Evaluation of Metabolizable Energy and Amino Acid Nutritional Value of Rapeseed Meal from Different Sources for Daheng Broiler Chickens (Post-print)

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Date: 2018-12-20T00:00:00+00:00

Abstract

This experiment aimed to evaluate the metabolizable energy (ME) and amino acid nutritional value of different sources of rapeseed meal for Daheng broiler chickens using the True Metabolizable Energy (TME) method. Twelve rapeseed meal samples were randomly collected from feed enterprises in Sichuan Province to evaluate their ME and True Amino Acid Availability (TAAA). ME evaluation: Three batches of metabolic trials were conducted, each batch using 48 normal chickens, randomly divided into 6 groups with 8 replicates per group and 1 chicken per replicate. TAAA evaluation: Three batches of metabolic trials were conducted, each batch using 36 cecectomized chickens, randomly divided into 6 groups with 6 replicates per group and 1 chicken per replicate. One endogenous group was included in each batch, with a 10-day recovery period between batches. The TME method was employed to determine ME: test chickens were starved for 48 h, then force-fed the test diet at 2% of body weight, with excreta collected for 48 h; endogenous group chickens were starved for 48 h, then continued starvation with excreta collected for 48 h. The results showed: 1) The average contents of Dry Matter (DM), Crude Protein (CP), Gross Energy (GE), Neutral Detergent Fiber (NDF), Acid Detergent Fiber (ADF), Crude Fiber (CF), Ether Extract (EE), and ash in the 12 rapeseed meal samples were 87.67%, 42.10%, 19.75 MJ/kg, 39.99%, 16.13%, 15.15%, 2.40%, and 9.10%, respectively; among these, the Coefficients of Variation (CV) for NDF, ADF, EE, and ash were greater than 15%. 2) The average values of Apparent Metabolizable Energy (AME), Nitrogen-corrected Apparent Metabolizable Energy (AMEn), TME, and Nitrogen-corrected True Metabolizable Energy (TMEn) for the 12 rapeseed meal samples were 8.627, 9.029, 9.326, and 8.970 MJ/kg, respectively, with significant differences in ME among different sources of rapeseed meal (P<0.05). 3) The average amino acid contents of the 12 rapeseed meal samples ranged from 0.72% to 6.55%, with lysine showing the greatest CV at 18.97%. 4) The average TAAA values of the 12 rapeseed meal samples ranged from 68.37% to 88.92%, with significant differences in TAAA among different sources of rapeseed meal (except for methionine, threonine, and serine) (P<0.05); the average True Amino Acid Availability values were 70.81% for essential amino acids, 70.43% for non-essential amino acids, and 70.45% for total amino acids. These results indicate: 1) Differences exist in AME, AMEn, TME, and TMEn among different sources of rapeseed meal; 2) Daheng broiler chickens exhibit differences in TAAA for different sources of rapeseed meal.

Full Text

Evaluation of Metabolizable Energy and Amino Acid Nutritional Value of Different Rapeseed Meals for Daheng Broilers

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Abstract: This study was conducted to evaluate the metabolizable energy (ME) and amino acid nutritional value of different rapeseed meals for Daheng broilers using the true metabolizable energy (TME) method. Twelve rapeseed meal samples were randomly collected from feed enterprises in Sichuan Province to determine their ME and true amino acid availabilities (TAAA). For ME evaluation, three batches of metabolic trials were conducted, with 48 normal broilers per batch randomly assigned to 6 groups (8 replicates per group, 1 chicken per replicate). For TAAA evaluation, three batches of metabolic trials were conducted with 36 caecectomized broilers per batch randomly assigned to 6 groups (6 replicates per group, 1 chicken per replicate). An endogenous group was included in each batch, with a 10-day recovery period between batches. The TME method was employed: test broilers were fasted for 48 h, then force-fed the test diet at 2% of body weight, with excreta collected for 48 h; endogenous group broilers were fasted for 48 h and continued fasting with excreta collection for 48 h. The results showed: 1) The average contents of dry matter (DM), crude protein (CP), gross energy (GE), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude fiber (CF), ether extract (EE), and ash in the 12 rapeseed meal samples were 87.67%, 42.10%, 19.75 MJ/kg, 39.99%, 16.13%, 15.15%, 2.40%, and 9.10%, respectively, with coefficients of variation (CV) greater than 15% for NDF, ADF, EE, and ash. 2) The average apparent metabolizable energy (AME), nitrogen-corrected AME (AMEn), TME, and nitrogen-corrected TME (TMEn) of the 12 samples were 8.627, 9.029, 9.326, and 8.970 MJ/kg, respectively, with significant differences in ME among rapeseed meals from different sources (P<0.05). 3) The average amino acid contents ranged from 0.72% to 6.55%, with lysine showing the highest CV at 18.97%. 4) The average TAAA ranged from 68.37% to 88.92%, with significant differences among rapeseed meals from different sources (except for methionine, threonine, and serine) (P<0.05). The mean true availabilities were 70.81% for essential amino acids, 70.43% for non-essential amino acids, and 70.45% for total amino acids. These results indicate that: 1) Differences exist in AME, AMEn, TME, and TMEn among rapeseed meals from different sources; 2) Differences exist in TAAA of different rapeseed meals for Daheng broilers.

Keywords: Daheng broilers; rapeseed meal; metabolizable energy; true amino acid availability

Daheng broilers are a meat-type chicken line independently developed in China, currently widely promoted across 18 provinces with increasing market share [1]. As the world' s second-largest oil crop after soybeans, rapeseed produces rapeseed meal that accounts for 13% of total oil meal production [2-3]. Research on rapeseed meal in livestock and poultry is extensive. Rapeseed meal contains 36%-39% crude protein (CP) with abundant essential amino acids, particularly sulfur-containing amino acids such as methionine (Met) and cysteine (Cys), but lower lysine (Lys) content. It is also an excellent source of available calcium, iron, manganese, selenium, and B vitamins [4], making it complementary to soybean meal in production. Evaluating the nutritional value of different rapeseed meals for local quality broilers holds significant production value and importance. This study aimed to determine the ME and true amino acid availability (TAAA) of different rapeseed meals for Daheng broilers, providing data support for effective diet formulation and efficient production of quality broilers.

1 Materials and Methods

1.3 Metabolic Trial

The metabolic trial was conducted at the research base of the Institute of Animal Nutrition, Sichuan Agricultural University. The ME was determined using the TME method according to McNab et al. [5]: after one week of adaptation with cloacal sutures for fecal collection caps, metabolic broilers were weighed and recorded; test broilers were fasted for 48 h, then force-fed the test diet at 2% of body weight, with collection bags attached and excreta collected for 48 h; endogenous group broilers were fasted for 48 h and continued fasting with excreta collection for 48 h. Diets were ground through a 40-mesh screen. Broilers were housed individually in cages with free access to water and 16 h of lighting.

The caecectomy procedure followed Poppema et al. [6]: pre-operative broilers were fasted for 24 h, feathers were plucked from a 10 cm × 5 cm area between the keel and cloaca, and the area was disinfected and anesthetized; a 4 cm incision was made, the cecum was located below the duodenum, ligated with standard sutures and severed, the resected end was retracted, the abdominal cavity was cleaned of blood and clots with gauze, penicillin was injected, and the peritoneum, abdominal muscle, and skin were sutured sequentially. Broilers underwent a 6-week recovery period post-surgery.

Excreta were collected using the total collection method according to Adeola et al. [7]: collection bags were replaced at 4, 8, 16, 32, and 48 h post-feeding; after collection, each broiler' s 48 h excreta were mixed uniformly, dried in a 65°C oven for 72 h, equilibrated in air for 24 h, weighed, recorded, ground through a 40-mesh screen, and stored at -20°C for fecal component analysis.

1.4 Analytical Methods

1.4.1 Conventional Nutrient Content of Rapeseed Meal The determination of DM, CP, GE, CF, NDF, ADF, EE, and ash in rapeseed meal followed the methods of Zhang Liying [8].

1.4.2 Nitrogen Retention Nitrogen retention indices were calculated using formulas from Guo Yuming [9]: - Endogenous nitrogen retention (ERN0) = nitrogen in excreta - RN1 = (total nitrogen intake - nitrogen in excreta) / dry matter intake - RN2 = (total nitrogen intake - nitrogen in excreta + endogenous nitrogen in excreta) / dry matter intake

Where RN1 represents nitrogen retention per kg of dietary dry matter intake, and RN2 represents true nitrogen retention per kg of dietary dry matter intake after endogenous nitrogen correction.

1.4.3 Metabolizable Energy ME indices were calculated using formulas from Adeola et al. [7]: - Endogenous energy loss (EEL) = gross energy in fasted broiler excreta - Apparent metabolizable energy (AME) = (gross energy intake - gross energy in excreta) / dry matter intake - Rapeseed meal AME = (diet AME × 100 - corn starch content in diet × corn starch AME) / rapeseed meal content in diet - Nitrogen-corrected AME (AMEn) = AME - RN1 × 34.39 - TME = (gross energy intake - gross energy in excreta + endogenous energy in excreta) / dry matter intake - Rapeseed meal TME = (diet TME × 100 - corn starch content in diet × corn starch TME) / rapeseed meal content in diet - Nitrogen-corrected TME (TMEn) = TME - RN2 × 34.39

Where 34.39 represents the heat production per gram of urinary nitrogen in chickens.

1.4.4 True Amino Acid Availability (TAAA) TAAA was calculated using formulas from Likuski et al. [10]: - TAAA = (total amino acid intake - total amino acid in excreta + total endogenous amino acid) / total amino acid intake × 100 - Total amino acid intake = total dry matter intake × amino acid content in diet - Total amino acid in excreta = total dry matter in excreta × amino acid content in excreta

Since rapeseed meal was the sole protein source in the test diet, the TAAA of rapeseed meal equaled that of the diet.

1.5 Statistical Analysis

Data were analyzed using one-way ANOVA with SAS 9.3 software. Duncan' s multiple range test was used for significant differences. $P<0.05$ was considered statistically significant.

2 Results

2.1 Conventional Nutrient Content of Rapeseed Meal

As shown in Table 3 , the average contents of DM, CP, GE, NDF, ADF, CF, EE, and ash in the 12 rapeseed meal samples were 87.67%, 42.10%, 19.75 MJ/kg, 39.99%, 16.13%, 15.15%, 2.40%, and 9.10%, respectively. The coefficients of variation (CV) for NDF, ADF, EE, and ash exceeded 15%, with EE showing the highest CV. Samples 2 and 4 had higher NDF, ADF, and CF contents but lower CP content than other samples (except sample 3). Sample 10 had lower NDF, ADF, and CF contents than other samples. Samples 5 and 10 had higher GE and EE contents than other samples. The difference between the lowest EE content (sample 9, 0.62%) and highest (sample 10, 10.07%) was 9.45%. Ash content was negatively correlated with GE: sample 10 had the highest GE (21.71 MJ/kg) and lowest ash (6.12%), while sample 8 had the lowest GE (18.83 MJ/kg) and highest ash (12.49%).

2.2 Metabolizable Energy of Rapeseed Meal

As shown in Table 4 , the 48 h endogenous nitrogen retention (ERN0) values for the three batches were -0.555, -0.549, and -0.528 g/kg BW, and the 48 h endogenous energy loss (EEL) values were 25.573, 28.192, and 25.267 MJ/kg BW, with no significant differences ($P>0.05$).

As shown in Table 5 , the average AME, AMEn, TME, and TMEn values for corn starch across three batches were 14.393, 15.251, 16.372, and 16.108 MJ/kg, respectively, with no significant differences ($P>0.05$).

As shown in Table 6 , the average AME, AMEn, TME, and TMEn values for the 12 rapeseed meal samples were 8.627, 9.029, 9.326, and 8.970 MJ/kg, respectively. Metabolizable energy differed significantly among rapeseed meals from different sources ($P<0.05$). Sample 5 showed higher AME, while sample 1 showed higher AMEn, TME, and TMEn than other samples. Sample 6 showed lower AME and AMEn, while sample 12 showed lower TME and TMEn than other samples. The lower TMEn of sample 7 was associated with its higher DM and NDF contents. Sample 5 had higher ME, with the highest GE content, EE content second only to the highest, and ash content second only to the lowest. Sample 6 had lower AME and AMEn, with GE and EE below average and NDF, CF, and ash above average. Sample 12 had lower TME and TMEn, with NDF, ADF, and CF above average and EE below average.

2.3 Amino Acid Content of Rapeseed Meal

As shown in Table 7 , the average amino acid contents of the 12 rapeseed meal samples ranged from 0.72% to 6.55%, with CVs ranging from 4.53% to 18.97%. Lysine showed the highest CV (18.97%), while glycine (Gly) showed the lowest (4.53%). Sample 2 had lower contents of arginine (Arg), histidine (His), isoleucine (Ile), leucine (Leu), Lys, Met, threonine (Thr), valine (Val), alanine (Ala), aspartic acid (Asp), cysteine (Cys), and serine (Ser) than other samples. Sample 3 had lower glutamic acid (Glu) and proline (Pro) contents than other samples. Sample 10 had higher Arg, His, Ile, Lys, Val, Cys, and Glu contents than other samples. Sample 6 had higher tyrosine (Tyr) and Ala contents than other samples.

2.4 True Amino Acid Availability (TAAA) of Rapeseed Meal

As shown in Table 8 , the average true availabilities of Arg, His, Ile, Leu, Lys, Met, phenylalanine (Phe), Thr, Val, Ala, Asp, Cys, Glu, Pro, Ser, Tyr, and Gly in the 12 rapeseed meal samples were 88.92%, 75.74%, 75.46%, 81.31%, 68.37%, 84.44%, 81.47%, 70.83%, 71.25%, 72.37%, 70.68%, 71.06%, 83.33%, 74.17%, 74.11%, 78.81%, and 72.05%, respectively. True amino acid availability differed significantly among rapeseed meals from different sources (except for Met, Thr, and Ser) ($P<0.05$). The mean true availabilities were 70.81% for essential amino acids, 70.43% for non-essential amino acids, and 70.45% for total amino acids. Sample 2 showed lower true availabilities for Arg, Met, Thr, Gly, Ala, Asp, Cys, Glu, Pro, and Ser, while sample 4 showed lower true availabilities for Leu, Lys, and Phe than other samples. Sample 10 showed higher true availabilities for Arg, Ile, Lys, Met, Gly, Asp, Glu, and Pro, while sample 3 showed higher true availabilities for His, Leu, Phe, Thr, Ala, Ser, and Tyr than other samples. The true availabilities of Arg, Ile, Gly, Asp, Cys, Glu, and Pro in sample 3 and His, Leu, Thr, and Ser in sample 10 were second only to the highest values. The true availabilities of Arg, Ile, Gly, Val, Ala, Asp, Cys, and Glu in sample 4 were only higher than the lowest values. In this study, most TAAA values of sample 10 were higher than those of other rapeseed meal samples.

3 Discussion

3.1 Energy Nutritional Value of Different Rapeseed Meals

Woyengo et al. [11] determined that expeller-extracted and press-extracted rapeseed meals had CP, GE, NDF, and EE contents of 41.4% and 41.8%, 20.133 and 21.753 MJ/kg, 29.90% and 23.84%, and 5.54% and 12.03%, respectively, which are consistent with our findings. Bayley et al. [12] measured ME values of 6.234 and 6.945 MJ/kg for two traditional rapeseed meals in 4-week-old broilers; when CF content was reduced to 8% and 10%, ME increased to 9.163 MJ/kg; when CF content increased to 23%, ME decreased to 5.690 and 6.527 MJ/kg, indicating that CF content affects ME. This study used corn starch dilution to determine ME, with diluted CF content of 5.78%-9.85%, yielding average rapeseed meal

ME values of 8.627-9.326 MJ/kg, which falls within the reported range. Chen et al. [13] reported TMEn values of 9.519 and 10.267 MJ/kg DM for conventional and new variety rapeseed meals, higher than our results, suggesting that breeding techniques to reduce glucosinolate content and dehulling technology during processing can increase rapeseed meal ME [14-15].

3.2 Amino Acid Nutritional Value of Different Rapeseed Meals

Woyengo et al. [11] reported amino acid contents of 0.69%-2.22% in expeller-extracted and 0.68%-2.43% in press-extracted rapeseed meals, with Met being the lowest and Arg the highest. In this study, except for sample 10 (press-extracted), all rapeseed meal samples were pre-press expeller-extracted, and amino acid contents were consistent with previous research. Woyengo et al. [11] reported higher apparent and standardized amino acid digestibility in press-extracted than expeller-extracted rapeseed meal, possibly due to higher oil content. Similar results were reported in pigs by Li et al. [16] and Cervantes-Pahm et al. [17], possibly because higher fat content reduces gastric emptying rate. Jia et al. [18] also reported that high protein and low fiber levels in rapeseed meal increased AMEn and amino acid utilization in broilers. The higher true availability of Met in rapeseed meal than other amino acids (except Arg) may be related to the higher sulfur-containing amino acid content in rapeseed meal compared to other oilseed meals. The lower true availabilities of 10 amino acids in sample 2 and 3 amino acids in sample 4 may be related to their higher NDF, ADF, and CF contents compared to other rapeseed meal samples.

4 Conclusion

1. The nutrient composition of rapeseed meals from different sources varied considerably, with high CVs for NDF, ADF, EE, and ash. The average amino acid contents of the 12 rapeseed meal samples ranged from 0.72% to 6.55%, with lysine showing the highest CV at 18.97%.
2. Metabolizable energy differed significantly among rapeseed meals from different sources ($P<0.05$). The average AME, AMEn, TME, and TMEn values for the 12 rapeseed meal samples were 8.627, 9.029, 9.326, and 8.970 MJ/kg, respectively. True amino acid availability also differed significantly among sources (except for Met, Thr, and Ser) ($P<0.05$). The mean true availabilities were 70.81% for essential amino acids, 70.43% for non-essential amino acids, and 70.45% for total amino acids.

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