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Short communication

Energy concentration of high-protein, low-oligosaccharide, and conventional full fat de-hulled soybeans fed to growing pigs

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ABSTRACT

An experiment was conducted to determine the energy concentration in de-hulled full fat soybeans (FFSB). Conventional (FFSB-CV; 435 g crude protein (CP)/kg and 241 g acid hydrolyzed ether extract (AEE)/kg), high-protein (FFSB-HP; 502 g CP/kg and 205 g AEE/kg), and low-oligosaccharide (FFSB-LO; 468 g CP/kg and 211 g AEE/kg) varieties of de-hulled FFSB were used. The digestible energy (DE) and metabolizable energy (ME) in the 3 sources of de-hulled FFSB were determined using 24 growing barrows (initial BW: 28.3 ± 3.7 kg). A corn-based basal diet and 3 diets containing corn and each source of de-hulled FFSB were formulated. Pigs were placed in metabolism cages and randomly allotted to the 4 diets with 6 replicate pigs per diet. After a 5 d adaptation period, feces and urine were collected for 5 d. The DE and ME in each source of de-hulled FFSB were calculated using the difference procedure. The concentrations of DE and ME in de-hulled FFSB-CV, FFSB-HP, and FFSB-LO were 18.8 ± 1.17 and 17.4 ± 1.36; 20.0 ± 1.62 and 18.3 ± 1.87; and 19.7 ± 1.63 and 18.1 ± 2.16 MJ/kg dry matter, respectively, but no significant differences among the 3 sources of de-hulled FFSB were observed. In conclusion, the same energy values can be used for de-hulled high-protein and low-oligosaccharide varieties of soybeans as the values used for de-hulled conventional soybeans.

1. Introduction

Soybean meal (SBM) is the most commonly used protein source in swine diets in the United States (Kohlmeier, 1990), but soybeans contain several anti-nutritional factors, one of which is oligosaccharides. Oligosaccharides are not digested in the small intestine of pigs, but they are fermented by the residing bacteria (Hayakawa et al., 1990; Slominski, 1994). The inclusion of 2% oligosaccharides decrease digestibility of energy and reduce growth rate of pigs, and may also affect fecal consistency in weanling pigs (Liying et al., 2003). Therefore, the soybean industry has developed new varieties of soybeans that have concentrations of oligosaccharides that are less than 0.5%, whereas conventional soybeans contain 4–6% oligosaccharides (Grieshop et al., 2003). The main oligosaccharides in soybeans are raffinose and stachyose. Research with low oligosaccharide

Abbreviations: AEE, acid hydrolyzed ether extract; ATTD, apparent total tract digestibility; CP, crude protein; CTTAD, coefficient of total tract apparent digestibility; DE, digestible energy; DM, dry matter; FFSB, full fat soybeans; FFSB-CV, conventional variety of full fat soybeans; FFSB-HP, high-protein variety of full fat soybeans; FFSB-LO, low-oligosaccharide variety of full fat soybeans; GE, gross energy; ME, metabolizable energy; SBM, soybean meal; TIU, trypsin inhibitor units.

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Table 1
Analyzed energy and nutrient composition of de-hulled full fat soybeans (g/kg, as-fed basis unless otherwise indicated).

Item	Ingredient[a]		
	FFSB-CV	FFSB-HP	FFSB-LO
Dry matter	960	970	948
Gross energy (MJ/kg)	23.2	23.0	22.7
Crude protein	435	502	468
Acid hydrolyzed ether extract	241	205	211
Ash	52.0	44.0	41.4
Calcium	3.1	2.2	2.2
Phosphorus	6.4	6.6	5.5
Acid detergent fiber	34.1	21.4	25.6
Sucrose	56.3	39.4	79.6
Raffinose	8.1	5.9	0.6
Stachyose	40.7	38.7	4.6
Trypsin inhibitor activity (TIU[b]/mg)	1.5	1.9	1.3
Indispensable amino acids			
Arginine	31.8	37.8	35.2
Histidine	11.1	12.6	11.9
Isoleucine	20.1	22.4	21.2
Leucine	33.6	38.2	35.4
Lysine	25.3	28.5	27.1
Methionine	5.7	6.4	6.3
Phenylalanine	22.7	26.0	23.8
Threonine	16.3	18.9	17.4
Tryptophan	6.1	6.9	6.7
Valine	20.8	23.3	22.3
Dispensable amino acids			
Alanine	18.0	20.5	19.0
Aspartic acid	48.1	56.1	51.1
Cysteine	5.5	5.6	5.9
Glutamic acid	75.1	92.5	80.3
Glycine	17.3	20.2	18.5
Proline	21.0	24.4	22.8
Serine	18.7	23.7	19.9
Tyrosine	16.3	18.5	17.2
Calculated values			
Lysine:crude protein	5.81	5.68	5.79

[a] FFSB-CV = de-hulled full fat soybeans from a conventional variety of soybeans; FFSB-HP = de-hulled full fat soybeans from a high-protein variety of soybeans; and FFSB-LO = de-hulled full fat soybeans from a low-oligosaccharide variety of soybeans.
[b] TIU = trypsin inhibitor units.

extruded-expelled SBM fed to growing pigs indicates that there is no difference in digestible energy (DE) and metabolizable energy (ME) between SBM produced from low oligosaccharide and conventional varieties (Baker and Stein, 2009).

In addition to the low-oligosaccharide soybeans, high protein varieties of soybeans have been selected. According to Baker and Stein (2009), ME values are not different between SBM produced from high protein and conventional varieties (Baker and Stein, 2009). There are, however, no data on the DE and ME of de-hulled low oligosaccharide and high protein full fat soybeans (FFSB).

Therefore, the experiment reported here was conducted to test the hypothesis that DE and ME are greater in de-hulled FFSB produced from high-protein or low-oligosaccharide varieties of soybeans than in de-hulled conventional FFSB (FFSB-CV) because of reduced concentrations of oligosaccharides and increased concentration of protein. The objective of the experiment was to determine the DE and ME in de-hulled FFSB-CV, high protein FFSB (FFSB-HP), and low-oligosaccharide FFSB (FFSB-LO) fed to growing pigs.

2. Materials and methods

2.1. General

The experimental protocol for this experiment was reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. The 3 sources of de-hulled FFSB included FFSB-CV, FFSB-HP, and FFSB-LO (Table 1). All 3 sources of de-hulled FFSB were sourced from Schillinger Genetics, Inc., Des Moines, IA, and processed at Natural Products (Grinnell, IA) where they were roasted via microwave and ground. The particle size for FFSB-CV, FFSB-HP, and FFSB-HP were 1089, 1219, 1170 μm, respectively. Pigs used in the experiment were sired by G performer (Duroc × Pietrain) boars that were mated to Fertilis 25 (3/4 Landrace 1/4 Large White) females (Genetiporc Inc., Alexandria, MN).

Table 2
Ingredient composition of experimental diets (g/kg, as-fed basis).

Ingredient	Diet[a]			
	Corn	FFSB-CV	FFSB-HP	FFSB-LO
Corn	972	632	691	676
FFSB-CV	–	345	–	–
FFSB-HP	–	–	285	–
FFSB-LO	–	–	–	300
Ground limestone	11.0	10.0	10.5	10.5
Monocalcium phosphate	10.0	6.0	6.5	6.5
Salt	4.0	4.0	4.0	4.0
Vitamin mineral premix[b]	3.0	3.0	3.0	3.0
Analyzed nutrients				
Dry matter	887	912	907	905
Gross energy (MJ/kg)	15.9	18.4	18.0	17.8
Crude protein	76.0	216	205	201
Acid hydrolyzed ether extract	30.9	103	81.5	82.6

[a] FFSB-CV = de-hulled full fat soybeans from a conventional variety of soybeans; FFSB-HP = de-hulled full fat soybeans from a high-protein variety of soybeans; and FFSB-LO = de-hulled full fat soybeans from a low-oligosaccharide variety of soybeans.

[b] Provided the following quantities of vitamins and micro minerals per kilogram of complete diet: Vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2204 IU; vitamin E as DL-alpha tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamin as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

2.2. Diets, animals, and experimental design

Four diets were formulated (Table 2). Three of the diets contained one of the sources of de-hulled FFSB and corn. The last diet was a corn diet that did not contain de-hulled FFSB. Corn and de-hulled FFSB were the only sources of energy in the diets. An attempt to formulate the three diets containing de-hulled FFSB to the same CP concentration was made and because of the different levels of CP among the three sources of FFSB, different quantities of each source was included in the diets. Vitamins and minerals were included in all diets to meet or exceed requirement estimates (NRC, 1998).

A total of 24 growing barrows (initial body weight: 28.3 ± 3.7 kg) were placed in metabolism cages equipped with a feeder and a nipple drinker. The experiment was conducted as a randomized complete block design with 4 diets and 6 replications per diet.

2.3. Feeding and sample collection

The quantity of feed provided per pig daily was calculated as 3 times the estimated requirement for maintenance energy (i.e., 106 kcal ME per $kg^{0.75}$; NRC, 1998) and divided into 2 equal meals that were fed at 0700 and 1700 h. Water was available at all times. The experiment lasted 12 d. The initial 5 d was considered an adaptation period to the diet, while urine and fecal materials were collected during the next 5 d according to standard procedures using the marker to marker approach (Adeola, 2001). Urine was collected in urine buckets over a preservative of 40 mL of 6 *N* HCl. Fecal samples and 20% of the collected urine were stored at −20 °C immediately after collection. At the conclusion of the experiment, urine samples were thawed and mixed within animal and diet, and a subsample was collected for chemical analysis.

2.4. Sample analysis and data processing

Fecal samples were dried in a forced air oven and finely ground prior to analysis, and urine samples were lyophilized before analysis as described by Kim et al. (2009). Fecal, urine, diet, and ingredient samples were analyzed in duplicate for gross energy (GE) using a bomb calorimeter (Model 6300, Parr Instruments, Moline, IL). Diets and ingredients were also analyzed for dry matter (DM; method 930.15; AOAC Int., 2007), CP (method 990.03; AOAC Int., 2007), and acid hydrolyzed ether extract (AEE; Sanderson, 1986; method 2003.06; AOAC Int., 2007). Ingredients were analyzed for ash (Method 975.03; AOAC Int., 2007), calcium and phosphorus (Method 975.03; AOAC Int., 2007), amino acids [Method 982.30 E (a, b, c); AOAC Int., 2007], ADF (Method 973.18; AOAC Int., 2007), trypsin inhibitor concentration (Method Ba 12-75; AOCS, 2006), and for sucrose, raffinose and stachyose as described by Cervantes-Pahm and Stein (2010).

Following chemical analysis, total tract digestibility values were calculated for energy using procedures previously described (Stein et al., 2004). The amount of energy lost in the feces and urine was calculated as well, and the quantities of DE and ME in each of the 4 diets were calculated (Stein et al., 2004). The DE and ME in the corn diet were divided by 0.972 to calculate the DE and ME in corn. The contributions of DE and ME from corn to the diets containing de-hulled FFSB-CV, FFSB-HP, and FFSB-LO were then calculated and subtracted from the total DE and ME of these diets, and the concentrations of DE and ME in de-hulled FFSB-CV, FFSB-HP, and FFSB-LO were calculated by difference (Adeola, 2001). The DE and ME in all ingredients were calculated on an as-fed basis as well as on a DM basis.

Table 3
Daily energy balance and coefficient of total tract apparent digestibility (CTTAD) of energy in experimental diets[a].

Item	Diet[b]					
	Corn	FFSB-CV	FFSB-HP	FFSB-LO	SEM[c]	*P*-value
Dry matter intake (kg/d)	1.04	1.05	1.05	1.04	0.01	0.32
Gross energy intake (MJ/d)	18.42^{z}	20.84^{x}	20.79^{xy}	20.32^{y}	0.23	<0.01
Gross energy in feces (MJ/d)	2.4^{z}	3.6^{x}	3.0^{xy}	2.9^{y}	0.20	<0.01
Gross energy in urine (MJ/d)	0.50	0.79	0.78	0.80	0.10	0.11
CTTAD	0.87^{x}	0.83^{y}	0.85^{xy}	0.85^{xy}	0.01	0.02
Digestible energy in diet (MJ/kg)	13.9^{y}	15.2^{x}	15.4^{x}	15.2^{x}	0.16	<0.01
Metabolizable energy in diet (MJ/kg)	13.4^{y}	14.5^{x}	14.6^{x}	14.5^{x}	0.20	<0.01

[xyz] Values within a row lacking a common letter are different ($P < 0.05$).
[a] Data are the least square means of 6 observations per treatment.
[b] FFSB-CV = de-hulled full fat soybeans from a conventional variety of soybeans; FFSB-HP = de-hulled full fat soybeans from a high-protein variety of soybeans; and FFSB-LO = de-hulled full fat soybeans from a low-oligosaccharide variety of soybeans.
[c] SEM = standard error of the means.

Table 4
Concentration of digestible energy (DE) and metabolizable energy (ME) in corn and in three sources of de-hulled full fat soybeans fed to growing pigs[a].

Item	Ingredient[b]					
	Corn	FFSB-CV	FFSB-HP	FFSB-LO	SEM[c]	*P*-value
DE (MJ/kg)	14.3^{y}	18.1^{x}	19.4^{x}	18.6^{x}	0.51	<0.01
ME (MJ/kg)	13.8^{y}	16.7^{x}	17.8^{x}	17.2^{x}	0.62	<0.01
DE (MJ/kg DM)	16.2^{y}	18.8^{x}	20.0^{x}	19.7^{x}	0.53	<0.01
ME (MJ/kg DM)	15.7^{y}	17.4^{x}	18.3^{x}	18.1^{x}	0.65	<0.05

[xy] Values within a row lacking a common superscript letter are different ($P < 0.05$).
[a] Data are the least square means of 6 observations per treatment.
[b] FFSB-CV = de-hulled full fat soybeans from a conventional variety of soybeans; FFSB-HP = de-hulled full fat soybeans from a high-protein variety of soybeans; and FFSB-LO = de-hulled full fat soybeans from a low-oligosaccharide variety of soybeans.
[c] SEM = standard error of the means.

The Proc UNIVARIATE procedure of SAS was used to identify outliers (SAS Institute Inc., Cary, NC) but no outlier was identified. Data were analyzed using the Proc MIXED of SAS with randomized complete block design. An analysis of variance was conducted with diet as fixed effect and block as random effect. When significant differences were detected, treatment means were separated using the Least Significant Difference test in Proc MIXED. The pig was the experimental unit for all analyses and an alpha value of 0.05 was used to assess significance among treatments.

3. Results

The intake of GE was less ($P < 0.05$) in pigs fed the corn diet than in pigs fed the FFSB-CV, FFSB-HP, or the FFSB-LO diets (Table 3). Intake of GE was greater ($P < 0.05$) in pigs fed the FFSB-CV diet than in pigs fed the FFSB-LO diet; however, the GE intake in pigs fed the FFSB-HP diet was not different from that of pigs fed the FFSB-CV diet or the FFSB-LO diet. Pigs fed the corn diet had less ($P < 0.05$) fecal excretion of GE than pigs fed the FFSB-CV, FFSB-HP, or FFSB-LO diets. Fecal excretion of GE was greater ($P < 0.05$) for pigs fed the FFSB-CV diet than for pigs fed the FFSB-LO diet, but fecal excretion of GE from pigs fed the FFSB-HP diet was not different from that of pigs fed the FFSB-CV diet or the FFSB-LO diet. Urine excretion of GE was not different among diets. The apparent total tract digestibility (ATTD) of GE was greater ($P < 0.05$) for the corn diet than for the FFSB-CV diet, but the ATTD of GE for the FFSB-HP and FFSB-LO diets was not different from that of the corn diet or the FFSB-CV diet. The DE and ME were less ($P < 0.05$) in the corn diet than in the FFSB-CV, FFSB-HP, and FFSB-LO diets, but there were no differences in DE and ME among the 3 FFSB diets. The DE and ME in corn were less ($P < 0.05$) than in FFSB-CV, FFSB-HP, and FFSB-LO (Table 4), but there were no significant differences in DE and ME among the 3 sources of FFSB; this was true when values were calculated on an as-fed basis as well as on a DM-basis.

4. Discussion

The DE and ME for corn used in this experiment are in accordance with the values reported by Baker and Stein (2009), but the DE and ME for FFSB-CV were greater than previously published values (17.6 MJ/kg of DE and 16.5 MJ/kg of ME; NRC, 2012). The main reason for this observation is most likely that the FFSB used in this experiment were de-hulled; therefore, the FFSB-CV used in this experiment contained more CP and fat than reported by NRC (1998; 2012). Therefore, the increased DE and ME that were observed in this experiment compared with the DE and ME reported by NRC (1998; 2012) were expected.

Baker and Stein (2009) reported that extruded-expelled SBM produced from high protein soybeans had greater concentration of DE compared with extruded-expelled SBM produced from low oligosaccharide or conventional varieties of soybeans. A greater value for true metabolizable energy was also observed in high-protein SBM compared with low oligosaccharide

SBM and conventional SBM (Baker et al., 2011). According to Baker and Stein (2009) and Baker et al. (2011), greater protein concentration in the high-protein meal was responsible for the greater DE and ME concentration in the high protein SBM. However, in the present experiment, we did not observe any difference in DE and ME values among the different varieties of de-hulled FFSB. This is most likely a consequence of the reduced concentration of AEE in the FFSB-HP and FFSB-LO that were used in this experiment compared with FFSB-CV. Thus, it appears that the reduced concentration of AEE in FFSB-HP and FFSB-LO offset the increased DE and ME that were expected for these beans.

The greater AEE concentration contributes to the greater ME values in the 3 sources of de-hulled FFSB compared with corn. According to NRC (2012), SBM and corn have similar ME values. Therefore, if de-hulled FFSB are used, the energy concentration in the diet will be increased. This observation indicates that de-hulled FFSB can be used to increase dietary energy in diets that contain low energy ingredients or in diets for young pigs where it may be advantageous to increase the energy concentration.

5. Conclusion

Results of the present experiment indicate that the energy concentration in high protein, low oligosaccharide, and conventional sources of de-hulled FFSB is not different. This observation also indicates that the same energy values can be used for the high-protein and low-oligosaccharide varieties of soybeans as the values used for conventional soybeans.

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