Nutritional Value of Steam-Enzyme Hydrolyzed Feather Meal and Evaluation of Energy and Amino Acid Utilization in Broiler Ducks: Postprint

Authors: Lai Anqiang, Dong Guozhong, Suning, Song Dynasty military, Tao Li, Liu Hongwei, Fu Xuemei, Chen Jie

Date: 2017-10-23T00:00:00+00:00

Abstract

This experiment aimed to evaluate the energy and amino acid nutritional values of three types of steam-hydrolyzed enzymatically treated feather meals for meat ducks using the True Metabolizable Energy (TME) method, thereby providing fundamental data for the rational development and utilization of feather meal protein resources.

The three feather meals (-) were derived from 42-day-old Cherry Valley meat ducks, 550-day-old Roman laying hens, and 100-day-old Sanhuang meat chickens, respectively.

Twenty 7-week-old Cherry Valley meat ducks were selected for the experiment and randomly assigned to 4 treatments, with 5 replicates per treatment and 1 duck per replicate, housed individually in cages. Treatment 1 (T1) was for evaluating feather meal , Treatment 2 (T2) for feather meal , Treatment 3 (T3) for feather meal , and Treatment 4 (T4) for the starvation treatment. The experimental period lasted 7 days.

The results showed: 1) On a dry matter (DM) basis, the gross energy (GE) values of the three feather meals were 21.31, 21.02, and 20.18 MJ/kg, respectively; the apparent metabolizable energy (AME) values were 13.71, 12.29, and 12.10 kJ/kg, respectively; and the TME values were 14.83, 13.42, and 13.22 MJ/kg, respectively.

2) On a DM basis, the crude protein (CP) contents of the three feather meals were 91.05%, 87.31%, and 91.06%, respectively; the total amino acid (TAA) contents of all three feather meals exceeded 80%, though the amino acid contents varied considerably among different feather meals.

3) The apparent metabolizable rates of TAA for the three feather meals were 81.51%, 73.07%, and 76.85%, respectively, while the true metabolizable rates of TAA were 85.09%, 76.89%, and 80.43%, respectively. Significant differences ($P < 0.05$) were also observed in the contents of apparent utilizable amino acids and true utilizable amino acids among the three feather meals.

In conclusion, using the TME method to determine the nutritional values of energy and amino acids in feather meals revealed obvious differences in metabolizable energy (ME), apparent utilizable amino acids, and true utilizable amino acids among the three feather meals. Feather meal   exhibited higher GE, ME, CP, and TAA metabolizable rates than feather meals   and .

Full Text

Nutritional Values of Steamed and Enzymatically Hydrolyzed Feather Meal and Evaluation of Energy and Amino Acid Utilization in Meat Ducks

LAI Anqiang[1,2], DONG Guozhong[1*], SU Ning[2], SONG Daijun[1], TAO Li[2], LIU Hongwei[2], FU Xuemei[2], CHEN Jie[2]

[1]College of Animal Science and Technology, Southwest University, Chongqing 400716, China
[2]Sichuan Giastar Group Co., Ltd., Chengdu 610021, China

Abstract: This experiment was conducted to evaluate the energy and amino acid nutritional values of three types of steamed and enzymatically hydrolyzed feather meal in meat ducks using the true metabolizable energy (TME) method, thereby providing fundamental data for the rational development and utilization of feather meal protein resources. The three feather meals (I–III) were derived from 42-day-old Cherry Valley duck feathers, 550-day-old Lohmann layer chicken feathers, and 100-day-old yellow-feathered broiler chicken feathers, respectively. Twenty 7-week-old Cherry Valley ducks were randomly allocated to four treatments, with five replicates per treatment and one duck per replicate housed individually. Treatment 1 (T1) evaluated feather meal I, treatment 2 (T2) evaluated feather meal II, treatment 3 (T3) evaluated feather meal III, and treatment 4 (T4) served as a fasting control. The experimental period lasted 7 days. The results showed that: 1) On a dry matter (DM) basis, the gross energy (GE) values of the three feather meals were 21.31, 21.02, and 20.18 MJ/kg, respectively; the apparent metabolizable energy (AME) values were 13.71, 12.29, and 12.10 kJ/kg, respectively; and the TME values were 14.83, 13.42, and 13.22 MJ/kg, respectively. 2) On a DM basis, the crude protein (CP) contents were 91.05%, 87.31%, and 91.06%, respectively; total amino acid (TAA) contents exceeded 80% for all three feather meals, though significant differences existed in amino acid composition among them. 3) The apparent metabolizable rates of TAA were 81.51%, 73.07%, and 76.85%, respectively, while the true metabolizable rates were 85.09%, 76.89%, and 80.43%, respectively. Significant differences ($P < 0.05$) were observed in both apparent and true available amino acid contents among the three feather meals. These findings demonstrate that evaluation of feather meal energy and amino acid nutritional values via the TME method reveals distinct differences in metabolizable energy and available amino acids among the three products. Feather meal I exhibited higher GE, ME, CP, and TAA metabolic rates compared to feather meals II and III.

Keywords: feather meal; crude protein; metabolizable energy; amino acid

---

Feathers constitute 5%-7% of the body weight of adult poultry and represent a promising animal protein resource due to their high protein content. Previous research has demonstrated that incorporating 5% feather meal into layer diets can partially replace soybean meal and improve feed conversion ratio. Studies on growing-finishing pigs have shown that enzymatically or hydrolyzed feather meal can partially substitute for fish meal or soybean meal, though the replacement ratio generally should not exceed 8%. Other studies in finishing pigs indicated that replacing soybean meal with 9.765% feather meal requires crystalline amino acid supplementation to avoid adverse effects on performance. These findings suggest that nutritional values vary considerably among different feather meals and that their amino acid profiles may be unbalanced. Although feather protein content reaches approximately 90% (primarily keratin), untreated keratin exhibits low digestibility, limiting feather utilization. Unprocessed feathers have minimal nutritional value, whereas hydrolyzed feather meal produced under appropriate conditions shows significantly improved protein digestibility, and supplementation with microbial proteases can further enhance feather meal protein digestibility.

Feather meal primarily consists of keratin with low digestibility. Variations in feather source lead to differences in keratinization degree and feather type, resulting in substantial nutritional differences among feather meals. Since Sibbald proposed the true metabolizable energy (TME) method, it has gained widespread attention and application due to its rapid, simple, and accurate advantages. The TME method is commonly used for evaluating feed nutritional value in chickens and can also be applied to meat ducks. Therefore, this study analyzed the conventional composition, volatile basic nitrogen (VBN) content, and in vitro protein digestibility via pepsin hydrolysis of steamed and enzymatically hydrolyzed feather meal, while simultaneously determining energy and amino acid nutritional values in Cherry Valley ducks using the TME method to provide an experimental basis for rational development and utilization of protein feed resources.

1. Materials and Methods

1.1. Experimental Materials

The feather meal production process involved washing and sun-drying feathers, followed by batch high-pressure steaming in a horizontal steamer (800 mm diameter, 3,000 mm length) at 135 °C and 0.4 MPa pressure for 30 minutes at pH 7. After cooling the reaction mixture to 70 °C, protease (activity: 50,000 IU/kg) was added at 1 kg per batch for 15 minutes of hydrolysis (protease purchased from Liaoning Huaxing Biological Technology Co., Ltd.). The product was then steam-dried, ground, and passed through a 40-mesh sieve. Feather meal I was derived from 42-day-old Cherry Valley duck feathers (duck feather meal). Feather meal II was derived from 550-day-old Lohmann layer chicken feathers (layer feather meal). Feather meal III was derived from 100-day-old yellow-feathered broiler chicken feathers (broiler feather meal).

1.2. Experimental Animals and Management

Twenty healthy 7-week-old Cherry Valley (SM3) male ducks with body weight of (3.26 ± 0.3) kg were randomly divided into four treatments, with five replicates per treatment and one duck per replicate housed individually. Treatment 1 (T1) evaluated feather meal I, treatment 2 (T2) evaluated feather meal II, treatment 3 (T3) evaluated feather meal III, and treatment 4 (T4) served as a fasting treatment to determine endogenous losses. The TME method was employed to determine energy and amino acid metabolic rates of the steamed and enzymatically hydrolyzed feather meal. Feathers around the cloaca were trimmed, and plastic bottle caps with holes were sutured in place to facilitate complete collection of excreta.

1.3. Sample Collection and Preparation

The metabolic trial was conducted at the Leshan Experimental Base of Sichuan Giastar Group. Except for the fasting group, each duck in the experimental groups was force-fed 60 g of feather meal. The metabolic procedure followed the Sibbald TME method, comprising a 72-hour adaptation period with a corn-soybean meal diet [metabolizable energy (ME): 12.55 MJ/kg, crude protein (CP): 16.21%, produced by Sichuan Giastar Group], a 24-hour pre-trial period with the test diet, a 36-hour fasting period, and subsequent force-feeding of 60 g test diet . During the trial period, excreta were collected three times daily, weighed, and preserved by adding 5 mL of 5% hydrochloric acid per 100 g fresh sample before storage at -20 °C. After collection, samples from the 36-hour period were thawed, mixed uniformly, dried at 65 °C, re-equilibrated for 24 hours, weighed, ground through a 40-mesh sieve, and prepared using quartering method for subsequent analysis.

1.4.1. Determination Indicators

Dietary measurements included dry matter (DM), CP, ether extract (EE), crude ash, calcium (Ca), and phosphorus (P) content according to Zhang Liying' s methods, amino acid content according to GB/T 18246-2000, gross energy (GE) using an oxygen bomb calorimeter, pepsin digestibility according to GB/T 17811-1999, and VBN content according to GB/T 19164-2003. Excreta samples were analyzed for DM and CP content following Zhang Liying' s methods, amino acid content according to GB/T 18246-2000, and GE using an oxygen bomb calorimeter.

1.4.2. Calculation Methods

Amino acid metabolic rate was calculated as follows:
Apparent amino acid metabolic rate (%) = [(Amino acid intake - Amino acid in excreta) / Amino acid intake] × 100;
True amino acid metabolic rate (%) = [(Amino acid intake - Amino acid in excreta + Endogenous amino acid) / Amino acid intake] × 100;
Apparent available amino acid content (%) = Amino acid content × Apparent amino acid metabolic rate;
True available amino acid content (%) = Amino acid content × True amino acid metabolic rate.

Energy metabolic rate was calculated as follows:
Apparent energy metabolic rate (%) = [(GE intake - Energy in feces - Energy in urine) / GE intake] × 100;
True energy metabolic rate (%) = [(GE intake - Energy in feces - Energy in urine + Endogenous energy) / GE] × 100;
Apparent metabolizable energy (MJ/kg) = (GE intake - Energy in feces - Energy in urine) / DM intake;
True metabolizable energy (MJ/kg) = (GE intake - Energy in feces - Energy in urine + Endogenous energy) / DM intake.

1.5. Data Processing

Data were analyzed using SPSS 16.0 software for analysis of variance, with Duncan' s multiple comparison test. Differences were considered significant at $P < 0.05$, non-significant at $P > 0.05$, and highly significant at $P < 0.01$. Results are expressed as "mean ± standard error."

2. Results

2.1.1. Gross Energy, Conventional Components, VBN, and Pepsin Digestibility of Feather Meals

As shown in Table 2 , feather meals I, II, and III contained 91.17%, 89.80%, and 92.47% DM, respectively. On a DM basis, CP contents were 91.05%, 87.31%, and 91.06%; GE values were 21.31, 21.02, and 20.18 MJ/kg; VBN contents were

984.2, 1,153.5, and 1,137.2 mg/kg; and pepsin digestibility values were 88.64%, 78.95%, and 81.54%, respectively.

2.2. Energy Metabolic Rate and Metabolizable Energy of Feather Meals

Table 3 presents the energy metabolic rates and metabolizable energy values. Feather meals I, II, and III exhibited AME values of 13.71, 12.29, and 12.10 kJ/kg, and TME values of 14.83, 13.42, and 13.22 MJ/kg, respectively. Highly significant differences ($P < 0.01$) in apparent and true energy metabolic rates were observed among the three feather meals, with feather meal I showing the highest and feather meal II the lowest values. AME and TME differed highly significantly between feather meal I and II and between feather meal I and III ($P < 0.01$), while significant differences were found between feather meal II and III ($P < 0.05$).

2.3.1. Amino Acid Composition of Feather Meals

The amino acid composition of feather meals, determined by acid hydrolysis, is presented in Table 4 . On a DM basis, the amino acid profiles of the three feather meals were similar but exhibited distinct differences. Total amino acid (TAA) and total essential amino acid (TEAA) contents followed the order: feather meal I > feather meal III > feather meal II. All three feather meals contained over 80% TAA, but TEAA contents were only approximately 30%. Non-essential amino acids such as serine, glutamic acid, glycine, and proline were present at high concentrations. Among essential amino acids, cystine, threonine, arginine, branched-chain amino acids (leucine, isoleucine, and valine), and phenylalanine were relatively abundant, whereas methionine and lysine contents were low and varied considerably among the three feather meals. Thus, feather meal represents a protein resource with high TAA content but relative deficiency in certain essential amino acids, particularly lysine and methionine.

2.3.2. Amino Acid Metabolic Rate of Feather Meals

The apparent amino acid metabolic rates and apparent available amino acids are shown in Table 5 , while true amino acid metabolic rates and true available amino acids are presented in Table 6 . Apparent metabolic rates were lower than true metabolic rates for all feather meals. Both true and apparent metabolic rates of TEAA and TAA differed highly significantly among feather meals I, II, and III ($P < 0.01$). The apparent metabolic rates of TAA were 81.51%, 73.07%, and 76.85%, while true metabolic rates were 85.09%, 76.89%, and 80.43% for feather meals I, II, and III, respectively. The apparent metabolic rates of TEAA were 81.60%, 72.98%, and 77.40%, with true metabolic rates of 85.55%, 76.91%, and 80.53%, respectively. Leucine exhibited the highest metabolic rate across all feather meals, while aspartic acid showed the lowest. Based on amino acid contents and metabolic rates, the available amino acid contents were calculated.

Feather meal I had significantly higher apparent and true available TAA contents than feather meals II and III ($P < 0.01$), and similarly higher apparent and true available TEAA contents ($P < 0.01$).

3. Discussion

3.1. Characteristics of Nutrient Composition in Different Feather Meals

As shown in Table 2, feather meals I and III had similar CP contents, which were 4.28% and 4.27% higher than that of feather meal II, respectively. Considerable variations in DM, ash, and EE contents among the three feather meals resulted in substantial differences in GE. Feather meal III exhibited the highest ash content and lowest EE content, leading to the lowest GE value. Conversely, feather meal I showed relatively high CP, EE, and DM contents with the lowest ash content, resulting in the highest GE value. VBN, comprising ammonia and nitrogenous amines produced from protein decomposition, serves as an indicator of raw material freshness and is commonly used to assess fish meal deterioration. In fish meal, VBN content below 500 mg/kg indicates excellent freshness, while values exceeding 1,500 mg/kg suggest spoilage. As an animal protein source, the three feather meals had VBN levels between 500 and 1,500 mg/kg, indicating none had spoiled. Higher VBN content signifies poorer freshness; thus, freshness ranked as feather meal I > feather meal III > feather meal II. In vitro digestibility offers a rapid and simple method for evaluating ingredient digestibility. Shen et al. reported that feather meal pepsin digestibility between 70%–85% correlates parabolically with true amino acid digestibility. In this study, feather meal I' s pepsin digestibility fell outside this range, precluding direct prediction of its amino acid digestibility from pepsin digestibility alone. However, it could be inferred that feather meal III had higher amino acid digestibility than feather meal II.

3.2. Energy Metabolic Rate

Highly significant differences in energy metabolic rates were observed among the three feather meals in this study. Han and Parsons reported TMEn values of 13.10 and 13.47 MJ/kg for feather meal in cecectomized and non-cecectomized roosters, respectively. Barbour et al. obtained TMEn values of 13.79, 12.93, and 12.99 MJ/kg for pre-pressed, enzyme-treated, and conventionally processed turkey feather meal in turkeys, with energy metabolic rates of 60.47%, 58.10%, and 54.73%, respectively. Dale measured TMEn values ranging from 12.94–16.72 MJ/kg across 15 feather meal samples in roosters. Jiang et al. reported an AME value of 10.20 MJ/kg for feather meal in yellow-feathered broilers, substantially lower than the AME values obtained in this study (13.71, 12.29, and 12.10 MJ/kg), possibly due to the exceptionally high ash content (22.16%) in their feather meal, which would negatively impact AME. These results demonstrate considerable variation in ME among different feather meals. Previous research has shown that TMEn can be predicted from CP, EE, and ash contents. Dale derived the regression equation TMEn (MJ/kg) = 11.97 + 0.32 × EE (R^2 = 0.821) for feather meal in roosters. Additionally, processing parameters including steaming pressure, duration, pH, and enzymatic treatment affect feather meal utilization. To maximize utilization efficiency, this study employed processing parameters of 0.4 MPa pressure, 30-minute steaming time, pH 7, and subsequent protease hydrolysis, yielding high energy utilization rates for all three feather meals. Despite identical processing conditions, energy utilization differed among feather meals, likely attributable to inherent nutritional differences. This study found that feather meals with higher oil and CP contents and lower ash content also had higher GE. Since feather meal protein exceeds 80%, CP utilization necessarily influences GE metabolic rate. Liu et al. reported a linear correlation between feather meal TMEn and true amino acid utilization in 8-week-old turkeys. In this study, feather meal I exhibited the highest pepsin digestibility and correspondingly highest energy utilization, suggesting that differences in energy metabolic rates and ME values primarily stemmed from variations in CP utilization (i.e., amino acid utilization). Although feather meal III showed higher pepsin digestibility than feather meal II, its ME was lower, possibly because feather meal II had substantially higher EE content, and feather meal fat is highly utilizable.

3.3. Amino Acid Metabolic Rate

The study revealed highly significant differences in amino acid metabolic rates among feather meal types, with considerable variation in amino acid contents, resulting in different available amino acid contents. Significant differences were observed in total available amino acid and total available essential amino acid contents among the three feather meals. Bandegan et al. reported ileal apparent and true metabolic rates of 39%-74% and 42%-78% for feather meal in 8-week-old broilers, substantially lower than this study' s results, likely due to species differences in amino acid digestibility between chickens and ducks. Studies in barrows and broilers have demonstrated large variations in amino acid metabolic rates among different feather meals and shown that processing parameters affect amino acid metabolic rates. In this study, identical processing parameters were used for all three feather meals, suggesting that differences in amino acid metabolic rates resulted from variations in nutritional composition, though the specific mechanisms remain unclear. It is speculated that differences in growth cycles among meat ducks, laying hens, and yellow-feathered broilers led to varying degrees of feather keratinization, which in turn affected hydrolysis efficiency during processing and resulted in different amino acid metabolic rates. These findings indicate that under fixed processing parameters, feathers with lower keratinization degrees yield higher amino acid metabolic rates after steaming and enzymatic hydrolysis, suggesting that different feathers may require different processing parameters for optimal results.

In summary: In 7-week-old meat ducks, feather meals I, II, and III had GE values of 21.31, 21.02, and 20.18 MJ/kg, AME values of 13.71, 12.29, and 12.11 kJ/kg, and TME values of 14.83, 13.42, and 13.22 MJ/kg, respectively, on a DM basis. On a DM basis, all three feather meals contained over 80% TAA, though amino acid contents varied significantly among them. In 7-week-old meat ducks, the apparent metabolic rates of TAA were 81.51%, 73.07%, and 76.85%, while true metabolic rates were 85.09%, 76.89%, and 80.43% for feather meals I, II, and III, respectively, with significant differences in both apparent and true available amino acid contents.

References

[1] Li Xiaoyan, Yu Yang, Xiao Yingping, et al. In vitro protein digestibility of enzymatically hydrolyzed feather meal and its application effects in growing pig diets[J]. Chinese Journal of Animal Science, 2012, 48(15): 33-36.

[2] Senkoylu N, Samli H E, Akyurek H, et al. Performance and egg characteristics of laying hens fed diets incorporated with poultry by-product and feather meals[J]. The Journal of Applied Poultry Research, 2005, 14(3): 542-547.

[3] Van Heugten E, Van Kempen T A T G. Growth performance, carcass characteristics, nutrient digestibility and fecal odorous compounds in growing-finishing pigs fed diets containing hydrolyzed feather meal[J]. Journal Animal Science, 2002, 80(1): 171-178.

[4] Divakala K C, Chiba L I, Kamalakar R B, et al. Amino acid supplementation of hydrolyzed feather meal diets for finisher pigs[J]. Journal of Animal Science, 2009, 87(4): 1270-1281.

[5] Pedersen M B, Yu S, Plumstead P, et al. Comparison of four feed proteases for improvement of nutritive value of poultry feather meal[J]. Journal of Animal Science, 2012, 90(Suppl 4): 350-352.

[6] Shen Yinshu, Huo Qiguang, Qi Guanghai, et al. Study on true digestibility of amino acids in feather meal and its correlation with in vitro physicochemical indices[J]. Acta Veterinaria et Zootechnica Sinica, 2000, 31(1): 9-15.

[7] Sibbald I R. A bioassay for true metabolizable energy in feedingstuffs[J]. Poultry Science, 1976, 55(1): 303-308.

[8] Du Yiting, Gao Qing, Yang Yufeng, et al. Research progress on determining suitable conditions for the duck TME method[J]. Feed Industry, 2011, 32(15): 48-51.

[9] Zhang Liying. Feed Analysis and Feed Quality Detection Technology[M]. Beijing: China Agricultural University Press, 2006.

[10] Peng Kan, Luo Qigang, Ye Yuantu, et al. Preliminary study on changes in protein and oil safety quality during fish meal production[J]. Chinese Journal of Animal Nutrition, 2015, 27(8): 2637-2648.

[11] Yang Yong, Xie Shouqi, Liu Jiankang. Research on application of fish meal in aquaculture feed[J]. Journal of Fisheries of China, 2004, 28(5): 573-578.

[12] Han Y, Parsons C M. Protein and amino acid digestibility of feather meals[J]. Poultry Science, 1991, 70(4): 812-822.

[13] Barbour G W, Werling M, Yersin A G, et al. The effect of enzyme predigestion on the nutritional quality of prepressed turkey feather meal[J]. Poultry Science, 2002, 81(7): 1032-1037.

[14] Dale N. True metabolizable energy of feather meal[J]. Journal of Applied Poultry Research, 1992, 1(3): 331-334.

[15] Jiang Shouqun, Lin Yingcai, Ding Fayuan, et al. Study on metabolizable energy of feed for yellow-feathered broilers[J]. Chinese Journal of Animal Science, 2002, 38(5): 26-27.

[16] Ahmadi H, Golian A, Mottaghitalab M, et al. Prediction model for metabolizable energy of feather meal and poultry offal meal using group method of data handling-type neural network[J]. Poultry Science, 2008, 87(9): 1909-1912.

[17] Latshaw J D. Quality of feather meal as affected by feather processing conditions[J]. Poultry Science, 1990, 69(6): 953-958.

[18] Liu J K, Waibel P E, Noll S L. Nutritional evaluation of blood meal and feather meal for turkeys[J]. Poultry Science, 1989, 68(11): 1513-1518.

[19] Bandegan A, Kiarie E, Payne R L, et al. Standardized ileal amino acid digestibility in dry-extruded expelled soybean meal, extruded canola seed-pea, feather meal, and poultry by-product meal for broiler chickens[J]. Poultry Science, 2010, 89(12): 2626-2633.

[20] Fan Hongping, Hou Shuisheng, Wen Shaohui, et al. Comparative study on amino acid utilization of feed in chickens and ducks[J]. Chinese Journal of Animal Nutrition, 2006, 18(4): 237-243.

[21] Sulabo R C, Chiba L I, Almeida F N, et al. Amino acid and phosphorus digestibility and concentration of digestible and metabolizable energy in hydrolyzed feather meal fed to growing pigs[J]. Journal of Animal Science, 2013, 91(12): 5829-5837.

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