Energy and Nitrogen Balance of Pigs Fed Four Corn Grains

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Story in Brief

Because corn is the primary energy source in diets for pigs, any variability in available energy content of the corns used could have a large economic impact on producers. These concerns could be minimized by more accurate determination of energy content of specific corn varieties. This study was conducted to determine the energy and nitrogen balance of growing pigs fed diets containing four corn grains (A, B, C, and D). Corns A, C, and D were normal varieties while corn B was a high-oil variety. Six sets of four littermate barrows (60.6 lb) were fed one of four diets, each containing one of the four corn grains at 90.48%. Pigs were individually housed in metabolism chambers, which allowed for the separate collection of feces and urine. Pigs were allowed a 7-d adjustment period to the diets followed by a 5-d collection of feces and urine. Because the diet gross energy concentrations for the four respective diets were 4,428, 4,718, 4,542, and 4,507 kcal/kg, and the percentage energy utilization of the diets was similar, the metabolizable energy concentrations were 3,868, 4,127, 4,006, and 3,935 kcal/kg. Nitrogen absorption and retention were similar for the diets containing the four corns. Adjusted ME concentrations of corns A, B, C, and D, on an as-fed basis, were 3,600, 3,841, 3,660, and 3,625 kcal/kg. These results suggest a large variation in metabolizable energy concentration of corn grains as a result of variations in gross energy attributed to varying nutrient compositions. However, nitrogen digestibility of pigs appears to be similar for the corns fed in this study.

Key Words: Corn, Metabolizable Energy, Pigs

Introduction

Due to the relatively high level of inclusion of corn as the primary energy source in diets fed to pigs, it is a major percentage of the cost of swine feeds. Thus, determining the amount of available energy content in specific varieties of corn could allow for more specific diet formulation. Cromwell et al. (1999) observed variability of nutrient composition of corn samples, depending on their area of origin. Kim et al. (1999) reported that there was about a 5% (±100 kcal/kg) variation in the metabolizable energy (ME) concentrations among corn samples.

A wide range of energy values of corn have been reported by a number of studies. Fent et al. (2000) reported an average ME value of three corn hybrids to be 3525 kcal/kg (as-fed bais). Kim et al. (1999) analyzed 21 corn samples and determined the average as-fed ME content to be 3,408 kcal/kg. According to NRC (1998), the as-fed metabolizable energy concentration of corn is 3,397 kcal/kg. Adeola and Bajjalieh (1997) analyzed one normal corn and three high-oil corns and found an average ME concentration of 3,698 kcal/kg on an as-fed basis. Thus, as seen by the variation in published values, the determination of metabolizable energy content of various varieties of corn would assist in more specific diet formulation. The objective of this study was to determine the metabolizable energy concentration of four corn grains (A, B, C, and D) through the use of a total collection energy and nitrogen balance experiment.

Materials and Methods

Twenty-four barrows initially averaging 60.6 lb BW were allotted in a randomized complete block design to four dietary treatments with six replicates per treatment. The barrows were allotted based on weight, keeping average replicate weights similar and littermates spread across treatments. Four diets were formulated to contain 90.48% of one of four corn grains (A, B, C, and D; Table 1). Corns A and B were nearly isogenic with A being normal corn, while B was a high-oil variety. Corns C and D were also normal varieties. Casein and amino acids were added to the diets to meet or exceed amino acid requirements, and limestone and dicalcium phosphate were utilized as sources of calcium and phosphorus. The four corn grains were each mixed thoroughly with the specified ingredients in a horizontal paddle mixer. Pigs were housed in metabolism chambers (Figure 1) that allowed for the separate collection of feces and urine. Pigs were allowed *ad libitum* access to water and an effort was made to keep feed intakes similar within replicate. The amount of feed consumed and feed wastage were also measured over the 5-d collection period.

Figure 1. Example of a metabolism chamber with feeder removed from front.

Table 1. Composition of diets (as-fed basis)[a]

Ingredient	**%**
Corn	90.48
Casein, dried	5.04
L-Lysine HCl	.50
DL-Methionine	.17
L-Threonine	.25
L-Tryptophan	.08
L-Isoleucine	.13
L-Valine	.04
Dicalcium phosphate	2.19
Limestone	.57
Salt	.25
Trace mineral/vitamin	.30
Calculated composition (%)	
Total lysine	1.00
Calcium	.80
Phosphorus	.70

[a]Corns A, B, C, and D were added to constitute the four diets.

Prior to collection, pigs underwent a 7-d adjustment period to the chambers and their respective dietary treatments. Then a 5-d period was used for the total but separate collection of feces and urine. Chromic oxide (.2%) was fed in the morning feeding on d 0 and 5 of the collection period for the purpose of a fecal marker to signify the beginning and ending of fecal collection. During the collection period, all feces and urine were collected, and fecal weight and urine volumes were recorded. Urine was collected daily in a pan that contained 10 mL HCl. Approximately 120 mL of the daily urine output from each pig was stored frozen (-20°C). Later, they were allowed to thaw at room temperature and were composited into one sample per pig. These subsamples were then stored at -20°C until subsequent analysis. Total feces collected per pig were dried for 96 h at 50°C. The total dried feces were ground through a 1-mm screen in a Wiley mill and stored for subsequent analysis.

Dry matters were determined for the corn grains, the four treatment diets, and the fecal samples by drying a subsample of each at 100°C for 24 h. Partially-dried fecal subsamples and as-is subsamples of the corn grains and the four diets were pelleted (approximately 1 g) and combusted in a bomb calorimeter for determination of gross energy. Nitrogen content of the corn grains, diets, and feces was analyzed using the Kjeldahl procedure. For urine analysis, Solkafloc[â] samples, a cellulose product, were dried at 100°C for 24 h to achieve a dry matter state and were weighed prior to and following drying. A 2-mL subsample of each composited urine sample was added to approximately .5 g of dry Solkafloc[â]. This wet mixture was weighed and then dried at 50°C for 24 h. The samples were then weighed and each sample was pelleted and later combusted to determine gross energy in a bomb calorimeter. Since the gross energy determined was for the Solkafloc[â]/urine mixture, calculations were made to determine the actual gross energy of the urine portion. Urine samples were analyzed for nitrogen content using the Kjeldahl procedure.

Data were analyzed as a randomized complete block design using analysis of variance procedures as described by Steel et al. (1997). The model contained the effects of block (rep), treatment, and block x treatment, which served as the error term. Pre-planned non-orthogonal contrasts were used to separate treatment means. Pig served as the experimental unit.

In a previous experiment in our lab, the metabolizable energy concentration of casein for pigs was determined. This analyzed ME on a DM basis was 4,560 kcal/kg. In order to determine the ME concentration of the corn grains in the experimental diets, the ME supplied by casein was subtracted from the ME of the diets, assuming that the only other ME supplied in the diet was supplied by casein. Since casein was included at 5.04% of the diet, then the ME supplied by casein was 230 kcal/kg (4560 * 0.0504). After subtracting this value, the resulting value was divided by the percentage of corn in the diet (90.48%), which resulted in ME of the corn on a DM basis.

Results and Discussion

All data are reported on a dry matter basis unless otherwise noted. Composition of the grains and diets are included within Tables 2 and 3. Average daily feed intake was greater ($P<.09$) for pigs consuming the diet containing corn A as compared with the diets containing corns B and D (Table 2). Daily fecal excretion and urine excretion were similar ($P=.11$) for all treatments.

Energy. All energy balance data are reported in Table 2. The gross energy concentrations of the four corn grains A, B, C, and D were 4,462, 4,761, 4,594, and 4,601 kcal/kg, and the gross energy of the respective diets were 4,428, 4,718, 4,542, and 4,507 kcal/kg. Fecal energy concentration was highest ($P<.01$) for pigs fed the diet containing corn B and lowest ($P<.02$) for those fed the diet containing corn C. Because little variation was observed in daily fecal excretion, only slight differences ($P=.11$) were found for the amount of fecal energy excreted per day. After substracting the energy excreted in the feces from the gross energy intake and adjusting for daily feed intake, the resulting digestible energy concentrations were 3,924, 4,186, 4,061, and 3,990 kcal/kg with each of the diets containing the respective corn grains being different (P<.04) from one another. Urinary energy concentration was greater (P<.08) in pigs fed the diet containing corn B than those fed the diet containing corn D. Because little variability was observed in dry matter urine excretion, calculation for urinary energy excreted per day resulted in no differences (P>.10). Subtracting the urinary gross energy excretion from the digestible energy concentration and adjusting for feed intake resulted in metabolizable energy concentrations of 3,868, 4,127, 4,006, and 3,935 kcal/kg for the respective diets with each of the diets being different (P<.04) from one another. The metabolizable energy as a percentage of gross energy were similar (P>.10) among treatments. Also, digestible energy as a percentage of gross energy and the content of metabolizable energy as a percentage of digestible energy were similar (P>.10) for all four dietary treatments.

Table 2. Energy balance of pigs fed four corn grains (DM basis)

Diet:	1	2	3	4	
Item Grain:	A	B	C	D	SE
Grain GE, kcal/kg	4,462	4,761	4,594	4,601	
Grain ash, %	1.32	1.41	1.39	1.46	
Grain fat, %	3.60	7.43	4.59	5.62	
GE (diet), kcal/kg	4,428	4,718	4,542	4,507	
ADFI, g/d	1,231[a]	1,122[b]	1,186[ab]	1,101[b]	41.7
GE intake, kcal/d	5,452	5,291	5,387	4,965	188
Daily fecal excr., g/d	128.1	116.4	120.3	115.3	4.93
Fecal GE, kcal/kg	4,675[a]	4,904[b]	4,580[c]	4,692[a]	23.6
Fecal GE excr., kcal/d	627	598	577	566	23.8
Daily urine excr., g/d	28.0	26.4	25.8	24.7	1.92
Urine GE, kcal/kg	2528[ab]	2,659[a]	2,572[ab]	2,407[b]	85.4
Urine GE excr., kcal/d	70.2	67.6	66.6	60.0	5.15
DE, kcal/d	4,825	4,693	4,810	4,399	172
DE, kcal/kg	3,924[a]	4,186[b]	4,061[c]	3,990[d]	18.9
ME, kcal/d	4,755	4,626	4,744	4,339	170
ME, kcal/kg	3,868[a]	4,127[b]	4,006[c]	3,935[d]	19.2
DE:GE, %	88.62	88.72	89.42	88.54	.416
ME:DE, %	98.57	98.61	98.64	98.63	.110
ME:GE, %	87.36	87.48	88.20	87.32	.425

[a,b,c,d]Least squares means within the same row with different superscripts differ P<.10.

Nitrogen. All nitrogen data are reported in Table 3. Nitrogen intake was greater (P<.09) for pigs consuming the diet containing corn C than pigs consuming diets containing corns B and D. Due to little differences (P=.12) in daily fecal nitrogen excretion, nitrogen absorption (g/d) followed the same trend as nitrogen intake. Because few differences (P>.10) were found for daily urinary nitrogen excretion, nitrogen retained (g/d) followed the same trend as nitrogen absorbed. However, nitrogen absorption and nitrogen retention, as a percentage of intake, were not different (P>.10) for the four dietary treatments.

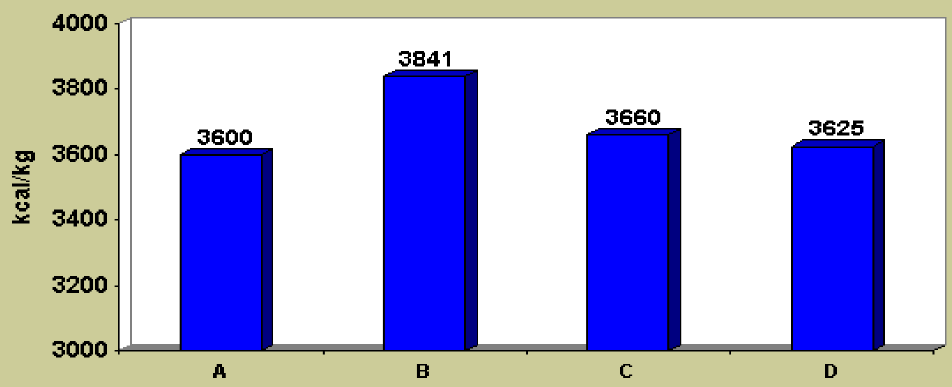
Table 3. Nitrogen balance of pigs fed four corn grains (DM basis)

Item	Diet: Grain:	1 A	2 B	3 C	4 D	SE
Grain N, %		1.397	1.463	1.515	1.443	
Grain CP, %		8.73	9.14	9.47	9.02	
Diet N, %		2.221	2.268	2.389	2.326	
Diet CP, %		13.88	14.17	14.93	14.54	
N intake, g/d		27.35[ab]	25.43[a]	28.33[b]	25.65[a]	.961
Fecal N excr., g/d		4.330	3.961	4.485	4.400	.223
N absorbed, g/d		23.02[ab]	21.47[a]	23.85[b]	21.25[a]	.904
N absorption, %		84.25	84.37	84.48	82.74	.942
Urine N excr., g/d		4.209	4.146	3.980	3.809	.217
N retained, g/d		18.81[ab]	17.32[a]	19.87[b]	17.44[a]	.782
N retention, %		69.12	68.49	70.62	67.78	1.08
N retained: N absorbed		.820[ab]	.812[a]	.836[b]	.819[ab]	.857

[a,b]Least squares means within the same row with different superscripts differ $P<0.10$.

ME of Corns. The metabolizable energy concentrations of the diets were corrected to a metabolizable energy concentration of each of the respective corn grains on an as-fed basis. In a previous experiment in our lab, the ME concentration of casein for pigs was determined to be 4,560 kcal/kg (DM basis). Thus, in the present experiment, the ME supplied by casein was subtracted from the ME of the diets, assuming that the only other ME supplied in the diet was supplied by casein. Since casein was included at 5.04% of the diet, then the ME supplied by casein was 230 kcal/kg (4560 * 0.0504). After subtracting this value, the resulting value was divided by the percentage of corn in the diet (90.48%), which resulted in ME of the corn grains on a DM basis. After adjusting for moisture content, the as-fed metabolizable energy concentrations of the corn grains A, B, C, and D were 3,600, 3,841, 3,660, and 3,625 kcal/kg, respectively (Figure 2). The 6.5% variation between the ME content of these four corn grains is similar to the 5% variation reported by Kim et al. (1999). The metabolizable energy concentrations of the corn grains used in this study are similar to those reported by Adeola and Bajjalieh (1997) who evaluated one normal and three high-oil corns and found an average ME of 3,698 kcal/kg (as-fed basis). However, the ME values are higher than those reported by Kim et al. (1999), as well as NRC (1998) and Fent et al. (2000). This increase in ME concentrations in the present experiment could be attributed to a higher fat content in these corn grains, especially corn grain B.

Figure 2. Adjusted ME of corn grains (as-fed basis)



Implications

This study indicates that energy concentrations of the four corn grains were variable, but the nitrogen absorption and retention of pigs fed these grains were not different. Although differences were observed in energy content of the grains, the efficiency of energy utilization was not different as shown by the similarities in the metabolizable energy to gross energy ratios. From this experiment, it seems that grains higher in fat content result in higher gross energy concentrations, but the efficiency with which this energy is utilized is similar to corns containing relatively low amounts of fat. More research is needed to determine specific metabolizable energy concentrations of feedstuffs for more specific diet formulation in order to improve economic efficiency.

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