



Ileal and total tract apparent crude protein, dry matter, gross energy and amino acids digestibility of soybean meal, solvent-extracted canola meal, and corn distillers dried grain with solubles for growing pigs

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ABSTRACT

The present study was conducted to determine the apparent total tract digestibility (ATTD) and apparent ileal digestibility (AID) of dry matter (DM), gross energy (GE), crude protein (CP), and amino acids (AA) in soybean meal (SBM), solvent-extracted canola meal (SECM) and corn distiller dried grain with solubles (corn-DDGS) for growing pigs. Three growing barrows (Landrace × Yorkshire × Duroc, 33.37±1.11 kg of BW) fitted with a simple T-cannula at the distal ileum were fed 31.61% SBM, 39.33% SECM, or 52.17% corn-DDGS as the sole protein source diets in a 3 × 3 Latin square design with 3 diets and 3 periods. The ATTD and AID for DM, CP, and GE in SBM were greater than in corn-DDGS. Similarly, the ATTD and AID of CP in SBM were greater than in SECM. SBM had greater AID for phenylalanine, cystine, proline, and tyrosine than corn-DDGS. SBM had greater AID for lysine, methionine, threonine, valine, aspartic acid, glutamic acid, glycine, serine, total essential AA, total non-essential AA, and total AA than SECM and corn-DDGS. SECM had greater AID for lysine, aspartic acid, glycine, and tyrosine, but less glutamic acid than corn-DDGS. In conclusion, the results imply that SBM had greater ATTD and AID of DM and GE than corn-DDGS. The values of AID of N and the majority of AA were higher in SBM than in SECM and corn-DDGS.

Key words: Corn distillers dried grains with soluble, Growing pigs, Nutrient digestibility, Soybean meal, Solvent-extracted canola meal

Soybean meal (SBM), a by-product oil production from soybeans, is a premier ingredient as a protein source worldwide for animal diets owing to the high protein content, relatively well-balanced amino acids (AA) profile, and high digestibility. However, as the price of SBM has sharply risen, there is a need to replace SBM with cost-effective plant protein sources to reduce feed cost (Woyengo *et al.* 2014).

Canola meal (CM), as a co-product of canola processing for edible oil and biofuel, is frequently used as protein-rich feed ingredient for livestock. In comparison to SBM, CM contains less lysine but more indispensable amino acids (AA), particularly sulphur-containing AA (Kasprzak *et al.* 2016). Distillers dried grains with solubles (DDGS), a by-product of ethanol and beverage industries, has been

increasingly included in swine diets due to their relatively high level of crude protein (CP) and price competitiveness (Kim *et al.* 2017). The increased ethanol production results in increased DDGS available to feed industry. Information on the digestibility of AA in protein ingredients is very useful to enable formulation of diets that maximize the growth of pigs by providing appropriate amounts of dietary CP and AA. Thus, the objective of the present study was to evaluate the ileal and total tract apparent digestibility of DM, GE, CP, and AA in SBM, solvent-extracted canola meal (SECM), and corn-DDGS for growing pigs.

MATERIALS AND METHODS

Animals, experimental design, diets and sample collection: The experimental protocols describing the management and care of animals were reviewed and approved by the Animal Care and Use Committee of Dankook University. Three crossbred barrows ((Yorkshire × Landrace) × Duroc) with an initial body weight (BW) of 33.37±1.11 kg were surgically fitted with a simple T-cannula in the distal ileum according to Sauer *et al.* (1983). Following the surgery, pigs were housed individually in stainless steel metabolism crates in a temperature controlled room (28°C). Each crate was installed with a one-hole feeder

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and a nipple drinker. The comprehensive description of pre- and post-operative care was described by Li *et al.* (1994). All pigs were given a 2-wk recovery period before initiation of the experiments.

The experimental design was a 3 × 3 Latin square design with 3 diets and 3 periods. The dietary treatments consisted of three protein feedstuffs (SBM, SECM and corn-DDGS) which were the only source of protein (Table 1). The analyzed nutrients content of SBM, SECM and corn-DDGS are presented in Table 2. The daily feed allowance was provided equivalent to 4% of body weight. Daily feed was divided into two equal portions and offered in the morning and evening (0800 and 2000 h, respectively). Pigs were given *ad lib.* access to water throughout the study. All diets were fed in mash form. Chromic oxide was added as an indigestible marker at the level of 0.2% to enable digestibility determination (Fenton and Fenton 1979). Each nine-day experimental period included a five-day of adaptation to the diets, a two-day of feces collection and a two-day of ileal digesta collection. The fresh fecal samples were obtained once daily from the three piglets on the sixth and seventh days of each experimental period. Ileal digesta

Table 1. Ingredient composition of experimental diets, as-fed basis

Item	SBM	SECM	corn-DDGS
<i>Ingredients, %</i>			
Corn starch	58.37	52.21	39.43
SBM	31.61	-	-
SECM	-	39.33	-
Corn-DDGS	-	-	52.17
Soybean oil	3.50	2.92	2.00
Cellulose fibre	3.00	3.00	3.00
Dicalcium phosphate	2.02	1.14	1.50
Limestone	0.50	0.40	0.90
Salt	0.50	0.50	0.50
Vitamin and mineral premix ¹	0.30	0.30	0.30
Chromic oxide	0.20	0.20	0.20
Total	100	100	100
<i>Calculated analysis</i>			
Metabolizable energy, kcal/kg	3,651	3,944	3,480
<i>Analyzed composition</i>			
Crude protein (%)	15.13	15.37	15.21
Lysine (%)	0.98	0.87	0.52
Methionine (%)	0.27	0.35	0.31
Calcium (%)	0.74	0.79	0.75
Total phosphorus (%)	0.61	0.64	0.62

corn-DDGS, corn distiller dried grain with solubles; SBM, soybean meal; SECM, solvent-extracted canola meal. ¹The premix supplied per 1 kg of the diet: vitamin A, 10,000 IU; vitamin D₃, 1,300 IU; vitamin E, 40 IU; vitamin K (menadione bisulfate complex), 3.0 mg; vitamin B₂, 5.2 mg; vitamin B₆, 2.6 mg; vitamin B₁₂, 26 µg; niacin, 32 mg; and d-pantothenic acid (as d-calcium pantothenate), 20 mg; Cu (as CuSO₄·5H₂O), 19 mg; Fe (as FeSO₄·7H₂O), 70 mg; Zn (as ZnSO₄), 50 mg; Mn (as MnO₂), 50 mg; I (as KI), 0.5 mg; Co (as CoSO₄·7H₂O), 0.3 mg; and Se (as Na₂SeO₃·5H₂O), 0.2 mg.

Table 2. Analysis values of soybean meal (SBM), solvent-extracted canola meal (SECM), and corn distiller dried grain with solubles (corn-DDGS), as-fed basis

Item	SBM	SECM	corn-DDGS
Gross energy (kcal/kg)	4,423	5,444	4,752
Dry matter (%)	89.33	89.76	89.37
Crude protein (%)	48.45	38.57	28.58
Crude ash (%)	6.29	6.15	4.67
Crude fibre (%)	3.87	11.14	8.86
<i>Essential amino acids (%)</i>			
Arginine	3.43	2.76	1.37
Histidine	1.31	1.01	0.81
Isoleucine	2.17	1.55	1.12
Leucine	3.65	2.5	3.22
Lysine	3.03	2.15	0.93
Methionine	0.65	0.88	0.58
Phenylalanine	2.43	1.57	1.42
Threonine	1.77	1.64	1.04
Tryptophan	0.67	0.49	0.22
Valine	2.24	1.88	1.46
<i>Non-essential amino acids (%)</i>			
Alanine	2.07	1.66	2.17
Aspartic acid	5.57	2.61	2.19
Cystine	0.73	0.89	0.42
Glutamic acid	8.72	6.11	5.41
Glycine	1.91	1.83	1.18
Proline	2.26	1.97	2.44
Serine	2.21	1.64	1.52
Tyrosine	1.71	0.93	1.26

samples were collected using plastic bags tied to the cannula from 0800 and 2000 h on the eighth and ninth days of each experimental period. The plastic bags were replaced whenever they were filled with digesta, or at least once every 30 min, and stored at -20°C. The collected feces and digesta were pooled for each pig within an experimental period and frozen in a refrigerator at -20°C.

Chemical analyses: Before chemical analysis, feces samples were thawed, oven-dried at 65°C for three days, and sub-sampled. Ileal digesta samples were thawed, homogenized, sub-sampled, and freeze-dried. The three protein feedstuffs, diets, digesta, and feces were ground to pass through a 1 mm screen for subsequent analysis. All protein ingredients, feces and ileal digesta were analyzed for dry matter and CP as per AOAC (2007). Nitrogen (N) was measured using a Kjeltac 2300 Analyzer (Foss Tecator AB, Hoeganaes, Sweden). CP contents were calculated by multiplying the content of N with 6.25. The three protein ingredients were also analyzed for crude ash and crude fibre as per AOAC (2007). The gross energy (GE) in protein ingredients, diets, and feces were determined using a Parr 6100 oxygen bomb calorimeter (Parr Instrument Co., Moline, IL, USA).

Samples of feeds, three protein ingredients and digesta were also analyzed for concentration of amino acids. The

amino acids content, with the exception of methionine, cystine and tryptophan, were analyzed by an amino acid analyzer (Beckman 6300; Beckman Coulter, Inc., Fullerton, CA, USA), after 24 h hydrolysis with 6 N HCl at 110°C. Methionine and cystine were analyzed after cold performic acid oxidation overnight before hydrolysing with 7.5 N HCl at 110°C for 24 h. Tryptophan was determined after LiOH hydrolysis for 22 h at 110°C. The chromium concentration of diets feces and ileal digesta samples were determined via UV absorption spectrophotometry (UV-1201; Shimadzu, Kyoto, Japan) following the method described by Williams *et al.* (1962).

Calculations: The apparent total tract digestibility (ATTD) of GE, DM and N were calculated using the following formula:

$$\text{ATTD of nutrient} = [1 - \{(\text{Nf} \times \text{Cd}) / (\text{Nd} \times \text{Cf})\}] \times 100\%$$

where Nf, nutrient concentration in feces (% DM); Nd, nutrient concentration in diet (% DM); Cf, chromium concentration in feces (% DM); and Cd, chromium concentration in diet (% DM).

Values for AID of nutrients and amino acid were calculated according to the method described by Stein *et al.* (2007).

Statistical analysis: The data were analyzed according to a 3 × 3 replicated Latin square design using the GLM procedures of the SAS software (1998). Differences among treatment means were determined using the Tukey's range test. Treatment differences were considered significant at a level of 0.05.

RESULTS AND DISCUSSION

The increasing cost of pig diets using SBM as protein supply has triggered a search for alternative sources to SBM. CM and corn-DDGS have been used as substitutes for SBM to reduce feed cost. However, the nutritional values of these ingredients may vary largely due to the different growing conditions and genetic background and manufacturing processes (Maison and Stein 2014). Therefore, this study tested the AID of DM, GE, CP, and AA, and ATTD of DM, CP, and GE in SBM, SECM, and corn-DDGS for growing pigs. In the present study, the concentrations of DM, CA, CF, CP, and AA in SBM, SECM, and corn-DDGS were close to expected values (NRC 2012, Tanghe *et al.* 2015). Generally, in the current study, SBM had higher concentrations of chemical composition compared with SECM and corn-DDGS except for CF, methionine, cystine. SECM had higher concentrations of CF and cystine than SBM and corn-DDGS. Corn-DDGS had higher concentrations of proline and alanine than SBM and SECM. The differences in chemical composition between SBM, SECM, and corn-DDGS were also in agreement with differences in the digestibility of nutrients between these experimental protein ingredients. All animals remained healthy throughout the experiment. The ATTD and AID of DM, CP, and GE in SBM, SECM, and corn-DDGS are presented in Table 3. The ATTD and AID for DM, CP, and GE in SBM were greater ($P < 0.05$) than the ATTD and AID

for DM, CP, and GE in corn-DDGS used in this experiment (Table 3). Similarly, the ATTD and AID of CP in SBM were greater ($P < 0.05$) than the ATTD and AID of CP in SECM. The ATTD and AID of DM and GE in SBM were not

Table 3. The apparent ileal digestibility and apparent total tract digestibility of dry matter, crude protein, and gross energy in soybean meal (SBM), solvent-extracted canola meal (SECM), and corn distiller dried grain with solubles (corn-DDGS) for growing pigs

Item	SBM	SECM	corn-DDGS	SE ¹
<i>Apparent total tract digestibility (%)</i>				
Dry matter	81.62 ^a	79.47 ^{ab}	78.04 ^b	0.93
Crude protein	82.24 ^a	79.51 ^b	76.32 ^c	0.91
Gross energy	81.56 ^a	78.99 ^a	75.63 ^b	1.05
<i>Apparent ileal digestibility (%)</i>				
Dry matter	76.80 ^a	74.56 ^{ab}	73.73 ^b	0.90
Crude protein	79.05 ^a	72.12 ^b	68.20 ^b	0.89
Gross energy	77.30 ^a	75.46 ^{ab}	73.83 ^b	0.88

¹SE, pooled standard error. ^{a,b,c}Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

Table 4. The apparent ileal digestibility of amino acids in soybean meal (SBM), solvent-extracted canola meal (SECM), and corn distiller dried grain with solubles (corn-DDGS) for growing pigs

Item	SBM	SECM	corn-DDGS	SE ¹
<i>Essential amino acids (%)</i>				
Arginine	77.32	73.35	74.38	1.43
Histidine	82.6	81.08	79.37	1.12
Isoleucine	82.63 ^a	77.93 ^b	79.44 ^{ab}	1.27
Leucine	86.68 ^a	80.08 ^b	84.66 ^a	1.06
Lysine	88.55 ^a	71.93 ^b	59.97 ^c	0.88
Methionine	87.10 ^a	82.89 ^b	80.48 ^b	0.90
Phenylalanine	84.48 ^a	81.72 ^{ab}	79.08 ^b	1.18
Threonine	81.07 ^a	67.27 ^b	66.52 ^b	0.81
Valine	85.03 ^a	72.77 ^b	71.97 ^b	1.36
Total essential amino acids	83.94 ^a	76.56 ^b	75.10 ^b	0.65
<i>Non-essential amino acids (%)</i>				
Alanine	79.57	77.85	76.00	0.76
Aspartic acid	81.87 ^a	73.38 ^b	63.56 ^c	0.89
Cystine	79.82 ^a	76.97 ^{ab}	67.19 ^b	1.97
Glutamic acid	90.82 ^a	75.21 ^c	79.44 ^b	0.48
Glycine	78.26 ^a	71.88 ^b	54.30 ^c	0.84
Proline	72.12 ^a	69.08 ^{ab}	65.80 ^b	1.26
Serine	81.23 ^a	72.22 ^b	70.56 ^b	0.59
Tyrosine	79.03 ^a	77.71 ^a	73.51 ^b	0.87
Total non-essential amino acids	80.34 ^a	74.29 ^b	68.52 ^b	1.11
Total amino acids (%)	80.82 ^a	75.48 ^b	72.13 ^b	0.99

¹SE, pooled standard error; ^{a,b,c}Values in the same row without a common superscript letter are significantly different ($P < 0.05$).

different from the ATTD and AID of DM and GE in SECM ($P > 0.05$). The AID for AA in SBM, SECM, and corn-DDGS are presented in Table 4. There were no differences in AID of arginine, histidine, and alanine among SBM, SECM, and corn-DDGS ($P > 0.05$). SBM had greater AID for phenylalanine, cystine, proline, and tyrosine than corn-DDGS ($P < 0.05$). SBM had greater ($P < 0.05$) AID for lysine, methionine, threonine, valine, aspartic acid, glutamic acid, glycine, serine, total essential AA, total non-essential AA, and total AA than SECM and corn-DDGS; but no differences between SECM and corn-DDGS were observed for AID of methionine, threonine, valine, serine, total essential AA, total non-essential AA and total AA ($P > 0.05$). However, SECM had greater AID for lysine, aspartic acid, glycine, and tyrosine, but less glutamic acid than corn-DDGS ($P < 0.05$). In agreement with the present study, González-Vega and Stein (2012) reported that CM had less AID of CP, essential AA and non-essential AA, except for methionine, alanine, cystine, glutamic acid, glycine, proline, than SBM. Data from NRC (2012) and Adebisi *et al.* (2015) also indicated that AID values for CP and AA in SBM were higher than in corn-DDGS. The differences may be due to the higher fibre concentration in corn-DDGS and DECM (Kerr and Shurson 2013). The fibre may decrease nutrients digestibility by reducing interaction between digesta, absorptive surface, and digestive enzymes (Grageola *et al.* 2013). Additionally, the presence of glucosinolates in SECM may also have contributed to the decreased AID and ATTD of nutrients (Yun *et al.* 2017).

In conclusion, SBM had greater ATTD and AID of DM and GE than corn-DDGS. The values of AID of N and the majority of AA in SBM were higher than these in SECM and corn-DDGS.

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