

Effect of Dietary Crude Protein Level on Production Performance and Egg Quality in Wenshi Barred Chickens (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary crude protein levels on production performance and egg quality of Wenshi Barred chickens, establish a regression model for crude protein requirement, and determine the dietary crude protein requirement of Wenshi Barred chickens during the laying period. A single-factor experimental design was adopted. Three hundred and sixty healthy Wenshi Barred chickens at 30 weeks of age with similar body weight were selected and randomly divided into 5 groups with 6 replicates per group and 12 chickens per replicate. Each group was fed experimental diets with dietary crude protein levels of 13%, 14%, 15%, 16%, and 17%, respectively, while other dietary nutrient levels remained consistent. The pre-experimental period lasted 7 days, and the formal experimental period lasted 35 days. The results showed that: 1) Average daily crude protein intake (ADCPI) increased significantly with increasing dietary crude protein level ($P < 0.05$). Egg number, laying rate, and average daily egg mass (ADEM) increased first and then decreased with increasing dietary crude protein level, reaching the maximum value in the 16% crude protein level group, which was significantly higher than the 13% and 14% crude protein level groups ($P < 0.05$). 2) Egg weight in the 13% crude protein level group was significantly lower than that in the other groups ($P < 0.05$). The Haugh unit in the 16% and 17% crude protein level groups was significantly or extremely significantly lower than that in the 13% crude protein level group ($P < 0.05$ or $P < 0.01$). The yolk color in the 13% crude protein level group was significantly lighter than that in the 14%, 15%, and 16% crude protein level groups ($P < 0.05$). In terms of eggshell color, the brightness in the 16% crude protein level group was significantly higher than that in the 14% crude protein level group ($P < 0.05$), and the redness in the 13% crude protein level group was significantly higher than that in the 16% crude protein level group ($P < 0.05$). 3) Using ADCPI as the dependent variable and average daily gain (ADG), ADEM, and

metabolic body weight (BW0.75) as independent variables, the regression model for dietary crude protein requirement of Wenshi Barred chickens was established as: $ADCPI=0.02ADG+0.22ADEM+4.20BW0.75$ ($R^2=0.9745$, $P<0.05$). It can be concluded that the appropriate dietary crude protein level for Wenshi Barred chickens aged 31 to 36 weeks is 15.55%.

Full Text

Effects of Dietary Crude Protein Level on Performance and Egg Quality of Wenshang Luhua Chickens

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Abstract

This experiment was conducted to investigate the effects of dietary crude protein level on the performance and egg quality of Wenshang Luhua chickens, establish a regression model for crude protein requirement, and determine the appropriate dietary crude protein level for Wenshang Luhua chickens during the laying period. A single-factor experimental design was employed, in which 360 healthy 30-week-old Wenshang Luhua chickens with similar body weight were randomly allocated to 5 groups, with 6 replicates per group and 12 chickens per replicate. The five groups were fed experimental diets containing 13%, 14%, 15%, 16%, and 17% crude protein, respectively, while other nutrient levels remained consistent across diets. The pre-test period lasted 7 days, and the formal test period lasted 35 days. The results showed: 1) Average daily crude protein intake (ADCPI) increased significantly with increasing dietary crude protein level ($P<0.05$). Egg number, laying rate, and average daily egg mass (ADEM) initially increased then decreased with increasing dietary crude protein level, reaching maximum values in the 16% crude protein group, which were significantly higher than those in the 13% and 14% crude protein groups ($P<0.05$). 2) Egg weight in the 13% crude protein group was significantly lower than in other groups ($P<0.05$). The Haugh unit in the 16% and 17% crude protein groups was significantly or extremely significantly lower than in the 13% crude protein group ($P<0.05$ or $P<0.01$). Yolk color in the 13% crude protein group was significantly lighter than in the 14%, 15%, and 16% crude protein groups ($P<0.05$). Regarding eggshell color, lightness in the 16% crude protein group was significantly higher than in the 14% group ($P<0.05$), and redness in the 13% group was significantly higher than in the 16% group ($P<0.05$). 3) Using ADCPI as the dependent variable and average daily gain (ADG), ADEM, and metabolic

body weight (BW0.75) as independent variables, the factorial model for dietary crude protein requirement of Wenshang Luhua chickens was established as: $AD-CPI=0.02ADG+0.22ADEM+4.20BW0.75$ ($R^2=974.5$, $P<0.05$). In conclusion, the suitable dietary crude protein level for Wenshang Luhua chickens aged 31-36 weeks is 15.55%.

Keywords: Wenshang Luhua chickens; crude protein; performance; egg quality

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Introduction

Protein is one of the essential nutrients for laying hens to maintain production, and dietary crude protein level significantly affects the performance and egg quality of laying hens [1]. Currently, numerous studies have investigated the effects of dietary crude protein level on laying hen performance, but the results have been inconsistent. Some studies have shown that with increasing dietary crude protein level, laying rate, egg production, egg weight, egg specific gravity, feed intake, and body weight increase significantly [2-3]. Other research has found that Huainan Partridge chickens at peak laying performance achieve optimal production when dietary crude protein level is 16% [4]. The appropriate dietary crude protein level for Beijing You chickens during peak laying period is 15.2% [5].

Wenshang Luhua chicken is an excellent local breed in Shandong Province, characterized by roughage tolerance, strong disease resistance, relatively high egg production, and good meat quality. However, no studies on its nutrient requirements have been reported to date. Therefore, this experiment aimed to investigate the effects of dietary crude protein level on the performance and egg quality of Wenshang Luhua chickens, providing an important reference for determining the appropriate dietary crude protein requirement during their laying period.

Materials and Methods

1.1 Experimental Animals and Design

A single-factor experimental design was adopted. A total of 360 healthy 30-week-old Wenshang Luhua chickens with similar body weight were randomly allocated to 5 groups, with 6 replicates per group and 12 chickens per replicate. Each group was fed an experimental diet with crude protein levels of 13%, 14%,

15%, 16%, and 17%, respectively, while other nutrient levels remained consistent. The pre-test period lasted 7 days (at 30 weeks of age), and the formal test period lasted 35 days (31–36 weeks of age).

1.2 Diet Composition and Nutrient Levels

Reference was made to the Chinese “Feeding Standard of Chickens” (NY/T 33-2004). Corn-soybean meal diets were formulated based on actual production practices, with composition and nutrient levels shown in Table 1 .

Table 1 Composition and nutrient levels of experimental diets (air-dry basis)
%

Notes: 1) The premix provided the following per kg of diet: VA 6,000 IU, VD₃ 2,500 IU, VB₁ 1.75 mg, VB₂ 5.5 mg, VB₆ 4 mg, VB₁₂ 0.18 mg, VE 25 mg, VK₃ 2.25 mg, Fe 75 mg, Cu 7.5 mg, Zn 60 mg, Mn 60 mg, Se 0.15 mg, Ca 6.5 g, P 2.0 g, Met 1.6 g, biotin 0.14 mg, folic acid 0.8 mg, nicotinic acid 34 mg, pantothenic acid 12 mg, phytase 400 U, choline chloride 350 mg, NaCl 3.7 g. 2) Nutrient levels were all calculated values.

1.3 Management

Chickens were housed in two-tier cages indoors. Natural light was supplemented with artificial lighting to provide 16 hours of light per day. Feed and water were provided ad libitum. Conventional management and immunization programs were implemented.

1.4 Performance and Egg Quality Measurements

1.4.1 Performance

During the experimental period, daily egg number, egg weight, and unqualified egg number were recorded by replicate to calculate laying rate, unqualified egg rate, average egg weight, and average daily egg mass (ADEM). Feed consumption was recorded weekly to calculate average daily feed intake (ADFI), average daily crude protein intake (ADCPI), and feed-to-egg ratio. At the beginning and end of the experiment, 4 chickens from each replicate were selected, tagged, and weighed to calculate average daily gain (ADG).

1.4.2 Egg Quality

At the end of the experiment, 5 eggs were randomly selected from each replicate and measured immediately. Eggshell color was measured using a colorimeter (CR-410, Minolta, Japan). Egg weight was measured using an electronic balance. Egg length and width were measured using vernier calipers. Eggshell thickness was measured using an eggshell thickness gauge (ETG-1061, Robotmation, Japan). Eggshell strength was measured using an eggshell strength tester (EFG-0503, Robotmation, Japan). Albumen height, yolk color, and Haugh unit

were measured using a multifunctional egg quality tester (EMT-5200, Robotmation, Japan). The yolk and eggshell were separated using an egg divider and weighed to calculate yolk ratio and eggshell ratio.

1.5 Statistical Analysis

Experimental data were analyzed using one-way ANOVA with SAS 9.2 software. $P < 0.05$ was considered significant, and $P < 0.01$ was considered extremely significant. Data are expressed as means \pm standard error. Stepwise regression analysis was used to establish a multiple linear regression equation to simulate dietary crude protein requirement.

Results

2.1 Effects of Dietary Crude Protein Level on Performance of Wenshang Luhua Chickens

As shown in Table 2, dietary crude protein level had significant effects on ADCPI, ADEM, egg number, and laying rate of Wenshang Luhua chickens ($P < 0.05$). ADCPI increased significantly with increasing dietary crude protein level ($P < 0.05$). Egg number, laying rate, and ADEM initially increased then decreased with increasing dietary crude protein level, reaching maximum values in the 16% crude protein group, which were significantly higher than those in the 13% and 14% crude protein groups ($P < 0.05$). The 16% crude protein group had the highest average daily feed intake, but differences among groups were not significant ($P > 0.05$). When dietary crude protein level exceeded 16%, average daily feed intake began to decrease.

Table 2 Effects of dietary crude protein level on performance of Wenshang Luhua chickens

Note: In the same row, values with the same letter or no letter superscripts mean no significant difference ($P > 0.05$), while values with adjacent letter superscripts mean significant difference ($P < 0.05$), and values with alternate letter superscripts mean extremely significant difference ($P < 0.01$). The same applies to Table 3.

2.2 Effects of Dietary Crude Protein Level on Egg Quality of Wenshang Luhua Chickens

As shown in Table 3, dietary crude protein level had significant effects on egg weight, yolk color, Haugh unit, and eggshell color (lightness and redness) ($P < 0.05$). Egg weight increased gradually with increasing dietary crude protein level, with the 13% crude protein group being significantly lower than other groups ($P < 0.05$). For yolk color, the 13% crude protein group had the lightest color, significantly lighter than the 14%, 15%, and 16% crude protein groups ($P < 0.05$). The Haugh unit initially decreased then increased with dietary crude protein level, with the 16% and 17% crude protein groups being significantly

or extremely significantly lower than the 13% crude protein group ($P < 0.05$ or $P < 0.01$). For eggshell color, lightness in the 16% crude protein group was highest, significantly higher than in the 14% crude protein group ($P < 0.05$), while redness in the 13% crude protein group was significantly higher than in the 16% crude protein group ($P < 0.05$).

Table 3 Effects of dietary crude protein level on egg quality of Wenshang Luhua chickens

2.3 Crude Protein Requirement of Wenshang Luhua Chickens Aged 31-36 Weeks

Stepwise regression analysis was used to establish a multiple linear regression equation for crude protein requirement of Wenshang Luhua chickens aged 31-36 weeks. Using ADCPI as the dependent variable and ADG, ADEM, and metabolic body weight (BW^{0.75}) as independent variables, the regression model is shown in Table 4. Based on the regression model and considering the effects of dietary crude protein level on performance, the dietary crude protein requirement for Wenshang Luhua chickens was determined to be 15.55%.

Table 4 Crude protein requirement of Wenshang Luhua chickens aged 31-36 weeks

Factorial model: $ADCPI = 0.02ADG + 0.22ADEM + 4.20BW^{0.75}$

Discussion

3.1 Effects of Dietary Crude Protein Level on Performance of Wenshang Luhua Chickens

Poultry feed intake is influenced by multiple factors, with dietary energy level playing a decisive role. However, when nutrition is unbalanced, the leverage balance of “eating for energy” in poultry is broken [6]. In this experiment, when dietary crude protein level was below 16%, average daily feed intake initially increased with increasing dietary crude protein level, but decreased when crude protein level exceeded 16%. This suggests that 16% dietary crude protein level is close to the appropriate level for Wenshang Luhua chickens. When dietary crude protein level was below 16%, as crude protein intake increased, the body required more energy to digest and absorb crude protein, leading to increased feed intake. The final degradation product of crude protein in poultry is uric acid; when dietary crude protein level exceeds 16%, excessive uric acid is produced and deposited in subcutaneous tissues, joints, kidneys, and other locations, causing severe gout and reducing feed intake [7]. The significant increase in ADCPI with dietary crude protein level is consistent with previous research results [8].

Dietary crude protein level is an important nutritional factor affecting body weight, and adequate crude protein intake is essential for maintaining normal life and production activities. In this experiment, dietary crude protein level had

no significant effect on average body weight or ADG, but the 15% and 16% crude protein groups had relatively higher average body weight and ADG compared with other groups. Although the 17% crude protein group had the highest ADCPI, it did not achieve the greatest average body weight or ADG, which is consistent with the findings of Qin et al. [9]. The reason may be that excessive dietary crude protein level causes stress in poultry, leading to indigestion, loss of other nutrients, and toxicity from excessive amino acid catabolism, which inhibits growth.

In this experiment, dietary crude protein level significantly affected egg number, laying rate, and ADEM, showing an increase within a certain range with increasing dietary crude protein level, which is consistent with previous reports. Xu et al. [10] found that in Jinghong No. 1 laying breeders, laying rate and daily egg mass increased significantly with dietary crude protein level at the same energy level. Sun et al. [11] reported that laying rate and daily egg mass of Hy-Line Brown hens at peak production also increased with dietary crude protein level. In this experiment, the highest laying performance was not achieved in the group with the highest dietary crude protein level, which is consistent with the results of Yin et al. [12]. This demonstrates that only when dietary crude protein level matches the animal's requirement can production potential be maximized and maximum returns be achieved with minimum input.

3.2 Effects of Dietary Crude Protein Level on Egg Quality of Wenshang Luhua Chickens

Approximately 50% of egg dry matter is protein, so dietary crude protein level has an important influence on egg weight. Fu et al. [13] found that low-protein diets significantly reduced egg weight of laying hens aged 22–44 weeks. Similar results were observed in this experiment, where egg weight in the 13% crude protein group was significantly lower than in other groups, showing a trend of increasing egg weight with dietary crude protein level. Dietary crude protein level had no significant effects on egg shape index, eggshell thickness, or eggshell strength, indicating that these egg quality traits have high heritability in Wenshang Luhua chickens.

The effect of dietary crude protein level on Haugh unit is unclear. Some reports indicate that 16% dietary crude protein can significantly improve Haugh unit compared with 12% crude protein [14], while others report no significant effect [15]. In this experiment, Haugh unit tended to decrease with increasing dietary crude protein level, which is inconsistent with previous studies and requires further investigation.

Yolk color and eggshell color are important subjective criteria for consumers to evaluate egg quality. In this experiment, dietary crude protein level significantly affected both yolk color and eggshell color, but no regular trend was observed, possibly due to differences in pigment content among feed ingredients.

3.3 Crude Protein Requirement of Wenshang Luhua Chickens During Laying Period

Crude protein is one of the basic nutritional requirements of laying hens. Factors affecting crude protein requirement include feeding management, environmental temperature, breed, body size, and physiological stage [16-17]. Different countries have different climate conditions and feeding management practices, resulting in different recommended crude protein requirements for laying hens. NRC (1994) recommends 17% dietary crude protein for laying hens, while the “Feeding Standard of Chickens” (NY/T 33-2004) suggests 15.5%-16.5%. Differences in crude protein requirements among breeds are also substantial. Geng et al. [18] reported that the appropriate dietary crude protein level for free-range Beijing You chickens during peak laying period is 15.2%, while Huang et al. [19] found that the appropriate level for Hy-Line W-36 hens aged 19-43 weeks is 17%. This experiment determined that under practical production conditions, the appropriate dietary crude protein level for Wenshang Luhua chickens aged 31-36 weeks is 15.5%.

The crude protein requirement of laying hens can be divided into three aspects: maintenance, egg production, and body weight gain [7]. Based on the established regression model, the crude protein requirements for these three aspects in Wenshang Luhua chickens were determined to be 4.20 g/kg BW^{0.75}, 0.22 g/g ADEM, and 0.02 g/g ADG, respectively. Yang [20] reported the maintenance requirement of laying hens as 2.39-3.83 g/kg BW^{0.75}, while Song et al. [21] found that the daily crude protein maintenance requirement for Lohmann Brown hens is approximately 1.71 g/kg BW^{0.75}. These differences may be due to variations in breed, individual metabolic body weight, physiological status, and production performance.

Conclusions:

1. Within a certain range, the performance of Wenshang Luhua chickens improved with increasing dietary crude protein level, but decreased when dietary crude protein level exceeded 16%.
2. Dietary crude protein level affected egg weight, yolk color, Haugh unit, and eggshell color (lightness and redness) of Wenshang Luhua chickens. Egg weight increased gradually with dietary crude protein level, while yolk color and eggshell color showed no regular trend.
3. The suitable dietary crude protein level for Wenshang Luhua chickens aged 31-36 weeks is 15.55%.

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