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Effects of inclusion level and adaptation period on nutrient digestibility and digestible energy of wheat bran in growing-finishing pigs

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Objective: This experiment was to evaluate the effect of different inclusion levels and adaptation periods on digestible energy (DE) and the apparent total tract digestibility (ATTD) of chemical constituents in diets supplemented with wheat bran.
Methods: Thirty-six crossbred barrows with an initial body weight of 85.0±2.1 kg were allotted to 6 diets in a completely randomized block design with 6 pigs per diet. Diets included a corn-soybean basal diet and 5 additional diets which were formulated by replacing corn and soybean meal in control diet with 15%, 25%, 35%, 45%, or 55% wheat bran. The experiment lasted for 34 d, and feces were collected from d 8 to 13, 15 to 20, 22 to 27, and 29 to 34 respectively.
Results: The results showed no interaction effects between inclusion level and adaptation period on the concentration of DE and the ATTD of gross energy (GE) and crude protein (CP) in wheat bran. The DE value and ATTD of GE in wheat bran decreased ($p<0.05$) significantly as the inclusion level of wheat bran increased, but no difference in the ATTD of CP was observed. The ATTD of CP in wheat bran increased ($p<0.10$) significantly as the adaptation period for pigs was prolonged. In addition, the concentration of DE and the ATTD of GE in wheat bran decreased linearly ($p<0.05$) when pigs were fed either an increased level of wheat bran or given an increased adaptation period to the diets.
Conclusion: Wheat bran showed a negative effect on the concentration of DE and ATTD of GE and CP as the inclusion level increased. A longer adaptation period can gradually increase the DE value and ATTD of GE and CP in wheat bran, and at least 14 to 21 d of adaptation might be recommended for growing-finishing pigs fed the high-fiber diets with wheat bran.

Keywords: Adaptation Period; Digestibility; Digestible Energy; Growing-Finishing Pig; Inclusion Level; Wheat Bran

INTRODUCTION

Dietary fiber is associated with impaired nutrient utilization and reduced net energy values, but a minimum of dietary fiber has to be included in the diets to maintain normal physiological functions in the gastrointestinal tract [1]. Wheat bran is a by-product of flour milling and frequently used as a fibrous ingredient in diets for pigs to reduce the cost of feed [2]. However, its application in pig feeding shows some limitations due to a high amount of insoluble fiber which is very resistant to natural degradation processes in the gut [3]. Pig diets with high levels of wheat bran usually have low digestible energy (DE) values and apparent total tract digestibility (ATTD) of nutrients [4,5]. Differences in fiber characteristic and inclusion level of fiber are most likely the primary reasons for the variation in DE and nutrient digestibility when fibrous ingredients are used in pig diets [5-7]. In addition, energy and nutrient digestibility were also influenced by adaptation period when pigs were fed high-fiber diets [8-10]. Longland et al [8] reported that a growing pig needs at least 1 week adaptation to high-fiber diet, but 3 to 5 weeks are required before there is sufficient stability to measure digestibility of non-starch polysaccharides (NSP). In contrast, a pregnant sow could completely adapt to a high-fiber diet in 2 weeks [11].

Therefore, we hypothesized that there may be an interaction effect on the DE and ATTD of energy and chemical constituents of diets in pigs between the inclusion level of wheat bran and adaptation period to diets. The present experiment was conducted to evaluate the effects of the inclusion level of wheat bran and adaptation period on the DE and ATTD of gross energy (GE), dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), and acid detergent fibre (ADF) in diets for growing-finishing pigs.

MATERIALS AND METHODS

This study involving pig handling and treatments was carried out in accordance with China Agricultural University Laboratory Animal Welfare and Animal Experimental Ethical Inspection Committee (Beijing, China) in this experiment.

Animals and housing

Forty-two barrows (Duroc×Landrace×Yorkshire) with an initial body weight (BW) of 85.0±2.1 kg were individually housed in stainless-steel metabolism crates (1.4×0.7×0.6 m) at the Fengning Swine Research Unit of China Agricultural University (Chengde). The crates had adjustable sides and were located in a room with temperature controlled at 22°C±2.5°C. Humidity varied from 55% to 65% during the experiment. An adjustable screen was placed under each cage that permitted the total collection of feces. All pigs had *ad libitum* access to water via a drinking nipple.

Table 1. Analyzed chemical composition of wheat bran (%, as-fed basis)[1)]

Items	Wheat bran
Dry matter	89.4
Organic matter	84.1
Crude protein	17.2
Acid detergent fibre	11.0
Neutral detergent fibre	37.5
Ash	5.3
Gross energy (MJ/kg)	16.36

[1)] All data are the results of a chemical analysis conducted in duplicate.

Experimental diets

Pigs were allotted to 6 diets in a completely randomized block design according to their initial BW and with 6 pigs fed each diet. The composition of wheat bran in the experiment was also analyzed (Table 1). Diets included a corn-soybean meal basal diet and five additional diets which were formulated by replacing corn and soybean meal in control diet with 15%, 25%, 35%, 45%, or 55% wheat bran (Table 2). Vitamins and minerals were supplemented in all diets to meet or exceed nutrient requirements of pigs according to NRC [12].

Experimental design and sample collection

All pigs were acclimated to the room for 7 d and fed a standard corn-soybean meal diet before the start of the experiment. Pigs were weighed at the beginning of the experiment to ensure the feed intake. Experimental diets were fed in a meal form and offered to pigs at a level of 3% of initial BW and provided in 2 equal daily meals at 0730 and 1630 h. Feed refusals were collected

Table 2. Inclusion level of wheat bran and analyzed chemical composition of experimental diets (%, as-fed basis)[1)]

Items	Basal diet	Inclusion level of wheat bran (%)				
		14.6	24.4	34.2	43.9	53.7
Ingredients						
Corn	76.6	65.1	57.4	49.7	42.1	34.4
Soybean meal	21.0	17.9	15.8	13.7	11.6	9.5
Wheat bran	-	14.6	24.4	34.2	43.9	53.7
Limestone	1.0	1.0	1.0	1.0	1.0	1.0
Dicalcium phosphate	0.6	0.6	0.6	0.6	0.6	0.6
Salt	0.3	0.3	0.3	0.3	0.3	0.3
Premix[2)]	0.5	0.5	0.5	0.5	0.5	0.5
Analyzed chemical composition (%)						
DM	88.4	88.4	88.1	87.8	87.6	87.3
CP	16.8	16.9	16.8	17.4	16.6	16.7
Ash	4.0	4.4	4.7	5.2	5.1	5.4
OM	84.4	84.1	83.4	82.6	82.5	82.0
NDF	10.1	13.8	16.5	19.9	21.8	24.5
ADF	3.5	4.3	4.9	5.9	6.4	7.0
GE (MJ/kg)	16.17	16.27	16.21	16.12	15.98	15.95

DM, dry matter; CP, crude protein; OM, organic matter; NDF, neutral detergent fibre; ADF, acid detergent fibre; GE, gross energy.
[1)] All data are the results of a chemical analysis conducted in duplicate.
[2)] Provided the following quantities per kg of complete diet: Mn, 50 mg (MnO); Fe, 125 mg ($FeSO_4 \cdot H_2O$); Zn, 125 mg (ZnO); Cu, 150 mg ($CuSO_4 \cdot 5H_2O$); I, 50 mg (CaI_2); Se, 0.30 mg (Na_2SeO_3); retinyl acetate, 4,500 IU; cholecalciferol, 1,350 IU; DL-α-tocopheryl acetate, 13.5 mg; menadione sodium bisulphite complex, 2.7 mg; niacin, 18 mg; vitamin B_{12}, 27.6 μg; thiamine, 0.6 mg; pyridoxine, 0.9 mg; riboflavin, 1.8 mg; D-Ca-pantothenate, 10.8 mg; nicotinic acid.

and weighed daily.

Pigs were fed the same experimental diets throughout the 34-d experiment. Feces were collected from d 8 to 13, d 15 to 20, d 22 to 27, and d 29 to 34. Fresh feces were stored at −18°C immediately after collection. At the end of each collection period, the collected feces were weighed, thawed, and then homogenized thoroughly. A 350 gram sub-sample of feces from each pig in each collection period was dried in a forced-air oven at 65°C for 72 h. Dried feces were ground through a 1-mm screen before chemical analysis.

Sample analysis and calculations

Ingredient, diets and feces samples were analyzed for GE using an isoperibolic oxygen bomb (Parr Instruments, Moline, IL, USA), DM (method 930.15; AOAC International, 2007), CP (method 990.03; AOAC International, 2007), ash (method 942.15; AOAC International, 2007). The NDF and ADF were determined using fiber bags and fiber analyzer equipment (Fiber Analyzer, Ankom Technology, Macedon, NY, USA) following a modification of the procedure of Van Soest et al [13].

The DE and ATTD of chemical components in diets were calculated according to the total feces collection method, and the DE values of wheat bran and the ATTD of GE and CP were calculated by the difference method. The OM (%) was calculated as the difference between DM (%) and ash (%).

Statistical analysis

Normality was verified and outliers were identified using the UNIVARIATE procedure of SAS 9.4 (SAS Institute, Cary, NC, USA). An observation was considered an outlier if the value was more than 3 standard deviations away from the grand mean. Because there were no interaction effects between inclusion level and adaptation duration for all the diets (not shown), data were separated by each diet/ingredient and analyzed by analysis of variance using the PROC general linear model procedure of SAS in a completely randomized design with the pig as the experimental unit. The statistical models studied the effects of: i) inclusion level of wheat bran, ii) adaptation duration of diets, iii) interaction between inclusion level of wheat bran and adaptation period of diets. In addition, means were separated using the LSMEANS statement and adjusted by Tukey's multiple comparison tests. Polynomial contrast were conducted to determine linear and quadratic effects of inclusion level or adaptation duration. Statistical significance and tendency were considered at $p<0.05$ and $0.05\leq p<0.10$, respectively.

RESULTS

The effect of inclusion level and adaptation period to wheat bran on the DE value and ATTD of chemical constituents in diets

No interaction effects between the inclusion level of wheat bran and the adaptation period on the concentration of DE and the ATTD of GE, DM, OM, NDF, ADF, and CP in diets were observed (Table 3). The DE value and the ATTD of GE, DM, OM, NDF, ADF, and CP in wheat bran decreased ($p<0.05$) significantly as the inclusion level of wheat bran increased. The adaptation period of diets which contained different inclusion levels of wheat bran can affect significantly the DE value and the ATTD of GE, DM, OM, and CP in diets for growing-finishing pigs, but there were no differences in the ATTD of NDF and ADF in diets were found. In addition, the concentration of DE and the ATTD of GE, DM, OM, NDF, ADF, and CP in diets decreased linearly ($p<0.05$) when fed to growing-finishing pigs as increasing the inclusion level of wheat bran.

The effect of inclusion level and adaptation period on the concentration of DE and the ATTD of GE and CP in wheat bran

No interaction effects were observed between the inclusion level of wheat bran and the adaptation period on the concentration of DE and the ATTD of GE and CP in wheat bran (Table 4). The DE value and the ATTD of GE in wheat bran decreased ($p<0.05$) significantly as the inclusion level of wheat bran increased, but no difference in the ATTD of CP was observed. The ATTD of CP in wheat bran increased ($p<0.05$) significantly as the adaptation period for growing-finishing pigs was increased. And it was a trend that the DE value and ATTD of GE in wheat bran improved as the adaptation period increased.

In addition, the concentration of DE and the ATTD of GE in wheat bran decreased linearly ($p<0.05$) with the increasing inclusion level of wheat bran fed to growing-finishing pigs. The concentration of DE and the ATTD of GE and CP in wheat bran increased linearly ($p<0.05$) with the increasing adaptation period for growing-finishing pigs.

DISCUSSION

Effects of inclusion levels on nitrient digestibility and DE in diets

The concentration of DE and the ATTD of GE decreased as the inclusion level of wheat bran increased, which was in agreement with the previous studies reported by Dégen et al [4] and Huang et al [5]. The decreased concentration of DE in diets may contribute to the high level of insoluble dietary fiber (IDF) in wheat bran which hardly ferments in the gastrointestinal tract of monogastric animals. It has been reported that the increased dietary fiber could shorten gut transit time and thereby leaving less time for fermentation digestion of nutrients in the hindgut [14]. This may be the explanation for the decrease of ATTD of GE and DE value in diets. Similar observations have been reported by Högberg and Lindberg [15], who reported the ATTD of GE decreased when pigs fed a diet containing 30% wheat bran. Similarly, increasing dietary fiber from 12% to 38% by increasing the inclusion level of wheat bran, maize brans, soybean hulls or sugar beet pulp re-

Table 3. The effect of adaptation period and inclusion level of wheat bran on DE and nutrient digestibility in diets fed to pigs[1),2)]

Items	Inclusion levels of wheat bran (%)						Mean[3)]	p-value		
	0	15	25	35	45	55		ANOVA[4)]	Linear	Quadratic
DE										
7 d	14.93	14.36^{a}	13.93^{a}	13.18^{b}	12.81^{b}	12.63^{b}	13.38^{A}	< 0.01	< 0.01	0.17
14 d	14.78	14.21^{a}	13.74^{a}	13.08^{b}	12.50^{c}	12.30^{c}	13.17^{B}	< 0.01	< 0.01	0.19
21 d	14.67	14.31^{a}	13.86^{ab}	13.31^{b}	12.70^{c}	12.53^{c}	13.34^{A}	< 0.01	< 0.01	0.31
28 d	14.69	14.13^{a}	13.88^{a}	13.35^{b}	12.68^{c}	12.63^{c}	13.33^{A}	< 0.01	< 0.01	0.46
Mean[3)]	14.77	14.25^{a}	13.85^{ab}	13.23^{b}	12.67^{c}	12.53^{c}	-	< 0.01	< 0.01	0.32
p-value										
ANOVA	-	0.66	0.75	0.31	0.52	0.33	0.04	-	-	-
Linear	-	0.36	0.93	0.14	0.75	0.73	0.42	-	-	-
Quadratic	-	0.89	0.41	0.52	0.34	0.15	0.48	-	-	-
ATTD of GE										
7 d	92.3	88.2^{a}	86.0^{ab}	81.7^{bc}	80.2^{c}	78.3^{c}	82.9^{A}	< 0.01	< 0.01	0.17
14 d	91.4	87.4^{a}	84.7^{a}	81.1^{b}	78.2^{bc}	76.2^{c}	81.5^{B}	< 0.01	< 0.01	0.19
21 d	90.7	87.8^{a}	85.5^{ab}	82.5^{bc}	79.5^{cd}	77.6^{d}	82.6^{A}	< 0.01	< 0.01	0.31
28 d	90.8	86.9^{a}	85.6^{a}	82.9^{b}	79.3^{c}	78.2^{c}	82.6^{A}	< 0.01	< 0.01	0.46
Mean	91.3	87.6^{a}	85.6^{a}	82.1^{ab}	79.3^{bc}	77.6^{c}	-	< 0.01	< 0.01	0.32
p-value										
ANOVA	-	0.66	0.75	0.31	0.52	0.33	0.04	-	-	-
Linear	-	0.36	0.93	0.14	0.75	0.73	0.42	-	-	-
Quadratic	-	0.89	0.41	0.52	0.34	0.15	0.48	-	-	-
ATTD of DM										
7 d	92.3	88.3^{a}	85.9^{a}	81.6^{b}	79.9^{bc}	77.3^{c}	82.6^{A}	< 0.01	< 0.01	0.53
14 d	91.3	87.5^{a}	84.6^{b}	80.7^{c}	77.7^{d}	75.4^{d}	81.2^{B}	< 0.01	< 0.01	0.42
21 d	90.6	87.7^{a}	84.8^{ab}	81.9^{b}	78.7^{c}	76.1^{c}	81.8^{AB}	< 0.01	< 0.01	0.88
28 d	90.8	86.5^{a}	85.0^{a}	81.8^{b}	78.3^{c}	76.8^{c}	81.7^{AB}	< 0.01	< 0.01	0.90
Mean	91.3	87.5^{a}	85.1^{a}	81.5^{b}	78.7^{c}	76.4^{c}	-	< 0.01	< 0.01	0.61
p-value										
ANOVA	-	0.49	0.67	0.56	0.29	0.27	0.01	-	-	-
Linear	-	0.18	0.47	0.54	0.32	0.81	0.58	-	-	-
Quadratic	-	0.81	0.37	0.56	0.25	0.08	0.34	-	-	-
ATTD of OM										
7 d	93.8	90.1^{a}	87.7^{a}	83.7^{b}	82.1^{c}	79.7^{c}	84.7^{A}	< 0.01	< 0.01	0.47
14 d	92.9	89.4^{a}	86.6^{b}	83.0^{c}	80.4^{d}	78.0^{d}	83.5^{B}	< 0.01	< 0.01	0.44
21 d	92.4	89.7^{a}	86.9^{ab}	84.1^{b}	81.3^{c}	78.8^{c}	84.2^{A}	< 0.01	< 0.01	0.79
28 d	92.6	88.6^{a}	87.2^{a}	84.0^{b}	81.0^{c}	79.5^{c}	84.1^{AB}	< 0.01	< 0.01	0.99
Mean	92.9	89.5^{a}	87.1^{ab}	83.7^{bc}	81.2^{c}	79.0^{c}	-	< 0.01	< 0.01	0.67
p-value										
ANOVA	-	0.55	0.75	0.54	0.42	0.31	0.04	-	-	-
Linear	-	0.22	0.71	0.46	0.45	0.99	0.66	-	-	-
Quadratic	-	0.83	0.34	0.56	0.33	0.10	0.62	-	-	-
ATTD of NDF										
7 d	68.5	61.9	56.4	53.6	51.9	49.9	54.7	0.09	< 0.01	0.49
14 d	68.9	60.8^{a}	54.7^{ab}	48.8^{b}	46.2^{b}	45.8^{b}	51.3	< 0.01	< 0.01	0.08
21 d	66.4	62.6^{a}	52.9^{ab}	52.9^{b}	48.1^{b}	46.4^{b}	52.6	< 0.01	< 0.01	0.31
28 d	67.2	56.8	56.2	52.6	48.8	49.9	52.9	0.07	< 0.01	0.71
Mean	67.8	60.5^{a}	55.1^{a}	52.0^{ab}	48.8^{b}	48.0^{b}	-	< 0.01	< 0.01	0.32
p-value										
ANOVA	-	0.72	0.76	0.25	0.30	0.11	0.21	-	-	-
Linear	-	0.44	0.85	0.87	0.44	0.91	0.47	-	-	-
Quadratic	-	0.55	0.35	0.22	0.14	0.02	0.28	-	-	-
ATTD of ADF										
7 d	61.2	55.7^{a}	46.2^{ab}	40.4^{ab}	36.4^{b}	31.8^{b}	42.1	< 0.01	< 0.01	0.42
14 d	68.5	52.3^{a}	43.5^{ab}	35.7^{bc}	30.5^{c}	27.2^{c}	37.8	< 0.01	< 0.01	0.21
21 d	66.7	56.5^{a}	41.8^{ab}	37.7^{ab}	33.7^{ab}	10.9^{b}	36.1	< 0.01	< 0.01	0.58
28 d	66.8	49.8^{a}	46.0^{a}	40.2^{ab}	34.7^{b}	33.0^{b}	40.7	< 0.01	< 0.01	0.63
Mean	65.8	53.6^{a}	44.4^{ab}	38.5^{bc}	33.8^{c}	25.7^{c}	-	< 0.01	< 0.01	0.51
p-value										
ANOVA	-	0.69	0.73	0.55	0.52	0.31	0.53	-	-	-
Linear	-	0.50	0.88	0.90	0.88	0.75	0.82	-	-	-
Quadratic	-	0.72	0.29	0.19	0.23	0.16	0.45	-	-	-
ATTD of CP										
7 d	93.1	90.2^{a}	89.5^{ab}	86.5^{bc}	86.0^{c}	85.5^{c}	87.5^{A}	< 0.01	< 0.01	0.35
14 d	92.1	89.8^{a}	88.0^{ab}	85.4^{bc}	84.9^{c}	83.3^{c}	86.3^{B}	< 0.01	< 0.01	0.44
21 d	91.5	89.7^{a}	88.5^{a}	87.5^{ab}	85.0^{b}	84.5^{b}	87.0^{AB}	< 0.01	< 0.01	0.94
28 d	91.9	88.6^{a}	89.3^{a}	87.4^{ab}	85.1^{b}	84.9^{b}	87.1^{AB}	< 0.01	< 0.01	0.47
Mean	92.2	89.6^{a}	88.8^{a}	86.7^{ab}	85.3^{b}	84.6^{b}	-	< 0.01	< 0.01	0.58
p-value										
ANOVA	-	0.61	0.59	0.25	0.65	0.09	< 0.01	-	-	-
Linear	-	0.22	0.98	0.19	0.40	0.85	0.32	-	-	-
Quadratic	-	0.70	0.20	0.56	0.40	0.04	0.44	-	-	-

DE, digestible energy; ANOVA, analysis of variance; ATTD, apparent total tract digestibility; GE, gross energy; DM, dry matter; OM, organic matter; NDF, neutral detergent fibre; ADF, acid detergent fibre; CP, crude protein.

1) Values were means of six observations per treatment.

2) Means within a column without a common capital letter (^{AB}) or within a row without a common lower case letter ($^{a-d}$) differ significantly ($p < 0.05$).

3) Values were the mean of five diets which contained 15%, 25%, 35%, 45%, and 55% wheat bran.

4) p-value for main is main effect of inclusion level of wheat bran or adaptation period. No interactive effect was observed (not shown).

Table 4. The effect of adaptation period and inclusion level of wheat bran on DE value, ATTD of GE and CP fed to pigs[1),2)]

Items	Inclusion levels of wheat bran (%)					Mean	p-value		
	15	25	35	45	55		ANOVA[3)]	Linear	Quadratic
DE (MJ/kg)									
7 days	11.40	11.23	10.18	10.47	11.02	10.86[AB]	0.69	0.51	0.30
14 days	11.28	10.87	10.17	9.95	10.52	10.56[B]	0.37	0.15	0.22
21 days	12.62	11.71	11.05	10.54	11.05	11.39[A]	0.06	0.01	0.13
28 days	11.23	11.72	11.12	10.45	11.21	11.15[AB]	0.49	0.42	0.81
Mean	11.63	11.38	10.63	10.35	10.95		0.04	0.26	0.41
p-value									
ANOVA	0.69	0.65	0.07	0.58	0.31	0.09	-	-	-
Linear	0.85	0.36	0.02	0.72	0.37	0.02	-	-	-
Quadratic	0.51	0.74	0.90	0.53	0.23	0.44	-	-	-
ATTD of GE (%)									
7 days	69.7	68.6	62.2	64.0	67.4	66.4[AB]	0.69	0.51	0.30
14 days	68.9	66.5	62.2	60.8	64.3	64.5[B]	0.37	0.15	0.22
21 days	77.2	71.6	67.5	64.4	67.6	69.7[A]	0.06	0.01	0.13
28 days	68.6	71.6	68.0	63.9	68.5	68.1[AB]	0.49	0.42	0.81
Mean	71.1	69.6	65.0	63.3	67.0		0.04	0.26	0.41
p-value									
ANOVA	0.69	0.65	0.07	0.58	0.31	0.09	-	-	-
Linear	0.85	0.36	0.02	0.72	0.37	0.02	-	-	-
Quadratic	0.51	0.74	0.90	0.53	0.23	0.44	-	-	-
ATTD of CP (%)									
7 days	75.6	80.8	76.1[B]	67.4	81.2	76.2[B]	0.43	0.43	0.91
14 days	91.2	84.3	79.6[AB]	64.3	79.7	79.8[AB]	0.09	0.02	0.16
21 days	94.0	88.2	86.1[A]	67.6	82.5	83.7[A]	0.08	0.01	0.38
28 days	84.3	90.4	85.1[A]	68.5	83.0	82.3[A]	0.57	0.38	0.63
Mean	86.3	85.9	81.7	67.0	81.6		0.29	0.06	0.32
p-value									
ANOVA	0.18	0.28	0.02	0.66	0.19	0.01	-	-	-
Linear	0.31	0.06	0.01	0.37	0.12	0.01	-	-	-
Quadratic	0.05	0.87	0.33	0.23	0.37	0.29	-	-	-

DE, digestible energy; ANOVA, analysis of variance; ATTD, apparent total tract digestibility; GE, gross energy; CP, crude protein.
1) Values were means of six observations per treatment.
2) Means within a column without a common capital letter (AB) or within a row without a common lower case letter differ significantly ($p<0.05$).
3) p-value for mean is main effect of inclusion level of wheat bran or adaptation period. No interactive effect was observed (not shown).

duced the ATTD of GE [16].

An increasing level of wheat bran resulted in a linear reduction in digestibility of CP in diet. This observation was in agreement with some studies previously reporting that dietary fiber had a negative effect on the digestibility of protein [4,17]. Several reasons for the negative effect of wheat bran on the ATTD of CP in diets were shorter gut transit time of digesta with less time for proteolytic enzymatic digestion of CP [14,18] and increasing excretion of endogenous nitrogen which mostly originates in microfiora in the hindgut of pigs [19]. In addition, a major effect of dietary fiber on nitrogen excretion in pigs was the shifting of nitrogen excretion from the urine to the feces [20]. This may be another reason for the ATTD of CP decreased as the inclusion level of wheat bran increased. However, diets containing beet pulp had a lower conversion ratio of urinary to fecal nitrogen excretion compared to diets that added tapioca meal and oat hulls [20,21]. The ratio of urinary nitrogen to fecal nitrogen tended to decrease ($p = 0.10$) as dietary sugar beet pulp level increased Zhang et al [19]. These inconsistent effects of fiber inclusion on nitrogen excretion in urinary and feces may be caused by the various sources of dietary fiber and the activity of gut microbiota in their study.

The ATTD of DM and OM decreased as the inclusion level of wheat bran increased. This was in agreement with the results previously reported by Noblet and Perez [22] and Wilfart et al [23]. One reason may be that wheat bran which contains most insoluble fiber is effective in increasing the passage rate through the digestive tract and hence less time for fermentation of digesta in the hindgut [14]. Another reason may be that the amount of daily fecal excretion in pigs increased as dietary fiber increased [24]. However, a study reported that a high level of 44% fermentable NSP in the diet did not affect the ATTD of DM and OM compared with a diet containing 28% fermentable NSP [11]. This difference may be caused by the different composition and physicochemical properties of feed ingredients used in the study.

The ATTD of NDF and ADF in diet decreased as the inclusion level of wheat bran increased. This observation was in agreement with the results reported by Huang et al [5]. In which study, the ATTD of NDF and ADF decreased from 70.7% to 56.9%, 59.0% to 37.2%, respectively as the inclusion level of wheat middlings increased from 0% to 50% in the diet. However, the ATTD of NDF and ADF observed in this experiment was in contrast with a previous study that the ATTD of total dietary fiber, soluble dietary fiber and IDF increased as the inclusion level of sugar beet pulp increased from 0% to 55% [19]. This difference may be due to sugar beet pulp being a rapid fermentable fiber can increase viscosity of digesta and decrease the time of evacuation to improve the digestibility of dietary fiber.

Effect of adaption duration on nutrient digestibility and digestible energy in diets

A lower concentration of DE and ATTD of all chemical constituents were observed when pigs were adapted to the diet for 14 d compared with 7 d adaptation. This suggests that growing-finishing pigs need time to gradually adapt to the high-fiber diets formulated with wheat bran, and this phenomenon may be related to the microflora activity of hindgut. It has been reported that 14 to 21 d postweaning may be enough for the establishment of microecologial homeostasis in the hind gut of growing pigs when fed a diet containing high level of wheat bran [9]. A previous study by van der Peet-Schwering et al [11] showed that there were no changes over time observed in the apparent digestibility of DM and OM in a starch diet or a non-starch polysaccharide diet during a 5-week adaptation. The apparent ileal digestibility of amino acids did not change as growing pigs were fed a diet that included 30% distillers dried grains with solubles for 14 or 28 d [25]. Other studies also showed that growing pigs are more easily adapt to high-fiber diets with added sugar beet pulp without a change to the microbiota diversity in the hindgut compared to diets with added wheat bran [26,27]. Reasons for the different results may be that different growth stage of animal, compositions and physicochemical properties of wheat bran and sugar beet pulp.

Effect of inclusion level and adaption duration on nutrient digestibility and digestible energy in wheat bran

Some previous studies reported that the DE value for wheat bran ranged from 10.9 to14.1 MJ/kg, and the ATTD of GE ranged from 61.2% to 78.0% as DM basis [28,29]. The DE and ATTD of GE were ranged from 11.1 to 14.1 MJ/kg (as DM basis) and 61.8% to 77.2% in the present study, which were consistent with the previous studies.

A high level of wheat bran added in the diet can lead to a greater concentrations of dietary fiber and lower palatability of the diets, although it can improve the accuracy of DE value or nutrient digestibility calculated by the difference method. In the present study, the DE value and ATTD of GE and CP of wheat bran decreased as inclusion levels increased when growing-finishing pigs were fed 15%, 25%, and 35% wheat bran supplementation, which may have been caused by the incremental increase of anti-nutritive factors in diets [1]. However, the DE value and ATTD of GE and CP for wheat bran increased when growing-finishing pigs were fed the diets contained 45% and 55% wheat bran compared with 35% wheat bran which may be explained that the diets including excess fiber could stimulate the gastrointestinal tract to secret more digestive juice and enzymes which then improved the DE and digestibility [9]. However, the lowest DE or the ATTD of GE was found in wheat middlings added to the diet at a level of 96.0 g/kg [5]. This may be caused by the different composition of wheat bran and wheat middlings. In addition, the DE value and ATTD of GE for wheat bran decreased as the prolongation of adaption duration in the first 2 weeks, because the microbes in the hindgut of growing-finishing pigs adapt to the high-fiber diets gradually. However, compared with 14 d adaptation, the concentration of DE and digestibility of GE and CP in wheat bran increased when growing-finishing pigs were fed for 21 and 28 days, which showed that the digestive capacity of growing-finishing pig could be improved after adapting to the high-fiber diets [9]. Overall, the coefficient of digestibility of wheat bran is influenced by the growth phase of pig and the length of adaptation periods for high-fiber diets, which may be relative to the activity of gut microbiota.

CONCLUSION

An increased level of wheat bran in the diet decreased the concentration of DE and ATTD of GE, but did not affect the ATTD of CP for growing-finishing pigs. Adaptation period to high-fiber diets with inclusion of wheat bran can affect the DE value and ATTD of GE and CP of growing-finishing pigs, which may need at least 14 to 21 days to adapt to the high-fiber diet. In addition, there were no interaction effects of inclusion level and adaptation period of diets on DE value and ATTD of GE and CP in wheat bran fed to growing-finishing pigs.

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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