Effects of Dietary Metabolizable Energy and Crude Protein Levels on Laying Performance, Egg Quality, and Plasma Biochemical Indices in Shaoxing Ducks (Postprint)

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Abstract

This study aimed to investigate the effects of dietary metabolizable energy (ME) and crude protein (CP) levels on laying performance, egg quality, and plasma biochemical indices of Shaoxing ducks, and to determine the appropriate dietary levels of metabolizable energy and crude protein for Shaoxing ducks. A 3$×$3 two-factor completely randomized design was employed, with 972 healthy 38-week-old Shaoxing ducks randomly allocated to 9 treatments, each consisting of 6 replicates of 18 ducks. Dietary metabolizable energy and crude protein were each set at 3 levels: metabolizable energy at 11.30, 10.88, and 10.46 MJ/kg; crude protein at 18%, 17%, and 16%. The experimental duration was 12 weeks. The results showed: 1) Dietary metabolizable energy level had no significant effects on laying rate, average egg weight, average daily feed intake, or feed-to-egg ratio of Shaoxing ducks (P>0.05), but significantly affected daily egg mass (P<0.05); at a dietary metabolizable energy level of 11.30 MJ/kg, daily egg mass was highest and feed-to-egg ratio was lowest. Dietary crude protein level had no significant effects on laying rate, average egg weight, daily egg mass, average daily feed intake, or feed-to-egg ratio (P>0.05); at a dietary crude protein level of 18%, laying rate and daily egg mass were highest. 2) Yolk color increased significantly with increasing dietary metabolizable energy level (P<0.05), but decreased significantly with increasing dietary crude protein level (P<0.05), and a significant interaction between dietary metabolizable energy and crude protein levels on yolk color was observed (P<0.05). 3) Dietary metabolizable energy and crude protein levels had no significant effects on total protein and albumin contents in plasma (P>0.05). Increasing dietary metabolizable energy level significantly increased hepatic triglyceride content (P<0.05). With increasing dietary crude protein level, hepatic fat content tended to decrease (P=0.08). In conclusion, under the conditions of this experiment, the productive performance of Shaoxing ducks was optimal at a dietary metabolizable energy level of 11.30 MJ/kg and a crude protein level of 18%.

Full Text

Effects of Dietary Metabolizable Energy and Crude Protein Levels on Laying Performance, Egg Quality and Plasma Biochemical Indexes of Shaoxing Ducks

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Abstract

This study was conducted to evaluate the effects of dietary metabolizable energy (ME) and crude protein (CP) levels on laying performance, egg quality, and plasma biochemical indexes of Shaoxing ducks, and to determine the optimal dietary levels of these nutrients. A 3$×$3 factorial arrangement of treatments was employed, examining three dietary ME levels (11.30, 10.88, and 10.46 MJ/kg) and three dietary CP levels (18.0%, 17.0%, and 16.0%). A total of 972 healthy Shaoxing ducks at 38 weeks of age were randomly allocated to 9 groups with 6 replicates per group and 18 birds per replicate. The experiment lasted for 12 weeks.

The results showed that: (1) Dietary ME and CP levels did not significantly affect egg production rate, average egg weight, average daily feed intake, or feed-to-egg ratio (P>0.05). However, dietary ME level significantly influenced daily egg mass (P<0.05). The highest daily egg mass and lowest feed-to-egg ratio were achieved at an ME level of 11.30 MJ/kg. While CP level did not significantly affect these parameters (P>0.05), the highest egg production rate and daily egg mass were observed at 18% CP. (2) Yolk color score increased significantly with increasing dietary ME level (P<0.05) but decreased significantly with increasing CP level (P<0.05). A significant interaction between dietary ME and CP levels was observed for yolk color (P<0.05). (3) Dietary ME and CP levels did not significantly affect plasma total protein or albumin content (P>0.05). Liver triglyceride content increased significantly with increasing dietary ME level (P<0.05), while liver lipid content tended to decrease with increasing CP level (P=0.08). These findings indicate that optimal performance in Shaoxing ducks is achieved with dietary ME and CP levels of 11.30 MJ/kg and 18%, respectively.

Key words: Shaoxing ducks; metabolizable energy; crude protein; laying performance; egg quality

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Introduction

China possesses one of the world' s richest waterfowl genetic resources. In recent years, the Chinese waterfowl industry has developed rapidly, establishing China as the global leader in waterfowl production. Shaoxing duck, a small-bodied breed of mallard duck, represents an excellent egg-laying breed widely raised in the riverine regions of southern China. This breed is characterized by small body size, early maturity, high egg production, low feed consumption, strong disease resistance, and broad adaptability [1-2], with production performance reaching internationally advanced levels for egg-type duck breeds. However, research on optimal dietary composition and key nutrient levels for Shaoxing ducks remains limited. Therefore, investigating the nutritional requirements of Shaoxing ducks is crucial for maximizing their genetic potential.

Efficient utilization of metabolizable energy (ME) and crude protein (CP) in feed ingredients is essential for controlling feed costs in production. Dietary ME and CP levels are primary nutritional factors affecting poultry productivity [3-5], yet few studies have examined the requirements of these nutrients in local breeds. Existing duck nutrition standards, including those from the U.S. NRC (1994), Japanese Ministry of Agriculture, Forestry and Fisheries (1992), and French AEC (1993), were developed for Pekin ducks, while the Taiwan Animal Science Association (1993) standards primarily target large Muscovy ducks and Tsaiya laying ducks. Consequently, this study was designed to investigate the effects of dietary ME and CP levels on laying performance, egg quality, and plasma biochemical indexes of Shaoxing ducks during the laying period, thereby establishing appropriate dietary ME and CP levels to support formulation of high-quality, efficient diets for laying ducks.

1.1 Experimental Animals and Design

A total of 972 healthy Shaoxing ducks at 38 weeks of age, with normal feed intake, similar body condition, and uniform genetic background, were randomly allocated to 9 treatments with 6 replicates per treatment and 18 ducks per replicate (2 ducks per cage). A 3$×$3 two-factor completely randomized design was employed, with each group receiving the corresponding experimental diet. The experiment lasted for 12 weeks. During the trial, weather conditions and temperature and humidity in the duck house were recorded daily at 06:00, 12:00, and 18:00.

1.2 Experimental Diets

A corn-soybean meal basal diet was used. Dietary treatments consisted of three ME levels (11.30, 10.88, and 10.46 MJ/kg) and three CP levels (18%, 17%, and 16%). Dietary lysine and methionine levels were adjusted correspondingly with CP levels. The composition and nutrient levels of experimental diets are presented in .

1.3.1 Laying Performance Measurement

During the experiment, feed allowance was adjusted based on consumption to ensure consistent feed intake across treatments. Ducks had ad libitum access to feed and water, with feeding at 08:00 and 15:00 daily. Daily feed intake, total egg weight, and egg number were recorded accurately for each group to calculate average egg production rate, average egg weight, average daily feed intake, feed-to-egg ratio, and daily egg mass.

1.3.2 Egg Quality Measurement

After 12 weeks of the experiment, eggs were collected for quality analysis. Four eggs per replicate were sampled to determine egg shape index, shell thickness, shell strength, albumen height, and yolk color. Egg shape index was calculated as the ratio of longitudinal to transverse diameter measured with a digital caliper (111-101). Shell strength, Haugh unit, albumen height, and yolk color were measured using an ORKA automatic egg analyzer (EA-01, ORKA Food Technology) and strength meter (EFR-01) within 48 hours of collection.

1.3.3 Plasma Biochemical Index Measurement

After 12 weeks, 2 ducks per replicate were randomly selected for blood collection. Wing vein blood (10 mL) was collected into anticoagulant-treated tubes, centrifuged at 3,000 rpm for 10 minutes at 4 °C to prepare plasma, and stored at -20 °C for subsequent analysis. Plasma total protein, albumin, urea nitrogen, and triglyceride contents were determined using assay kits from Nanjing Jiancheng Bioengineering Institute.

1.3.4 Liver Index Measurement

Following blood collection, ducks were euthanized by exsanguination. The abdomen was opened, and approximately 1 g of tissue from the middle portion of the right liver lobe was immediately frozen in liquid nitrogen overnight, then stored at -80 °C. Liver fat and triglyceride contents were determined by Soxhlet extraction method using assay kits from Nanjing Jiancheng Bioengineering Institute.

1.4 Statistical Analysis

Experimental data were analyzed using the GLM procedure of SAS 9.0 software for two-way ANOVA. The statistical model included ME level, CP level, and their interaction. When significant effects were detected, Student-Newman-Keuls multiple comparison tests were performed. Differences were considered significant at $P<0.05$.

2.1 Effects of Dietary ME and CP Levels on Laying Performance of Shaoxing Ducks

As shown in , dietary ME and CP levels did not significantly affect egg production rate, average egg weight, average daily feed intake, or feed-to-egg ratio ($P>0.05$). However, dietary ME level significantly influenced daily egg mass ($P<0.05$). With increasing dietary CP level, egg production rate, average egg weight, and daily egg mass showed an upward trend, though differences were not significant ($P>0.05$). The highest egg production rate and daily egg mass were achieved at 18% CP, while the highest daily egg mass and lowest feed-to-egg ratio occurred at an ME level of 11.30 MJ/kg.

2.2 Effects of Dietary ME and CP Levels on Egg Quality of Shaoxing Ducks

As presented in , both dietary ME and CP levels significantly affected yolk color ($P<0.05$). Yolk color score increased significantly with increasing dietary ME level ($P<0.05$) but decreased significantly with increasing CP level ($P<0.05$). A significant interaction between dietary ME and CP levels was observed for yolk color ($P<0.05$). Dietary ME level also significantly affected egg shape index ($P<0.05$), with the 11.30 MJ/kg group being significantly higher than the 10.88 MJ/kg group ($P<0.05$). Neither ME nor CP levels significantly influenced shell thickness, shell strength, or albumen height ($P>0.05$).

2.3 Effects of Dietary ME and CP Levels on Plasma Biochemical Indexes and Liver Lipid Indexes of Shaoxing Ducks

As shown in , dietary ME and CP levels did not significantly affect plasma total protein or albumin content ($P>0.05$). However, plasma urea nitrogen content was highest at 17% CP ($P=0.09$). Liver triglyceride content was significantly higher at an ME level of 11.30 MJ/kg compared with 10.88 MJ/kg ($P<0.05$), with the highest liver fat and triglyceride contents observed at 11.30 MJ/kg. Dietary CP level was negatively correlated with liver fat content [$y = -4.19x + 92.367$ ($R^2 = 0.872$, $r = 0.934$)]. A significant interaction between dietary ME and CP levels was observed for liver triglyceride content ($P<0.05$).

3.1 Effects of Dietary ME and CP Levels on Laying Performance of Shaoxing Ducks

In this study, dietary ME level significantly affected daily egg mass of Shaoxing ducks, with maximum daily egg mass and minimum feed-to-egg ratio achieved at 11.30 MJ/kg. Although CP level did not significantly affect laying performance, the 17% and 18% CP treatments showed similar egg production rates, with the 18% CP treatment yielding numerically superior daily egg mass and feed-to-egg ratio. The combination of 11.30 MJ/kg ME and 18% CP produced the best overall performance. These findings differ somewhat from previous research. Yin et al. [6] reported that Shaoxing ducks achieved satisfactory performance with 17.5% CP and 11.09 MJ/kg. Different duck breeds show varying requirements for ME and CP. Lin et al. [7] found that 17% CP met the production needs of Hainan laying ducks with satisfactory performance, a finding supported by Wei et al. [8-9] who reported that ME level significantly affected feed intake and egg production rate, with optimal results at 11.3 MJ/kg ME and 17% CP for laying ducks in Hainan. Mi and Wang [10] demonstrated that 11.51 MJ/kg ME met the laying requirements of caged Jinding ducks, with an associated egg-to-energy ratio of 14.77 g/MJ. Wang et al. [11] showed that high-energy, high-protein diets resulted in lower feed intake, with optimal egg weight, feed-to-egg ratio, and egg number at 11.30 MJ/kg ME and 17.07% CP. The ME and CP requirements of laying ducks may be influenced by breed, climate, weather conditions, and geography. The present study was conducted in Zhejiang during spring, where rainy and humid conditions may have contributed to differences from previous results. Under the conditions of this experiment, dietary ME and CP levels of 11.30 MJ/kg and 18% produced optimal performance.

3.2 Effects of Dietary ME and CP Levels on Egg Quality of Shaoxing Ducks

This study demonstrated that dietary ME and CP levels significantly affected yolk color. Yolk color score increased significantly with increasing ME level but decreased significantly with increasing CP level, with a significant interaction between these factors. These findings align with Tian et al. [12], who reported that high-energy diets significantly improved yolk color in broiler breeders at 35 and 40 weeks of age compared with controls, while low-energy diets showed no significant effect, and ME level did not significantly affect other egg quality parameters. Fu et al. [13-14] also demonstrated a close relationship between dietary CP level and yolk color, with yolk color deepening significantly as CP level decreased. This effect likely occurs because yolk color depends primarily on dietary lutein and carotenoid content [15]. Since all diets in these studies were corn-soybean meal based, the relatively higher corn content in low-CP diets may have enhanced yolk color deposition.

3.3 Effects of Dietary ME and CP Levels on Plasma Biochemical Indexes and Liver Lipid Indexes of Shaoxing Ducks

Plasma total protein content can reflect dietary protein nutrition level and protein digestion and absorption in animals. Luo and Chen [16] reported that in piglets, plasma total protein, albumin content, and albumin/globulin ratio initially increased then decreased with increasing dietary CP level, reaching maximum values at 23% CP. In the present study, dietary ME and CP levels did not significantly affect plasma total protein or albumin content, possibly due to differences in dietary CP levels and breed. Increased ME level and decreased CP level enhanced lipid deposition in duck livers. The liver is the primary site of fat synthesis in poultry, with nearly all fat synthesized and metabolized in this organ, making it crucial for lipid metabolism. Cao et al. [17] reported similar results in laying hens, where high-energy, low-protein diets resulted in significantly or extremely significantly higher liver wet weight, liver fat content, and liver fat percentage compared with controls. High-energy diets lead to conversion of excess energy into lipids in the liver [18], while low-protein diets may result in insufficient supply of lipoproteins or apolipoproteins necessary for transporting hepatic lipids to extrahepatic tissues, impairing hepatic fat transport and disrupting the dynamic balance of fat metabolism among hepatocytes, adipose tissue, and plasma. This leads to excessive deposition of neutral lipids in hepatocytes, highlighting the importance of an appropriate energy-to-protein ratio for maintaining normal lipid and protein metabolism in poultry.

Based on comprehensive evaluation of laying performance and egg quality, optimal production performance in Shaoxing ducks was achieved with dietary ME and CP levels of 11.30 MJ/kg and 18%, respectively.

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