Effects of Dietary Metabolizable Energy Levels on Production Performance, Serum Biochemical Parameters, and Egg Quality in Wenshang Barred Laying Hens (Postprint)

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Date: 2017-11-07T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of dietary metabolizable energy (ME) levels on production performance, serum biochemical indices, and egg quality of Wenshi Barred chickens during the laying period, and to establish a factorial model for ME requirement to determine the dietary ME requirement of Wenshi Barred chickens during the laying period. A single-factor completely randomized design was adopted. A total of 360 healthy Wenshi Barred chickens aged 40 weeks 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 metabolizable energy levels of 10.68, 10.89, 11.10, 11.30, and 11.51 MJ/kg, respectively, while other major nutrient levels were kept consistent. The pre-trial period lasted 7 days, and the experimental period lasted 35 days. The results showed that: 1) Dietary ME level had significant effects ($P<0.05$) on average daily feed intake (ADFI), average daily metabolizable energy intake (ADMEI), average body weight, metabolic body weight (BW0.75), egg number, laying rate, and average daily egg mass (ADEM) of Wenshi Barred chickens during the laying period. With the increase of dietary ME level, ADFI, ADMEI, egg number, laying rate, and ADEM showed an increasing trend, but decreased when the ME level was 11.51 MJ/kg. With the increase of dietary ME level, feed-to-egg ratio showed a decreasing trend, but increased when the ME level was 11.51 MJ/kg. The average body weight and BW0.75 at dietary ME levels of 11.51 and 11.30 MJ/kg were significantly higher than those at the ME level of 11.10 MJ/kg ($P<0.05$). 2) With the increase of dietary ME level, the contents of serum glucose (GLU), triglycerides (TG), and total cholesterol (TCHO) of Wenshi Barred

chickens during the laying period showed an increasing trend. 3) Dietary ME level had significant effects (P<0.05) on albumen height, yolk color, Haugh unit, and yolk ratio of Wenshi Barred chickens during the laying period. The albumen height and Haugh unit of the low-energy groups (10.68, 10.89, and 11.10 MJ/kg) were significantly higher than those of the high-energy groups (11.30 and 11.51 MJ/kg) (P<0.05). With the increase of dietary ME level, yolk color and yolk ratio showed an increasing trend, with the yolk color and yolk ratio at the ME level of 11.51 MJ/kg being significantly higher than those at other ME levels (P<0.05). 4) Using ADMEI as the dependent variable and average daily gain (ADG), ADEM, and BW0.75 as independent variables, the factorial model for dietary ME requirement of Wenshi Barred chickens aged 41-45 weeks was fitted as: ADMEI=0.88ADG+10.63ADEM+476.40BW0.75 (R2=0.982 5, P<0.05). The appropriate dietary ME requirement for optimal production performance of Wenshi Barred chickens aged 41-45 weeks was 11.29 MJ/kg.

Full Text

Effects of Dietary Metabolizable Energy Level on Performance, Serum Biochemical Indices, and Egg Quality of Wenshang Luhua Laying Hens

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Abstract: This experiment was conducted to investigate the effects of dietary metabolizable energy (ME) level on the performance, serum biochemical indices, and egg quality of Wenshang Luhua hens during the laying period, and to establish a factorial model for metabolizable energy requirements. A single-factor completely randomized design was employed, with 360 healthy 40-week-old Wenshang Luhua hens of similar body weight randomly allocated to five groups, each consisting of six replicates of twelve hens. The groups were fed experimental diets with metabolizable energy levels of 10.68, 10.89, 11.10, 11.30, and 11.51 MJ/kg, while other major nutrient levels remained consistent. The pre-test period lasted 7 days, followed by a 35-day experimental period. The results showed that: 1) Dietary ME level significantly affected average daily feed intake (ADFI), average daily metabolizable energy intake (ADMEI), average body weight, metabolic body weight (BW・), egg number, laying rate, and average daily egg mass (ADEM) (P<0.05). ADFI, ADMEI, egg number, laying rate, and ADEM increased with rising dietary ME levels but decreased at 11.51 MJ/kg. The feed-to-egg ratio decreased with increasing ME levels but increased at 11.51 MJ/kg. Average body weight and BW · at 11.51 and 11.30 MJ/kg were significantly higher than at 11.10 MJ/kg ($P<0.05$). 2) Serum glucose (GLU), triglyceride (TG), and total cholesterol (TCHO) contents increased with rising dietary ME levels. 3) Dietary ME level significantly affected albumen height, yolk color, Haugh unit, and yolk percentage ($P<0.05$). Albumen height and Haugh units in low-energy groups (10.68, 10.89, and 11.10 MJ/kg) were significantly higher than in high-energy groups (11.30 and 11.51 MJ/kg) ($P<0.05$). Yolk color and yolk percentage increased with rising dietary ME levels, with values at 11.51 MJ/kg significantly exceeding those at other levels ($P<0.05$). 4) Using ADMEI as the dependent variable and ADG, ADEM, and BW · as independent variables, the factorial model for dietary ME requirements of 41-45-week-old Wenshang Luhua hens was: ADMEI = 0.88ADG + 10.63ADEM + 476.40BW · ($R^2 = 0.9825$, $P<0.05$). The suitable dietary ME requirement for optimal performance in 41-45-week-old Wenshang Luhua hens is 11.29 MJ/kg.

Keywords: Wenshang Luhua hens; performance; serum biochemical indices; metabolizable energy level

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Energy plays a crucial role in poultry nutrition and physiology. Energy deficiency impedes growth and reduces production efficiency, while excess energy not only causes waste but also predisposes birds to disease. Consequently, numerous researchers have focused on determining optimal energy intake levels for laying hens. Studies indicate that within a certain range, increasing dietary energy levels reduces feed intake while increasing egg number and mass, thereby improving feed conversion ratio [1-2]. However, other reports suggest that dietary energy level has no significant effect on laying rate, daily egg mass, or feed-to-egg ratio [3].

In recent years, substantial research has investigated the nutritional requirements of local chicken breeds [4-7]. Energy requirements vary among different breeds, production systems, environmental conditions, and physiological stages. The Wenshang Luhua chicken, originating from Wenshang County in Shandong Province, is an excellent dual-purpose local breed renowned for its historical significance, distinctive plumage and body type, and highly nutritious meat and eggs. Currently, no studies have reported on the energy requirements of Wenshang Luhua chickens, and the effects of energy levels remain unclear. This experiment aimed to investigate how dietary metabolizable energy (ME) level affects the performance, serum biochemical indices, and egg quality of Wenshang Luhua hens during the laying period, obtain parameters for ME requirements, and provide a theoretical basis for establishing feeding standards and production practices for this breed.

1.1 Experimental Animals and Design

A single-factor completely randomized design was employed. Three hundred sixty healthy 40-week-old Wenshang Luhua hens with similar body weight were randomly divided into five groups, each comprising six replicates of twelve hens. The groups were fed experimental diets with metabolizable energy levels of 10.68, 10.89, 11.10, 11.30, and 11.51 MJ/kg, while maintaining consistent levels of other major nutrients. The pre-test period lasted 7 days (at 40 weeks of age), and the experimental period lasted 35 days (41-45 weeks of age).

1.2 Experimental Diets

Corn-soybean meal diets were formulated based on the *Feeding Standard of Chicken* (NY/T 33-2004) and actual production practices. The composition and nutrient levels of the experimental diets are presented in Table 1 .

1.3 Management Practices

Hens were housed in two-tier cages with natural lighting supplemented by artificial light to provide 16 hours of illumination daily. Feed and water were provided ad libitum. Conventional management and immunization programs were implemented.

1.4 Measurements

1.4.1 Performance Parameters During the experimental period, daily egg number, egg mass, and defective egg count were recorded by replicate to calculate laying rate, defective egg rate, average egg weight, and average daily egg mass (ADEM). Feed consumption was measured weekly by replicate to determine average daily feed intake (ADFI), average daily metabolizable energy intake (ADMEI), and feed-to-egg ratio. At the start of the experiment, four hens per replicate were tagged and weighed, with subsequent weighings every two weeks to calculate average daily gain (ADG).

1.4.2 Serum Biochemical Indices At the end of the experiment, two hens per replicate were randomly selected for blood collection from the wing vein. Serum was separated by centrifugation at 3,000 r/min for 10 minutes and analyzed using an automatic biochemical analyzer (7170A, Hitachi, Japan) to determine serum glucose (GLU), triglyceride (TG), total cholesterol (TCHO), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) concentrations.

1.4.3 Egg Quality At the end of the experiment, five eggs per replicate were randomly selected for immediate quality assessment. Egg weight was measured using an electronic balance. Vernier calipers were used to measure length and width for calculation of egg shape index. Eggshell thickness was measured with an eggshell thickness gauge (ETG-1061, Robotmation, Japan), eggshell strength with an eggshell force gauge (EFG-0503, Robotmation, Japan), and albumen height, yolk color, and Haugh unit with a multifunctional egg quality tester (EMT-5200, Robotmation, Japan). Yolk and shell were separated and weighed using an egg separator to calculate yolk percentage and shell percentage.

1.5 Data Processing

Experimental data were analyzed using SAS 9.2 software for one-way ANOVA, with $P<0.05$ considered statistically significant. Data are expressed as "mean ± standard error." Stepwise regression analysis was used to establish multiple linear regression models with significance testing.

2.1 Effects of Dietary ME Level on Performance

As shown in Table 2 , dietary ME level significantly affected ADFI, ADMEI, average body weight, metabolic body weight (BW ·), egg number, laying rate, and ADEM ($P<0.05$). ADFI increased with rising dietary ME levels but decreased significantly at 11.51 MJ/kg ($P<0.05$). ADMEI also increased with rising ME levels but decreased at 11.51 MJ/kg. Average body weight and BW · at 11.51 and 11.30 MJ/kg were significantly higher than at 11.10 MJ/kg ($P<0.05$). Egg number, laying rate, and ADEM increased with rising dietary ME levels, reaching maximum values at 11.30 MJ/kg, but decreased significantly at 11.51 MJ/kg ($P<0.05$). Average egg weight increased with rising dietary ME levels. The feed-to-egg ratio decreased with increasing ME levels, reaching a minimum at 11.30 MJ/kg, but increased at 11.51 MJ/kg. In summary, dietary ME level of 11.30 MJ/kg resulted in the highest ADFI, ADMEI, egg number, laying rate, and ADEM, along with the lowest feed-to-egg ratio, indicating optimal performance.

2.2 Effects of Dietary ME Level on Serum Biochemical Indices

As shown in Table 3 , dietary ME level influenced serum biochemical indices, with serum GLU, TG, and TCHO contents increasing as dietary ME levels rose.

2.3 Effects of Dietary ME Level on Egg Quality

As shown in Table 4 , dietary ME level significantly affected albumen height, yolk color, Haugh unit, and yolk percentage ($P<0.05$). Albumen height and Haugh units in low-energy groups (10.68, 10.89, and 11.10 MJ/kg) were significantly higher than in high-energy groups (11.30 and 11.51 MJ/kg) ($P<0.05$). Yolk color and yolk percentage increased with rising dietary ME levels, with values at 11.51 MJ/kg significantly exceeding those at other ME levels ($P<0.05$).

2.4 Dietary ME Requirements for 41-45 Week-Old Hens

Using ADMEI as the dependent variable and ADG, ADEM, and BW · as independent variables, a factorial model for dietary ME requirements of 41-

45-week-old Wenshang Luhua hens was developed (Table 5). Based on the comprehensive effects of dietary ME level on performance and the factorial model, the dietary ME requirement for optimal performance in 41-45-week-old Wenshang Luhua hens was determined to be 11.29 MJ/kg.

3.1 Effects of Dietary ME Level on Performance

Poultry exhibit "eating for energy" behavior, instinctively adjusting feed intake according to dietary energy level [8]. Research indicates that dietary energy level changes within a certain range do not significantly affect feed intake in small laying hens, but excessively high energy levels significantly reduce intake [9]. The current results support this view: when dietary ME level did not exceed 11.30 MJ/kg, feed intake of Wenshang Luhua hens remained unchanged, but decreased significantly at 11.51 MJ/kg. During peak production, relatively high-energy diets are necessary to meet the energy demands for maintaining high laying rates in small laying hens. As dietary energy levels increase, laying rate rises, but excessive energy levels reduce laying rate, possibly because long-term high energy intake leads to excessive fat deposition, thereby affecting laying performance. The current findings align with these reports: laying rate increased with dietary ME levels up to 11.30 MJ/kg but decreased at 11.51 MJ/kg. Although body weight was highest at 11.51 MJ/kg, laying rate was lowest, indicating that high-energy diets exacerbated fat accumulation and reduced laying performance.

Energy requirements of laying hens comprise three components: weight gain, maintenance, and egg production. This experiment established a factorial model using ADG, BW ·, and ADEM to represent these components. The model demonstrates that metabolizable energy intake in Wenshang Luhua hens is primarily used for maintenance and egg production, with ADG being relatively low during the laying period and energy for weight gain accounting for a small proportion.

3.2 Effects of Dietary ME Level on Serum Biochemical Indices

Serum biochemical indices accurately reflect metabolic status of nutrients including fats, proteins, and carbohydrates in animals. Serum TG and TCHO contents in poultry influence lipid deposition and metabolism, reflecting blood lipid levels. When animals consume high energy, the liver synthesizes TG, increasing blood TG content, which indicates enhanced fat synthesis. Mabray et al. [10] found that dietary energy level significantly affected blood TG content in broilers, which increased with rising dietary energy. Guan et al. [11] reported that serum TG content in growing Sai Bei black-bone chickens increased with dietary energy in hens but decreased in roosters. These findings align with the current results, indicating that serum TG content is related to dietary energy level and lipid metabolism in poultry, and correlates with fat deposition associated with body weight changes. Jiang et al. [12] found that serum TCHO content in Lingnan yellow broilers decreased with rising dietary energy, while

Chen et al. [13] observed that adding 3% soybean oil to diets increased serum TCHO in lambs. The current study found that serum TCHO content in Wenshang Luhua hens increased with dietary energy level, with discrepancies likely attributable to differences in species, age, and energy sources.

Blood glucose content relates to energy intake and is influenced by lipid metabolism intensity, as vigorous lipid metabolism enhances gluconeogenesis. Duo et al. [14] found that high-energy diets significantly increased serum GLU levels in Shiqiza chickens, and Fan [15] observed a similar increasing trend in broilers. The current results are consistent with these findings.

3.3 Effects of Dietary ME Level on Egg Quality

Egg weight is a crucial quality indicator directly related to hatching egg qualification rate and hatchability. Guo [16] suggested that maximum egg weight can be achieved through appropriate energy-to-protein ratio, and Yang et al. [17] found that both excessively high and low dietary energy levels reduce egg weight. March et al. [18] reported that linoleic acid, an essential fatty acid in poultry, participates in lipid metabolism and significantly affects yolk and egg weight. In this experiment, dietary energy levels were primarily adjusted through soybean oil content, which is rich in linoleic acid, likely explaining why high-energy groups had greater egg weight than low-energy groups.

Yolk serves as a carrier for egg flavor compounds and represents an important quality parameter for consumers. Yin [19] found that dietary energy level affects yolk formation, and Yuan et al. [20] reported that dietary energy level positively correlated with yolk relative weight and negatively correlated with albumen relative weight in broiler breeder hens. Yolk color results from deposition of fat-soluble pigments, and dietary oil supplementation enhances absorption of these pigments, promoting their deposition in yolk. Zhang [21] found that increasing dietary energy level significantly improved yolk color in late-stage broiler breeders. The current study similarly demonstrated that dietary ME level significantly affected yolk color and yolk percentage, both increasing with rising dietary ME levels.

The Haugh unit is an important indicator of egg quality and freshness. Yuan et al. [20] reported no significant effect of dietary energy level on Haugh unit, and Gunawardana et al. [22] found no significant effect on albumen height. These findings differ from the current results, and the reasons require further investigation.

Conclusions

1. Dietary metabolizable energy level significantly affected the performance, blood biochemical indices, and egg quality of Wenshang Luhua hens. Within a certain range, performance improved with increasing dietary ME levels, but excessive energy levels reduced performance. Blood lipid metabolism increased with rising dietary ME levels. Yolk color and yolk

percentage increased while albumen height decreased as dietary ME levels rose.

2. The suitable dietary metabolizable energy level for optimal performance in 41-45-week-old Wenshang Luhua hens is 11.29 MJ/kg.

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