Effects of Dietary Metabolizable Energy Levels on Laying Performance, Egg Quality, and Serum Biochemical Indices of Caged Laying Ducks (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary metabolizable energy (ME) levels on laying performance, egg quality, and serum biochemical indices of caged laying ducks during peak production. A total of 250 healthy 29-week-old Linwu ducks with similar body weight were selected and randomly divided into 5 groups with 5 replicates per group and 10 ducks per replicate. A single-factor experimental design was adopted with 5 dietary ME levels: 10.09, 10.59, 11.09, 11.59, and 12.09 MJ/kg, and all diets contained 18% crude protein. The pre-trial period was 7 days, and the formal trial period was 63 days. The results showed: 1) With increasing dietary ME level, average daily feed intake decreased significantly in a linear manner ($P<0.05$). The group with dietary ME level of 12.09 MJ/kg had significantly lower laying rate and daily egg weight than the other groups ($P<0.05$). The feed-to-egg ratio was highest in the group with dietary ME level of 10.09 MJ/kg, which was significantly higher than the other groups ($P<0.05$). 2) Dietary ME level had no significant effect on any egg quality parameters of caged laying ducks ($P>0.05$). 3) With increasing dietary ME level, serum cholesterol and low-density lipoprotein contents increased significantly in a linear manner ($P<0.05$), while serum urea nitrogen content decreased significantly in a linear manner ($P<0.05$). Serum glucose content in the group with dietary ME level of 12.09 MJ/kg was significantly higher than that in the group with dietary ME level of 10.09 MJ/kg ($P<0.05$). Regression analysis showed that based on the criteria of high laying rate, high daily egg weight, and low feed-to-egg ratio, the recommended dietary ME level for 29- to 38-week-old Linwu ducks is 10.73-11.29 MJ/kg.

Full Text

Effects of Dietary Metabolizable Energy Level on Laying Performance, Egg Quality and Serum Biochemical Indices of Cage-Rearing Laying Ducks

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Abstract

This experiment was conducted to investigate the effects of dietary metabolizable energy (ME) level on laying performance, egg quality, and serum biochemical indices of cage-rearing laying ducks during peak production. Two hundred fifty healthy 29-week-old Linwu ducks with similar body weights were randomly allocated to 5 groups, each consisting of 5 replicates of 10 ducks. Using a single-factor experimental design, five dietary ME levels were established: 10.09, 10.59, 11.09, 11.59, and 12.09 MJ/kg, with crude protein maintained at 18% across all diets. The adaptation period lasted 7 days, followed by a 63-day formal experimental period.

The results showed: (1) Average daily feed intake decreased significantly in a linear manner as dietary ME level increased ($P<0.05$). The group fed 12.09 MJ/kg ME exhibited significantly lower laying rate and daily egg yield compared to other groups ($P<0.05$). The feed-to-egg ratio was highest in the 10.09 MJ/kg group, significantly exceeding all other groups ($P<0.05$). (2) Dietary ME level had no significant effects on any egg quality parameters ($P>0.05$). (3) Serum cholesterol and low-density lipoprotein contents increased significantly in a linear fashion with increasing dietary ME level ($P<0.05$), while serum urea nitrogen decreased significantly in a linear manner ($P<0.05$). Serum glucose content in the 12.09 MJ/kg group was significantly higher than in the 10.09 MJ/kg group ($P<0.05$). Regression analysis indicated that, based on optimal laying rate, daily egg yield, and feed-to-egg ratio, the recommended dietary ME level for 29- to 38-week-old Linwu ducks is 10.73–11.29 MJ/kg.

Keywords: cage-rearing laying ducks; metabolizable energy; laying performance; egg quality; serum biochemical indices
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Introduction

Dietary metabolizable energy (ME) level is a critical factor influencing poultry productivity. When dietary crude protein level remains constant, excessive energy intake can lead to abdominal fat accumulation and decreased laying performance in laying birds, whereas insufficient ME levels fail to meet growth and production requirements. Previous research has reported that under cage-rearing conditions, the ME requirement for Sansui ducks during mid-laying period (23-37 weeks) is 10.89 MJ/kg. Another study demonstrated that 16- to 50-week-old Shaoxing ducks achieved optimal performance when fed diets containing 18% crude protein and 11.70 MJ/kg ME. Additionally, research on cage-rearing blue-shell laying ducks found that 10.67 MJ/kg ME was optimal during late laying period.

China' s *Feeding Standard of Meat Ducks* (NY/T 2122-2012) recommends appropriate dietary ME levels for various duck breeds: 11.51 MJ/kg for mid-laying Pekin ducks (27–45 weeks), 11.30 MJ/kg for laying Muscovy and mule ducks (27–65 weeks), 11.30 MJ/kg for dual-purpose meat-egg ducks during mid-laying (23–45 weeks), and 10.87 MJ/kg for egg-type ducks during laying (24–70 weeks). Linwu duck, an excellent dual-purpose native breed in China, has been widely promoted in southern Hunan. However, research on nutrient requirements for Linwu ducks remains limited, and ME requirements during peak laying have not been reported. Therefore, this study aimed to determine the effects of dietary ME level on laying performance, egg quality, and serum biochemical indices of 30- to 38-week-old Linwu ducks, providing a theoretical basis for establishing appropriate ME levels during peak production.

1.1 Experimental Design and Diets

Two hundred fifty 29-week-old Linwu ducks with uniform genetic background, similar body weight, and good health were randomly divided into 5 groups with 5 replicates each and 10 ducks per replicate. Following a 7-day adaptation period, a 63-day feeding trial was conducted. Dietary crude protein, amino acids, calcium, phosphorus, and other nutritional parameters were formulated according to the *Nutrient Requirements of Linwu Ducks* (DB43/T 898-2014). Dietary composition and nutrient levels are presented in Table 1 . The experimental diets contained ME levels of 10.09, 10.59, 11.09, 11.59, and 12.09 MJ/kg, with crude protein maintained at 18% in all diets.

1.2 Management

The feeding trial was conducted at the Waterfowl Experimental Farm of Hunan Institute of Animal Science and Veterinary Medicine. Ducks were housed individually in closed duck houses using double-layer plastic-coated metal cages. Each group received the corresponding experimental diet, fed manually twice daily. Fresh water was available ad libitum throughout the trial, and normal management and immunization procedures were followed.

1.3.1 Laying Performance

During the experimental period, feed was provided at 08:00 and 16:00 daily. Feed intake, total egg weight, egg number, and defective eggs (including soft-shelled, broken, misshapen, and sand-shelled eggs) were accurately recorded for each replicate. Average egg weight, daily egg yield, laying rate, qualified egg rate, average daily feed intake, and feed-to-egg ratio were calculated on a group basis.

1.3.2 Egg Quality

At the end of week 9, 15 eggs (3 per replicate) approaching the average egg weight were collected from each group and measured within 24 hours. Parameters including egg weight, yolk weight, shell weight, shell thickness (measured with shell thickness gauge), egg width and length (measured with vernier calipers), yolk color (measured with yolk color fan), and albumen height (measured with albumen height gauge) were determined. Yolk percentage, shell percentage, egg shape index, and Haugh unit were calculated using the following formulas:

Yolk percentage = yolk weight / egg weight
Shell percentage = shell weight / egg weight
Egg shape index = egg length / egg width
Haugh unit = $100 \times \log(H - 1.7W \cdot^{3} + 7.57)$

where H represents albumen height (mm) and W represents egg weight (g).

1.3.3 Serum Biochemical Indices

At the conclusion of the trial, 10 ducks (2 per replicate) approaching the average body weight were randomly selected from each group (50 ducks total). Before morning feeding, 5 mL of blood was collected from the wing vein, placed at an angle for 1–2 hours, then centrifuged at 3,000 rpm for 15 minutes. Serum was separated for analysis of total protein, albumin, urea nitrogen, uric acid, glucose, total cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein contents, as well as alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase activities.

1.4 Statistical Analysis

Data were analyzed using SPSS 18.0 software for one-way ANOVA and regression analysis. Results are expressed as means and standard error of the mean

(SEM). Differences were considered significant at P<0.05, with Duncan' s multiple comparison test applied for significant differences. Significant indicators were further subjected to linear and quadratic regression analysis to determine appropriate dietary ME levels.

2.1 Effects of Dietary ME Level on Laying Performance of Cage-Rearing Laying Ducks

As shown in Table 2 , dietary ME level had no significant effects on average egg weight or qualified egg rate (P>0.05). Average daily feed intake decreased significantly in a linear manner as dietary ME level increased (P<0.05). The 12.09 MJ/kg group exhibited significantly lower laying rate and daily egg yield compared to all other groups (P<0.05). The feed-to-egg ratio was highest in the 10.09 MJ/kg group, significantly exceeding other groups (P<0.05).

Table 2 Effects of dietary ME level on laying performance of cage-rearing laying ducks

Item	Dietary ME level (MJ/kg)	P-value
Average daily feed intake (g/d)	154.93 , 152.26 , 149.94 , 149.09 , 146.12	<0.01
Laying rate (%)	80.41 , 80.50 , 80.57 , 80.19 , 77.35	<0.01
Average egg weight (g)	57.34 , 57.53 , 57.73 , 56.94 , 55.37	<0.01
Daily egg yield (g/d)		
Feed-to-egg ratio	2.70 , 2.65 , 2.60 , 2.62 , 2.64	<0.01
Qualified egg rate (%)		

In the same row, values with different superscripts differ significantly (P<0.05), while those with the same or no superscript do not differ significantly (P>0.05). The same applies below.

2.2 Effects of Dietary ME Level on Egg Quality of Cage-Rearing Laying Ducks

As shown in Table 3 , dietary ME level had no significant effects on any egg quality parameters (P>0.05).

Table 3 Effects of dietary ME level on egg quality of cage-rearing laying ducks

Item	Dietary ME level (MJ/kg)	P-value
Egg shape index		
Eggshell thickness (mm)		
Yolk color		
Albumen height (mm)		
Percentage of yolk (%)		
Percentage of eggshell (%)		
Haugh unit	11.72	

2.3 Effects of Dietary ME Level on Serum Biochemical Indices of Cage-Rearing Laying Ducks

As shown in Table 4 , serum cholesterol and low-density lipoprotein contents increased significantly in a linear manner with increasing dietary ME level (P<0.05). Specifically, serum cholesterol in the 11.59 and 12.09 MJ/kg groups was significantly higher than in the 10.09 MJ/kg group (P<0.05). Serum low-density lipoprotein in the 12.09 MJ/kg group was significantly higher compared to the 10.09 and 10.59 MJ/kg groups (P<0.05). Serum urea nitrogen in the 10.09 MJ/kg group was significantly higher than in the other four groups (P<0.05). Serum glucose content in the 12.09 MJ/kg group was significantly higher than in the 10.09 MJ/kg group (P<0.05).

Table 4 Effects of dietary ME level on serum biochemical indices of cage-rearing laying ducks

Item	Dietary ME level (MJ/kg)	P-value
Total protein (g/L)		
Albumin (g/L)		
Glucose (mmol/L)	9.38 , 9.96 , 10.14 , 9.95 , 10.49	
Cholesterol (mmol/L)	3.39 , 3.91 , 3.96 , 4.39 , 4.66	
Triglycerides (mmol/L)		
HDL (mmol/L)		
LDL (mmol/L)	0.58 , 0.60 , 0.63 , 0.72 , 0.85	
ALT (U/L)		
AST (U/L)		
ALP (U/L)		
Urea nitrogen (mmol/L)	0.51 , 0.32 , 0.39 , 0.37 , 0.28	

Item	Dietary ME level (MJ/kg)	P-value
Uric acid (mol/L)		

2.4 ME Requirement of Linwu Ducks During Peak Laying Period

Based on P-values in Tables 2 and 4, average daily feed intake and serum cholesterol, low-density lipoprotein, and urea nitrogen contents exhibited only linear trends with dietary ME level ($P<0.05$). Table 5 shows that regression analysis revealed quadratic trends for laying rate, daily egg yield, and feed-to-egg ratio with increasing dietary ME level. Derivatives of the quadratic equations indicated optimal dietary ME levels of 10.73, 10.74, and 11.29 MJ/kg, respectively, corresponding to maximum laying rate, maximum daily egg yield, and minimum feed-to-egg ratio.

Table 5 The ME requirement of Linwu laying ducks in peaking laying period

Item	Regressive formula	P-value	Dietary ME requirement (MJ
Average daily feed intake (g/d)	$y = -4.158x + 196.5$		
Laying rate (%)	$y = -1.8029x^2 + 38.701x - 126.76$		10.73
Daily egg yield (g/d)	$y = -1.2866x^2 + 27.675x - 90.805$		10.74
Feed-to-egg ratio	$y = 0.0686x^2 - 1.5489x + 11.348$		11.29
Cholesterol (mmol/L)	$y = 0.604x - 2.636$		
LDL (mmol/L)	$y = 0.132x - 0.787$		
Urea nitrogen (mmol/L)	$y = -0.082x + 1.283$		

Discussion

3.1 Effects of Dietary ME Level on Laying Performance and Egg Quality of Cage-Rearing Laying Ducks

Poultry possess an instinct to "eat for energy," maintaining relatively stable ME intake to support growth and production. Dietary ME level determines feed intake, which subsequently influences production performance parameters such as average egg weight and laying rate. Previous research demonstrated that increasing dietary ME level significantly improved nutrient utilization and egg weight in laying hens. One study reported that increasing dietary ME from 11.21 to 11.76 MJ/kg reduced feed intake by 5% without affecting laying performance. Research on cage-rearing laying ducks showed that increasing dietary ME level elevated laying rate and daily egg yield while decreasing feed-to-egg ratio during late laying period. Other studies found that dietary ME levels of 11.08 and 11.05 MJ/kg produced the highest laying rates in Shaoxing and Jinding ducks, respectively. Additionally, increasing dietary energy level significantly increased egg weight in 16- to 50-week-old Shaoxing ducks.

The current study demonstrated that average daily feed intake decreased gradually as dietary ME level increased. When dietary ME reached 12.09 MJ/kg, laying rate and daily egg yield decreased significantly compared to lower levels, while excessively low ME (10.09 MJ/kg) increased feed-to-egg ratio. These findings indicate that excessively high dietary ME promotes abdominal fat accumulation, negatively impacting laying rate and daily egg yield, whereas excessively low ME increases feed intake and feed-to-egg ratio. The results confirm that ducks can regulate feed intake according to dietary ME level, with optimal laying performance achieved at ME levels of 10.59–11.59 MJ/kg. Furthermore, no significant differences in egg quality parameters were observed across dietary ME levels of 10.09–12.09 MJ/kg, consistent with findings from several previous studies but contrasting with others. These discrepancies may be attributed to differences in dietary formulation methods and composition when adjusting ME levels while maintaining constant crude protein.

3.2 Effects of Dietary ME Level on Serum Biochemical Indices of Cage-Rearing Laying Ducks

Serum biochemical indices reflect animal health status and metabolic conditions. Glucose serves as the direct energy source for vital activities and correlates with energy intake, with high-energy diets significantly increasing serum glucose content. Serum total cholesterol and low-density lipoprotein reflect lipid metabolism, while urea nitrogen and uric acid, as protein metabolism end products, indicate protein utilization efficiency. Previous research reported that increasing dietary ME level under low and optimal temperatures elevated serum free fatty acids and glucose while decreasing uric acid. Another study found that serum total cholesterol and low-density lipoprotein in 1- to 3-week-old Sichuan white geese exhibited fluctuating patterns with increasing dietary ME.

The current results demonstrate that dietary ME level significantly affected serum cholesterol, low-density lipoprotein, and glucose contents, all increasing significantly with higher dietary ME. This suggests that increasing dietary ME through soybean oil supplementation enhanced energy utilization and energy storage. The significant decrease in serum urea nitrogen with increasing ME further confirms that higher ME levels reduced feed intake, consequently decreasing crude protein and other nutrient intake, ultimately lowering serum urea nitrogen, though the specific mechanism requires further investigation.

3.3 ME Requirement of Linwu Ducks During Peak Laying Period

Research on ME requirements has primarily focused on laying hens, with limited studies on laying ducks, particularly systematic research on appropriate dietary ME levels for different production stages. One study recommended 11.30 MJ/kg ME for cage-rearing laying ducks in Hainan during laying period. The current results indicate that dietary ME levels of 10.59–11.59 MJ/kg produced optimal laying performance during peak production. Using laying rate, daily egg yield, and feed-to-egg ratio as sensitive indicators, quadratic modeling estimated the

ME requirement for 30- to 38-week-old Linwu ducks at 10.73–11.29 MJ/kg. This recommendation aligns closely with the *Feeding Standard of Meat Ducks* (11.30 MJ/kg for dual-purpose ducks) and research on Shaoxing ducks (11.30 MJ/kg), but is higher than one study on late-laying ducks (10.67 MJ/kg) and slightly lower than recommendations for Shaoxing ducks (11.70 MJ/kg) and Jinding ducks (11.51 MJ/kg). Variations among studies may be attributed to differences in evaluation criteria, production stage, management systems, and duck breeds.

Conclusion

Under the conditions of this experiment, dietary ME levels of 10.73–11.29 MJ/kg are recommended for 29- to 38-week-old Linwu ducks to achieve high laying rate, high daily egg yield, and low feed-to-egg ratio.

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