Evaluation of Energy and Amino Acid Nutritional Value of Soybean Meal from Different Sources for Daheng Broilers (Postprint)

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Abstract

This experiment aimed to evaluate the nutritional value of energy and amino acids in soybean meals from different sources for Daheng broiler chickens using the true metabolizable energy (TME) method with appropriate force-feeding. Twelve soybean meal samples were randomly collected from feed enterprises in Sichuan Province to evaluate metabolizable energy and true amino acid availability (TAAA). The metabolizable energy evaluation was conducted in three batches of metabolism trials, with 48 normal Daheng broiler roosters per batch, divided into 6 groups with 8 replicates per group and 1 bird per replicate. The TAAA evaluation was conducted in three batches of metabolism trials, with 36 cecectomized chickens per batch, divided into 6 groups with 6 replicates per group and 1 bird per replicate. One endogenous group was set up for each batch, with a 10-day recovery period between batches. Using the TME method, test birds were fasted for 48 h, force-fed 2% of the test diet, and excreta were collected for 48 h; the endogenous group was fasted for 48 h and excreta were collected for 48 h. The results showed: the average contents of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude fiber (CF), ether extract (EE), crude ash, and gross energy (GE) in the 12 soybean meals were 85.74%, 52.81%, 13.61%, 6.47%, 6.67%, 1.52%, 6.63%, and 19.790 MJ/kg, respectively; among them, the coefficients of variation (CV) for NDF, CF, and EE were greater than 15%. The average amino acid content of the 12 soybean meals ranged from 0.56% to 7.99%, with CV ranging from 6.36% to 10.94%; total essential amino acid content was 19.26% with a CV of 7.35%; total non-essential amino acid content was 24.66% with a CV of 7.10%; total amino acid content was 43.92% with a CV of 7.18%. The average values of apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), true metabolizable energy (TME), and nitrogen-corrected true metabolizable energy (TMEn) for the 12 soybean meals were 12.523, 12.933, 12.795, and 12.339 MJ/kg, respectively, with significant differences among sources ($P<0.05$); TAAA values ranged from 78.16% to 94.38%, with significant differences among sources ($P<0.05$). The results indicated: 1) Metabolizable energy values differed among the 12 soybean meals from different sources, with average values of AME, AMEn, TME, and TMEn being 12.523, 12.933, 12.795, and 12.339 MJ/kg; 2) TAAA of soybean meals from different sources differed for Daheng broiler chickens, with the average true utilization rate of total essential amino acids being 84.32%.

Full Text

Nutritional Evaluation of Energy and Amino Acid in Different Source Soybean Meals for Daheng Broilers

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Abstract: This experiment was conducted to evaluate the energy and amino acid nutritional value of different source soybean meals for Daheng broilers using the true metabolizable energy (TME) method with appropriate force-feeding levels. Twelve soybean meal samples were randomly collected from feed enterprises in Sichuan Province to evaluate metabolizable energy and true amino acid availability (TAAA). The metabolizable energy evaluation consisted of three batches of metabolic trials, with 48 normal Daheng roosters in each batch, divided into 6 groups with 8 replicates per group and one bird per replicate. The TAAA evaluation also consisted of three batches of metabolic trials, with 36 caecectomized roosters in each batch, divided into 6 groups with 6 replicates per group and one bird per replicate. One endogenous group was established in each batch, with a 10-day recovery period between batches. The TME method was employed: test broilers were fasted for 48 h, force-fed 2% of their body weight with the test diet, and excreta were collected for 48 h; the endogenous group was fasted for 48 h with excreta collected for 48 h. The results showed that the average contents of dry matter (DM), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), crude fiber (CF), ether extract (EE), ash, and gross energy (GE) in the 12 soybean meals were 85.74%, 52.81%, 13.61%, 6.47%, 6.67%, 1.52%, 6.63%, and 19.790 MJ/kg, respectively. The coefficients of variation (CV) for NDF, CF, and EE were greater than 15%. The average amino acid content of the 12 soybean meals ranged from 0.56% to 7.99%, with CVs ranging from 6.36% to 10.94%. The total essential amino acid content was 19.26% (CV = 7.35%), total non-essential amino acid content was 24.66% (CV = 7.10%), and total amino acid content was 43.92% (CV = 7.18%). The average apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), TME, and nitrogen-corrected true metabolizable energy

(TMEn) of the 12 soybean meals were 12.523, 12.933, 12.795, and 12.339 MJ/kg, respectively, with significant differences among sources ($P < 0.05$). The average TAAA ranged from 78.16% to 94.38%, with significant differences among sources ($P < 0.05$). The results indicate that: (1) the metabolizable energy values of 12 different source soybean meals vary, with average AME, AMEn, TME, and TMEn values of 12.523, 12.933, 12.795, and 12.339 MJ/kg, respectively; and (2) the TAAA of different source soybean meals for Daheng broilers varies, with an average true utilization rate of total essential amino acids of 84.32%.

Keywords: Daheng broilers; soybean meal; metabolizable energy; amino acid availability

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Introduction

With rising living standards, consumer demand for poultry product quality, particularly flavor, has increased, with greater preference for high-quality local poultry products. Daheng broilers are a local yellow-feathered broiler line developed by Sichuan Daheng Poultry Breeding Co., Ltd. In feed nutritional evaluation, the true metabolizable energy (TME) method proposed by McNab et al. [**?**] offers advantages of rapid determination, simple analytical procedures, high repeatability, and accurate assessment of single ingredients. With progressive improvements in determination conditions and applications, the TME method is now widely used in over 30 countries and has been extended from evaluating ingredient metabolizable energy to nutrient digestibility and amino acid utilization [**?**]. Parsons [**?**] proposed a method for determining true amino acid availability (TAAA) in ingredients using caecectomized birds based on the TME method, providing greater flexibility and practicality. Differences in digestive tract structure, growth rate, and body size among poultry species can all affect nutritional value evaluation [**?**, **?**]. Zhao Jia [**?**] evaluated the metabolizable energy of 30 different corn sources for Daheng broilers, obtaining values of (14.624 ± 0.469) MJ/kg for AME, (14.646 ± 0.462) MJ/kg for AMEn, (16.062 ± 0.488) MJ/kg for TME, and (16.083 ± 0.481) MJ/kg for TMEn. However, no reports have been published on the nutritional value evaluation of soybean meal for Daheng broilers. Therefore, this experiment aimed to evaluate the metabolizable energy and TAAA of different source soybean meals for Daheng broilers, establish appropriate evaluation methods for Daheng broilers or other high-quality local broilers, construct a feed database for Daheng broilers, and provide data support for effective feed formulation and development of the high-quality broiler industry chain.

Materials and Methods

1.1 Experimental Design

Determination of appropriate force-feeding level for Daheng broilers: Forty Daheng roosters aged 18 weeks or older were selected for force-feeding and divided into 5 groups with force-feeding levels of 0, 1.0%, 1.5%, 2.0%, and 2.5% of body weight. Each group had 8 replicates with one bird per replicate. The group with 0% force-feeding served as the control group for measuring endogenous nitrogen and energy losses.

Metabolizable energy evaluation: Conducted in 3 batches, each batch used 48 normal, healthy adult Daheng roosters with an average body weight of 4 kg, randomly divided into 6 groups (one fasting control group, one corn starch group, and four test diet groups). Each group had 8 replicates with one bird per replicate. Corn starch metabolizable energy was determined by direct force-feeding and repeated three times.

TAAA evaluation: Conducted in 3 batches, each batch used 36 normal, healthy caecectomized Daheng roosters, randomly divided into 6 groups with 6 replicates per group and one bird per replicate.

1.2 Experimental Diets

Diets were formulated according to NRC (1994). The diet for determining the appropriate force-feeding level was the basal diet. For metabolizable energy and TAAA determination, test diets were prepared by diluting soybean meal to 17% crude protein (CP) content with corn starch. Diet composition and nutrient levels are shown in Table 1 . The 12 soybean meals were sampled from feed enterprises in Sichuan Province, with sampling information provided in Table 2 .

1.3 Metabolic Trials

The trials were conducted at the research base of the Institute of Animal Nutrition, Sichuan Agricultural University. Metabolic birds were force-fed following McNab et al.’ s [?] TME method: after one week of adaptation with a cloacal sutured fecal collection bottle, birds were weighed and recorded. Following a 48 h fast, birds were force-fed, fecal collection bags were attached, time was recorded, and excreta were collected for 48 h. Force-feeding was performed using a stainless-steel tube with an inner diameter of 8 mm and length of 26 cm, fused into a funnel shape at the top to deliver feed through the esophagus into the crop. Feed was ground to pass through a 40-mesh sieve. Birds were housed individually in cages (30 cm × 57 cm × 50 cm) with free access to water and a 16 h lighting period.

Caecectomy method: Performed according to Poppema et al. [?]. Preoperative birds 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 ceca were located below the duodenum, ligated with standard sutures and excised. The excised ends were 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. Birds underwent a 6-week recovery period post-surgery.

Excreta collection: Following Adeola et al. [**?**], fecal collection bags were replaced at 4, 8, 16, 32, and 48 h post-feeding. After collection, each bird' s 48 h excreta were thoroughly mixed, dried in a 65 °C oven for 72 h, reconditioned in air for 24 h, weighed, recorded, ground to pass through a 40-mesh sieve, and stored at -20 °C for fecal component analysis.

1.4 Measurements and Methods

1.4.1 Body Weight Body weight before fasting was recorded as pre-feeding weight, and body weight after 48 h excreta collection was recorded as post-feeding weight. Body weight loss was the difference between pre- and post-feeding weights.

1.4.2 Nitrogen and Energy Content of Diets and Excreta Nitrogen content was determined using a Foss Kjeltec 8400 automatic protein analyzer. Energy was determined by oxygen bomb calorimetry using a Parr 1281 automatic adiabatic calorimeter: - Total energy intake = diet energy × total diet intake - Total excreta energy = excreta energy × total excreta amount

1.4.3 Nitrogen Retention Nitrogen retention was calculated using Guo Yuming' s [**?**] formulas: - Endogenous nitrogen retention (ERN0) = -excreta nitrogen from fasted birds - RN1 = (total nitrogen intake - excreta nitrogen) / dry matter intake - RN2 = (total nitrogen intake - excreta nitrogen + endogenous excreta nitrogen) / dry matter intake

Where RN1 represents nitrogen deposited per kg of diet dry matter intake, and RN2 represents true nitrogen deposited per kg of diet dry matter intake after removing endogenous losses.

1.4.4 Soybean Meal Nutrient Composition Determination of DM, CP, crude fiber (CF), NDF, ADF, ether extract (EE), and ash in soybean meal followed Zhang Liying' s [**?**] methods.

1.4.5 Diet Metabolizable Energy Metabolizable energy calculation followed Adeola et al. [**?**]. Endogenous energy loss (EEL), AME, AMEn, TME, and TMEn were calculated on a replicate basis using dry matter-based formulas:

- EEL = total energy of excreta from fasted birds
- AME = (total energy intake - total excreta energy) / dry matter intake
- AMEn = AME - RN1 × 34.39

- TME = (total energy intake - total excreta energy + endogenous energy excretion) / dry matter intake
- TMEn = TME - RN2 × 34.39

Where 34.39 is the heat production per gram of urinary nitrogen in chickens (MJ/kg). Energy utilization rate = (excreta energy / total energy intake) × 100.

Soybean meal AME = (diet AME - corn starch content in diet × corn starch AME) / soybean meal content in diet

Soybean meal TME = [(diet TME - corn starch content in diet × corn starch TME) / soybean meal content in diet]

1.4.6 Amino Acid Content Amino acid content in diet samples or excreta after CP hydrolysis was determined by high-performance liquid chromatography using an automatic amino acid analyzer (Hitachi L-8900). Sulfur-containing amino acids were determined separately.

1.4.7 Soybean Meal TAAA Calculated according to Likuski et al. [?]: - TAAA = (total amino acid intake - total excreta amino acids - endogenous amino acids) / total amino acid intake × 100

Where total amino acid intake = total diet dry matter × amino acid content in diet; total excreta amino acids = total excreta dry matter × amino acid content in excreta. Since soybean meal was the sole protein source in the mixed diet, soybean meal TAAA equals diet TAAA.

1.5 Statistical Analysis

Data were analyzed as a one-way completely randomized design using one-way ANOVA and LSD methods with the ANOVA module in SAS 9.3. Duncan' s multiple comparison test was used for significant differences. $P < 0.05$ indicated significant differences.

Results

2.1 Effects of Different Force-Feeding Levels on Metabolic Body Weight Loss and Nitrogen Deposition

Under specific fasting conditions, this experiment investigated the effects of different force-feeding levels on body weight loss, nitrogen balance, metabolizable energy, and energy utilization in Daheng broilers. No adverse reactions such as choking or vomiting occurred during the trial, though force-feeding at 2.5% was difficult. Table 3 shows that body weight loss and nitrogen deposition differed significantly among groups ($P < 0.05$). As broilers were in a fasting state before feeding, body weight loss and nitrogen deposition decreased with increasing force-feeding levels, with significant differences between each feeding group and the control group ($P < 0.05$). Absolute nitrogen deposition values tended to decrease with increasing force-feeding levels. The ERN0 in this trial was -0.541 g/kg BW, slightly higher than Zhao Jia' s [?] average value of -0.609 g/kg BW for adult Daheng broilers measured by fasting, but substantially different from Askbran' s [?] value of 0.29-0.36 g/kg BW, possibly because other experiments fed glucose and starch to endogenous control groups.

2.2 Effects of Different Force-Feeding Levels on Metabolizable Energy and Energy Utilization

The fasting group served as the control, with EEL measured at 24.941 MJ/kg BW, essentially equivalent to Zhao Jia' s [?] average EEL of 24.878 MJ/kg BW for adult Daheng broilers, but lower than Askbran' s [?] value of 29.748-31.380 MJ/kg BW for Rhode Island Red roosters weighing 2.9-4.9 kg, likely due to differences in breed and age. Ren et al. [?] reported EEL values of 25.355-27.070 MJ/kg BW for yellow-feathered broilers, consistent with our results.

As shown in Table 4 , basal diet AME and AMEn tended to increase with higher force-feeding levels, but differences among groups were not significant ($P > 0.05$). However, TME and TMEn decreased significantly with increasing force-feeding levels ($P < 0.05$). Energy utilization rates did not differ significantly among groups ($P > 0.05$) but tended to increase with higher force-feeding levels.

Significant differences in TME and TMEn among groups with different force-feeding levels ($P < 0.05$) contradicted Sibbald' s [?] hypothesis, possibly due to differences in EEL and nitrogen deposition values between fed and fasted birds. The 1.5% and 2.0% force-feeding groups showed no significant differences in AME, AMEn, TME, or TMEn ($P > 0.05$), indicating stable energy utilization. Additionally, the 2.5% group' s TMEn did not differ significantly from the 2.0% group ($P > 0.05$), suggesting complete metabolism at the 2.0% feeding level. Studies report that when excreta collection time was extended from 24 h to 48 h for meat and bone meal and fish meal, TME values decreased slightly, while alfalfa TME decreased significantly, indicating 24 h emptying for meat/bone meal and fish meal versus 48 h for alfalfa [?]. The emptying time of force-fed diets in fasted birds depends on the amount fed and the storage-digestion process in the stomach, with NDF-rich feeds requiring longer emptying times than low-NDF feeds [?]. Although reducing force-feeding amounts decreases emptying time, it increases standard errors and reduces TME precision. Previous studies reported decreased standard errors when force-feeding amounts increased from 10 g to 30 g in adult Single Comb White Leghorn roosters [?]. In this trial, the standard error for metabolizable energy at the 2.0% force-feeding level was lower than other groups. Overall, these results indicate that force-feeding at 2.0% of body weight is appropriate for Daheng broilers.

2.3 Soybean Meal Nutrient Composition

As shown in Table 5 , the average DM, CP, NDF, ADF, CF, EE, ash, and GE contents of the 12 soybean meals were 85.74%, 52.81%, 13.61%, 6.47%, 6.67%, 1.52%, 6.63%, and 19.790 MJ/kg, respectively. The CVs for NDF, CF, and EE exceeded 15%, with EE showing the highest variation. GE ranged from 19.414 to 20.041 MJ/kg with the lowest CV (0.82). Soybean meal 3 had lower CF content (4.78%) than other meals. Soybean meal 1 had lower GE (19.414 MJ/kg) and EE (1.10%) contents than other meals. The difference between the highest (soybean meal 9, 2.46%) and lowest (soybean meal 1, 1.10%) EE values was 1.36 percentage points. Soybean meals 5 and 6 had lower CP, EE, and GE but higher NDF, ADF, and CF contents, while soybean meals 7, 9, and 10 had higher CP, EE, and GE but lower NDF, ADF, and CF contents.

2.4 Soybean Meal Metabolizable Energy

As shown in Table 6 , the 48 h ERN0 values for the three batches were -0.468, -0.408, and -0.402 g/kg BW, and the 48 h EEL values were 26.229, 19.853, and 20.456 MJ/kg BW, with no significant differences ($P > 0.05$). Table 7 shows that the average AME, AMEn, TME, and TMEn values for corn starch measured in three replicate trials were 14.393, 15.251, 16.372, and 16.108 MJ/kg, respectively. As shown in Table 8 , the average AME, AMEn, TME, and TMEn values for the 12 soybean meals were 12.523, 12.933, 12.795, and 12.339 MJ/kg, respectively, with ranges of 11.439-14.305 MJ/kg, 11.916-14.790 MJ/kg, 11.422-14.410 MJ/kg, and 11.221-14.042 MJ/kg. Significant differences were observed among different soybean meal varieties ($P < 0.05$). AME, AMEn, TME, and TMEn showed similar trends. Soybean meals 8 and 9 had higher metabolizable energy than other meals, soybean meal 2 had lower AMEn, and soybean meal 6 had lower AME, TME, and TMEn than other meals.

2.5 Soybean Meal Amino Acid Content

As shown in Table 9 , the CVs for 17 amino acids in the 12 soybean meals ranged from 6.36% to 10.94%, with glycine (Gly) showing the smallest CV (6.36%) and proline (Pro) the largest (10.94%). Average amino acid contents ranged from 0.56% to 7.99%. Except for methionine (Met), Gly, cysteine (Cys), and Pro, the other 13 amino acids showed consistent variation patterns, with soybean meal 8 having the lowest and soybean meal 9 the highest amino acid contents. For Met, Gly, and Cys, soybean meal 2 had the lowest contents while soybean meal 9 had the highest.

2.6 Soybean Meal TAAA

As shown in Table 10 , the mean true utilization rates for 17 amino acids—arginine (Arg), histidine (His), isoleucine (Ile), leucine (Leu), lysine (Lys), Met, phenylalanine (Phe), threonine (Thr), valine (Val), alanine (Ala), aspartic acid (Asp), Cys, glutamic acid (Glu), Pro, serine (Ser), tyrosine (Tyr), and Gly—in the 12 soybean meals were 94.38%, 84.76%, 85.75%, 87.56%, 89.13%, 78.16%, 89.27%, 82.93%, 84.04%, 79.04%, 84.50%, 81.85%, 88.52%, 87.22%, 86.61%, 89.17%, and 80.30%, respectively, with significant differences among samples ($P < 0.05$). Except for Met, Gly, Cys, Pro, and Ser, soybean meal 9 had higher TAAA than other meals. Except for Met, Gly, Cys, and Ser, soybean meal 1 had lower TAAA than other meals. Soybean meal 2 had lower true utilization values for Gly and Ser than other meals. Additionally, soybean meal 8 had higher true utilization for Arg, His, Leu, Phe, Ala, and Tyr, while soybean meal 3 had higher true utilization for Ile, Lys, and Val than other meals except soybean meal 9. Conversely, soybean meal 2 had lower true utilization for Thr, Ala, Glu, Pro, and Tyr, while soybean meal 5 had lower true utilization for Arg, His, Leu, Phe, and Gly than other meals except soybean meal 1.

Discussion

3.1 Energy Nutritional Value of Different Source Soybean Meals

The nutrient composition values measured in this trial are consistent with data published by Dale et al. [?] and NRC (1994). The highest CV was observed for EE (28.66%), primarily related to oil extraction methods (pressing vs. solvent extraction). The lowest CV for GE indicates that gross energy is not affected by single nutrient levels but by multiple factors. De Coca-Sinova et al. [?] reported DM, CP, NDF, EE, ash, and GE values of 88.93%, 47.20%, 9.02%, 1.52%, 6.17%, and 19.790 MJ/kg for six soybean meals from South America and the USA—slightly lower than our results, possibly due to differences in origin, variety, processing, and storage conditions.

In this trial, soybean meal 2 had lower AMEn, and soybean meal 6 had lower AME, TME, and TMEn than other meals, likely due to their higher NDF, ADF, and CF contents and lower EE and GE values. Soybean meals 8 and 9 with higher metabolizable energy had higher GE and EE contents and lower NDF and ADF contents than average, consistent with Baker' s [?] findings. Coon et al. [?] measured TMEn values of 11.690 and 14.092 MJ/kg for normal soybean meal (46.1% CP) and oligosaccharide-free soybean meal (64.4% CP), respectively. Baker et al. [?] used the TME method with 24 h fasting followed by 30 g force-feeding of single soybean meal and 48 h excreta collection, obtaining TMEn values of 12.987, 12.485, and 12.397 MJ/kg for high-protein, low-oligosaccharide, and conventional soybean meals in White Leghorn roosters—slightly different from our results, possibly due to different experimental conditions and processing methods.

3.2 Amino Acid Nutritional Value of Different Source Soybean Meals

De Coca-Sinova et al. [?] evaluated amino acids in soybean meals from Argentina, Brazil, Spain, and the USA, reporting that meals with higher crude protein content had higher sulfur amino acid content and utilization. Chen et al. [?] measured amino acid contents in conventional and low-oligosaccharide soybean meals, suggesting that higher crude protein content in low-oligosaccharide meals resulted in higher amino acid contents. In this trial, soybean meals 9 and 10 had higher amino acid contents than other meals, possibly related to crude protein content and dehulling processing. Variations in amino acid contents among different soybean meals were consistent with previously reported lysine ranges of 2.09%-3.04% and 2.87%-3.20% [?, ?].

Dozier et al. [?] summarized that amino acid availability in soybean meals ranged from 82% to 93% across studies. Our values for Met (78.16%), Gly (80.30%), Ala (79.04%), Cys (81.85%), and Arg (94.38%) differed somewhat from this range. Most TAAA values for soybean meal 9 were higher than other meals; combined with nutrient composition data, it had the highest GE (20.041 MJ/kg) and EE (2.46%) contents and the lowest NDF content (10.92%) except for soybean meal 10 (10.80%) and soybean meal 7 (10.84%). Soybean meal 1 had lower TAAA than most meals, with the lowest GE (19.414 MJ/kg) and EE (1.10%) contents and higher NDF than other meals except soybean meal 6 (18.24%). Soybean meal 9 was processed by single solvent extraction with dehulling, while soybean meal 1 was processed by double solvent extraction without dehulling, indicating that TAAA is closely related to processing method. These results are consistent with previous reports of significant negative correlations between soybean meal amino acid utilization and NDF content [?]. Our Met true utilization (78.16%) was substantially lower than values of 93.15% reported by Baker et al. [?] and Jia Gang et al. [?], while other TAAA values were slightly lower, possibly due to differences in test ingredients and amino acid analysis methods for excreta.

Conclusion

1. Using the excreta collection method with force-feeding (TME method) involving 48 h fasting + 48 h excreta collection at a force-feeding level of 2% body weight can accurately evaluate the metabolizable energy and TAAA of diets for adult Daheng broilers.
2. Significant differences exist in nutrient composition among 12 different source soybean meals, with the highest CVs for EE, CF, NDF, and ADF, while differences in DM, CP, GE, and ash were less pronounced.
3. The average AME, AMEn, TME, and TMEn values of 12 different source soybean meals for Daheng broilers were 12.523, 12.933, 12.795, and 12.339 MJ/kg, respectively, with significant differences among sources ($P < 0.05$). The average TAAA values for Arg, His, Ile, Leu, Lys, Met, Phe, Thr, Val, Ala, Asp, Cys, Glu, Pro, Ser, Tyr, and Gly were 94.38%, 84.76%, 85.75%, 87.56%, 89.13%, 78.16%, 89.27%, 82.93%, 84.04%, 79.04%, 84.50%, 81.85%, 88.52%, 87.22%, 86.61%, 89.17%, and 80.30%, respectively, with significant differences among sources ($P < 0.05$). The average TAAA values for total essential amino acids, total non-essential amino acids, and total amino acids were 84.32%, 82.29%, and 82.88%, respectively.

References

[1] MCNAB J M, BLAIR J C. Modified assay for true and apparent metabolisable energy based on tube feeding[J]. British Poultry Science, 1988, 29(4): 697–707.

[2] DUDLEY-CASH W A. A landmark contribution to poultry science—a bioassay for metabolizable energy in feedingstuffs[J]. Poultry Science, 2009, 88(4): 832–834.

[3] PARSONS C M. Determination of digestible and available amino acids in meat meal using conventional and caecectomized cockerels or chick growth assays[J]. British Journal of Nutrition, 1986, 56(1): 227–240.

[4] SIREGAR A P, FARRELL D J. A comparison of the energy and nitrogen metabolism of fed ducklings and chickens[J]. British Poultry Science, 1980, 21(3): 213–227.

[5] SIBBALD I R. The effect of level of feed input on true metabolizable energy values[J]. Poultry Science, 1977, 56(5): 1662–1663.

[6] 赵佳. 优质肉鸡的玉米代谢能评定及近红外预测模型的构建 [D]. 硕士学位论文. 雅安: 四川农业大学, 2014.

[7] POPPEMA T F, DUKE G E. The effectiveness of ligating or detaching ceca as an alternative to cecectomy[J]. Poultry Science, 1992, 71(8): 1384–1390.

[8] ADEOLA O, RAGLAND D, KING D. Feeding and excreta collection techniques in metabolizable energy assays for ducks[J]. Poultry Science, 1997, 76(5): 728–732.

[9] 呙于明. 家禽营养 [M]. 2 版. 北京: 中国农业大学出版社, 2004: 403–404.

[10] 张丽英. 饲料分析及饲料质量检测技术 [M]. 2 版. 中国农业大学出版社, 2003: 48–135.

[11] LIKUSKI H J A, DORRELL H G. A bioassay for rapid determinations of amino acid availability values[J]. Poultry Science, 1978, 57(6): 1658–1660.

[12] ASKBRANT S U S. Metabolisable energy content of rapeseed meal, soyabean meal and white-flowered peas determined with laying hens and adult cockerels[J]. British Poultry Science, 1988, 29(3): 445–455.

[13] REN L Q, TAN H Z, ZHAO F, et al. Using corn starch as basal diet to determine the true metabolizable energy protein feedstuffs in Chinese Yellow chickens[J]. Poultry Science, 2012, 91(6): 1394–1399.

[14] 丁耿芝. 鸡内源能的估测方法与影响因素 [J]. 饲料博览, 2011(4): 16–17.

[15] SIBBALD I R. Effects of level of feed input, dilution of test material, and duration of excreta collection on true metabolizable energy values[J]. Poultry Science, 1979, 58(5): 1325–1329.

[16] DALE N M, FULLER H L. Repeatability of true metabolizable energy versus nitrogen corrected true metabolizable energy values[J]. Poultry Science, 1986, 65(2): 352–354.

[17] DE COCA-SINOVA A, VALENCIA D G, JIMÉNEZ-MORENO E, et al. Apparent ileal digestibility of energy, nitrogen, and amino acids of soybean meals of different origin in broilers[J]. Poultry Science, 2008, 87(12): 2613–2623.

[18] BAKER K M. Nutritional value of high-protein and low oligosaccharide varieties of soybeans fed to pigs and poultry[D]. Master Thesis. Urbana: University of Illinois at Urbana-Champaign, 2009.

[19] COON C N, LESKE K L, AKAVANICHAN O, et al. Effect of oligosaccharide-free soybean meal true metabolizable energy fiber digestion adult roosters[J]. Poultry Science, 1990, 69(5): 787–793.

[20] BAKER K M, UTTERBACK P L, PARSONS C M, et al. Nutritional value of soybean meal produced from conventional, high-protein, or low-oligosaccharide varieties of soybeans and fed to broiler chicks[J]. Poultry Science, 2011, 90(2): 390–395.

[21] CHEN X, PARSONS C M, BAJJALIEH N. Nutritional evaluation of new reduced oligosaccharide soybean meal in poultry[J]. Poultry Science, 2013, 92(7): 1830–1836.

[22] VAN KEMPEN T A T G, KIM I B, JANSMAN A J M, et al. Regional and processor variation in the ileal digestible amino acid content of soybean meals measured in growing swine[J]. Journal of Animal Science, 2002, 80(2): 429–439.

[23] DOZIER W A, HESS J B. Soybean meal quality and analytical techniques[M]. Rijeka: Intech Open Access Publisher, 2011.

[24] VAN KEMPEN T A T G, SIMMINS P H. Near-infrared reflectance spectroscopy in precision feed formulation[J]. The Journal of Applied Poultry Research, 1997, 6(4): 471–477.

[25] 贾刚, 王康宁, 黄兰. 畜禽可消化氨基酸的测定及应用中应注意的问题 [J]. 湖北农业科学, 2010, 49(8): 2020–2023.

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

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