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

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Abstract

This experiment aimed to investigate the effects of dietary metabolizable energy (ME) levels on production performance, serum biochemical indices, and egg quality of laying Wenshi Barred chickens, and to establish a factorial model for ME requirement and determine the dietary ME requirement of laying Wenshi Barred chickens. The experiment adopted a single-factor completely randomized design. A total of 360 healthy Wenshi Barred chickens at 40 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 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 was 7 days, and the experimental period was 35 days. The results showed: 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 laying Wenshi Barred chickens. 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), triglyceride (TG), and total cholesterol (TCHO) of laying Wenshi Barred chickens 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 laying Wenshi Barred chickens. 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 41-45 weeks old Wenshi Barred chickens 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 41-45 weeks old Wenshi Barred chickens was 11.29 MJ/kg.

Full Text

Effects of Dietary Metabolizable Energy Level on Performance, Serum Biochemical Indexes 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 performance, serum biochemical indexes and egg quality of Wenshang Luhua hens during laying period, and to establish a factorial model of metabolizable energy requirements to determine the dietary metabolizable energy requirements for Wenshang Luhua hens during laying period. A single-factor completely randomized design was adopted. Three hundred and sixty healthy Wenshang Luhua hens aged 40 weeks with similar body weight were randomly allocated to five groups with six replicates per group and twelve hens per replicate. The hens were 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 remained consistent. The pretest period lasted 7 days, and the experimental period lasted 35 days. The results showed: 1) Dietary metabolizable energy level had significant effects on 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) of Wenshang Luhua hens during laying period ($P<0.05$). ADFI, ADMEI, egg number, laying rate, and ADEM showed an increasing trend with increasing dietary metabolizable energy level, but decreased when the metabolizable energy level was 11.51 MJ/kg. The feed-to-egg ratio showed a decreasing trend with increasing dietary metabolizable energy level, but increased when the metabolizable energy level was 11.51 MJ/kg. The average body weight and BW · at dietary metabolizable energy levels of 11.51 and 11.30 MJ/kg were significantly higher than those at 11.10 MJ/kg ($P<0.05$). 2) The contents of serum glucose (GLU), triglyceride (TG), and total cholesterol (TCHO) of Wenshang Luhua hens during laying period showed an increasing trend with increasing dietary metabolizable energy level. 3) Dietary metabolizable energy level had significant effects on albumen height, yolk color, Haugh unit, and yolk ratio of Wenshang Luhua hens during laying period ($P<0.05$). Albumen height and Haugh unit in the low-energy groups (10.68, 10.89, and 11.10 MJ/kg) were significantly higher than those in the high-energy groups (11.30 and 11.51 MJ/kg) ($P<0.05$). Yolk color and yolk ratio showed an increasing trend with increasing dietary metabolizable energy level, and the yolk color and yolk ratio at the metabolizable energy level of 11.51 MJ/kg were significantly higher than those at other metabolizable energy levels ($P<0.05$). 4) Using ADMEI as the dependent variable and ADG, ADEM, and BW · as independent variables, the factorial model for dietary metabolizable energy requirements of Wenshang Luhua hens aged 41-45 weeks was fitted as: ADMEI=0.88ADG+10.63ADEM+476.40BW · ($R^2=0.982\ 5$, $P<0.05$). The suitable dietary metabolizable energy requirement for optimal performance of Wenshang Luhua hens aged 41-45 weeks is 11.29 MJ/kg.

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

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Introduction

Energy plays a crucial role in poultry nutrition and physiological metabolism. Energy deficiency can hinder poultry growth and development, reducing production efficiency, while energy excess not only causes waste but also predisposes to diseases. Therefore, many researchers have dedicated themselves to studying reasonable energy intake levels for laying hens. Studies have shown that within a certain range, as dietary energy level increases, feed intake of laying hens decreases, while egg number and egg mass increase, and feed-to-egg ratio decreases [1-2]. However, other reports suggest that dietary energy level has no significant effect on laying rate, daily egg mass, and feed-to-egg ratio of laying hens [3].

In recent years, researchers have conducted numerous studies on nutrient requirements of local chicken breeds [4-7]. Dietary energy requirements vary among laying hens of different breeds, rearing systems, environmental conditions, and physiological stages. Wenshang Luhua chicken, originating from Wenshang County, Shandong Province, is an excellent local poultry breed for both meat and egg production, renowned both domestically and internationally for its long historical culture, unique plumage color and body conformation, and highly nutritious meat and egg products. Currently, no studies have been reported on the energy requirements of Wenshang Luhua chickens, and the effects of energy levels remain unclear. This experiment aimed to investigate the effects of dietary metabolizable energy (ME) level on performance, serum biochemical indexes, and egg quality of Wenshang Luhua hens during laying period, obtain parameters for metabolizable energy requirements, and provide theoretical basis for the formulation of feeding standards and production practices for Wenshang Luhua chickens.

1.1 Experimental Animals and Design

A single-factor completely randomized design was adopted. Three hundred and sixty healthy Wenshang Luhua hens aged 40 weeks with similar body weight were randomly allocated to five groups with six replicates per group and twelve hens per replicate. The hens were 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 remained consistent. The pretest 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

A corn-soybean meal diet was used, formulated with reference to the "Feeding Standard of Chickens" (NY/T 33-2004) and combined with actual production practices. The composition and nutrient levels of the experimental diets are shown in Table 1 .

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

1) The premix provided the following per kg of diets: VA 6,000 IU, VD 2,500 IU, VB 1.75 mg, VB 5.5 mg, VB 4 mg, VB 0.18 mg, VE 25 mg, VK 2.25 mg, Fe 75 mg, Cu 7.5 mg, Zn 60 mg, Mn 60 mg, Se 0.15 mg, 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 calculated values.

1.3 Management

The hens were raised in two-tier cages indoors with natural light supplemented by artificial lighting for 16 hours daily, and had free access to feed and water. Conventional management and immunization programs were adopted.

1.4.1 Performance

During the experiment, daily egg number, egg mass, 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 was weighed by replicate weekly to calculate average daily feed intake (ADFI), average daily metabolizable energy intake (ADMEI), and feed-to-egg ratio. At the beginning of the experiment, four hens per replicate were selected, tagged, and weighed, and then weighed every two weeks thereafter to calculate average daily gain (ADG).

1.4.2 Serum Biochemical Indexes

At the end of the experiment, two hens per replicate were randomly selected, blood was collected from the wing vein, centrifuged at 3,000 r/min for 10 minutes, and serum was separated. Serum glucose (GLU), triglyceride (TG), total cholesterol (TCHO), low-density lipoprotein (LDL), and high-density lipoprotein (HDL) contents were determined using an automatic biochemical analyzer (7170A, HITACHI, Japan).

1.4.3 Egg Quality

At the end of the experiment, five eggs per replicate were randomly selected for immediate egg quality determination. Egg weight was measured with an electronic balance; egg length and width were measured with a vernier caliper to calculate egg shape index; eggshell thickness was measured with an eggshell thickness gauge (ETG-1061, Robotmation, Japan); eggshell strength was measured with an eggshell strength tester (EFG-0503, Robotmation, Japan); albumen height, yolk color, and Haugh unit were measured with a multifunctional egg quality tester (EMT-5200, Robotmation, Japan). The yolk was separated with an egg separator, yolk and eggshell were weighed, and yolk ratio and eggshell ratio were calculated.

1.5 Data Processing

Experimental data were analyzed by one-way ANOVA using SAS 9.2 software, with $P<0.05$ considered statistically significant. Data for each group were expressed as "mean ± standard error". Stepwise regression analysis was used to establish a multiple linear regression model and conduct significance tests.

2.1 Effects of Dietary Metabolizable Energy Level on Performance of Wenshang Luhua Hens During Laying Period

As shown in Table 2 , dietary metabolizable energy level had significant effects on ADFI, ADMEI, average body weight, metabolic body weight (BW・), egg number, laying rate, and ADEM of Wenshang Luhua hens during laying period (P<0.05). ADFI showed an increasing trend with increasing dietary metabolizable energy level, but decreased significantly when the metabolizable energy level was 11.51 MJ/kg (P<0.05). ADMEI also showed an increasing trend with increasing dietary metabolizable energy level, but decreased at 11.51 MJ/kg. The average body weight and BW・ at dietary metabolizable energy levels of 11.51 and 11.30 MJ/kg were significantly higher than those at 11.10 MJ/kg (P<0.05). Egg number, laying rate, and ADEM showed an increasing trend with increasing dietary metabolizable energy level, reaching maximum values at 11.30 MJ/kg, but decreased significantly at 11.51 MJ/kg (P<0.05). Average egg weight showed an increasing trend with increasing dietary metabolizable energy level. The feed-to-egg ratio showed a decreasing trend with increasing dietary metabolizable energy level, reaching a minimum at 11.30 MJ/kg, but increased at 11.51 MJ/kg. In summary, when dietary metabolizable energy level was 11.30 MJ/kg, Wenshang Luhua hens during laying period exhibited the highest ADFI, ADMEI, egg number, laying rate, and ADEM, and the lowest feed-to-egg ratio, indicating optimal performance.

2.2 Effects of Dietary Metabolizable Energy Level on Serum Biochemical Indexes of Wenshang Luhua Hens During Laying Period

As shown in Table 3 , dietary metabolizable energy level had certain effects on serum biochemical indexes of Wenshang Luhua hens during laying period, with serum GLU, TG, and TCHO contents showing an increasing trend as dietary metabolizable energy level increased.

2.3 Effects of Dietary Metabolizable Energy Level on Egg Quality of Wenshang Luhua Hens During Laying Period

As shown in Table 4 , dietary metabolizable energy level had significant effects on albumen height, yolk color, Haugh unit, and yolk ratio of Wenshang Luhua hens during laying period (P<0.05). Albumen height and Haugh unit in the low-energy groups (10.68, 10.89, and 11.10 MJ/kg) were significantly higher than those in the high-energy groups (11.30 and 11.51 MJ/kg) (P<0.05). Yolk color and yolk ratio showed an increasing trend with increasing dietary metabolizable energy level, with the yolk ratio at 11.51 MJ/kg being significantly higher than at other metabolizable energy levels (P<0.05), and yolk color at 11.51 MJ/kg being extremely significantly higher than at 10.68 MJ/kg (P<0.01) and significantly higher than at other metabolizable energy levels (P<0.05).

2.4 Dietary Metabolizable Energy Requirements of Wenshang Luhua Hens Aged 41-45 Weeks

Using ADMEI as the dependent variable and ADG, ADEM, and BW・ as independent variables, the factorial model for dietary metabolizable energy requirements of Wenshang Luhua hens aged 41-45 weeks was fitted (Table 5). Based on the comprehensive effects of dietary metabolizable energy level on performance of Wenshang Luhua hens aged 41-45 weeks, the ADG, ADEM, and BW・ of the group with optimal performance were selected according to the factorial model, and the dietary metabolizable energy requirement for Wenshang Luhua hens aged 41-45 weeks was determined to be 11.29 MJ/kg.

3.1 Effects of Dietary Metabolizable Energy Level on Performance of Wenshang Luhua Hens During Laying Period

Poultry have the characteristic of "eating for energy" and can instinctively regulate feed intake according to dietary energy level [8]. Studies have shown that variations in dietary energy level within a certain range have no significant effect on feed intake of small-type laying hens, but excessively high dietary energy levels significantly reduce feed intake [9]. The results of this experiment verified these viewpoints: when dietary metabolizable energy level did not exceed 11.30 MJ/kg, feed intake of Wenshang Luhua hens during laying period showed no significant changes, but decreased significantly when dietary metabolizable energy level reached 11.51 MJ/kg. During peak laying period, diets with higher energy levels must be adopted to satisfy the energy requirements for maintaining high laying rates in small-type laying hens. As dietary energy level increases, laying rate of laying hens shows an increasing trend, but excessively high dietary energy levels can lead to decreased laying rate, possibly because long-term excessive energy intake results in excessive fat deposition, thereby affecting laying rate. The results of this experiment are consistent with the above findings: when dietary metabolizable energy level did not exceed 11.30 MJ/kg, laying rate of Wenshang Luhua hens during laying period increased with increasing dietary metabolizable energy level, but decreased when dietary metabolizable energy level reached 11.51 MJ/kg; hens had the highest body weight at 11.51 MJ/kg metabolizable energy level, but the lowest laying rate, indicating that high-energy diets exacerbated fat accumulation and reduced laying rate.

The energy requirements of laying hens are divided into three parts: weight gain requirement, maintenance requirement, and egg production requirement. In this experiment, ADG, BW・ , and ADEM were used to represent these three components, respectively, to establish a factorial model. The model shows that metabolizable energy intake of Wenshang Luhua hens is mainly used for maintenance and egg production requirements. The ADG of Wenshang Luhua hens during laying period is relatively low, and metabolizable energy used for weight gain requirement is minimal.

3.2 Effects of Dietary Metabolizable Energy Level on Serum Biochemical Indexes of Wenshang Luhua Hens During Laying Period

Serum biochemical indexes can accurately reflect the metabolic status of nutrients such as fat, protein, and carbohydrates in animals. Serum TG and TCHO contents in poultry can affect lipid deposition and metabolism, reflecting blood lipid levels. When the body ingests high energy, the liver begins to synthesize TG, increasing blood TG content, which indicates enhanced fat synthesis.

Mabray et al. [10] found that dietary energy level had significant effects on blood TG content in broilers, with blood TG content increasing as dietary energy level increased. Guan Lihui et al. [11] found in their study on Saibei silky fowl during rearing period that serum TG content in hens increased with increasing dietary energy level, while that in roosters decreased. These findings are consistent with the results of this experiment, indicating that serum TG content is related to dietary energy level and poultry lipid metabolism, and has some correlation with fat deposition caused by body weight changes.

Jiang Shouqun et al. [12] studied Lingnan yellow broilers and found that serum TCHO content in broilers decreased with increasing dietary energy level. Chen et al. [13] found that adding 3% soybean oil to diets increased serum TCHO content in lambs. This experiment found that serum TCHO content of Wenshang Luhua hens during laying period increased with increasing dietary energy level. The differences in research results may be due to variations in livestock and poultry breeds, ages, and energy sources.

Blood glucose content is related to animal energy intake and is affected by the intensity of lipid metabolism in the body. Enhanced lipid metabolism can strengthen gluconeogenesis. Duo Le et al. [14] found that high-energy diets significantly increased serum GLU levels in Shiqizai chickens. Fan Chunhe [15] also found an increasing trend in blood GLU content of broilers with increasing dietary energy level. The results of this experiment are consistent with these findings.

3.3 Effects of Dietary Metabolizable Energy Level on Egg Quality of Wenshang Luhua Hens During Laying Period

Egg weight is an important indicator for measuring egg quality and is directly related to qualified egg rate and hatchability. Guo Yuming [16] suggested that maximum egg weight can be achieved through appropriate egg-to-energy ratio. Yang Fuyou et al. [17] also found that either excessively high or low dietary energy levels could reduce egg weight. March et al. [18] found that linoleic acid is an essential fatty acid for poultry, participates in fat synthesis and metabolism, and has significant effects on both yolk weight and egg weight. In this experiment, dietary energy level was mainly adjusted by soybean oil content, which is rich in linoleic acid. This may be the reason why egg weight in the high-energy groups was higher than in the low-energy groups.

Yolk is the carrier of flavor compounds in eggs and is one of the egg quality indicators widely valued by consumers. Yin Jingdong [19] found that dietary energy level can affect yolk formation. Yuan et al. [20] found that dietary energy level was significantly positively correlated with relative yolk weight and significantly negatively correlated with relative albumen weight in broiler breeder hens during laying period. Yolk color results from deposition of fat-soluble pigments into the yolk, and adding oil to diets can increase poultry absorption of fat-soluble pigments, thereby promoting pigment deposition in the yolk. Zhang Jing [21] found in a study on broiler breeder hens during late laying period that increasing dietary energy level significantly improved yolk color. This experiment found that dietary metabolizable energy level had significant effects on yolk color and yolk ratio of Wenshang Luhua hens during laying period, with both yolk color and yolk ratio increasing as dietary metabolizable energy level increased, which is consistent with the above research results.

Haugh unit is an important indicator for measuring egg quality and freshness. Yuan et al. [20] suggested that dietary energy level had no significant effect on Haugh unit, and Gunawardana et al. [22] suggested that dietary energy level had no significant effect on albumen height. These findings are inconsistent with the results of this study, and the reasons require further investigation.

Conclusions

Dietary metabolizable energy level affected the performance, blood biochemical indexes, and egg quality of Wenshang Luhua hens. Within a certain range, the performance of Wenshang Luhua hens during laying period increased with increasing dietary metabolizable energy level, but excessively high dietary metabolizable energy level decreased their performance. As dietary metabolizable energy level increased, lipid metabolism level in blood increased. As dietary metabolizable energy level increased, yolk color and yolk ratio increased, while albumen height decreased.

The suitable dietary metabolizable energy level for optimal performance of Wenshang Luhua hens aged 41-45 weeks is 11.29 MJ/kg.

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