Dietary Energy and Protein Requirements of 5-9 Week-Old Dawufen No. 1 Commercial Layer Chicks (Postprint)

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Abstract

This experiment aimed to determine the dietary energy and protein requirements of 5- to 9-week-old Dawufen No. 1 commercial layer chicks by establishing regression models between dietary energy or protein levels and growth performance, serum biochemical indices, organ indices, and other parameters. A total of 810 healthy 28-day-old Dawufen No. 1 commercial layer chicks with similar genetic background and body weight were randomly allocated to 9 groups, with 6 replicates per group and 15 chicks per replicate. A 3×3 factorial design was employed, with dietary energy levels set at 12.42, 11.92, and 11.42 MJ/kg, and protein levels at 18.75%, 17.75%, and 16.75%, resulting in 9 experimental diets. The trial lasted for 35 days. The results showed: 1) As dietary energy level increased, tibia length, breast width, keel length, and serum triglyceride content at 9 weeks of age showed an upward trend, while average daily gain from 5 to 9 weeks of age exhibited a trend of first decreasing then increasing. 2) As dietary protein level increased, body weight (final body weight) at 9 weeks of age, breast width, and average daily gain from 5 to 9 weeks of age showed a trend of first increasing then decreasing. 3) The interaction between dietary energy and protein levels had significant effects on breast width, keel length, and serum triglyceride content in 9-week-old Dawufen No. 1 commercial layer chicks ($P<0.05$). 4) Through quadratic curve fitting of breast width, keel length, and serum triglyceride content against dietary energy level, the optimal dietary energy levels were determined to be 11.420, 11.483, and 11.379 MJ/kg, respectively, with a mean value of 11.427 MJ/kg; through quadratic curve fitting of body weight at 9 weeks of age against dietary protein level, the optimal dietary protein level was determined to be 17.902%. Based on comprehensive consideration of body measurement indices, growth performance, organ indices, and serum biochemical indices, the energy and protein requirements for 5- to 9-week-old Dawufen No. 1 commercial layer chicks were determined to be 11.427 MJ/kg

and 17.902%, respectively.

Full Text

Study on Dietary Energy and Protein Requirements of Dawufen No.1 Commercial Layer Chicks Aged 5 to 9 Weeks

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Abstract: This study established regression models between dietary energy or protein levels and growth performance, serum biochemical indices, and organ indexes to determine the dietary energy and protein requirements of Dawufen No.1 commercial layer chicks aged 5 to 9 weeks. A total of 810 healthy 28-day-old Dawufen No.1 commercial layer chicks with similar body weight and uniform genetic background were randomly allocated to 9 groups, with 6 replicates per group and 15 chicks per replicate. A 3×3 factorial design was employed with dietary energy levels of 12.42, 11.92, and 11.42 MJ/kg and protein levels of 18.75%, 17.75%, and 16.75%, resulting in 9 experimental diets. The trial lasted 35 days. The results showed: (1) As dietary energy level increased, tibia length, chest breadth, keel length, and serum triglyceride content at 9 weeks of age showed an upward trend, while average daily gain (ADG) during 5-9 weeks first decreased then increased. (2) As dietary protein level increased, final body weight, chest breadth at 9 weeks, and ADG during 5-9 weeks first increased then decreased. (3) The interaction between dietary energy and protein levels significantly affected chest breadth, keel length, and serum triglyceride content ($P < 0.05$). (4) Quadratic curve fitting between dietary energy level and chest breadth, keel length, and serum triglyceride content yielded optimal energy levels of 11.420, 11.483, and 11.379 MJ/kg, respectively, averaging 11.427 MJ/kg. Quadratic curve fitting between dietary protein level and final body weight yielded an optimal protein level of 17.902%. Based on comprehensive analysis of body measurements, growth performance, organ indexes, and serum biochemical indices, the energy and protein requirements for 5-9 week-old Dawufen No.1 commercial layer chicks were determined to be 11.427 MJ/kg and 17.902%, respectively.

Keywords: Dawufen No.1 commercial layer chicks; energy; protein; requirement; regression analysis

Feed cost represents one of the primary factors affecting economic efficiency in the poultry industry, with dietary energy and protein levels serving as crucial indicators for evaluating feed nutritional value. Energy and protein feed ingredients account for approximately 85% of total feed costs. Decuypere et al. found that dietary energy level significantly affects laying hen performance and resistance to common skeletal disorders. Morris reported that excess protein impacts the utilization of limiting amino acids in laying hens, while Forbes et al. demonstrated that hens fed low-protein diets could selectively consume high-protein diets to meet nutritional requirements. Therefore, adequate dietary energy and protein constitute the foundation for healthy growth in laying hens. Although numerous studies have investigated energy requirements for laying hens, different breeds exhibit varying needs. Murakami et al. found that feeding Hy-Line Brown pullets a single diet containing 12.35 MJ/kg energy and 21% protein from 1-16 weeks had no significant effect on laying period performance. Kang et al. reported that suitable dietary energy and protein levels for Gushi chickens aged 5-8 weeks were 12.69 MJ/kg and 18.20%, respectively. Raul da Cunha et al. determined that optimal energy and protein levels for Lohmann Brown pullets were 12.14 MJ/kg and 21% at 1-6 weeks, and 11.30 MJ/kg and 20% at 7-12 weeks. Tong et al. recommended an appropriate protein level of 18.0% for Xianju chickens. Dawufen No.1, a Chinese indigenous layer breed developed in 2013, features high egg production and strong stress resistance, but its feeding standards remain incomplete. This study investigated the effects of dietary energy and protein levels on growth performance, blood biochemical indices, and organ indexes of Dawufen No.1 commercial layer chicks aged 5-9 weeks to determine optimal dietary energy and protein levels and provide scientific basis for establishing feeding standards.

1.1 Experimental Animals and Design

The experiment utilized 810 healthy 28-day-old Dawufen No.1 commercial layer chicks with uniform genetic background, similar body weight, and good health status, randomly divided into 9 groups (I-IX) with 6 replicates per group and 15 chicks per replicate. A 3×3 factorial design was employed with energy levels of 12.42 (high), 11.92 (medium), and 11.42 MJ/kg (low) and protein levels of 18.75% (high), 17.75% (medium), and 16.75% (low), resulting in 9 experimental diets: high-energy high-protein (Group I), high-energy medium-protein (Group II), high-energy low-protein (Group III), medium-energy high-protein (Group IV), medium-energy medium-protein (Group V), medium-energy low-protein (Group VI), low-energy high-protein (Group VII), low-energy medium-protein (Group VIII), and low-energy low-protein (Group IX). Diet composition and nutrient levels are presented in . All experimental diets were mash form, with consistent nutrient composition except for energy and protein levels. The feeding trial lasted 35 days.

1.2 Management

The feeding trial was conducted at the National Layer Breeding and Extension Base of Hebei Dawu Farming and Animal Husbandry Group. Chicks were housed in a closed chicken house with longitudinal ventilation in A-frame three-tier cages. The house was heated by boiler water warming, with manual feeding and nipple drinkers. Temperature, humidity, disinfection, and vaccination procedures strictly followed the *Dawufen No.1 Feeding Manual*. Chicks had ad libitum access to feed and water throughout the experiment.

1.3.1 Growth Performance

On a weekly basis, feed troughs were cleaned at 20:00 on the last day of each week after fasting (water provided). Feed consumption was recorded by replicate. At 08:00 on the first day of each week, 5 chicks per replicate were selected for measurement of body weight, tibia length, chest breadth, and keel length. Average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G) were calculated by replicate.

1.3.2 Serum Biochemical Indices

At the end of the trial, one chick per replicate was randomly selected. Blood (3 mL) was collected from the wing vein into procoagulant tubes, allowed to clot naturally, then centrifuged at 3,500 r/min for 10 minutes to obtain serum. Serum glucose, uric acid, total triglycerides, total cholesterol, albumin, and total protein were measured using assay kits purchased from Nanjing Jiancheng Bioengineering Institute.

1.3.3 Organ Indexes

At trial conclusion, one chick per replicate was randomly selected, weighed, euthanized by jugular exsanguination, and dissected to remove the heart, liver, spleen, thymus, pancreas, bursa of Fabricius, duodenum, jejunum, and ileum. Adipose tissue was trimmed, blood was absorbed with filter paper, and organs were weighed to calculate organ indexes. Lengths of duodenum, jejunum, and ileum were measured to calculate relative lengths. Organ index (%) = (organ weight/body weight) $\times$ 100; relative length of small intestine segment = segment length/total small intestine length.

1.4 Data Analysis

Experimental data were processed using Excel 2013 and analyzed using SPSS 22.0 one-way ANOVA. Main effects and interactions were analyzed using the general linear model (GLM) multivariate procedure. Differences among groups were tested using LSD multiple comparison with $P < 0.05$ considered significant. When interaction effects were significant, multiple linear equations were established using curve estimation in the regression procedure. When interaction effects were not significant but main effects were significant, quadratic equations for main effects were fitted. When quadratic effects reached significance, maximum response values were obtained according to Yao' s method to determine optimal dietary energy and protein levels, which were considered the requirements.

2.1 Effects of Dietary Energy and Protein Levels on Growth Performance

As shown in , dietary protein level significantly affected final body weight ($P < 0.05$), while dietary energy level and its interaction with protein level had no significant effect ($P > 0.05$). Final body weight in Groups III, V, VII, VIII, and IX was significantly higher than in Group VI ($P < 0.05$). Both dietary energy and protein levels significantly affected ADG ($P < 0.05$), but their interaction did not ($P > 0.05$). ADG in Groups II, V, VII, VIII, and IX was significantly higher than in Group VI ($P < 0.05$). Dietary energy, protein levels, and their interaction had no significant effects on ADFI or F/G ($P > 0.05$), though ADFI and F/G tended to first increase then decrease with increasing energy level. No significant differences in ADFI or F/G were observed among groups ($P > 0.05$).

2.2 Effects of Dietary Energy and Protein Levels on Body Measurements

As shown in , dietary energy level significantly affected tibia length, chest breadth, and keel length ($P < 0.05$), while protein level had no significant effect on these measurements ($P > 0.05$). The energy-protein interaction had no significant effect on tibia length ($P > 0.05$) but significantly affected chest breadth and keel length ($P < 0.05$). Tibia length in Groups V, VIII, and IX was significantly shorter than in Group III ($P < 0.05$). Except for Groups I and II, which did not differ significantly from Group III in chest breadth ($P > 0.05$), all other groups were significantly lower than Group III ($P < 0.05$). Keel length in Group IX was significantly shorter than in Groups I, II, and III ($P < 0.05$), with no significant differences among Groups I, II, and III ($P > 0.05$). As dietary energy level increased, tibia length, chest breadth, and keel length increased. Tibia length was significantly shorter at 11.42 MJ/kg than at 12.42 MJ/kg ($P < 0.05$), while chest breadth and keel length were significantly shorter at 11.42 MJ/kg than at 11.92 and 12.42 MJ/kg ($P < 0.05$).

2.3 Effects of Dietary Energy and Protein Levels on Organ Indexes

As shown in , dietary energy, protein levels, and their interaction had no significant effects on heart, liver, spleen, or bursa of Fabricius indexes ($P > 0.05$). Heart index in Groups I, V, VII, and IX was significantly lower than in Group VI ($P < 0.05$). Liver index in Groups I and VIII was significantly lower than in Groups II and IX ($P < 0.05$). Bursa of Fabricius index in Group V was significantly higher than in Groups IV and VI ($P < 0.05$). Dietary energy and protein levels had no significant effect on pancreas index ($P > 0.05$), but their interaction was significant ($P < 0.05$). Pancreas index in Groups I, III, VI, VII, and VIII was significantly lower than in Group IV ($P < 0.05$). Dietary protein level significantly affected thymus index ($P < 0.05$), while energy level and its interaction with protein level did not ($P > 0.05$). Thymus index at 18.75% protein was significantly higher than at 16.75% and 17.75% protein ($P < 0.05$).

2.4 Effects of Dietary Energy and Protein Levels on Small Intestinal Development

As shown in , dietary energy, protein levels, and their interaction had no significant effects on total small intestine length or relative lengths of duodenum, jejunum, or ileum ($P > 0.05$). Total small intestine length in Group I was significantly shorter than in Group V ($P < 0.05$). Relative jejunum length in Group I was significantly higher than in all groups except Group IV ($P < 0.05$).

2.5 Effects of Dietary Energy and Protein Levels on Serum Biochemical Indices

As shown in , dietary energy level and its interaction with protein level significantly affected serum triglyceride content ($P < 0.05$), while protein level had no significant effect ($P > 0.05$). Serum triglyceride content in Groups I, II, and III was significantly higher than in Groups V, VI, VIII, and IX ($P < 0.05$). Serum triglyceride content increased with dietary energy level and was significantly higher at 12.42 MJ/kg than at 11.92 and 11.42 MJ/kg ($P < 0.05$). Additionally, serum uric acid content in Group I was significantly higher than in all other groups ($P < 0.05$).

2.6 Determination of Energy and Protein Requirements for Dawufen No.1 Layer Chicks Aged 5-9 Weeks

2.6.1 Estimation Using Multiple Linear Regression Models Using indicators with significant energy-protein interactions as dependent variable Y, dietary protein level as independent variable X , and energy level as X , binary linear regression was performed according to the model Y = aX + bX + c. As shown in Table 7, all obtained linear equations were non-significant for dietary protein level ($P > 0.05$).

2.6.2 Energy Requirement for Dawufen No.1 Layer Chicks Using dietary energy level as independent variable X and indicators significantly affected by energy level as dependent variable Y, quadratic regression equations were established according to the model $Y = aX^2 + bX + c$. As shown in , integrating chest breadth, keel length, and serum triglyceride content, the energy requirement for 5-9 week-old layer chicks was 11.427 MJ/kg.

2.6.3 Protein Requirement for Dawufen No.1 Layer Chicks Using dietary protein level as independent variable X and indicators significantly affected by protein level as dependent variable Y, quadratic regression equations were established. As shown in , based on final body weight, the optimal dietary protein level for 5-9 week-old layer chicks was 17.902%.

3.1 Combined Effects of Dietary Energy and Protein on Dawufen No.1 Layer Chicks Aged 5-9 Weeks

The nutritional relationship between energy and protein in animal diets is interdependent. Improper energy-to-protein ratios cause nutritional disorders and reduce feed utilization efficiency, while appropriate ratios maximize dietary utilization. This study found that the energy-protein interaction had no significant effect on growth performance of 5-9 week-old Dawufen No.1 layer chicks, consistent with Kang et al. The interaction significantly affected chest breadth, keel length, and serum triglyceride content, but multiple linear regression revealed no significant differences in response values attributable to dietary protein level.

3.2 Effects of Dietary Energy and Protein Levels on Growth Performance

Livestock performance is closely related to dietary energy level. When dietary energy exceeds threshold levels, digesta composition and nutrient absorption concentrations change, causing feed intake to decrease with increasing energy. Shi et al. found that increasing dietary energy from 11.49 to 12.57 MJ/kg significantly decreased feed intake and increased body weight in Hy-Line White W-36 pullets. In contrast, this study found no significant differences in ADFI or final body weight when energy increased from 11.42 to 12.42 MJ/kg, possibly due to different environmental conditions and breeds. Xu found that increasing energy from 11.65 to 12.85 MJ/kg significantly increased F/G in Guangxi Guixiang chickens during rearing, consistent with our results. Combined with ADFI and F/G data, feed utilization was highest at 11.42 MJ/kg energy level. Xu also reported that increasing protein level (15% to 18%) had no significant effect on F/G in Guangxi Guixiang chickens, matching our findings. Halle identified protein as an important factor affecting feed intake, but this study found no significant effect of protein level on ADFI, possibly because our protein levels did not reach the limit of requirements or due to breed differences. Quadratic fitting of final body weight (Y) against dietary protein level (X) yielded $Y = -30.918X^2 + 1106.99X - 8846.874$ ($R^2 = 0.634$), indicating maximum body weight at 9 weeks was achieved at 17.902% protein.

3.3 Effects of Dietary Energy and Protein Levels on Body Measurements

Body conformation reflects poultry growth status and indicates flock management uniformity, while tibia length is an important production performance indicator. This study showed that tibia length, chest breadth, and keel length increased with dietary energy level. Quadratic fitting of energy level (X) against chest breadth (Y) gave $Y = 2.093X^2 - 47.805X + 334.602$ ($R^2 = 0.902$), yielding optimal energy of 11.420 MJ/kg for tibia length. Fitting energy level (X) against keel length (Y) gave $Y = 2.293X^2 - 52.660X + 383.823$ ($R^2 = 0.869$), yielding optimal energy of 11.483 MJ/kg for keel length. Dietary protein level had no significant effect on tibia length, chest breadth, or keel length, consistent with Wang et al., suggesting that protein levels of 16.75%-18.75% meet the protein requirements of 5-9 week-old layer chicks.

3.4 Effects of Dietary Energy and Protein Levels on Organ Indexes

The thymus, spleen, and bursa of Fabricius directly participate in humoral and cellular immunity. Akyuzdames et al. indicated that the weight of these organs can evaluate chick immune status, with greater weights indicating stronger immune function. Organ indexes reflect poultry immune function. The thymus, the primary endocrine gland regulating the immune system, produces polypeptide hormones that regulate peripheral mature T cells and promote thymocyte differentiation and maturation. This study showed that dietary protein level significantly affected thymus index, with the high-protein group showing significantly higher thymus index than medium- and low-protein groups, possibly because high-protein diets provided more protein for thymic stromal cell growth, promoting thymus development. Protein level had no significant effect on other organ indexes, suggesting these organs develop in coordination with overall body growth, likely due to animals' innate capacity for coordinated organ and whole-body development. Energy level had no significant effect on organ indexes, indicating that energy levels of 11.42-12.42 MJ/kg and protein levels of 16.75%-18.75% meet organ growth requirements.

3.5 Effects of Dietary Energy and Protein Levels on Serum Biochemical Indices

Blood triglyceride and cholesterol levels are primary indicators of lipid metabolism function. Hepatocyte damage or chronic overnutrition increases blood cholesterol and triglyceride levels, causing hyperlipidemia and potentially arteriosclerosis, while low levels impair metabolism and normal growth. This study found that serum triglyceride and total cholesterol levels increased with dietary energy level, consistent with Ju et al. Quadratic fitting of energy level (X) against serum triglyceride content (Y) gave $Y = 0.400X^2 - 9.103X + 52.283$ ($R^2 = 0.646$), yielding minimum triglyceride content at 11.379 MJ/kg. Dietary protein level had no significant effect on any measured serum biochemical indices, consistent with Yu et al.

4 Conclusion

Under the conditions of this experiment, comprehensive analysis of growth performance, body measurements, organ indexes, and serum biochemical indices indicates that the energy and protein requirements for 5-9 week-old Dawufen No.1 commercial layer chicks are 11.427 MJ/kg and 17.902%, respectively.

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