary crude protein level exerted an extremely significant effect on average daily crude protein intake (ADCPI) ($P < 0.01$), with ADCPI increasing markedly as dietary crude protein level rose; (2) dietary crude protein level significantly or extremely significantly affected total egg number, qualified egg number, and chick hatch number ($P < 0.05$ or $P < 0.01$); (3) in chicks hatched from eggs collected at 44 weeks, breeder dietary crude protein level only significantly affected heart index ($P < 0.05$), while in chicks hatched from eggs collected at 48 weeks, it significantly affected small intestine index ($P < 0.05$) and extremely significantly affected liver index and serum uric acid content ($P < 0.01$). Based on these comprehensive findings, the optimal dietary crude protein level for maximizing reproductive performance in 41–48-week-old Jining Bairi breeder hens is 14.81%.

Keywords: crude protein level; Jining Bairi chickens; reproductive performance; newborn chicks

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Crude protein represents one of the fundamental nutritional requirements for laying poultry, and determining appropriate dietary crude protein levels is crucial for enhancing production performance, reducing costs, and improving farming

profitability. Dietary crude protein level not only influences breeder performance but also significantly affects chick quality. Previous research has shown that hatching eggs weighing 58.9–64.9 g yielded significantly higher healthy chick rates and hatchability compared to eggs weighing 52.0–57.9 g, while embryonic mortality was extremely significantly higher in the lighter egg group. However, other studies have reported that dietary crude protein level did not significantly affect hatchability, fertilization rate, chick emergence rate, or healthy chick rate, although excessively high protein levels tended to reduce hatchability.

Jining Bairi chickens, indigenous to the suburbs of Jining City in Shandong Province, are named for their early-maturing individuals that typically begin laying around 100 days of age. The breed has now been distributed to over 20 provinces nationwide, including Shandong, Hunan, Hubei, Guizhou, and Yunnan, with increasing recognition of its economic value and genetic resource significance. Nevertheless, research on the crude protein requirements for this breed remains scarce, and breed-specific feeding standards have yet to be established. This study investigated the effects of dietary crude protein level on reproductive performance and on organ indexes and serum biochemical parameters in newborn chicks to determine the optimal crude protein requirement for 41–48-week-old Jining Bairi chickens, thereby providing a scientific basis for future research and practical production.

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Corresponding author: Professor, Doctoral supervisor, E-mail: zhigangs@sdau.edu.cn

1.1 Experimental Design

A total of 525 healthy 40-week-old Jining Bairi breeder hens with similar body weight and no significant difference in laying rate ($P > 0.05$) were selected and randomly allocated according to a single-factor completely randomized design into five treatment groups, each comprising five replicates of 21 birds. The treatments consisted of five experimental diets with crude protein levels of 13%, 14%, 15%, 16%, and 17%, respectively, while other major nutrient levels remained consistent across treatments. The pre-trial period lasted 7 days, followed by a 56-day experimental period.

1.2 Experimental Diets

Corn-soybean meal-based diets were formulated according to the *Feeding Standard of Chickens* (NY/T 33—2004) and adjusted based on practical production conditions. The composition and nutrient levels of the experimental diets are presented in Table 1 . The premix provided per kilogram of diet: VA 230,000 IU, VD_3 100,000 IU, VE 1,000 IU, VK_3 60 mg, VB_1 60 mg, VB_2 350 mg, VB_6 100 mg, VB_{12} 0.6 mg, Cu 0.5–2.5 g, Fe 1.6 g, Mn 2.5 g, Zn 2.5 g, Se 10–18 mg, biotin

5 mg, choline 16 g, folic acid 32 mg, nicotinic acid 2,000 mg, and pantothenic acid 400 mg. Crude protein was a measured value, while other nutrients were calculated values.

1.3 Management Practices

Birds were housed in three-tier step cages. Lighting consisted of natural daylight supplemented with artificial illumination to provide 16 hours of light daily. Mash feed was provided twice daily with four redistributions, allowing ad libitum access. Nipple drinkers supplied water ad libitum. Eggs were collected once each afternoon.

1.4 Measurements

1.4.1 Reproductive Performance

At the end of week 4 (44 weeks of age), eggs were reserved for 3 days per replicate. Twenty-five qualified eggs were randomly selected from each replicate and incubated as a group (first hatch). At the end of week 8 (48 weeks of age), eggs were reserved for 5 days per replicate, and all qualified eggs were incubated as a group (second hatch) using a constant-temperature incubator (EI FDZ19200, Bengbu, Anhui). Total eggs laid, qualified eggs, eggs set, fertilized eggs, and hatched chicks were recorded, along with daily qualified egg weight per replicate, to calculate egg qualification rate, fertilization rate, hatchability, and average daily egg mass (ADEM).

1.4.2 Birth Weight and Organ Indexes of Newborn Chicks

During hatching at the end of weeks 4 and 8, three newly hatched chicks per replicate were randomly selected, weighed (birth weight), and then slaughtered to determine the weights of heart, liver, and small intestine using an electronic balance (FA2104A, Shanghai Jingtian Electronic Instrument Factory). Organ indexes (heart index, liver index, small intestine index) were subsequently calculated.

1.4.3 Serum Biochemical Parameters of Newborn Chicks

During hatching at the end of weeks 4 and 8, three newly hatched chicks per replicate were randomly selected for cardiac blood collection. Blood samples were allowed to clot at room temperature with gentle agitation, then centrifuged at 3,000 r/min for 10 minutes (Feige KA-1000, Shanghai Anting Scientific Instrument Factory) to obtain serum, which was stored at -20°C for analysis. Serum total protein (TP), albumin (ALB), uric acid (UA), and urea (UREA) concentrations were determined using an automatic biochemical analyzer (Hitachi 7170A).

1.4.4 Feed Consumption

During the trial, 14-day batches of experimental diets were prepared for each replicate, with total feed amount and residual feed accurately recorded. Feed consumption was calculated per replicate every two weeks to determine average daily feed intake (ADFI) and average daily crude protein intake (ADCPI).

1.4.5 Body Weight

Every two weeks during the trial, six birds per replicate were randomly selected and weighed to calculate body weight, average daily gain (ADG), and metabolic body weight ($BW^{0 \cdot 75}$).

Statistical Analysis

Data were analyzed using one-way ANOVA in SAS 9.2, with statistical significance set at $P < 0.05$ and $P < 0.01$. Duncan' s multiple range test was applied for significant differences. Sensitive indicators were subjected to linear and quadratic regression analysis. A factorial model for crude protein requirement was fitted using interactive data analysis.

2.1 Effects of Dietary Crude Protein Level on Feed Intake, Body Weight, and Egg Production

As shown in Table 2 , dietary crude protein level extremely significantly affected ADCPI ($P < 0.01$), which increased markedly with rising dietary crude protein level. Dietary crude protein level also significantly affected ADEM ($P < 0.05$), which decreased as protein level increased from 13% to 15% but reached its maximum at 16% crude protein, with both high-protein groups (16% and 17%) outperforming the low-protein groups (13%, 14%, and 15%).

2.2 Effects of Dietary Crude Protein Level on Reproductive Performance

Table 3 reveals that dietary crude protein level significantly or extremely significantly affected total egg number, qualified egg number, and hatched chick number ($P < 0.05$ or $P < 0.01$), with maximum values observed in the high-protein groups (16% and 17%). In the first hatch, crude protein level extremely significantly affected hatched chick number and hatchability ($P < 0.01$), with the low-protein groups (13% and 14%) showing significantly or extremely significantly higher values than the 17% group ($P < 0.05$ or $P < 0.01$). Fertilization rate and hatchability in the second hatch were not significantly affected ($P > 0.05$), though both peaked in the 14% crude protein group. Notably, while the high-protein group (17%) had the most eggs set, it did not achieve the highest numbers for hatched chicks, fertilization rate, or hatchability, indicating that excessive dietary crude protein impaired reproductive performance.

2.3 Effects of Breeder Dietary Crude Protein Level on Birth Weight and Organ Indexes of Newborn Chicks

Table 4 shows that breeder dietary crude protein level significantly affected heart index in chicks from the first hatch ($P < 0.05$), with the highest value in the 14% group and the lowest in the 15% group. In the second hatch, crude protein level significantly affected small intestine index ($P < 0.05$) and extremely significantly affected liver index ($P < 0.01$).

2.4 Effects of Breeder Dietary Crude Protein Level on Serum Biochemical Parameters of Newborn Chicks

According to Table 5 , breeder dietary crude protein level only extremely significantly affected serum UA content in chicks from the second hatch ($P < 0.01$), with no significant effects on other serum biochemical parameters ($P > 0.05$). Serum UA content increased with rising dietary crude protein levels under high-protein conditions (15%, 16%, and 17%). A factorial model for crude protein requirement of 41–48-week-old Jining Bairi breeder hens was established using ADCPI as the dependent variable and ADG, ADEM, and $BW^{0 \cdot 75}$ as independent variables: ADCPI = 0.3347ADG + 0.2784ADEM + 3.3684$BW^{0 \cdot 75}$ (R^2 = 0.9931, $P < 0.0001$). Integrating the effects of dietary crude protein level on reproductive performance and neonatal chick parameters, the optimal dietary crude protein level for 41–48-week-old Jining Bairi breeder hens was determined to be 14.81% based on the factorial model and the ADG, ADEM, and $BW^{0 \cdot 75}$ values from the optimal reproductive performance group.

3.1 Effects of Dietary Crude Protein Level on Feed Intake, Body Weight, and Egg Production in Jining Bairi Breeder Hens

Poultry exhibit "eating for energy" behavior, where feed intake decreases as dietary energy level increases. Under the consistent dietary metabolizable energy level in this trial, feed intake was not significantly affected, aligning with established theory and previous findings. ADCPI increased significantly with dietary crude protein level, consistent with literature reports. While dietary crude protein level did not significantly affect body weight or ADG, a trend toward increased body weight with higher protein levels disappeared at excessive protein levels, where body weight actually declined. This likely reflects impaired digestion and nutrient absorption caused by excessive protein, a phenomenon demonstrated in Kangdal yellow-feathered broilers where the 17% crude protein group showed inferior performance compared to the 16% group. Some studies have reported contrasting results, showing significant effects of dietary crude protein level on body weight and ADG in Hetian chickens, with ADG positively correlated with protein level. Other research has demonstrated significant effects on ADG, ADFI, and feed conversion ratio in 42-week-old Guifei chickens. Under consistent metabolizable energy (11.68 MJ/kg), dietary crude protein levels of 15%, 16%, and 17% did not significantly affect ADFI, average egg weight, or body weight in 24–40-week-old Huainan partridge chickens. The significant effect of dietary crude protein level on ADEM observed in this study aligns with several previous reports.

3.2 Effects of Dietary Crude Protein Level on Reproductive Performance of Jining Bairi Chickens

The high-protein group (17%) in this study failed to achieve superior chick numbers, fertilization rate, or hatchability, consistent with previous research showing that reducing dietary crude protein to 15% did not significantly affect

hatchability or fertilization rate in broiler breeders. Similarly, graded protein levels of 16%, 14%, 12%, and 10% did not significantly affect these parameters. Comparable results were reported for Huainan partridge chickens, where different crude protein levels did not significantly affect fertilization or hatchability rates, though 16% dietary crude protein significantly improved laying rate and feed-to-egg ratio without affecting reproductive performance.

3.3 Effects of Breeder Dietary Crude Protein Level on Birth Weight and Organ Indexes of Newborn Chicks

When commercial broiler mortality exceeds normal levels, feeding low-nutrient diets to breeder hens can significantly reduce offspring mortality. While chick birth weight correlates positively with egg weight, post-hatch nutrition becomes the primary factor affecting chick growth. Consistent findings were reported in Yuzhou brown layers, where egg weight significantly affected chick birth weight and early growth (first 3 weeks) but not subsequent development. The significant effect of dietary crude protein level on birth weight in the second hatch of this study may reflect differences in egg weight, though egg weight was not measured. Visceral organs constitute the primary sites for nutrient digestion and absorption, playing a vital role in poultry growth and development. Healthy organs ensure normal growth, stress resistance, and adaptability, with organ indexes indicating developmental status. While some studies found no significant effects of dietary crude protein level on visceral organ weights or indexes in chickens, this study revealed significant effects on heart index in the first hatch and on small intestine index and extremely significant effects on liver index in the second hatch.

3.4 Effects of Breeder Dietary Crude Protein Level on Serum Biochemical Parameters of Newborn Chicks

Blood composition reflects metabolic status and health, with stable biochemical parameters required for normal metabolism and optimal performance. In this study, breeder dietary crude protein level had minimal impact on serum biochemical parameters in newborn chicks, suggesting no significant effect on protein metabolism.

Conclusions

Dietary crude protein level significantly affected total egg number, qualified egg number, and hatched chick number in 41–48-week-old Jining Bairi chickens, but did not significantly affect fertilization rate. In chicks hatched from eggs collected at 44 weeks, breeder dietary crude protein level only significantly affected heart index; in chicks hatched from eggs collected at 48 weeks, it significantly affected small intestine index and extremely significantly affected liver index and serum UA content. ADCPI in Jining Bairi chickens showed a clear increasing trend with rising dietary crude protein level. The optimal dietary

crude protein level for maximizing reproductive performance in 41–48-week-old Jining Bairi breeder hens is 14.81%.

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