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Partial dehulling increases the energy content and nutrient digestibility of barley in growing pigs

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Objective: The hull attached to the barley kernel can be mechanically removed thus reducing the fiber content of the barley. This experiment was carried out to evaluate the effects of partial dehulling on the nutrient digestibility as well as the digestible energy (DE) and metabolizable energy (ME) content of barley in pigs.
Methods: Two hulled barley samples (high fiber barley [HF] and low fiber barley [LF]) with either high or low fiber contents were obtained from the Hubei and Jiangsu Provinces of China. A portion of the two barleys was mechanically dehulled (dehulled high fiber barley [DHF] and dehulled low fiber barley [DLF]). Thirty barrows (initial BW = 31.5±3.2 kg) were assigned to one of five diets in a randomized complete block design. The five diets consisted of 96.9% corn, HF, LF, DHF, or DLF supplemented with 3.1% minerals and vitamins. Each diet was fed to six barrows housed in individual metabolism crates for a 10-d acclimation period followed by a 5-day total but separate collection of feces and urine.
Results: The daily loss of gross energy (GE) in feces was lower ($p<0.01$) for pigs fed DHF than for those fed HF. The daily N intake and fecal N loss were lowest ($p<0.01$) for pigs fed the corn diet. The DE and ME as well as the apparent total tract digestibility (ATTD) of dry matter, GE, organic matter, neutral detergent fiber (NDF) and acid detergent fiber (ADF) of DHF or DLF were higher ($p<0.01$) than the values in HF and LF, respectively while the values except the ATTD of NDF and ADF in DLF were higher ($p<0.01$) than the values in DHF and were comparable to corn.
Conclusion: The DE and ME contents as well as the ATTD of nutrients in both DHF and DLF barley were improved compared with the HF and LF barley. Moreover, the nutritive value of DLF barley was comparable to the yellow-dent corn used in the study.

Keywords: Barley; Dehulling; Digestible Energy; Metabolizable Energy; Nutrient Digestibility; Pigs

INTRODUCTION

Barley (*Hordeum vulgare* L.) is a common feedstuff used in many countries in Europe as well as Canada, the United States and Australia. Total global production is around 140 million tons per year [1], which ranks 4th in terms of volume after maize, rice, and wheat. Approximately two-thirds of the global barley crop is used for animal feed, one third for malting and brewing of beer and whiskey and about 2% is used directly for food [2].

During the last few years, the high cost of ingredients such as corn has resulted in a significant increase in the cost of producing swine. As a consequence, alternative ingredients are being evaluated and increasing amounts of barley are being incorporated into swine diets as a result of the price advantage of barley over corn and wheat. Barley is a suitable ingredient for inclusion in swine diets and is used primarily as an energy source [3]. However, barley fiber contains mixed linked β-glucans in addition to arabinoxylans and cellulose and is therefore more fermentable than the fiber contained in wheat and maize [4]. Because of the greater concentration of fiber in barley than in other cereal grains, the digestible energy (DE) and metabolizable energy (ME) content of barley is lower than most other cereal grains. In addition, there is significant variability in the concentrations of fiber in different varieties of barley [5].

Although the energy content of barley is about 10% to 15% lower than corn, it is still a very attractive ingredient for use in swine feeding because of its higher content of protein, lysine, and digestible phosphorus compared with corn [6,7]. Therefore, the development of methods to improve the feeding value of barley can have a major impact on the overall profitability of swine production.

As the hull attached to the kernel can be mechanically removed, it is necessary to accurately evaluate the effects of partial dehulling on the effective energy and nutrient digestibility of barley with different fiber contents. We hypothesized that barley cultivars with reduced fiber content will have a higher DE and ME content than unprocessed barley cultivars and could be comparable to corn. Therefore, the objectives of the current study were to determine the DE and ME content as well as the apparent total tract digestibility (ATTD) of nutrients in yellow-dent corn, two hulled barley samples and two partially dehulled barley samples when fed to growing pigs.

MATERIALS AND METHODS

The China Agricultural University Laboratory Animal Welfare and Animal Experimental Ethical Inspection Committee (Beijing, China) reviewed and approved all protocols used in this experiment.

Sample preparation

Yellow-dent corn was obtained from the China Agriculture University Animal Experimental Base (Fengning, China). Two barley samples (approximately 1,000 kg per sample) were obtained from the Hubei (high fiber) and Jiangsu (low fiber) Provinces of China, respectively. A portion of the barley was weighed and mechanically dehulled to obtain two partially dehulled barley samples (dehulled high fiber barley [DHF] and dehulled low fiber barley [DLF]). The machine used in the study was purchased from a machine making factory (Dahua Machiner, Shandong, China). The sources and percentage hull of the barley are shown in Table 1.

All samples were stored at –18°C prior to analysis and diet formulation. Before the start of the experiment, barley sub-samples were collected and analyzed for their chemical composition and amino acid content (Table 2).

Table 1. Source and percentage hull in the two barleys used in the experiment

Barley type	Source	Total hulled barley processed (kg)	Total dehulled barley obtained (kg)	% Hull
High fiber	Hubei	198.5	169.9	14.4
Low fiber	Jiangsu	203.8	179.2	12.1

Diets, animals and experimental design

Five diets were formulated to contain 96.9% of corn or one of the four barley samples and 3.1% minerals and vitamins (Table 3). Vitamins and minerals were supplied at levels to meet the estimated nutrient requirements for growing pigs recommended by the NRC [6].

The experiment was conducted as a completely randomized design. Thirty barrows (Duroc×Landrace×Yorkshire; initial body weight [BW] was 31.5±3.2 kg) were individually housed in stainless-steel metabolic crates (1.4×0.7×0.6 m) at the Fengning Swine Research Unit of China Agricultural University (Hebei, China). The experiment was conducted with a 10-d adaptation period followed by a 5-d total collection of feces and urine. The

Table 2. Analyzed chemical composition of ingredients[1)] (% DM)

Item	Corn	Hulled barley		Dehulled barley	
		HF	LF	DHF	DLF
Dry matter	87.73	89.33	88.56	89.71	89.29
Gross energy (kcal/kg)	4,364	4,447	4,448	4,422	4,376
Total starch	73.22	43.46	53.06	51.90	58.85
Neutral detergent fiber	9.34	37.26	16.12	24.80	11.60
Acid detergent fiber	2.05	8.15	5.54	4.15	2.62
Total dietary fiber	11.99	33.86	20.94	19.00	12.19
Insoluble dietary fiber	9.45	21.82	15.42	10.13	7.10
Crude protein	11.44	13.98	12.96	16.28	14.66
Ether extract	3.97	2.64	2.57	2.79	2.75
Ash	1.51	3.44	2.50	2.16	2.02
Calcium	0.02	0.06	0.04	0.02	0.02
Total phosphorus	0.29	0.30	0.33	0.35	0.38
Essential AA					
Arginine	0.46	0.60	0.58	0.72	0.63
Histidine	0.23	0.23	0.21	0.28	0.24
Isoleucine	0.33	0.48	0.44	0.59	0.48
Leucine	1.24	0.96	0.91	1.12	1.10
Lysine	0.29	0.42	0.40	0.50	0.47
Methionine	0.20	0.19	0.18	0.23	0.21
Phenylalanine	0.44	0.70	0.59	0.88	0.69
Threonine	0.45	0.41	0.40	0.49	0.46
Tryptophan	0.08	0.18	0.16	0.20	0.18
Valine	0.51	0.71	0.64	0.86	0.72
Non-essential AA					
Alanine	0.77	0.57	0.53	0.68	0.59
Asparagine	0.62	0.62	0.65	0.72	0.76
Cysteine	0.21	0.26	0.25	0.31	0.29
Glutamine	1.72	2.98	2.66	3.50	3.10
Glycine	0.41	0.47	0.49	0.56	0.55
Proline	0.97	1.63	1.38	1.88	1.54
Serine	0.46	0.52	0.50	0.62	0.57
Tyrosine	0.25	0.29	0.27	0.34	0.32

DM, dry matter; AA, amino acid.
[1)] The ingredients are HF, hulled high fiber barley; LF, hulled low fiber barley; DHF, dehulled high fiber barley; DLF, dehulled low fiber barley.

5 experimental diets were fed to six barrows to provide 6 six replicates per diet. The room temperature was maintained at 22°C±2°C to meet the environmental needs of the pigs.

Barrows were provided with *ad libitum* access to water and were fed a daily amount of feed equivalent to 4% of their BW determined at the beginning of the experimental period. The ration was divided into two equal sized feedings at 08:00 and 16:00. The amount of feed provided was recorded at each feeding. Orts were removed and weighed at each meal and daily feed consumption was calculated.

Sample collection

Samples of the diets and ingredients were collected and stored at –20°C until needed for analysis. During the 5-d collection period, all feces were quickly collected into plastic bags and stored at –20°C according to the methods described by Li et al [8]. At the end of each period, the total 5 d production of feces from each pig was pooled and weighed and a 300-g sample was taken and dried in a forced-draft oven at 65°C for 72 h. After drying and grinding, sub-samples were stored at –20°C for further chemical analysis.

At the same time as the fecal collection, urine was collected into plastic buckets attached to funnels located under the metabolic crates according to the methods described by Li et al [8]. Approximately 50 mL of 6 N HCl was added to the buckets to limit microbial growth and reduce the loss of ammonia. Urine volume was recorded daily and a sub-sample of 10% of the urine excreted from each pig was collected and stored at –20°C. At the end of the collection period, urine samples were pooled for each pig and a sub-sample (about 45 mL) was saved for further analysis. Urine samples (4 mL) were dried at 65°C for 8 h with quantitative filter paper in crucibles prior to energy determination. Two unaltered sheets of quantitative filter paper from each box were used to calibrate the energy content of the paper.

Chemical analysis

The dry matter (DM) (method 934.01), ether extract (EE) (method 920.39), crude protein (CP) (method 990.03), ash (method 942.05), Ca (method 985.01), and P (method 985.01) content of the diets and ingredients were determined according to the procedures of AOAC International. Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined using fiber bags (Model F57; Ankom Technology, Macedon, NY, USA) and a fiber analyzer (ANKOM200 Fiber Analyzer; Ankom Technology, USA) following an adaptation of the procedure as described by Van Soest et al [9]. The concentration of NDF was analyzed using heat-stable α-amylase and sodium sulfite without correction for insoluble ash. Total dietary fiber (TDF) and insoluble dietary fiber (IDF) were analyzed according to the procedures of AOAC (method 992.16). The gross energy (GE) of feces, urine, diets, corn and barley samples were measured using an Automatic Isoperibol Oxygen Bomb Calorimeter (Parr 1281 Calorimeter; Parr Instrument Company, Moline, IL, USA). Total starch was analyzed according to the enzymatic method described by Xiong et al [10].

Before analysis for amino acid (AA), corn and barley samples were hydrolyzed with 6 N HCl for 24 h at 110°C (AOAC Method 999.13) and subsequently analyzed for their AA content using an AA Analyzer (Hitachi L-8900, Tokyo, Japan). Methionine and cysteine were determined as methionine sulfone and cysteic acid after cold performic acid oxidation overnight and hydrolyzed with 7.5 N HCl for 24 h at 110°C (AOAC Method 994.12). Tryptophan was determined after LiOH hydrolysis for 22 h at 110°C (AOAC Method 998.15) using High Performance Liquid Chromatography (Agilent 1200 Series, Santa Clara, CA, USA). All analyses were conducted in duplicate.

Table 3. Ingredient composition of the experimental diets (%, as-fed)

Ingredient	Diets	
	Corn	Barley
Corn	96.9	-
Barley	-	96.9
Dicalcium phosphate	1.7	1.7
Limestone	0.6	0.6
Salt	0.3	0.3
Vitamin and mineral premix[1)]	0.5	0.5

[1)] Provided the following quantities of vitamins and minerals per kg of complete diet: 50 mg Mn (MnO), 125 mg Fe ($FeSO_4 \cdot H_2O$), 125 mg Zn (ZnO), 150 mg Cu ($CuSO_4 \cdot 5H_2O$), 50 mg I (CaI_2), 0.30 mg Se (Na_2SeO_3), 4,500 IU retinyl acetate, 1,350 IU cholecalciferol, 13.5 mg dl-α-tocopheryl acetate, 2.7 mg menadione sodium bisulfite complex, 18 mg niacin, 27.6 μg vitamin B_{12}, 0.6 mg thiamine, 0.9 mg pyridoxine, 1.8 mg riboflavin, 10.8 mg d-calcium-pantothenate, 30.3 mg nicotinic acid, and 210 mg choline chloride.

Calculations

The DE and ME in the five feed samples were measured and then later converted to reflect the digestibility of corn and the individual barley samples. Corn and barley were assumed to be the only sources of energy in the diets as the slight contribution of energy from the vitamin and mineral premix (3.1%) was assumed to be negligible. Following chemical analysis, the ATTD of various chemical constituents as well as the DE and ME content for each diet were calculated. The DE and ME values contributed by each ingredient was calculated by dividing the total by 0.969.

Statistical analysis

All data were analyzed using the Statistical Analysis System (SAS, 2008: Version 114 9.2). Data were analyzed as a randomized complete block design with pig as the experimental unit using the general linear model procedures of SAS followed by Tukey's multiple range test. Values are presented as least square means± the standard error. Significant differences were declared at p<0.05.

RESULTS

Partial dehulling on chemical composition

Analyzed DM, total starch, NDF, ADF, TDF, IDF, CP, EE, ash, calcium and total phosphorous of the corn used in this experiment were 87.73%, 73.22%, 9.34%, 2.05%, 11.99%, 9.45%, 11.44%, 3.97%, 1.51%, 0.02%, and 0.29%, respectively (Table 2). Corresponding values for the high fiber barley (HF) barley used in the experiment were 89.33%, 43.46%, 37.26%, 8.15%, 33.86%, 21.82%, 13.98%, 2.64%, 3.44%, 0.06%, and 0.30%, respectively. The analyzed chemical constituents of the low fiber barley (LF) barley used in the experiment were 88.56%, 53.06%, 16.12%, 5.54%, 20.94%, 15.42%, 12.96%, 2.57%, 2.50%, 0.04%, and 0.33%.

Partial dehulling increased the nutrient content of barley. Analyzed DM, total starch, NDF, ADF, TDF, IDF, CP, EE, ash, Ca and total phosphorous of the DHF barley used in the experiment were 89.71%, 51.90%, 24.80%, 4.15%, 19.00%, 10.13%, 16.28%, 2.79%, 2.16%, 0.02%, and 0.35%. Corresponding values for the DLF barley used in the experiment were 89.29%, 58.85%, 11.60%, 2.62%, 12.19%, 7.10%, 14.66%, 2.75%, 2.02%, 0.02%, and 0.38%.

Daily balance of gross energy and nitrogen

There were no differences in the daily GE intake and the daily loss of GE in urine among pigs fed the different cereal grains but the daily loss of GE in feces was lower ($p<0.01$) for pigs fed DHF than for those fed HF (Table 4). The digested and metabolized GE of DHF or DLF were higher than the values in HF and LF, respectively while the values in DLF were higher ($p<0.01$) than the values in DHF and were comparable to corn. The daily N intake and fecal N loss were lowest ($p<0.01$) for pigs fed the corn diet while the daily urinary N excretion did not differ among the five treatments. No differences in the digestibility and retention rate of N were found between the corn and barley diets. Partial dehulling of barley (DHF vs HF and DLF vs LF) did not change the daily N balance or the nutrient digestibility and retention rate of N.

Concentration of digestible and metabolizable energy

The DE and ME for DHF or DLF were higher ($p<0.01$) than the values for HF and LF, respectively while the values for DLF were higher ($p<0.01$) than the values for DHF and were comparable to corn. No differences in ME/DE were found among pigs fed any of the diets (Table 5).

Apparent total tract digestibility of various chemical constituents

The ATTD of DM, GE, and organic matter (OM) for pigs fed DHF were higher ($p<0.01$) than for pigs fed HF but lower ($p<0.05$) than for pigs fed corn (Table 6). Meanwhile, the ATTD of DM, GE, and OM for pigs fed DLF were higher ($p<0.01$) than for pigs fed LF while ATTD did not differ to pigs fed corn. The ATTD of NDF for pigs fed DHF and DLF were higher ($p<0.05$) than for pigs fed HF and LF, respectively. The ATTD of ADF for pigs fed DLF were increased in comparison with pigs fed HF and LF but showed no differences with those fed corn and DHF.

DISCUSSION

Corn is the predominant cereal used in pig diet formulation in most countries of the world because of its high starch and low fiber levels [11]. Alternative cereal grains such as hulled barley are available for animal feeding and may contribute to a local sustainable pig production when corn is not available. For example, barley is typically produced in areas where corn production is not agronomically feasible. However, compared with corn, hulled barley contains more fiber with values reported as high as 21% of grain weight [12]. The β-glucan and pentosan contents in whole barley grain are 4.2% and 6.6%, respectively,

Table 4. Effects of hulled or dehulled barley on the daily balance of gross energy (GE) and nitrogen (N) for growing pigs[1)]

Item	Corn	Hulled barley		Dehulled barley		SEM	p-value
		HF	LF	DHF	DLF		
Daily balance of GE (MJ/d)							
GE intake	19.07	21.57	20.06	20.30	20.90	1.62	0.85
GE in feces	2.51^{b}	4.69^{a}	3.62a^{b}	3.33^{b}	2.79^{b}	0.28	<0.01
GE in urine	0.27	0.43	0.49	0.27	0.35	0.07	0.19
Digestibility (%)	86.67^{a}	78.00^{d}	81.67^{c}	83.67^{b}	86.67^{a}	0.00	<0.01
Metabolizability (%)	85.33^{a}	76.50^{d}	79.50^{c}	82.33^{b}	85.00^{a}	0.00	<0.01
Daily balance of N (g/d)							
N intake	16.83^{b}	29.87^{a}	25.19^{ab}	28.94^{a}	26.96^{a}	2.05	<0.01
N in feces	3.84^{b}	6.68^{a}	5.16^{ab}	6.04^{a}	4.82^{ab}	0.56	0.01
N in urine	6.06	8.54	8.86	8.54	9.45	1.20	0.35
Digestibility (%)	77.28	77.62	79.20	79.48	82.03	1.49	0.20
Retention rate (%)	41.67	47.08	37.42	49.94	46.52	3.46	0.12

SEM, standard error of the mean.
[1)] The treatments are: HF, hulled high fiber barley; LF, hulled low fiber barley; DHF, dehulled high fiber barley; DLF, dehulled low fiber barley.
[a–d] Within a row, different superscripts indicate a significant difference ($p<0.05$).

Table 5. The concentration of digestible (DE) and metabolizable energy (ME) in hulled or dehulled barley fed to growing pigs[1)]

Item	Corn	Hulled barley		Dehulled barley		SEM	p-value
		HF	LF	DHF	DLF		
DE in ingredient (MJ/kg)							
As-fed basis	13.95[b]	12.89[d]	13.36[c]	13.89[b]	14.27[a]	0.06	<0.01
DM basis	15.82[a]	14.36[d]	14.97[c]	15.51[b]	15.98[a]	0.06	<0.01
ME in ingredient (MJ/kg)							
As-fed basis	13.73[b]	12.58[d]	12.97[c]	13.67[b]	14.00[a]	0.05	<0.01
DM basis	15.56[a]	14.02[d]	14.53[c]	15.27[b]	15.68[a]	0.05	<0.01
ME/DE	0.984	0.976	0.971	0.984	0.981	0.00	0.05

SEM, standard error of the mean; DM, dry matter.
[1)] The treatments are: HF, hulled high fiber barley; LF, hulled low fiber barley; DHF, dehulled high fiber barley; DLF, dehulled low fiber barley.
[a–d] Within a row, different superscripts indicate a significant difference (p<0.05).

with only 1.8% and 1.4% in the endosperm [13]. Thus, the major portion of the non-starch polysaccharides content of barley is contained in the hull fraction.

Fiber content is negatively correlated with the energy value of a feed [14] and nutrient digestibility [15]. Thacker and Rossnagel [16] reported that the removal of the hull from barley could improve its nutritive value. Determination of the effective energy and nutrient digestibility in partially dehulled barley could provide information as to how to more effectively substitute barley for corn in feed formulations for swine.

The nutrient concentrations except total starch and EE in corn were lower than the barley cultivars used in the present study. These data are consistent with the average values published by NRC [6]. Barley has a greater concentration of fiber and a reduced concentration of starch compared with corn while the digestibility of starch in barley is lower than in wheat and corn [17,18]. The analyzed GE as well as the nutrient profile of HF and LF barley used in the current study were 4,447 and 4,448 kcal GE, 13.98% and 12.96% for CP as well as 2.64% and 2.57% for EE. Lin et al [19] reported similar component concentrations of 4,480 kcal for GE, 2.4% for EE but a greater CP of 15.2% DM. Other studies have reported 4,527 and 4,532 kcal of GE, 13.5% and 12.3% for CP, 14.9% and 12.3% for NDF, 7.9% and 6.4% for ADF as well as 2.6% and 1.9% for EE, respectively for hulled barleys grown in Denmark (Lami variety) and Canada [20,21].

The content of total starch, CP, EE, and total phosphorus in dehulled barley were increased whereas the levels of ash and calcium were decreased compared with the unprocessed barley. Partial dehulling reduced GE slightly whereas the levels of ADF and NDF were decreased by 27.8% and 33.4% in HF as well as 49.1% and 28.0% in LF, respectively. Hennig et al [22] showed that partial dehulling reduced the levels of ADF and NDF to a greater extent in two-row barley than in six-row barley varieties. The content of total dietary fiber and insoluble dietary fiber in DLF were decreased more than in DHF in comparison with LF and HF, respectively. The fibrous contents of dehulled barley were lower than those of the hulled barley. Since the majority of the fiber found in barley is associated with the hull fraction, it stands to reason that removal of the hull would result in a lower fiber content which agrees with the findings of Thacker et al [23].

The essential AA except Leu and Met as well as the non-essential AA except Ala in the barley varieties were higher than those in corn. Barley AA concentrations reported by Bolarinwa et al [24] and NRC [6] are similar to those for the barley used in the current study. The concentrations of the essential AA in the two dehulled barleys were higher than the two unprocessed barleys used in the present experiment. Similarly, the concentrations of all selected AA including Lys, Met, Cys, Thr, and Try were higher in dehulled two-row barley and six-row barley compared with intact seeds [22].

The similar daily GE intake among the cereal grains and the

Table 6. Effects of hulled or dehulled barley on the apparent total tract digestibility of various chemical constituents for growing pigs[1)]

Item	Corn	Hulled barley		Dehulled barley		SEM	p-value
		HF	LF	DHF	DLF		
Dry matter	87.80[a]	78.86[d]	82.63[b]	85.19[b]	88.19[a]	0.30	<0.01
Gross energy	86.86[a]	78.22[d]	81.82[c]	83.68[b]	87.07[a]	0.31	<0.01
Organic matter	89.33[a]	80.77[d]	84.46[c]	86.76[b]	89.74[a]	0.27	<0.01
Crude protein	77.28	77.62	79.20	79.48	82.03	1.49	0.20
Neutral detergent fiber	48.15[c]	58.92[b]	42.76[d]	76.53[a]	77.03[a]	1.24	<0.01
Acid detergent fiber	25.48[a]	11.98[c]	12.56[c]	18.23[b]	21.97[ab]	1.55	<0.01

SEM, standard error of the mean; DM, dry matter.
[1)] The treatments are: HF, hulled high fiber barley; LF, hulled low fiber barley; DHF, dehulled high fiber barley; DLF, dehulled low fiber barley.
[a–d] Within a row, different superscripts indicate a significant difference (p<0.05).

greater daily fecal GE loss in pigs fed the HF barley than in pig fed corn, DHF, and DLF barleys indicates lower digestibility of GE, metabolized GE as well as lower DE and ME in hulled barley varieties than in corn and dehulled barley. These results suggest that the energy in corn as well as DHF and DLF barley is better digested and absorbed than the energy in hulled HF and LF barley varieties.

Barley is primarily placed in the diet as a source of energy, but also provides a substantial proportion of the dietary protein required by the pig [25]. In the current study, the daily N intake and fecal N loss were higher for pigs fed the HF and DHF barleys than corn which may be attributed to the greater CP content in the HF and DHF barley varieties. The digestibility and retention rate of N for pigs fed barley were similar to that for pigs fed corn and did not differ to partially dehulled barley. This is consistent with the results reported by Fairbairn et al [5] who showed that no differences were found in nitrogen balance among 20 barley samples. In the current study, these results indicate that N utilization for pigs fed LF and DLF barley is similar to that for pigs fed corn and that the N from HF and DHF barley varieties would increase N excretion to the environment when fed to growing pigs.

The ATTD of DM, GE, OM, NDF, and ADF in dehulled barley were increased compared with the unprocessed hulled barley confirming the fact that DE and ME levels were improved due to partial dehulling of barley. The digestibility and retention rate of N were not changed in the current study and this is consistent with the results reported by Hennig et al [22]. The decreases in digestibility and metabolizability of energy are presumably related to the relatively high fiber concentration in barley compared with corn. Fibrous components, particularly β-glucans and arabinoxylans, present in hulled barley have anti-nutritional properties that induce viscosity, limit gastrointestinal enzyme access to substrates, and reduce the absorption of digested nutrients [26]. As a consequence, utilization of nutrients and energy is reduced as observed in the present study. Furthermore, the digestibility of fiber for pigs is generally lower compared with other nutrients and negatively influences the digestion of other nutrients.

In the current study, the DE and ME content of the two hulled barleys were 14.36 and 14.02 MJ/kg as well as 14.97 and 14.53 MJ/kg, respectively. The DE is in agreement with average values published by NRC [6] and Patience et al [27] and somewhat lower than the values of 15.35 to 15.89 MJ/kg of DM reported by Wiseman et al [28]. The ME of barley in the present study was lower than previously published values of 14.87 MJ/kg of DM reported by Wiseman et al [28], but greater than the values of 13.28 MJ/kg of DM reported by Fairbairn et al [5]. Although the DE and ME in DHF and DLF barley were improved in comparison with the HF and LF barley, respectively, the DE and ME values were similar between DLF barley and corn, which means that DLF barley is comparable to corn in terms of its effective energy.

The fibrous hull of the barley kernel limits its potential inclusion in rations for young and rapidly growing swine, as the hull lowers the nutrient density of the diet [29]. As well, high levels of fiber tend to increase the rate of passage of digesta and this may limit the time available for digestion of the feed and subsequent nutrient uptake [30]. Hulless barley offers a potential advantage over hulled feed barley due to its lower fiber, higher digestible energy and increased crude protein content [23]. Dehulling of barley could enhance its nutritional value but there is a dearth of studies on the growth performance of pigs fed mechanically dehulled barley, so further study is still necessary to investigate its effect on pig performance.

The DE and ME content as well as the ATTD of nutrients in both DHF and DLF barley were improved compared with the HF and LF barley, respectively. The increases in digestibility and metabolizability of energy are presumably related to the lower fiber concentrations in dehulled barley compared with hulled barley. Fibrous components present in hulled barley have anti-nutritional properties that induce viscosity, limit gastrointestinal enzyme access to substrates and increase the rate of passage of digesta which may limit the time available for digestion of the feed and subsequent nutrient uptake. It would appear that these fibrous components are primary anti-nutrients in barley and should not be ignored when formulating diets for swine. The overall results of this experiment indicate that the nutritive value of DLF barley is comparable to that of yellow-dent corn.

CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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