Effects of Fermented Rapeseed Meal on Growth Performance, Nutrient Digestion and Absorption, and Meat Quality in Broiler Chickens: Postprint

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Abstract

This experiment investigated the effects of replacing soybean meal with fermented rapeseed meal at different ratios on growth performance, nutrient digestion and absorption, and meat quality in broilers. Two hundred 7-day-old healthy Arbor Acres (AA) broiler chicks were randomly divided into 4 groups, with 5 replicates per group and 10 birds per replicate (half male and half female). Group A served as the control group and was fed the basal diet; Groups B, C, and D were experimental groups, in which fermented rapeseed meal was used to isonitrogenously replace 15%, 35%, and 50% of the soybean meal in the basal diet, respectively. The experiment lasted from 7 to 42 days of age. The results showed: 1) During the 7–42 day period, the average daily gain of Groups C and D was extremely significantly lower than that of Group A ($P < 0.01$), the feed-to-gain ratio was extremely significantly higher than that of Group A ($P < 0.01$), while the average daily feed intake of Group C was extremely significantly higher than that of Group A ($P < 0.01$); the average daily gain, average daily feed intake, and feed-to-gain ratio of Group B did not differ significantly from those of Group A ($P > 0.05$). 2) At 42 days of age, the intestinal chyme pH of Groups B, C, and D decreased by 1.57% ($P < 0.01$), 1.41% ($P < 0.01$), and 0.16% ($P > 0.05$) compared with Group A, respectively; the intestinal chyme viscosity of Groups B, C, and D decreased by 4.17% ($P < 0.05$), 4.17% ($P < 0.05$), and 1.67% ($P > 0.05$) compared with Group A, respectively. At 42 days of age, compared with Group A, the apparent digestibility of protein, energy, and fat in Group B increased significantly or extremely significantly ($P < 0.05$ or $P < 0.01$), while the apparent digestibility of protein and fat in Groups C and D decreased significantly or extremely significantly ($P < 0.05$ or $P < 0.01$). 3) Compared with Group A, the pH45 min and pH24 h of breast muscle in all experimental groups showed varying degrees of decrease, but the pH24 h of

Group B did not differ significantly from that of Group A (P > 0.05); compared with Group A, the lightness (L*) value of breast muscle in Group B increased extremely significantly (P < 0.01), while the redness (a*) and yellowness (b*) values decreased extremely significantly (P < 0.01); the drip loss of breast muscle in all experimental groups was extremely significantly lower than that of Group A (P < 0.01); the shear force of breast muscle in Groups B and C was extremely significantly lower than that of Group A (P < 0.01); the inosinic acid content of breast muscle in Groups B, C, and D increased by 2.55% (P < 0.01), 0.66% (P > 0.05), and 0.21% (P > 0.05) compared with Group A, respectively. In conclusion, isonitrogenous replacement of 15% soybean meal with fermented rapeseed meal in broiler diets had no negative effects on growth performance, while also promoting nutrient digestion and absorption and improving meat quality in broilers.

Full Text

Effect of Fermented Rapeseed Meal on Growth Performance, Nutrient Digestion and Absorption, and Meat Quality of Broilers

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Abstract

This experiment investigated the effects of substituting different proportions of soybean meal with equal-nitrogen fermented rapeseed meal on the growth performance, nutrient digestion and absorption, and meat quality of broilers. Two hundred 7-day-old healthy Arbor Acres (AA) broilers were randomly allocated to four groups with five replicates per group and ten broilers per replicate (half male and half female). Group A served as the control group receiving a basal diet, while groups B, C, and D were experimental groups fed basal diets in which 15%, 35%, and 50% of soybean meal was replaced with equal-nitrogen fermented rapeseed meal, respectively. The trial ran from 7 to 42 days of age. The results showed: (1) During the 7–42 day period, the average daily gain (ADG) of groups C and D was extremely significantly lower than that of group A (P < 0.01), the feed-to-gain ratio (F/G) was extremely significantly higher than group A (P < 0.01), and the average daily feed intake (ADFI) of group C was extremely significantly higher than group A (P < 0.01). In contrast, group B showed no significant differences in ADG, ADFI, or F/G compared to group A (P > 0.05). (2) At 42 days of age, the intestinal chyme pH of groups B, C, and D decreased by 1.57% (P < 0.01), 1.41% (P < 0.01), and 0.16% (P > 0.05), respectively, compared to group A; intestinal chyme viscosity decreased by 4.17% (P < 0.05), 4.17% (P < 0.05), and 1.67% (P > 0.05), respectively. Additionally, group B exhibited significantly or extremely significantly higher apparent digestibility of protein, energy, and fat compared to group A ($P < 0.05$ or $P < 0.01$), while groups C and D showed significantly or extremely significantly lower apparent digestibility of protein and fat ($P < 0.05$ or $P < 0.01$). (3) Compared to group A, the pH_{45} and pH_{24} of breast muscle in all experimental groups decreased to varying degrees, though group B' s pH_{24} showed no significant difference ($P > 0.05$). Group B exhibited extremely significantly higher lightness (L*) values (P < 0.01) and extremely significantly lower redness (a*)* and yellowness (b*) values ($P < 0.01$). All experimental groups showed extremely significantly lower drip loss ($P < 0.01$), and groups B and C displayed extremely significantly lower shear force ($P < 0.01$). The inosine monophosphate (IMP) content in groups B, C, and D increased by 2.55% ($P < 0.01$), 0.66% ($P > 0.05$), and 0.21% ($P > 0.05$), respectively. In conclusion, replacing 15% of soybean meal with equal-nitrogen fermented rapeseed meal in broiler diets has no negative effect on growth performance while improving nutrient digestion and absorption and enhancing meat quality.

Keywords: fermented rapeseed meal; growth performance; digestion and absorption; meat quality

Introduction

Rapeseed meal, a byproduct of oil extraction from rapeseed, is rich in nutrients with high amino acid content, particularly sulfur-containing amino acids, making it an excellent high-protein animal feed [1]. However, rapeseed meal contains various anti-nutritional factors, including fiber, tannins, phytic acid, and glucosinolates and their degradation products (oxazolidinethione, isothiocyanate), which severely limit its application in poultry and livestock feed [2]. Research has demonstrated that microbial fermentation can effectively remove these anti-nutritional factors and toxic substances while improving palatability and generating beneficial substances that help maintain gastrointestinal balance in animals [3]. Current studies on fermented rapeseed meal have primarily focused on animal growth performance, serum biochemical indices, and immune function. Chiang et al. [4] found that fermented rapeseed meal could improve broiler growth performance and nutrient apparent digestibility. Hu et al. [5] reported that dietary supplementation with 25% fermented rapeseed meal had no significant effect on broiler growth performance but significantly enhanced immune function and digestive enzyme activity. Yu et al. [6] observed that 10% fermented rapeseed meal supplementation did not significantly affect growth performance or thyroid index in broilers. Xu et al. [7] fed broilers diets containing 5% and 10% fermented rapeseed meal for 42 days and found that 10% supplementation had no significant effect on growth performance while increasing serum immunoglobulin G (IgG) and immunoglobulin M (IgM) levels. However, few studies have examined the optimal substitution proportion of fermented rapeseed meal in broiler diets and its effects on digestion and absorption. This experiment utilized two-step solid-state fermented rapeseed meal to replace soybean meal at different proportions, investigating its effects on broiler growth, digestion and absorption, and meat quality to determine the appropriate substitution ratio and provide a theoretical basis for the rational and effective use of rapeseed meal in production.

Materials and Methods

1.1 Materials and Experimental Animals

The rapeseed meal was subjected to two-step mixed-culture fermentation based on preliminary experiments in our laboratory, using preserved strains. The raw rapeseed meal was produced in Hefei, Anhui. The fermentation procedure was as follows: rapeseed meal, ammonium sulfate, and glucose were mixed at a ratio of 40:6:1. In the first step, *Aspergillus niger* and brewer's yeast (*A. niger*:brewer' s yeast = 1:2) were used as fermentation strains at a 12% inoculation rate with 65% substrate moisture content, fermenting at 30 °C for 60 h. In the second step, *Bacillus subtilis* and *Lactobacillus bulgaricus* (*B. subtilis*:*L. bulgaricus* = 1:3) were used at a 14% inoculation rate with 60% substrate moisture content, fermenting at 30 °C for 3 days. The nutritional and anti-nutritional component changes before and after fermentation are shown in Table 1 .

Two hundred healthy 7-day-old Arbor Acres (AA) broilers with similar body weight were randomly divided into four groups with five replicates per group and ten broilers per replicate (half male and half female). Group A was the control group fed a corn-soybean meal basal diet, while groups B, C, and D were experimental groups fed diets in which 15%, 35%, and 50% of soybean meal was replaced with equal-nitrogen and equal-energy fermented rapeseed meal, respectively. The trial lasted from 7 to 42 days of age.

1.2 Experimental Diets and Management

Based on NRC (1994) and NY/T 33-2004 Feeding Standard of Chickens, basal diets were formulated for two phases (7–21 days and 22–42 days) using corn, soybean meal, and other primary ingredients. Three experimental diets were then prepared by replacing 15%, 35%, and 50% of soybean meal with equal-nitrogen fermented rapeseed meal. The composition and nutrient levels of the experimental diets are presented in Table 2 .

The experiment was conducted at the Animal Hospital Experimental Base of Anhui Agricultural University. Broilers were raised in four-tier stacked cages with one replicate per cage. Routine immunization and disinfection procedures were followed, and all groups received identical management. Mash feed was provided ad libitum with free access to water throughout the experiment.

1.3 Measurement Indicators

1.3.1 Growth Performance Body weight was measured at 7 and 42 days of age after 12 h of fasting (with free access to water). Feed intake was recorded by replicate from 7 to 42 days, including feed provided, remaining feed, and wastage, to calculate average daily gain (ADG), average daily feed intake (ADFI), and feed-to-gain ratio (F/G).

1.3.2 Nutrient Digestion and Absorption Indicators At 42 days of age, one broiler from each replicate was selected, and the intestines (duodenum, jejunum, ileum) were isolated. The chyme was extruded and stored at -20 °C.

Intestinal chyme pH: Approximately 0.1 g of thawed chyme was mixed with deionized water at a 1:9 volume ratio, homogenized for 30 s, and centrifuged at 6,000 r/min for 10 min. The pH of the supernatant was then measured.

Intestinal chyme viscosity: Approximately 0.2 g of chyme was mixed with deionized water at a 1:9 volume ratio, homogenized at low temperature for 30 s, and centrifuged at 6,000 r/min for 10 min at 4 °C. The supernatant was collected, and viscosity was measured using an Ubbelohde viscometer with distilled water as the control. Results are expressed as relative viscosity.

Nutrient apparent digestibility: At 42 days of age, two broilers from each replicate were individually caged. After 1 day of fasting (with free access to water), they were fed the corresponding diets for 3 days, followed by complete fecal collection for 4 days with feathers and dander removed. Fecal samples were dried to constant weight at 65 °C, equilibrated at room temperature for 24 h, ground to pass through a 40-mesh sieve, and stored at 4 °C. Energy content was determined using an oxygen bomb calorimeter, crude protein by the Kjeldahl method, and crude fat by Soxhlet extraction [8]. Apparent digestibility was calculated as follows:

Apparent digestibility of a nutrient (%) = 100 × (feed intake × nutrient content in feed - fecal output × nutrient content in feces) / (feed intake × nutrient content in feed).

1.3.3 Meat Quality Indicators At 42 days of age, two broilers from each replicate were randomly selected, fasted and weighed, then slaughtered to obtain the left breast muscle. Meat quality parameters including pH, color, drip loss, and shear force were measured according to Mikulski et al. [9].

pH: Breast muscle pH was measured at 45 min post-slaughter (pH_{45}) and again after 24 h storage at 4 °C (pH_{24}).

Meat color: Approximately 200 g of breast muscle was used to measure lightness (L*), redness (a*), and yellowness (b*) values using a colorimeter at room temperature. Three measurements were taken at different locations and averaged.

Drip loss: Between 45-60 min post-slaughter, breast muscle samples (4 cm × 3 cm × 2 cm) were weighed (W_0), suspended in sealed containers, stored at 4 °C for 24 h, surface moisture removed with filter paper, and reweighed (W_1). Drip loss was calculated as: Drip loss (%) = 100 × (W_0 - W_1) / W_0.

Shear force: Breast muscle samples were cooled at 4 °C for 24 h, brought to room temperature, heated in a water bath to an internal temperature of approximately 75 °C, cooled to room temperature, and cored (5 cm × 2 cm × 2 cm) along the muscle fiber direction. Shear force was measured along the fiber direction using a texture analyzer.

Inosine monophosphate (IMP) content: Five grams (accurate to 0.0001 g) of breast muscle was used to determine IMP content according to the method of Wu et al. [10].

1.4 Statistical Analysis

Data were preprocessed using Excel 2003 and analyzed with SPSS 17.0 software. Duncan' s multiple range test was used for pairwise comparisons. Results are expressed as mean ± standard deviation, with $P < 0.05$ and $P < 0.01$ considered as thresholds for significant and extremely significant differences, respectively.

Results

2.1 Effects of Fermented Rapeseed Meal on Broiler Growth Performance

As shown in Table 3 , during the 7-42 day period, the ADG of groups C and D decreased by 21.68% ($P < 0.01$) and 28.31% ($P < 0.01$), respectively, compared to group A, while group B showed a slight increase ($P > 0.05$). The ADFI of groups B and C increased by 2.67% ($P > 0.05$) and 15.62% ($P < 0.01$), respectively, whereas group D decreased by 6.40% ($P > 0.05$). The F/G of groups B, C, and D increased by 1.60% ($P > 0.05$), 48.13% ($P < 0.01$), and 31.55% ($P < 0.01$), respectively, compared to group A.

2.2 Effects of Fermented Rapeseed Meal on Nutrient Digestion and Absorption

Table 4 shows that at 42 days of age, intestinal chyme pH in groups B, C, and D decreased by 1.57% ($P < 0.01$), 1.41% ($P < 0.01$), and 0.16% ($P > 0.05$), respectively, compared to group A. Intestinal chyme viscosity decreased by 4.17% ($P < 0.05$), 4.17% ($P < 0.05$), and 1.67% ($P > 0.05$), respectively.

As presented in Table 5 , at 42 days of age, group B exhibited a 1.77% increase in protein apparent digestibility ($P < 0.01$), while groups C and D showed decreases of 3.32% ($P < 0.01$) and 3.52% ($P < 0.01$), respectively. For fat apparent digestibility, groups B and D increased by 1.85% ($P < 0.05$) and 1.36% ($P < 0.05$), respectively, whereas group C decreased by 0.59% ($P < 0.05$). Group B also showed a 1.04% increase in energy apparent digestibility ($P < 0.01$), while groups C and D exhibited 0.19% decreases ($P > 0.05$).

2.3 Effects of Fermented Rapeseed Meal on Broiler Meat Quality

Table 6 reveals that compared to group A, breast muscle pH_{45} in groups B, C, and D decreased by 3.18% ($P < 0.01$), 9.20% ($P < 0.01$), and 9.53% ($P < 0.01$), respectively. The pH_{24} values decreased by 1.16% ($P > 0.05$), 5.49% ($P < 0.01$), and 8.99% ($P < 0.01$), respectively. Lightness (L*) values increased by 4.91% (P < 0.01), 9.04% (P < 0.01), and 14.52% (P < 0.01), respectively. Redness (a*) values decreased by 9.86% ($P < 0.01$) and 3.87% ($P < 0.01$) in groups B and D, respectively, but increased by 5.63% ($P < 0.01$) in group C. Yellowness (b*) values decreased by 6.43% ($P < 0.01$) and 4.02% ($P < 0.01$) in groups B and D, respectively, while group C showed a 1.61% increase ($P > 0.05$). Shear force decreased by 24.66% ($P < 0.01$) and 4.24% ($P < 0.05$) in groups B and C, respectively, but increased by 0.51% ($P > 0.05$) in group D. Drip loss decreased by 40.23% ($P < 0.01$), 20.42% ($P < 0.01$), and 15.95% ($P < 0.01$) across all experimental groups. IMP content increased by 2.55% ($P < 0.01$), 0.66% ($P > 0.05$), and 0.21% ($P > 0.05$) in groups B, C, and D, respectively.

Discussion

3.1 Effects on Growth Performance

Research indicates that glucosinolates and other anti-nutritional factors in rapeseed meal can adversely affect feed intake and animal performance [11]. In this study, two-step solid-state fermentation optimized the nutritional value and palatability of rapeseed meal, increasing crude protein and fat content while reducing anti-nutritional factors, consistent with findings by Vig et al. [12] and Chiou et al. [13]. Chiang et al. [4] demonstrated that fermented rapeseed meal could replace soybean meal in broiler diets, while Wu et al. [14] found that 9% fermented rapeseed meal supplementation yielded optimal feeding results without significantly affecting growth performance. In the present study, when the replacement proportion was 15%, no significant differences were observed in ADG, ADFI, or F/G compared to the control group. However, when the replacement proportion exceeded 15%, ADFI began to decline and ADG decreased, aligning with results from Hu et al. [5] and Yu et al. [6]. This may be attributed to the high crude fiber content in fermented rapeseed meal, which at high inclusion levels could cause gastrointestinal blockage and impair digestion. Although dietary nutrient levels were equivalent across groups, nutrient utilization efficiency differed. Fermentation increased amino acid content, and at higher inclusion levels, broilers may expend excessive energy on amino acid absorption, thereby inhibiting growth, as previously reported by Kephart and Sherritt [15]. Additionally, incomplete removal of glucosinolates and other anti-nutritional factors at higher substitution levels may have negatively impacted feed intake and growth.

3.2 Effects on Nutrient Digestion and Absorption

Few studies have reported the effects of fermented rapeseed meal on intestinal chyme pH and viscosity. Dietary fiber dissolves and degrades in the digestive tract, stimulating and flushing the gastrointestinal tract, which can alter chyme pH and viscosity and reduce nutrient digestibility [16-17]. Chyme viscosity is an important indicator of feed digestibility; lower viscosity indicates shorter retention time in the intestine, potentially reducing nutrient absorption [18]. All experimental groups showed decreased intestinal chyme pH and viscosity compared to the control, similar to findings by Sima et al. [19] who reported that fermented compound protein reduced pig intestinal chyme pH and viscosity. This may be due to lactic acid bacteria produced during rapeseed meal fermentation, which lower intestinal pH and reduce chyme retention time, thereby decreasing viscosity and enhancing nutrient absorption and intestinal development, consistent with Chiang et al. [4].

Compared to the control group, the 15% replacement group showed improved apparent digestibility of protein, fat, and energy. Hu et al. [5] found that fermented rapeseed meal could improve nutrient apparent digestibility in broilers, with similar reports from Chiang et al. [20] and Chang et al. [21]. This improvement may result from microbial fermentation breaking down large protein molecules into smaller peptides and amino acids, enhancing protein quality and digestibility while increasing opportunities for protein synthesis. Microbial fermentation also produces lipases that improve fat digestibility. The increased energy digestibility may be attributed to bioactive peptides affecting feed intake. The reduced nutrient digestibility in the 35% and 50% replacement groups may be due to higher dietary fiber content impairing absorption, as excessive fiber and glucosinolate content can reduce protein and energy digestibility.

3.3 Effects on Meat Quality

Limited research has reported on fermented rapeseed meal' s effects on broiler meat quality. Muscle pH directly reflects post-slaughter muscle acidity [22]; rapid pH decline impairs meat flavor. Meat color indicates changes in muscle composition, while drip loss reflects water-holding capacity, which directly affects meat quality attributes including flavor, tenderness, and color. Shear force indicates meat tenderness, with lower values representing more tender meat, and IMP content is a primary indicator of meat freshness [23]. In this study, the 15% replacement group showed slightly lower pH_{45} and pH_{24} but higher L* values and lower b* values, indicating improved meat color. Ruan et al. [24] found that double-low rapeseed meal had no significant effect on broiler muscle L, *a*, or b* values, with similar conclusions from Wu et al. [14]. All experimental groups showed lower drip loss than the control, indicating higher water-holding capacity and improved meat flavor and texture, consistent with Wu et al. [14]. Lower shear force in all experimental groups indicated improved tenderness, while higher IMP content aligned with Li et al. [25] who reported significantly increased IMP content in duck breast muscle when fermented rapeseed meal replaced two-thirds of dietary soybean meal. The improved meat quality may be attributed to beneficial bacteria produced during fermentation, which inhibit harmful microorganisms and promote intestinal health, while microbial enzymes facilitate degradation of macromolecules and enhance nutrient digestion and absorption.

Conclusion

1. Two-step solid-state fermentation of rapeseed meal increased crude and true protein content while reducing glucosinolate and other antinutritional factors, demonstrating that fermented rapeseed meal can safely replace conventional soybean meal in broiler diets.

2. Equal-nitrogen replacement of 15% soybean meal with fermented rapeseed meal does not negatively affect broiler growth performance, while improving nutrient digestion and absorption and enhancing meat quality. However, replacement proportions exceeding 15% significantly reduce growth performance. From a comprehensive benefit perspective, 15% replacement is recommended as the optimal proportion.

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