

Comparative digestibility of nutrients and amino acids in high-fiber diets fed to crossbred barrows of Duroc boars crossed with Berkshire×Jiaxing and Landrace×Yorkshire

Jinbiao Zhao¹, Qiuyun Wang¹, Ling Liu¹, Yiqiang Chen¹, Aiming Jin², Guoliang Liu², Kaizhen Li², Defa Li¹, and Changhua Lai^{1,*}

* Corresponding Author: Changhua Lai
Tel: +86-6273-3688, Fax: +86-6273-3688,
E-mail: laichanghua999@163.com

¹ State Key Laboratory of Animal Nutrition, China Agricultural University, Beijing 100193, China
² Zhejiang Qinglian Food Company, Jiaxing 314300, China

ORCID

Changhua Lai
<https://orcid.org/0000-0002-6736-7179>

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Objective: This experiment was conducted to determine the differences in the apparent ileal (AID) and total tract digestibility (ATTD) of nutrients and indispensable amino acids (IAA) in high-fiber diets with wheat middlings, rice bran or alfalfa meal fed to Duroc×(Landrace×Yorkshire) (DLY) and Duroc×(Berkshire×Jiaxing) (DBJ) growing barrows.

Methods: Eighteen DLY and 18 DBJ growing barrows were randomly allotted to a 2×3 factorial arrangement involving 2 crossbreeds and 3 high-fiber diets. The experiment lasted 15 d with 10 d for diets adaptation, 3 d for feces collection and 2 d for digesta collection. Three diets were based on corn and soybean meal with 25% wheat middlings, rice bran and alfalfa meal respectively.

Results: DBJ had a greater ($p<0.05$) AID of isoleucine, leucine, lysine, phenylalanine and valine and a lower ($p<0.05$) AID of methionine than DLY. The hindgut disappearance of acid detergent fiber for DBJ was greater ($p<0.05$) than DLY. The ATTD of gross energy, dry matter, organic matter, neutral detergent fiber and acid detergent fiber in wheat middlings diet were greater ($p<0.05$) than in rice bran and alfalfa meal diets. The hindgut disappearance of neutral detergent fiber and acid detergent fiber in wheat middlings diet or rice bran diet were the highest or lowest ($p<0.05$), and those of alfalfa meal diet were the middle. Barrows fed rice bran diet had a greater ($p<0.05$) hindgut disappearance of gross energy, dry matter and organic matter and lower hindgut disappearance of neutral detergent fiber and acid detergent fiber than barrows fed alfalfa meal diet.

Conclusion: DBJ growing barrows showed a significant higher digestibility of fiber in the hindgut and most IAA in the small intestine compared with DLY barrows. The digestibilities of chemical constituents and IAA were affected by the diets formulated with different fiber sources.

Keywords: Apparent Ileal Digestibility; Apparent Total Tract Digestibility; Fiber; Barrow; Crossbreed

INTRODUCTION

With the development of animal husbandry, the cost of conventional feed ingredients has markedly increased, resulting in increased use of cheaper co-products to partially replace them in swine diets [1,2]. However, fiber ingredients are limited in application to the feed industry as a consequence of their high anti-nutritional factor and low palatability resulting in the low utilization of nutrients and energy [3,4].

Generally speaking, indigenous breeds of pigs have been shown to utilize high-fiber diets more efficiently than exotic crossbreeds [5,6]. Meishan pigs fed a diet based on corn, wheat, and barley had greater apparent total tract digestibility (ATTD) of crude fiber and energy

than Dutch Landrace pigs [7]. Khieu et al [8] reported that Mong-Cai have a greater capacity for digesting dietary fiber than modern pig breeds. In addition, the fermentation of dietary fiber was also influenced by the fiber sources owing to their different composition and physico-chemical properties [9,10]. Urriola and Stein [11] reported that Meishan pigs had a greater ATTD of dry matter (DM), gross energy (GE), crude protein (CP), carbohydrates and total dietary fiber (TDF) than Yorkshire pigs when fed diets containing distillers dried grains with soluble, but no differences in the ATTD of nutrients between Meishan and Yorkshire pigs fed the soybean hulls or sugar beet pulp.

Jiaying barrow is one of the indigenous breeds in China that has a high ability to utilize fibrous ingredients [12], and it belongs to the pig breed of Taihu that originate in Taihu Lake Region and has great reproductive performance but low growth performance. Duroc×(Berkshire×Jiaying) (DBJ) barrow is produced by crossing Jiaying pig breed with Duroc and Berkshire pig breeds. DBJ barrows as a new crossbreed are fed the same feed on the farm as Duroc×(Landrace×Yorkshire) (DLY) barrows. Therefore, there are no differences in diets, feeding and housing environment. However, the average daily gain and feed conversion ratio in DBJ barrow are lower than in DLY pigs. From birth to slaughter, DBJ pigs take 8 months and the feed to gain ratio is only 3.5:1. Yet, there is a market niche for pigs with black color and good carcass quality particularly in Asia-Australasia region, DBJ therefore, has been cultivated with little knowledge of their digestibility of nutrients. Feeding standards have not yet been developed for this crossbreed. The objective of this experiment was to compare the apparent ileal digestibility (AID) of chemical constituents and amino acids and ATTD of chemical constituents in high-fiber diets from different fiber sources of DBJ and DLY growing barrows.

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.

Animals and housing

Eighteen DLY barrows (initial body weight: 42.14±1.08 kg; 3 months old) and 18 DBJ barrows (initial body weight: 43.39±0.89 kg; 4 months old), supplied by the Zhejiang Qinglian Food Company (Jiaying, China), were surgically fitted with a T-cannula in the distal ileum. The DBJ barrows were one month older than the DLY in this study. After surgery, the barrows were allowed a 15 d period to recover during which time they were fed a corn-soybean meal diet. All barrows were housed at the Beijing Swine Research Unit of China Agricultural University (Beijing, China) in individual stainless-steel

metabolism crates (1.4×0.7×0.6 m) that had a nipple drinker and a self-feeder. The room temperature was kept between 20°C and 25°C throughout the experiment.

Experimental diets

Three fibrous ingredients were used and analyzed (Table 1) including wheat middlings, rice bran and alfalfa meal. The control diet was based on corn and soybean meal. Three additional diets were formulated by replacing 25% corn and soybean meal in the control diet with wheat middlings, rice bran and alfalfa meal respectively (Table 2). Vitamins and minerals were included in all diets to meet or exceed the nutrient requirements of growing pigs (NRC [13]). All diets contained 0.30% chromic oxide as an indigestible marker.

Experimental design and sample collection

Barrows were randomly allotted to a 2×3 factorial arrangement involving 2 pig breeds and 3 diets. The experiment lasted

Table 1. Analyzed chemical composition of experimental ingredients (% , as-fed basis)

Items	Wheat middlings	Rice bran	Alfalfa meal
Gross energy (MJ/kg)	16.68	18.33	16.17
Dry matter	88.64	91.42	93.27
Organic matter	85.62	85.74	81.65
Crude protein	16.22	8.46	16.10
Ether extract	3.82	7.15	3.15
Total dietary fiber	37.22	68.41	65.80
Insoluble dietary fiber	32.16	62.90	52.56
Soluble dietary fiber	5.06	5.51	13.24
Neutral detergent fiber	28.78	57.65	46.21
Acid detergent fiber	7.84	31.47	29.25
Indispensable amino acids			
Arginine	1.03	0.43	0.56
Histidine	0.40	0.16	0.21
Isoleucine	0.48	0.24	0.52
Leucine	0.87	0.60	0.93
Lysine	0.54	0.39	0.69
Methionine	0.27	0.17	0.18
Phenylalanine	0.50	0.28	0.62
Threonine	0.56	0.32	0.62
Tryptophan	0.22	0.08	0.18
Valine	0.71	0.35	0.63
Dispensable amino acids			
Alanine	1.36	0.56	0.78
Aspartic acid	1.16	0.65	1.45
Cysteine	0.52	0.16	0.19
Glutamic acid	3.01	0.94	1.29
Glycine	1.21	0.38	0.68
Proline	0.12	0.45	0.89
Serine	1.21	0.35	0.62
Tyrosine	0.42	0.19	0.36

All data are the results of a chemical analysis conducted in duplicate.

Table 2. Analyzed chemical composition of experimental diets (% , as-fed basis)

Items	Diets			
	Control	Wheat middlings	Rice bran	Alfalfa meal
Ingredients				
Corn	72.38	54.29	54.29	54.29
Soybean meal	24.12	18.09	18.09	18.09
Wheat middlings	—	24.12	—	—
rice bran	—	—	24.12	—
Alfalfa meal	—	—	—	24.12
Dicalcium phosphate	1.30	1.30	1.30	1.30
Limestone	0.90	0.90	0.90	0.90
Sodium chloride	0.30	0.30	0.30	0.30
Chromic oxide	0.30	0.30	0.30	0.30
Choline chloride	0.20	0.20	0.20	0.20
Premix ¹⁾	0.50	0.50	0.50	0.50
Analyzed composition (%)				
Dry matter	88.64	89.07	89.44	89.46
Gross energy (MJ/kg)	15.89	15.99	16.28	15.68
Crude protein	16.96	16.36	15.08	16.21
Neutral detergent fiber	11.55	16.36	22.54	19.54
Acid detergent fiber	3.37	6.17	10.86	9.87
Ash	4.81	4.94	4.94	7.49
Ether extract	2.86	2.81	2.81	2.67
Calcium	0.81	0.85	0.85	1.30
Phosphorus	0.50	0.57	0.57	0.53
Indispensable amino acids				
Arginine	0.88	1.01	0.84	0.80
Histidine	0.38	0.41	0.35	0.34
Isoleucine	0.57	0.60	0.57	0.57
Leucine	1.40	1.36	1.30	1.24
Lysine	0.79	0.86	0.81	0.83
Methionine	0.26	0.31	0.23	0.25
Phenylalanine	0.71	0.73	0.70	0.68
Threonine	0.59	0.62	0.58	0.60
Tryptophan	0.18	0.17	0.16	0.17
Valine	0.65	0.72	0.66	0.67
Dispensable amino acids				
Alanine	0.86	0.88	0.85	0.82
Aspartic acid	1.43	1.47	1.37	1.46
Cysteine	0.26	0.30	0.23	0.24
Glutamic acid	2.62	2.74	2.41	2.29
Glycine	0.61	0.61	0.61	0.63
Proline	1.04	1.12	0.98	1.01
Serine	0.76	0.79	0.72	0.72
Tyrosine	0.45	0.47	0.45	0.40

¹⁾ Premix provided the following per kg of complete feed for growing pigs: vitamin A, 5,512 IU; vitamin D₃, 2,200 IU; vitamin E, 64 IU; vitamin K₃, 2.2 mg; vitamin B₁₂, 27.6 µg; riboflavin, 5.5 mg; pantothenic acid, 13.8 mg; niacin, 30.3 mg; choline chloride, 551 mg; Mn, 40 mg; Fe, 100 mg; Zn, 100 mg; Cu, 100 mg; I, 0.3 mg; Se, 0.3 mg.

15 d comprising 10 d for diet adaptation, 3 d for fecal collection and 2 d for digesta collection. Barrows were provided *ad libitum* access to water and were fed an amount of feed equivalent to 4% of body weight (BW) each day divided into 2

equal feedings provided at 0800 and 1600 h. The barrow's body weight was recorded at the beginning of the experiment and at the end of each period to calculate the necessary feed allowance.

Fecal samples were collected on d 11 to d 13 via grab-sampling and stored at -20°C. At the end of the experiment, the feces collected from each pig were pooled and dried in a forced-draft oven at 65°C for 72 h. After drying and grinding through a 1-mm screen, sub-samples were stored at -20°C until needed for chemical analysis. Digesta samples were collected on d 14 and d 15 following the procedures described by Cervantes-Pahm and Stein [14]. Collection of ileal digesta was initiated at 0800 h and ceased at 1600 h each collection day. For digesta collection, a plastic bag was attached to the barrel of the cannula using a cable tie. Bags were removed as they were filled and were stored at -20°C to prevent bacterial degradation of the samples. At the conclusion of the experiment, digesta samples were thawed and mixed within pig and diet. A sub-sample was lyophilized and ground through a 1-mm screen and stored at -20°C prior to chemical analysis.

Chemical analyses

The DM (Method 934.01), CP (Method 990.03), ether extract (EE; Method 920.39), ash (Method 942.05), calcium (Ca), and phosphorus (P) (Method 985.01) content of the ingredients, diets, digesta and feces were analyzed according to the procedures of the Association of Official Analytical Chemists [15]. The chromium (Method 990.08) in diets, digesta and feces was also analyzed. The TDF (AOAC, 2007; method 985.29) and insoluble dietary fiber (IDF; AOAC, 2007; method 991.43) of ingredients was also measured, and soluble dietary fiber (SDF) was calculated by difference as total and IDF. 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) after an adaptation of the procedure as described by Van Soest et al [16]. The concentration of NDF was analyzed using heat stable α -amylase and sodium sulphite without correction for insoluble ash. The GE of feces and diets were measured using an Automatic Isoperibol Oxygen Bomb Calorimeter (Parr 1281 Calorimeter, Moline, IL, USA).

The amino acid content of diets and digesta were analyzed according to AOAC (2005; Method 151 982.30). Samples were hydrolyzed with 6 N HCl at 110°C for 24 h and analyzed for 15 amino acids (AAs) using an Amino Acid Analyzer (Hitachi L-8900, Tokyo, Japan). Methionine and cystine were determined as methionine sulfone and cysteic acid after cold performic acid oxidation overnight and hydrolyzing with 7.5 N HCl at 110°C for 24 h using an Amino Acid Analyzer (Hitachi L-8800, Japan). Tryptophan was determined after LiOH hydrolysis for 22 h at 110°C using high performance liquid chromatography

(Agilent 1200 Series, Santa Clara, CA, USA).

Calculations

The equation used to calculate the AID of indispensable amino acids (IAA) in diets was obtained from Stein et al [17]: $AID = 100 - (AA_{digesta}/AA_{diet}) \times (Cr_{diet}/Cr_{digesta}) \times 100$. In this equation, AID is the apparent ileal digestibility of AA, $AA_{digesta}$ is the AA concentration in the ileal digesta (g/kg DM), AA_{diet} is the AA concentration in the diet (g/kg DM), while Cr_{diet} and $Cr_{digesta}$ are the chromium concentrations in the diet and digesta respectively (g/kg DM).

The AID and ATTD of chemical constituents were determined using the indicator method described by Maneewan et al [18]: $ND = 100 - (DC \times FN) / (FC \times DN) \times 100$. In this equation, ND is the AID or ATTD, DC is the content of chromium in the assay diet, FN is the content of chemical constituents in the feces, FC is the content of chromium in the feces, and DN is the content of chemical constituents in the diet.

The hindgut disappearance of nutrients and energy was calculated according to the following equation: Hindgut disappearance = ATTD - AID. In this equation, ATTD is the apparent total tract digestible chemical constituents (g) or energy (MJ/kg), and AID is the apparent ileal digestible chemical constituents (g) or energy (MJ/kg).

Statistical analysis

The UNIVARIATE procedure of SAS was used to check for normal distribution of the model residuals and equal variances. The residual vs the predicted plot procedure was used to identify outliers. The model included the effect of cross-breed, diets and their interaction for all measurements. Data were analyzed using the MIXED procedure of SAS (SAS Inst. Inc., Cary NC, USA). The individual animal and dietary treatment were the experimental units for analyzing the data from the digestibility trial. The model included diet as a fixed effect and animal as a random effect. The significance level was set at $p \leq 0.05$, whereas $0.05 \leq p \leq 0.10$ was considered to constitute

a tendency.

RESULTS

In our study, each barrow consumed all the ration offered. At the end of the experiment, the average BW of DLY and DBJ barrows are 52.1 ± 0.74 kg and 50.3 ± 0.59 kg respectively. No interaction effects between hybrids and fiber source on the AID of IAA and the digestibility of GE, DM, OM, NDF, ADF, EE, and CP in diets were observed.

Effects of fiber source on the digestibility of chemical constituents and indispensable amino acids

The diets with different fiber sources had a significant differences ($p < 0.05$) in the AID, ATTD, and hindgut disappearance of most chemical constituents (Tables 3, 5, 6). Wheat middlings diet had a greater AID ($p < 0.05$) of CP than rice bran and alfalfa meal diets. The AID of GE, DM, and OM in wheat middlings and alfalfa meal diets were the highest and lowest ($p < 0.05$) values, and those of values of rice bran diet were the middle. Wheat middlings and alfalfa meal diets had a greater ($p < 0.05$) AID of NDF and ADF than rice bran diet. The ATTD of GE, DM, and OM in wheat middlings diet were greater ($p < 0.05$) than in rice bran and alfalfa meal diets. The ATTD of CP in alfalfa meal diet was lower ($p < 0.05$) than in wheat middlings and rice bran diets. The ATTD of NDF and ADF were the greatest or lowest ($p < 0.05$) in wheat middlings or rice bran diet. The hindgut disappearances of GE, CP, DM, and OM in rice bran diet were greater ($p < 0.05$) than in wheat middlings and alfalfa meal diets. The hindgut disappearances of NDF and ADF in wheat middlings diet or rice bran diet were the highest or lowest ($p < 0.05$), and those of values in alfalfa meal diet were the middle. The hindgut disappearance of EE in wheat middlings diet was lower ($p < 0.05$) than in rice bran and alfalfa meal diets. In addition, barrows fed the wheat middlings diet had a greater ($p < 0.05$) AID of all IAA, expect for Phe, than these barrows fed the rice bran and alfalfa meal

Table 3. Effect of pig breed and fiber source on the apparent ileal digestibility (AID, %) of gross energy and nutrients in diets¹⁾

Items	DLY			DBJ			Mean			SEM	p-value				
	WM	RB	AM	WM	RB	AM	DLY	DBJ	WM		RB	AM	Breed	Diet	Interaction
GE	64.5	49.2	55.5	63.5	48.7	54.4	56.4	55.5	64.0 ^a	49.0 ^c	54.9 ^b	1.48	0.87	0.01	0.78
CP	68.4	62.3	63.2	71.9	62.9	61.9	64.6	65.5	70.1 ^a	62.6 ^b	62.6 ^b	1.45	0.45	0.01	0.27
DM	62.6	48.1	54.0	64.0	47.1	52.9	54.9	54.7	63.3 ^a	47.6 ^c	53.4 ^b	1.29	0.84	0.01	0.54
OM	66.1	51.6	57.5	67.4	50.8	56.7	58.4	58.3	66.8 ^a	51.2 ^c	57.1 ^b	1.30	0.91	0.01	0.66
NDF	10.7	3.4	9.2	6.2	0.7	7.3	6.4	3.4	8.4 ^a	2.1 ^b	8.3 ^a	3.16	0.25	0.01	0.91
ADF	6.6	2.9	6.2	5.0	1.1	2.5	4.9	2.9	5.8 ^a	2.0 ^b	4.7 ^a	3.16	0.09	0.01	0.53
EE	76.7	72.4	68.0	76.5	71.5	66.8	72.4	71.6	76.6 ^a	71.9 ^{ab}	67.4 ^b	2.68	0.72	0.01	0.98

SEM, standard error of the mean; GE, gross energy; CP, crude protein; DM, dry matter; OM, organic matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; EE, ether extract.

¹⁾ DLY, Duroc × (Landrace × Yorkshire); DBJ, Duroc × (Berkshire × Jianxing) pigs; WM, wheat middlings; RB, rice bran; AM, alfalfa meal.

^{a-c} Means in the same row bearing different superscripts differ significantly ($p < 0.05$).

Table 4. Effect of pig breed and fiber source on the apparent ileal digestibility (AID, %) of indispensable amino acids in diets¹⁾

Items	DLY			DBJ			Mean			SEM	p-value				
	WM	RB	AM	WM	RB	AM	DLY	DBJ	WM		RB	AM	Breed	Diet	Interaction
Arginine	82.9	78.5	78.6	86.6	79.5	78.5	80.0	81.5	84.8 ^a	79.0 ^b	78.6 ^b	1.37	0.18	0.01	0.35
Histidine	72.9	69.9	65.3	77.3	71.4	67.2	69.4	72.0	75.1 ^a	70.7 ^b	66.3 ^c	2.24	0.17	0.01	0.79
Isoleucine	75.7	70.9	69.5	81.7	74.2	71.2	72.0 ^b	75.7 ^A	78.7 ^a	72.6 ^b	70.4 ^b	1.76	0.02	0.01	0.46
Leucine	77.7	73.7	72.9	82.5	77.1	72.9	74.8 ^b	77.5 ^A	80.1 ^a	75.4 ^b	72.9 ^b	1.40	0.02	0.01	0.21
Lysine	75.9	71.8	70.7	78.7	74.5	73.1	72.8 ^b	76.2 ^A	77.3 ^a	73.2 ^b	71.9 ^b	1.31	0.03	0.01	0.87
Methionine	87.5	78.7	78.8	84.1	74.9	74.8	81.7 ^A	77.9 ^B	85.8 ^a	76.8 ^b	76.8 ^b	1.45	0.01	0.01	0.97
Phenylalanine	73.9	71.6	71.2	80.9	77.6	77.2	72.2 ^b	78.6 ^A	77.4	74.6	74.2	1.72	0.01	0.14	0.33
Threonine	65.1	56.9	59.8	66.9	57.8	58.5	60.6	61.1	66.0 ^a	57.4 ^b	59.2 ^b	1.69	0.73	0.01	0.64
Tryptophan	67.7	64.4	64.6	71.2	66.1	63.2	65.6	66.8	69.5 ^a	65.3 ^b	63.9 ^b	1.85	0.41	0.02	0.41
Valine	73.5	67.7	68.1	76.8	71.1	71.1	69.8 ^b	73.0 ^A	75.2 ^a	69.4 ^b	69.6 ^b	1.37	0.01	0.01	0.99

SEM, standard error of the mean.

¹⁾ DLY, Duroc × (Landrace × Yorkshire); DBJ, Duroc × (Berkshire × Jianxing) pigs; WM, wheat middlings; RB, rice bran; AM, alfalfa meal.

^{A,B,a,b,c} Means in the same row bearing different superscripts differ significantly (p < 0.05).

Table 5. Effect of pig breed and fiber source on the apparent total tract digestibility (ATTD, %) of gross energy and nutrients in diets¹⁾

Items	DLY			DBJ			Mean			SEM	p-value				
	WM	RB	AM	WM	RB	AM	DLY	DBJ	WM		RB	AM	Breed	Diet	Interaction
GE	79.0	67.3	68.6	79.0	68.2	67.7	71.6	71.6	79.0 ^a	67.8 ^b	68.1 ^b	0.74	0.95	0.01	0.48
CP	77.2	75.5	66.9	77.8	77.5	67.3	73.2	74.2	77.5 ^a	76.5 ^a	67.1 ^b	0.94	0.21	0.01	0.68
DM	79.4	67.4	69.4	79.5	68.4	68.4	72.1	72.1	79.4 ^a	67.9 ^b	68.9 ^b	0.69	0.96	0.01	0.36
OM	82.7	70.1	72.8	82.6	71.1	72.0	75.2	75.2	82.6 ^a	70.6 ^b	72.4 ^b	0.65	0.97	0.01	0.41
NDF	37.5	18.0	29.9	40.6	17.8	30.4	28.4	29.6	39.1 ^a	17.9 ^c	30.2 ^b	2.36	0.72	0.01	0.38
ADF	27.3	7.8	19.0	33.7	9.2	17.7	18.0	20.2	30.5 ^a	8.5 ^c	18.4 ^b	2.42	0.28	0.01	0.29
EE	44.1	56.3	50.9	43.1	56.2	48.3	50.5	49.2	43.6 ^c	56.3 ^a	49.6 ^b	2.87	0.60	0.01	0.91

SEM, standard error of the mean; GE, gross energy; CP, crude protein; DM, dry matter; OM, organic matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; EE, ether extract.

¹⁾ DLY, Duroc × (Landrace × Yorkshire); DBJ, Duroc × (Berkshire × Jianxing) pigs; WM, wheat middlings; RB, rice bran; AM, alfalfa meal.

^{a-c} Means in the same row bearing different superscripts differ significantly (p < 0.05).

diets (Table 4). No differences in the AID of all IAA except for His and Phe between rice bran diet and alfalfa meal diet were observed.

Effects of crossbred pig on the digestibility of chemical

constituents and indispensable amino acids

There were no differences (p < 0.05) in the AID and ATTD of chemical constituents between DLY and DBJ barrows (Tables 3, 5). However, the AID of GE, NDF, and ADF in DBJ barrows decreased by 1.6, 47.1% and 40.8%, but the AID of CP

Table 6. Effect of pig breed and fiber source on the hindgut disappearance (%) of gross energy and nutrients in diets¹⁾

Items	DLY			DBJ			Mean			SEM	p-value				
	WM	RB	AM	WM	RB	AM	DLY	DBJ	WM		RB	AM	Breed	Diet	Interaction
GE	14.5	18.1	13.1	15.5	19.5	13.3	15.2	16.2	15.0 ^b	18.8 ^a	13.2 ^b	1.67	0.86	0.01	0.76
CP	8.8	13.2	3.7	6.0	14.6	5.4	8.6	8.7	7.4 ^b	13.9 ^a	4.5 ^b	1.49	0.94	0.01	0.25
DM	16.9	19.3	15.4	15.5	21.3	15.5	17.2	17.4	16.2 ^b	20.3 ^a	15.8 ^b	1.51	0.84	0.01	0.53
OM	16.6	18.5	15.3	15.2	20.3	15.3	16.8	16.9	15.9 ^b	19.4 ^a	15.3 ^b	1.49	0.91	0.02	0.56
NDF	26.8	14.6	20.7	34.5	17.1	23.1	22.1	26.2	30.6 ^a	15.9 ^c	21.9 ^b	3.62	0.25	0.01	0.44
ADF	21.8	4.9	13.8	28.7	8.1	15.3	13.5 ^b	17.3 ^A	25.2 ^a	6.5 ^c	14.6 ^b	2.55	0.03	0.02	0.99
EE	-32.5	-16.1	-17.1	-33.4	-15.3	-18.5	-21.9	-22.4	-33.0	-15.7	-17.8	4.62	0.90	0.01	0.97

SEM, standard error of the mean; GE, gross energy; CP, crude protein; DM, dry matter; OM, organic matter; NDF, neutral detergent fiber; ADF, acid detergent fiber; EE, ether extract.

¹⁾ DLY, Duroc × (Landrace × Yorkshire); DBJ, Duroc × (Berkshire × Jianxing) pigs; WM, wheat middlings; RB, rice bran; AM, alfalfa meal.

^{A,B,a,b,c} Means in the same row bearing different superscripts differ significantly (p < 0.05).

increased by 1.4% compared with DLY barrows. The ATTD of NDF and ADF increased by 4.1% and 12.2% in DBJ barrows compared with DLY barrows. The hindgut disappearance of ADF in DBJ barrows was greater ($p < 0.05$) than in DLY barrows (Table 6). The hindgut disappearance of GE, NDF, and ADF increased by 6.2%, 18.8%, and 28.1% in DBJ barrows compared with DLY barrows, but not significantly different ($p > 0.05$). In addition, DBJ barrows had a greater ($p < 0.05$) AID of Ile, Leu, Lys, Phe, and Val and a lower ($p < 0.05$) AID of Met than DLY pigs when fed the diets (Table 4). No differences in the AID of Arg, His, Thr, and Trp between DBJ and DLY pigs were observed.

DISCUSSION

In the current study, the analyzed values of chemical constituents and amino acids in wheat middlings and alfalfa meal were comparable with those published in NRC [13]. However, rice bran used in the experiment had a greater concentration of fiber compared with those values published in NRC, which may be caused by the high proportion of rice hulls. And the low concentration of CP and AA in rice bran were also analysed due to its high content of fiber.

Effect of fiber source on the digestibility of chemical constituents and indispensable amino acids

Barrows of both crossbreeds had a greater AID of IAA, GE, DM, and OM when fed the wheat middlings diet than the rice bran and alfalfa meal diets in our study. The result was caused by a higher fiber level in rice bran and alfalfa meal than in wheat middlings, because the concentration of dietary fiber has a negative effect on the digestibility of AA and nutrients [19]. Chen et al [20] reported that the corn-soybean meal diet containing 10% of alfalfa meal did not affect ileal AA digestion, but increasing the proportion of alfalfa meal from 12.3% to 21.4% in the control diet induced a linear reduction in AID of most AA. These results indicated that total ileal endogenous AA losses tended to increase with high concentration of fiber in diets fed to growing pigs [21], which is another reason for lower AID of AA in rice bran and alfalfa meal diets than in wheat middlings diet. In addition, the AID of GE, DM, OM, NDF, and ADF were greater in alfalfa meal diet than in rice bran diet, although they had a similar concentration of dietary fiber. The results were caused by higher SDF/TDF ratio in alfalfa meal than in rice bran, which resulted in increasing the retention time of digesta and improving the AID of nutrients and dietary fiber. Furthermore, barrows fed rice bran and alfalfa meal diets had a lower ATTD of GE, DM, DM, NDF, and ADF than barrows fed the wheat middlings diet due to their higher content of dietary fiber. The phenomenon could be explained by the decrease in the mean retention time of nutrients in the gastrointestinal tract and by hindering the ac-

cess of digestive enzymes to the chyme in the intestine [22,23] when pigs are fed the diets containing high concentration of fiber. Previous studies also showed that the high inclusion levels of alfalfa meal in a swine diet decreased the ATTD of GE and some nutrients and affected the hindgut fermentation [24,25]. In addition, another reason for the greater ATTD of chemical constituents in wheat middlings diet than in rice bran and alfalfa meal diets is wheat middlings have higher SDF/TDF ratio, which could increase the viscosity and decrease the evacuation rate of digesta [26]. Hindgut disappearance of GE, DM, OM, and CP in rice bran diet were greater than in wheat middlings and alfalfa meal diets, which may have been caused by the secretion of digestive enzymes due to a higher proportion of IDF in rice bran. However, barrows fed wheat middling and alfalfa meal diets had a greater hindgut disappearance of dietary fiber and a lower hindgut disappearance of EE than in rice bran diet. Those results resulted from the higher fermentable fiber in wheat middlings and alfalfa meal compared with rice bran, and result in more synthesis of volatile fatty acids in the hindgut.

Effect of crossbred pig on the digestibility of chemical constituents and amino acids

In the present study, there were no differences in the AID of DM, GE, OM, and EE between DBJ and DLY barrows. The result was consistent with Urriola and Stein [11] who reported that there were no differences in the AID of GE and nutrients between Meishan and Yorkshire pigs when fed the high-fiber diets. However, DBJ barrows had a lower AID of dietary fiber than DLY barrows, which may be caused by the difference in the secretion of digestive enzyme in the small intestine. In our study, DBJ barrows have a greater capacity for fiber utilization in the hindgut than DLY barrows under the same feeding conditions. This result agreed with the previous study that reported indigenous breeds of pigs have been shown to utilize high-fiber diets more efficiently than exotic crossbreeds due to higher microbial activity and longer gut length [6,27]. Kemp et al [7] and Ndindana et al [28] also showed that Meishan and Mukota pigs had a greater capacity for digesting dietary fiber than modern pig breeds. Therefore, the result in our study indicated that DBJ pigs may have special microbiota in the hindgut relative to the digestibility of fiber, but further study must be conducted to compare the gut microbiota between DBJ and DLY barrows. Another important reason for the above result is that due to their slow growth rate it took an additional month of growth to obtain DBJ barrows with almost equal weights compared with DLY barrows (42.14 kg vs 43.39 kg). Consequently, the different digestibility of fiber between DBJ and DLY barrows is due to their difference in age. Furthermore, DBJ had a greater AID of CP, Lys, Leu, Ile, and Trp, but a lower AID of Met than DLY barrows. This indicated that it is reasonable for decreasing the supplementation of Lys, Leu, Ile,

and Val and increasing the addition of Met in diets fed to DBJ barrows compared with DLY barrows. This result was consistent with Urriola and Stein [11] who reported that Meishan pig have a greater AID of CP than Yorkshire pig when fed the high-fiber diets with soybean hulls or sugar beet pulp. Those results may be relative to the different morphology and function of small intestine between pig breeds, and resulted in the different digestibility of CP and IAA and the nitrogen retention. A further study should be conducted to evaluate the differences in the morphology and function of small intestine between DLY and DBJ barrows. In addition, adaptation of pigs to dietary fiber digestion is a long process that requires 5 weeks [29]. To verify our results, it is necessary to study the effects of adaptation period on the difference in nutrients and amino acids digestibilities between DLY and DBJ barrows.

There were no differences in the ATTD of GE, CP, and OM between DBJ and DLY barrows. The result was consistent with the previous study that showed there were also no differences in the ATTD of GE, DM, CP, and OM between exotic breeds and indigenous breeds such as Meishan pig when fed wheat bran or alfalfa meal diets [30]. In contrast, Len et al [6] showed that Mong-Cai pigs had a greater ATTD of OM, CP, NDF, and EE than Landrace×Yorkshire (LY) pigs when fed a rice bran diet. The reasons for those different results may be related to the sources and concentrations of fiber in diets as well as the crossbred pigs studied. Overall, DBJ growing barrows showed a significant higher digestibility of fiber in the hindgut and most indispensable amino acids in the small intestine, but no difference in the ATTD of GE, CP, NDF, and ADF compared with DLY barrows in our study.

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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