Effects of Brewer' s Grains on Production Performance, Blood Biochemical Indices, and Gastrointestinal Tract Development in 31- to 59-Day-Old Jianchang Partridge Meat Ducks (Postprint)

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Abstract

This experiment aimed to investigate the effects of dietary beer lees at different inclusion levels on growth performance, blood biochemical indices, and gastrointestinal development of 31- to 59-day-old partridge meat ducks. A total of 420 31-day-old Jianchang partridge meat ducks were randomly allocated into 5 groups with 6 replicates per group and 14 ducks per replicate, and each group was fed experimental diets containing beer lees at levels of 0, 15%, 30%, 45%, and 60%, respectively. The feeding trial lasted until 59 days of age. The results showed that with increasing dietary beer lees levels, body weight at 59 days of age, body weight gain, feed-to-gain ratio, and length of the 4th primary wing feather of the ducks exhibited linear or quadratic changes ($P<0.05$), and the growth performance of ducks in the 60% beer lees group was significantly lower than that of other groups ($P<0.05$). The concentrations of serum total protein, globulin, triglycerides, and low-density lipoprotein decreased linearly with increasing dietary beer lees levels ($P<0.05$), while the activities of alanine aminotransferase and alkaline phosphatase increased linearly ($P<0.05$). The duodenal capacity, relative length and weight, ileal capacity and relative length, relative cecal weight, and relative gizzard weight of the ducks increased linearly with increasing dietary beer lees levels ($P<0.05$). Using body weight gain, feed-to-gain ratio, and length of the 4th primary wing feather as evaluation criteria, the optimal dietary beer lees levels were determined to be 17.4%, 16.1%, and 18.94%, respectively. These results suggest that when formulating diets based on digestible amino acids, the optimal dietary beer lees level for 31- to 59-day-old partridge meat ducks is 15.00%-18.94%, with a maximum level up to 45%.

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Full Text

Effects of Dry Brewer' s Grain on Performance, Serum Biochemical Indices and Gastrointestinal Tract Development of Jianchang Ducks Aged from 31 to 59 Days

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Abstract: This study aimed to investigate the effects of dietary dry brewer' s grain (DBG) level on growth performance, serum biochemical indices, and gastrointestinal tract development of Jianchang ducks aged 31 to 59 days. A total of 420 31-day-old Jianchang ducks were randomly allocated to 5 groups with 6 replicates per group and 14 ducks per replicate. The five groups were fed experimental diets supplemented with 0, 15%, 30%, 45%, and 60% DBG, respectively, until 59 days of age. The results showed that as dietary DBG level increased, body weight at 59 days, body weight gain, feed-to-gain ratio, and 4th primary wing feather length exhibited significant linear or quadratic changes ($P<0.05$), with the 60% DBG group showing significantly poorer performance than other groups ($P<0.05$). Serum concentrations of total protein, globulin, triglyceride, and low-density lipoprotein decreased linearly ($P<0.05$), while activities of alanine aminotransferase and alkaline phosphatase increased linearly ($P<0.05$). The capacity, relative length, and relative weight of the duodenum; capacity and relative length of the ileum; and relative weight of the cecum and gizzard increased linearly with dietary DBG level ($P<0.05$). Based on body weight gain, feed-to-gain ratio, and 4th primary wing feather length, the optimal dietary DBG levels were determined to be 17.4%, 16.1%, and 18.94%, respectively. These results indicate that when formulating diets based on digestible amino acids, the appropriate DBG level for 31- to 59-day-old ducks is 15.00%-18.94%, with a maximum level of 45%.

Key words: Jianchang ducks; performance; gastrointestinal tract development; serum biochemical indices; dry brewer' s grain

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Introduction

Dry brewer' s grain (DBG) is the primary by-product of beer production. Mussatto et al. [1] reported that approximately 20 kg of DBG is generated per 100 L of beer produced. Compared with corn dried distillers grains with solubles (DDGS), DBG has lower crude protein content but higher crude fiber content [2]. Studies have indicated that DBG dry matter contains 25.13% crude protein, 7.13% crude fat, 13.81% crude fiber, 3.64% ash, 0.4% calcium, and 0.57% phosphorus, along with abundant amino acids and trace elements such as iron, copper, and manganese, giving it high nutritional value [3]. Zuo [4] determined the apparent metabolizable energy value of DBG for meat ducks to be 10.06 MJ/kg with a protein content of 29.96%. Evidently, the nutritional value of DBG from different sources varies considerably, necessitating analysis of its main nutritional components before rational utilization. Furthermore, Zuo [4] added 20% DBG to a corn-soybean meal diet on an isoenergetic, isonitrogenous, and essential amino acid (lysine, methionine, threonine, tryptophan) basis for 20-day-old Cherry Valley × Jianchang male ducks and found no significant differences in feed intake, daily gain, or feed-to-gain ratio compared with the control group, while saving 0.14 yuan in feed cost per kg of weight gain. Similarly, Denstadli et al. [2] found that using 10%-20% DBG in broiler diets had no significant effect on performance but promoted gizzard development. Currently, no studies have investigated the optimal DBG level in meat duck or quality local meat duck diets based on measured nutritional values of DBG using different biological indicators as evaluation criteria. Therefore, this study aimed to examine the effects of varying dietary DBG levels on growth performance, gastrointestinal development, and serum biochemical indices of 31- to 59-day-old Jianchang ducks, and to further determine the optimal DBG level using regression models, providing a scientific basis for DBG application in quality meat duck diets.

1.1 Experimental Materials

DBG was purchased from Sichuan Tieqi Lishi Group, with nutritional composition as follows: apparent metabolizable energy for meat ducks 11.72 MJ/kg, protein content 19.11%, digestible lysine (DLys) content 0.69%, digestible methionine (DMet) content 0.30%, and digestible threonine (DThr) content 0.56% [5].

The experimental Jianchang ducks were a new strain developed by Sichuan Agricultural University with the following genetic background: the male parent was Jianchang duck, and the female parent was the hybrid offspring of Jianchang duck male and Shanma duck female. The growth potential is a market weight of 2.0-2.5 kg at 8 weeks with good feather development. The diet for 1- to 30-day-old ducks had an energy level of 13.72 MJ/kg and crude protein content of 19.5%. Temperature was controlled at 30-32°C for days 1-3, 28-30°C for days 4-7, then reduced by 2°C weekly until reaching 24-26°C; relative humidity was maintained at 60%-70%; lighting was provided 24 hours with free access to feed and water.

1.2 Experimental Design

This experiment used a single-factor design with dietary DBG levels of 0, 15%, 30%, 45%, and 60%. A total of 420 31-day-old ducks were randomly allocated to 5 groups according to body weight with no significant differences ($P>0.05$), with 6 replicates per group and 14 ducks per replicate. The experimental period lasted 28 days.

1.3 Experimental Diets

Diet composition and nutrient levels referenced previous research from the Institute of Animal Nutrition, Sichuan Agricultural University [6], ensuring isoenergetic and isonitrogenous diets with balanced digestible lysine, methionine, tryptophan, and threonine across groups. Detailed composition and nutrient levels are shown in Table 1. The 15%, 30%, and 45% DBG diets were prepared by mixing the 60% DBG diet with the control diet at ratios of 1:3, 1:1, and 3:1, respectively. Feed form was pellets.

1.4 Feeding Management

The feeding trial was conducted at the Institute of Animal Nutrition, Sichuan Agricultural University using cage housing. During the formal experimental period, ducks had free access to feed and water, 24-hour lighting, temperature maintained at 24-26°C, and relative humidity at 60%-70%. Manure was cleaned every 4 days.

1.5 Performance Metrics

At 59 days of age, after 4 hours of feed withdrawal, ducks were weighed by replicate in a fasted state, and residual feed was recorded. Additionally, 4 ducks per replicate were selected to measure 4th primary wing feather length (4thFL). Body weight gain (BWG), feed-to-gain ratio (F/G), and average daily feed intake (ADFI) were calculated.

1.6 Serum Biochemical Indices

At 59 days of age, one duck per replicate with body weight close to the group mean was selected for blood collection (10 mL) from the jugular vein. Blood was centrifuged at 3,000 r/min for 10 minutes, and serum was separated and stored at 4°C for analysis. Serum samples were sent to Ya' an People' s Hospital for determination of alanine aminotransferase, aspartate aminotransferase, -glutamyl transpeptidase, and alkaline phosphatase activities, as well as concentrations of total bile acids, total protein, albumin, total bilirubin, triglyceride, cholesterol, high-density lipoprotein, low-density lipoprotein, and very low-density lipoprotein.

1.7 Gastrointestinal Development Indices

After blood collection, ducks were euthanized by jugular exsanguination. The abdominal cavity was opened to collect the proventriculus, gizzard, duodenum, jejunum, ileum, cecum, and rectum. Contents were removed from each segment, and surface moisture was absorbed with filter paper before obtaining fresh weights. Length and width of each intestinal segment were measured. Relative weight, relative length, intestinal density, and intestinal capacity were calculated using the following formulas:

Relative weight (%) = (fresh weight of digestive organ / live body weight) × 100; Relative length (%) = (intestinal segment length / live body weight) × 100; Intestinal density (g/cm) = intestinal segment weight / intestinal segment length; Intestinal capacity (cm^3) = (intestinal width × intestinal length) / 4 .

1.8 Statistical Analysis

Experimental data were organized and preliminarily calculated using Excel 2007. One-way ANOVA and linear and quadratic regression analyses were performed using SAS 9.0 software. Significant differences were further analyzed using LSD multiple comparisons. The quadratic regression model in the nonlinear model procedure of SAS 9.0 software was used to fit duck responses to dietary DBG levels: $Y = aX^2 + bX + c$, where Y is the dependent variable, X is dietary DBG level, a is the quadratic coefficient, b is the linear coefficient, and c is the intercept. The DBG level for maximum effect was calculated as -b/2a. Results are expressed as means with SEM, and $P<0.05$ was considered statistically significant.

Results

2.1 Performance

As shown in Table 2 , with increasing dietary DBG level, body weight at 59 days, body weight gain, feed-to-gain ratio, and 4th primary wing feather length showed significant linear and quadratic changes ($P<0.05$). The 60% DBG group exhibited significantly poorer performance (body weight at 59 days, body weight gain, feed-to-gain ratio, 4th primary wing feather length) than other groups ($P<0.05$), characterized by significantly decreased body weight gain ($P<0.05$) and significantly increased feed-to-gain ratio ($P<0.05$). The 45% DBG group differed significantly from the 60% group ($P<0.05$) but not from other groups ($P>0.05$). Dietary DBG level had no significant effect on average daily feed intake ($P>0.05$).

2.2 Serum Biochemical Indices

As shown in Table 3 , serum concentrations of total protein, globulin, triglyceride, and low-density lipoprotein decreased linearly with increasing dietary DBG level ($P<0.05$). The 60% DBG group had significantly lower serum total protein, globulin, and low-density lipoprotein concentrations than the 0% DBG group ($P<0.05$), and significantly lower serum triglyceride concentration than the 0% and 15% DBG groups ($P<0.05$). Serum alanine aminotransferase and alkaline phosphatase activities increased linearly ($P<0.05$), with the 60% DBG group showing significantly higher alanine aminotransferase activity than the 0% and 15% DBG groups (P<0.05) and significantly higher alkaline phosphatase activity than the 0% DBG group (P<0.05). Serum very low-density lipoprotein concentration showed a significant quadratic change with increasing dietary DBG level (P<0.05). No significant differences were observed among groups for other serum biochemical indices (P>0.05).

2.3 Gastrointestinal Development

As shown in Table 4 , with increasing dietary DBG level, duodenal capacity, relative length, and relative weight; ileal capacity and relative length; cecal relative weight; and gizzard relative weight increased linearly (P<0.05). The 15% DBG group had significantly higher duodenal capacity and relative weight than the 0% DBG group (P<0.05). The 60% DBG group showed significantly higher duodenal capacity, relative length, and weight, as well as gizzard relative weight, than the 0% DBG group (P<0.05), and duodenal relative length and weight were also significantly higher than in the 30% and 45% DBG groups (P<0.05). Dietary DBG level had no significant effect on other gastrointestinal development indices (P>0.05).

2.4 Optimal Level of DBG in Diets for Ducks Aged 31-59 Days

As shown in Table 5 , based on body weight at 59 days and body weight gain, the optimal dietary DBG levels were 17.13% and 17.36%, respectively. Based on feed-to-gain ratio, the optimal level was 16.1%, and based on 4th primary wing feather length, the optimal level was 18.94%.

Discussion

The results showed that as dietary DBG level increased, duck body weight and weight gain exhibited a trend of initial increase followed by decrease. Compared with other groups, the 60% DBG diet caused significant performance reduction, while the 45% DBG group showed reduced performance compared with the 0%, 15%, and 30% groups, but differences were not significant. Regression analysis determined the optimal DBG level to be 16.10%-17.36%, which is consistent with reports by Nie [7] and Zuo [4] that 20% DBG in diets for ducks aged 25-55 days and 15-30 days yielded good results. In this experiment, diets were formulated based on measured apparent metabolizable energy and digestible amino acids of DBG for meat ducks, resulting in similar apparent metabolizable energy values across groups, as reflected by the non-significant differences in feed intake among groups. The significant performance reduction in the 60% DBG group may be attributed to the high dietary fiber content of 12.5% at this level, leading to reduced nutrient digestibility. Denstadli et al. [2] found that as dietary DBG level increased to 40%, ileal protein and energy digestibility in broilers decreased linearly. Using 15% DBG in broiler diets increased pancreas size, reduced abdominal fat, and decreased liver size, possibly due to low dietary fiber utilization and negative nutrient balance [8]. This study also found that the optimal DBG level for feather growth was 18.94%, higher than that for optimal performance. This may be because appropriate crude fiber content benefits feather growth, while insufficient crude fiber can lead to feather pecking [9]. Studies in laying hens also show that feather pecking is related to dietary crude fiber content [10-12].

Blood biochemical indices are important indicators of animal metabolism and functional status of organs and tissues. Currently, few studies have reported on the effects of DBG on blood biochemical indices in meat ducks. Serum protein concentration is a key marker of protein anabolism. In this study, serum total protein and globulin concentrations decreased linearly with increasing dietary DBG level, reaching significant reduction in the 60% DBG group, consistent with the significant performance decline, indicating that 60% DBG cannot meet normal protein requirements and may be related to negative nutrient balance caused by high-fiber diets [8]. Alkaline phosphatase catalyzes the hydrolysis of phosphate monoesters, nucleotides, and 6-phosphate sugars, and is closely related to bone metabolism [13]; alanine aminotransferase and aspartate aminotransferase are sensitive indicators of liver protein synthesis function and liver health [14]. This study found that serum alkaline phosphatase and alanine aminotransferase activities increased linearly with dietary DBG level, with significant differences in the 60% group, indicating that 60% DBG caused malnutrition, affecting bone growth and liver health. Clinically, serum triglyceride, cholesterol, and low-density lipoprotein concentrations reflect lipid metabolism and can be used to diagnose atherosclerosis, coronary heart disease, and fatty liver disease. This study found that serum triglyceride and low-density lipoprotein concentrations decreased linearly with increasing dietary DBG level, with significant reduction in the 60% DBG group, indicating altered lipid metabolism, consistent with the significantly reduced body weight and serum albumin concentration in this group.

Some studies have shown that DBG does not affect weight gain performance or major organ and gastrointestinal development in small white-feathered meat ducks [15]. This study found that compared with the control group without DBG, dietary DBG supplementation promoted gastrointestinal development to some extent, with 15% DBG showing better development of digestive segments than other groups, possibly because the fiber level in the 15% DBG diet approached the requirement of Jianchang ducks. Denstadli et al. [16] found that when dietary DBG level reached 30%-40% in broilers, gizzard development reached a plateau, and Starck [17] also found that when indigestible fiber reached 30% in quail diets, gizzard development plateaued, indicating that gizzard capacity for fiber digestion is physiologically limited. However, this study found that gizzard weight increased linearly with dietary DBG level without reaching a plateau, suggesting that DBG promotes gizzard development in Jianchang ducks. The absence of a plateau at DBG levels up to 60% in this study indicates that the effect of dietary fiber on gizzard development varies among poultry species, possibly due to stronger crude feed tolerance in meat ducks than in broilers and quail, and also due to compensatory hyperplasia of digestive organs at excessive DBG levels, as evidenced by higher gastrointestinal development indices but lowest performance in the 60% DBG group.

Conclusion

1. When formulating diets based on digestible amino acids, the appropriate DBG level for 31- to 59-day-old Jianchang ducks is 15.00%-18.94%, with a maximum level of 45%.
2. DBG can promote gastrointestinal development in 31- to 59-day-old ducks, with relatively strong effects on the gizzard, duodenum, ileum, and cecum.
3. Dietary DBG levels as high as 60% can alter protein and lipid metabolism, cause negative nutrient balance, and impair liver function to some extent in Jianchang ducks.

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