Development of a Prediction Equation for the Apparent Metabolizable Energy of Northeast Corn in Broilers: Postprint

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Abstract

This study aimed to establish regression equations between nutrient content and metabolizable energy of Northeast corn through laboratory analysis and broiler metabolism trials, providing a convenient method for estimating corn metabolizable energy in production. Experiment 1: Twenty types of Northeast corn with different maturity seasons were selected to determine nutrient content and bulk density, and to analyze the variation range of nutrient content. Experiment 2: Artificial corn was formulated using corn, corn bran, and corn grits according to NDF and ADF content gradients, with certain amounts of vitamins and minerals added to formulate artificial corn metabolic diets. Commercial Arbor Acres male broilers under normal feeding conditions were selected for metabolism trials. At 11-13 days and 25-27 days of age, the apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), and apparent nutrient digestibility of the artificial corn metabolic diets were determined using the total excreta collection method, and stepwise regression was used to establish regression equations for AME or AMEn with nutrient content. The results showed that the coefficients of variation for ether extract (EE), neutral detergent fiber (NDF), and acid detergent fiber (ADF) contents in Northeast corn were relatively large, at 16.72%, 14.65%, and 14.72%, respectively. The apparent nutrient digestibility of the artificial corn metabolic diets differed between 11-13 days and 25-27 days of age; the apparent digestibility of crude protein (CP), EE, and total starch (STC) in the artificial corn metabolic diets was significantly higher in 25-27-day-old broilers than in 11-13-day-old broilers ($P<0.05$). The AME and AMEn of the artificial corn metabolic diets were also significantly higher in 25-27-day-old broilers than in 11-13-day-old broilers ($P<0.05$). The prediction equations for metabolizable energy of Northeast corn in broilers established by stepwise regression were: at 11-13 days, $AME=17.661-0.853\times ADF(R^2=0.870,P<0.01)$,

AMEn=17.468-0.878×ADF(R^2=0.873,P<0.01); at 25-27 days, AME=18.102-0.792×ADF(R^2=0.781,P<0.05), AMEn=17.935-0.830×ADF(R^2=0.784,P<0.05). The predicted values of AME for the artificial corn metabolic diets calculated through the prediction equations were very close to the measured values, and the calculated AME values for Northeast corn were consistent with expected values. It was concluded that the contents of EE, NDF, and ADF differed relatively greatly among different varieties of Northeast corn; metabolizable energy of corn differed between broiler stages, and corresponding metabolizable energy values should be used when formulating broiler diets at different stages; for broilers younger than 14 days, the prediction equations for AME and AMEn of Northeast corn were AME=17.661-0.853×ADF and AMEn=17.468-0.878×ADF, respectively; for broilers older than 14 days, the prediction equations for AME and AMEn of Northeast corn were AME=18.102-0.792×ADF and AMEn=17.935-0.830×ADF, respectively.

Full Text

Prediction Equation of Apparent Metabolizable Energy of Corn in Northeast China for Broilers

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Abstract

This study aimed to establish regression equations for metabolizable energy of corn in Northeast China for broilers based on nutrient contents using laboratory analysis and metabolic testing methods, in order to provide a convenient estimation approach for corn metabolizable energy in production. In trial 1, twenty corn varieties from Northeast China with different maturity seasons were used to measure nutrient contents and volume-weight, and to analyze variation ranges of nutrient contents. In trial 2, artificial corn metabolic diets were formulated using artificial corn plus vitamins and minerals, where the artificial corn was prepared from corn, samp, and corn bran based on graded levels of neutral detergent fiber (NDF) and acid detergent fiber (ADF). Arbor Acres broilers raised under normal production conditions were used to complete metabolism tests at 11-13 days and 25-27 days of age using the total collection method. The apparent metabolizable energy (AME), nitrogen-corrected apparent metabolizable energy (AMEn), and nutrient apparent digestibility of artificial corn metabolic diets for broilers were measured, and stepwise regression was used to establish regression equations for AME or AMEn based on nutrient contents. The results showed that the coefficients of variation for ether extract (EE), NDF, and ADF contents of corn in Northeast China were relatively large at 16.72%, 14.65%, and 14.72%, respectively. Nutrient apparent digestibility of artificial corn metabolic diets differed between 11-13 days and 25-27 days of age. Broilers fed artificial corn metabolic diets at 25-27 days showed significantly greater crude protein (CP), EE, and total starch (STC) apparent digestibility, AME, and AMEn than those at 11-13 days ($P<0.05$).

The prediction equations for metabolizable energy of corn in Northeast China for broilers using stepwise regression were: AME=17.661-0.853×ADF ($R^2=0.870$, $P<0.01$) and AMEn=17.468-0.878×ADF ($R^2=0.873$, $P<0.01$) for 11-13 days; AME=18.102-0.792×ADF ($R^2=0.781$, $P<0.05$) and AMEn=17.935-0.830×ADF ($R^2=0.784$, $P<0.05$) for 25-27 days. Calculated AME values for artificial corn metabolic diets using these prediction equations were close to measured values, and calculated AME values for corn in Northeast China met expected values.

In conclusion, the differences in EE, NDF, and ADF contents of corn in Northeast China are relatively large among varieties. Different stage diets should use corresponding metabolizable energy values when formulating broiler feed, as broilers at different stages have different corn metabolizable energy values. The prediction equations for AME and AMEn of corn in Northeast China are AME=17.661-0.853×ADF ($R^2=0.870$, $P<0.01$) and AMEn=17.468-0.878×ADF ($R^2=0.873$, $P<0.01$) for broilers less than 14 days of age, and AME=18.102-0.792×ADF ($R^2=0.781$, $P<0.05$) and AMEn=17.935-0.830×ADF ($R^2=0.784$, $P<0.05$) for broilers more than 14 days of age.

Key words: corn; metabolic energy; nutrient; prediction equation

1. Materials and Methods

1.1. Nutrient Content Analysis of Corn Samples

Twenty corn varieties from Northeast China with different maturity seasons were collected to measure nutrient contents and volume-weight (VW). The variation ranges of nutrient contents were analyzed. All samples were ground through a 0.42 mm sieve. Dry matter (DM) content was determined according to GB/T 6435-2006, crude protein (CP) according to GB/T 6432-1994, ether extract (EE) according to GB/T 6433-2006, total starch (STC) using a Megazyme kit (K-TSTA), crude fiber (CF) according to GB/T 6433-2006, neutral detergent fiber (NDF) according to GB/T 20806-2006, acid detergent fiber (ADF) according to GB/T 20806-2006, and gross energy (GE) using a bomb calorimeter. Volume-weight was measured according to GB 1353-1999. All analyses were performed in duplicate.

1.2. Metabolic Experiment

1.2.1. Artificial Corn Metabolic Diets Artificial corn metabolic diets were formulated using artificial corn with added vitamins and minerals. The artificial corn was prepared from corn, samp, and corn bran based on graded NDF and ADF levels. The diets were formulated to contain different CP, EE, STC, NDF, and ADF levels. The composition and nutrient levels of the artificial corn metabolic diets are shown in Table 1 .

Table 1 Composition and nutrient levels of artificial corn metabolic diets (DM basis), %

Note: Vitamin premix provided per kilogram of diet: VA 12,000 IU, VD_3 2,500 IU, VE 30 IU, VK_3 2.65 mg, VB_1 2 mg, VB_2 6 mg, VB_{12} 0.025 mg, biotin 0.0325 mg, folic acid 1.25 mg, pantothenic acid 12 mg, niacin 50 mg. Trace-mineral premix provided per kilogram of diet: Cu 8 mg, Fe 80 mg, Mn 100 mg, Zn 100 mg, Se 0.30 mg, I 0.35 mg.

1.2.2. Experimental Animals and Design Nine hundred 1-day-old Arbor Acres broilers were randomly allocated to 11 treatments with 6 replicates of 15 birds each. The experiment included two phases: 11–13 days and 25–27 days of age. Broilers were housed in stainless steel cages (1.0 × 0.5 × 0.3 m) with 15 birds per cage. The room temperature was maintained at 32°C for the first 3 days and then gradually reduced to 24°C. Lighting was continuous. Feed and water were provided ad libitum. The artificial corn metabolic diets were fed for 3 days adaptation followed by 4 days total collection of excreta.

1.2.3. Measurement of AME and AMEn Apparent metabolizable energy was calculated using the total collection method. The AME and AMEn of artificial corn metabolic diets were calculated as follows:

$$AME(MJ/kg\ DM) = \frac{FI \times GE_i - FE \times GE_e}{FI}$$

$$AMEn(MJ/kg\,DM) = AME - \frac{RN \times 34.39}{FI} = AME - \frac{(FI \times N_i - FE \times N_e) \times 34.39}{FI}$$

where FI is feed intake (kg), FE is excreta output (kg), GE_i is gross energy of feed (MJ/kg), GE_e is gross energy of excreta (MJ/kg), RN is nitrogen retention (g), N_i is nitrogen content of feed (%), and N_e is nitrogen content of excreta (%).

Nutrient apparent digestibility (%) was calculated as:

$$\text{Nutrient apparent digestibility} = \frac{\text{Nutrient intake} - \text{Nutrient excreted}}{\text{Nutrient intake}} \times 100$$

The AME and AMEn of corn were calculated as:

$$AME_{corn}(MJ/kg\ DM) = \frac{AME_{diet} - (1 - X) \times AME_{basal}}{X}$$

where X is the proportion of corn in the diet (0.9615).

1.3. Statistical Analysis

Data were analyzed using SPSS 16.0 software. One-way ANOVA was used to determine treatment effects, and Duncan' s multiple range test was used for multiple comparisons. Significance was declared at P<0.05 and P<0.01. Correlation analysis was performed between AME, AMEn, and nutrient contents. Stepwise regression was used to establish prediction equations for AME and AMEn.

2. Results

2.1. Nutrient Contents of Corn Samples

The nutrient contents and volume-weight of 20 corn varieties from Northeast China are presented in Table 2 . The average values were: CP 9.46%, EE 4.07%, STC 68.64%, NDF 9.21%, ADF 1.93%, CF 2.78%, GE 18.83 MJ/kg, and VW 748.73 g/L. The coefficients of variation for EE, NDF, and ADF were relatively large at 16.72%, 14.65%, and 14.72%, respectively, indicating significant variation among corn varieties.

Table 2 Conventional nutrient contents of 20 kinds of corn in Northeast China (DM basis)

2.2. Correlation Analysis of Nutrient Contents

Correlation analysis showed that CP was positively correlated with EE (r=0.905, P<0.01) and negatively correlated with STC (r=-0.860, P<0.01). EE was negatively correlated with STC (r=-0.874, P<0.01). NDF was positively correlated with ADF (r=0.981, P<0.01) and negatively correlated with STC (r=-0.807, P<0.01). ADF was positively correlated with NDF (r=0.981, P<0.01) and negatively correlated with STC (r=-0.852, P<0.01). These correlations are presented in Table 3 .

Table 3 Correlation analysis of conventional nutrient contents of artificial corn metabolic diets

Note: ** indicates extremely significant correlation (P<0.01).

2.3. AME, AMEn, and Nutrient Apparent Digestibility

2.3.1. Effects of Age on Energy Values and Digestibility Broilers aged 25-27 days showed significantly higher AME and AMEn of artificial corn metabolic diets compared to those aged 11-13 days (P<0.01). The apparent digestibility of EE, STC, NDF, and ADF was also significantly higher in older broilers (P<0.01), while CP digestibility was not significantly different (P>0.05). The interaction between age and diet was significant for AME, AMEn, and nutrient digestibility (P<0.01). These results are summarized in Table 4 .

Table 4 Measured results of AME, AMEn, nutrient apparent digestibility and BWG of broilers

2.3.2. Prediction Equations for AME and AMEn Stepwise regression analysis showed that ADF was the best predictor of AME and AMEn for both age groups. The prediction equations are:

For 11-13 days of age:

$$AME = 17.661 - 0.853 \times ADF\ (R^2 = 0.870,\ P < 0.01)$$

$$AMEn = 17.468 - 0.878 \times ADF\ (R^2 = 0.873,\ P < 0.01)$$

For 25-27 days of age:

$$AME = 18.102 - 0.792 \times ADF\ (R^2 = 0.781,\ P < 0.05)$$

$$AMEn = 17.935 - 0.830 \times ADF\ (R^2 = 0.784,\ P < 0.05)$$

The stepwise selection of regression models is presented in Table 5 .

Table 5 Stepwise selection of regression models for AME and AMEn based on nutrient composition of corn in Northeast China

2.3.3. Validation of Prediction Equations The calculated AME values for artificial corn metabolic diets using the prediction equations were close to measured values (Table 6). The calculated AME values for corn in Northeast China met expected values, indicating the equations are reliable for practical use.

Table 6 Comparison of calculated and measured AME and AMEn values of artificial corn metabolic diets for broilers (MJ/kg DM)

3. Discussion

3.1. Variation in Corn Nutrient Contents

The coefficients of variation for EE, NDF, and ADF contents in Northeast China corn were relatively large (16.72%, 14.65%, and 14.72%, respectively), consistent with previous reports [1-3]. The average CF content of 2.78% was higher than the 1.70% reported in some studies [2], while STC content of 68.64% was slightly lower than the 73.21% reported elsewhere [2]. These variations may be attributed to differences in corn varieties, growing conditions, and processing methods [4-6].

3.2. Age-Related Differences in Energy Utilization

Broilers aged 25-27 days showed significantly higher AME, AMEn, and nutrient digestibility compared to 11-13 days, consistent with previous findings that older birds have better-developed digestive systems and can utilize nutrients more efficiently [7, 8]. The significant interaction between age and diet indicates that the effect of diet composition on energy utilization differs with age, suggesting that age-specific prediction equations are necessary.

3.3. Prediction Equations for Metabolizable Energy

The prediction equations developed in this study using ADF as the sole predictor showed high accuracy (R^2=0.870-0.873 for younger birds, R^2=0.781-0.784 for older birds). This simplicity is practical for feed formulation. Previous studies have reported various prediction equations using different nutrient parameters [9, 10]. For example, some equations include multiple nutrients such as CP, EE, CF, NDF, and STC [2], while others use only ADF or CF [1]. The current equations are specific to Northeast China corn and broiler age groups, improving accuracy for local feed formulation.

The validation results showed that calculated AME values closely matched measured values, confirming the reliability of the equations. The age-specific equations account for differences in digestive capacity, providing more accurate energy values for precision feeding.

4. Conclusion

The differences in EE, NDF, and ADF contents among corn varieties in Northeast China are relatively large. Broilers at different ages exhibit different metabolizable energy values for corn, so stage-specific energy values should be used in feed formulation. The prediction equations for AME and AMEn of Northeast China corn for broilers are:

For broilers <14 days:

$$AME = 17.661 - 0.853 \times ADF \ (R^2 = 0.870,\ P < 0.01)$$

$$AMEn = 17.468 - 0.878 \times ADF \ (R^2 = 0.873,\ P < 0.01)$$

For broilers >14 days:

$$AME = 18.102 - 0.792 \times ADF \ (R^2 = 0.781,\ P < 0.05)$$

$$AMEn = 17.935 - 0.830 \times ADF \ (R^2 = 0.784,\ P < 0.05)$$

These equations provide a convenient and accurate method for estimating corn metabolizable energy in broiler production.

References

[1] Zhang et al. Prediction of metabolizable energy of corn for broilers[J]. Chinese Journal of Animal Science, 1981, 12(4): 223-230.

[2] Zhao. Study on metabolizable energy of corn for poultry[D]. Master' s thesis, China Agricultural University, 2008: 14-35.

[3] Alvarenga RR, Rodrigues PB, Zangeronimo MG, et al. Validation of prediction equations to estimate the energy values of feedstuffs for broilers: performance and carcass yield[J]. Asian-Australasian Journal of Animal Sciences, 2013, 26(10): 1474-1483.

[4] Cowieson AJ. Factors that affect the nutritional value of maize for broilers[J]. Animal Feed Science and Technology, 2005, 119(3/4): 293-305.

[5] O' Neill HVM, Liu N, Wang JP, et al. Effect of xylanase on performance and apparent metabolisable energy in starter broilers fed diets containing one maize variety harvested in different regions of China[J]. Asian-Australasian Journal of Animal Sciences, 2012, 25(4): 515-523.

[6] Yegani M, Korver DR. Effects of corn source and exogenous enzymes on growth performance and nutrient digestibility in broiler chickens[J]. Poultry Science, 2013, 92(5): 1208-1220.

[7] Batal AB, Parsons CM. Effects of age on nutrient digestibility in chicks fed different diets[J]. Poultry Science, 2002, 81(3): 400-407.

[8] Wang, Zhang. Research on metabolizable energy of corn for broilers[J]. Feed Industry, 2006, 18(1): 1-5.

[9] Meloche KJ, Kerr BJ, Shurson GC, et al. Apparent metabolizable energy and prediction equations for reduced-oil corn distillers dried grains with solubles in broiler chicks from 10 to 18 days of age[J]. Poultry Science, 2013, 92(12): 3176-3183.

[10] Li. Study on metabolizable energy of corn and its influencing factors[D]. PhD thesis, Northeast Agricultural University, 2014: 38-50.

[11] Kato RK, Bertechini AG, Fassani EJ, et al. Metabolizable energy of corn hybrids for broiler chickens at different ages[J]. Ciência e Agrotecnologia, 2011, 35(6): 1218-1226.

[12] Huang KH, Ravindran V, Li X, et al. Influence of age on the apparent ileal amino acid digestibility of ingredients in broiler chickens[J]. British Poultry Science, 2005, 46(2): 236-245.

[13] De Lima MB, Rabello CBV, De Silva EP, et al. Effect of broiler chicken age on ileal digestibility of corn germ meal[J]. Acta Scientiarum Animal Sciences, 2012, 34(2): 137-141.

[14] Liu. Study on metabolizable energy of corn for poultry[D]. Master' s thesis, China Agricultural University, 2008: 31-40.

[15] Zhao F, Zhang HF, Hou SS, et al. Predicting metabolizable energy of normal corn from its chemical composition in adult Pekin ducks[J]. Poultry Science, 2008, 87(8): 1603-1608.

[16] Pishnamazi A, Pourreza J, Edriess MA, et al. Influence of broiler breeder and laying hen breed on the apparent metabolizable energy of selected feed ingredients[J]. International Journal of Poultry Science, 2005, 4(3): 163-166.

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