KJOAS

ISSN (Print) : 2466-2402
ISSN (Online) : 2466-2410

ANIMAL

Evaluation of rapeseed meal as a protein source to replace soybean meal in growing pigs

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Abstract

A total of 112 crossbred pigs [(Yorkshire × Landrace) × Duroc] with an average body weight (BW) of 27.98 ± 1.28 kg were used to evaluate the effects of replacing soybean meal (SBM) with rapeseed meal (RSM) as a source of protein on growth performance, nutrient digestibility, blood characteristics, and fecal noxious gas emission in growing pigs. The pigs were blocked and stratified based on BW into one of four dietary treatments in a 6-week trial. Each treatment consisted of 7 replicate pens with 4 pigs per pen (2 barrows and 2 gilts). Treatments were 1) maize-SBM based diet, 2) diet containing 2% RSM, 3) diet containing 4% RSM, and 4) diet containing 6% RSM. Supplementation with RSM resulted in no differences in growth performance, nutrient digestibility, and noxious gas emission, as compared with SBM supplementation during the experimental period ($p > 0.05$). Pigs fed with increased dietary RSM (0, 2, 4, and 6% of feed) had linear decreases in average daily gain (ADG) ($p = 0.010$) and nitrogen digestibility ($p = 0.036$) and a linear increase in blood creatinine concentration. In conclusion, RSM fed pigs had no detrimental effects on their growth performance, nutrient digestibility, blood characteristics, and fecal noxious gas emissions, as compared with SBM fed pigs. Thus, RSM is a good alternative to SBM as a protein source in growing pigs' diets.

Keywords: growing pig, growth performance, nutrient digestibility, rapeseed meal, soybean meal

Citation: Kim JK, Lei XJ, Lee SI, Lee IS, Kim IH 2017. Evaluation of rapeseed meal as a protein source to replace soybean meal in growing pigs. Korean Journal of Agricultural Science 44:235-243.

DOI: https://doi.org/10.7744/kjoas.20170023

Editor: Jung Min Heo, Chungnam National University, Korea

Received: March 2, 2017

Revised: May 29, 2017

Accepted: May 31, 2017

Introduction

The rising cost of soybean meal (SBM), an important protein source in swine diets, has resulted in the search for low cost protein sources for many animal farms (O'Doherty et al., 2001; Park et al., 2016a). Rapeseed meal (RSM) is a by-product of the biodiesel industry that is recycled through animal feed. In comparison with SBM, RSM has less crude protein and amino acids and higher fiber. However, RSM contains higher contents of phosphorus and sulfur-containing amino acids such as methionine and cysteine.

In swine and poultry farms, RSM is mainly used 'as a protein source because of the development of low glucosinolate-type rapeseed by Canadian and European plant breeders. The use of RSM in pigs' diets is limited by its relatively high of fiber, low energy yielding oligosaccharides, and sub-optimal protein and amino acids utilization (Bourdon and Aumaître, 1990; Sauer and Ozimek, 1986; Slominski et al., 1994; Zduńczyk et al., 2013). In addition, RSM supplementation of pigs' diets has yielded inconsistent results on growth performance and nutrient digestibility depending on its glucosinolate levels (Corino et al., 1991; McDonnell et al., 2010; Seneviratne et al., 2010; Siljander-Rasi et al., 1996).

To overcome the limitations of RSM in pig diets, many attempts have been made to reduce anti-nutritional factor levels and optimize fiber content by enhancing methods of dietary processing and formulation (Fang et al., 2007; Woyengo et al., 2009; Park et al., 2016b). Fang et al. (2007) improved growth performance and nutrient digestibility in pigs by supplementing xylanase, a non-starch polysaccharide (NSP)-degrading enzymes in diet containing RSM. Thus, to test maximum inclusion levels of RSM to replace SBM as a protein source in pig diets, we evaluated the effects of different levels of RSM on growth performance, nutrient digestibility, blood characteristics, and fecal noxious gas emissions in growing pigs.

Materials and Methods

The Animal Care and Use Committee of Dankook University approved all experimental protocols used in the current study.

Experimental design, animals, housing, and diets

A total of 112 crossbred pigs [(Yorkshire × Landrace) × Duroc] with an average body weight (BW) of 27.98 ± 1.28 kg were used in a 6-week trial. The pigs were blocked and stratified based on BW into four dietary treatments. Each treatment consisted of 7 replicate pens with 4 pigs per pen (2 barrows and 2 gilts). Treatments were 1) maize-SBM based control, 2) diet containing 2% RSM, 3) diet containing 4% RSM, and 4) diet containing 6% RSM. All diets were formulated to meet or exceed nutrition requirements (Table 1) (NRC, 2012). All pigs were housed in an environmentally controlled room with a slatted plastic floor. Each pen was equipped with a self-feeder and nipple water to allow ad libitum access to feed and water throughout the experimental period.

Sampling and measurements

Individual pig BW was recorded at the beginning and week 6 of the experimental period. Feed consumption was recorded on a per pen basis during the experiment to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain/feed intake ratio (G/F).

During the experimental period, pigs were fed diets mixed with 0.2% Cr_2O_3 (Chromic Oxide) as an indigestible marker for the determination of apparent total tract digestibility (ATTD) for dry matter (DM), gross energy (GE), and nitrogen. At week 6, fecal samples were collected from at least 2 pigs in each pen via rectal massage. All feed and fecal samples were stored at -20℃ until analysis. Feces samples were thawed at 57℃ for 72 h, ground to pass through a 1-mm screen for subsequent analysis. All of the feed and fecal samples were then analyzed for DM and nitrogen following the procedures outlined by the AOAC (AOAC, 2012). Chromium was analyzed using UV absorption

Table 1. Feed composition of experimental diets (as-fed basis).

Items	Rapeseed meal			
	0%	2%	4%	6%
Ingredients (%)				
Maize	66.00	66.00	66.00	66.00
Soybean meal (48% CP)	23.96	21.96	19.96	17.96
Rapeseed meal	0.00	2.00	4.00	6.00
Animal fat	4.24	4.24	4.24	4.24
Molasses	3.00	3.00	3.00	3.00
Dicalcium phosphate	1.26	1.26	1.26	1.26
Salt	0.25	0.25	0.25	0.25
Limestone	1.01	1.01	1.01	1.01
Vitamin premix[y]	0.12	0.12	0.12	0.12
Trace mineral premix[z]	0.10	0.10	0.10	0.10
L-Lysine-HCl	0.01	0.01	0.01	0.01
Antioxidant, Ethoxyquin 25%	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated composition (%)				
Metabolizable energy (kcal/kg)	3400	3400	3400	3400
Crude protein (%)	18.00	18.00	18.00	18.00
Lysine (%)	0.90	0.90	0.90	0.90
Methionine (%)	0.28	0.28	0.28	0.28
Calcium (%)	0.70	0.70	0.70	0.70
Phosphorus (%)	0.60	0.60	0.60	0.60
Analyzed composition (%)				
Metabolizable energy (kcal/kg)	3423	3427	3421	3424
Crude protein (%)	17.80	18.10	17.80	17.90
Lysine (%)	1.08	1.09	1.06	1.07
Methionine (%)	0.30	0.31	0.30	0.31
Calcium (%)	0.72	0.74	0.73	0.71
Phosphorus (%)	0.59	0.61	0.62	0.61

[y]Provided per kg of complete diet: vitamin A, 11,025 IU; vitamin D3, 1,103 IU; vitamin E, 44 IU; vitamin K, 4.4 mg; riboflavin, 8.3 mg; niacin, 50 mg; thiamine, 4 mg; pantothenic acid, 29 mg; choline, 166 mg; and vitamin B12, 33 μg.
[z]Provided per kg of complete diet: Mn,12.5 mg; Zn, 179 mg; Cu, 5 mg; I, 0.5 mg; Se, 0.4 mg.

spectrophotometry (Shimadzu, UV-1201, Kyoto, Japan) and nitrogen content was determined using a Kjeltec 2300 Analyzer (Foss Tecator AB, Hoeganaes, Sweden). Gross energy was determined by measuring the heat of combustion in the samples using a Parr 6100 oxygen bomb calorimeter (Parr instrument Co., Moline, IL, USA).

The digestibility was calculated according to the following formula:

ATTD = [1-{(Nf × Cd)/(Nd × Cf)}], where Nf = nutrient concentration in feces (%DM), Nd = nutrient concentration in diets (%DM), Cf = chromium concentration in feces (%DM), and Cd = chromium concentration in diets (%DM).

On the initial and final day of the experiment, blood samples were collected from the cervical vein in K_3EDTA vacuum and clot activator vacuum tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) from 2 pigs in each pen and the same pigs were sampled again on the final day of the experiment. The whole blood concentrations of red blood cells (RBC), white blood cells (WBC), and lymphocytes were measured using the automatic blood analyzer (ADVIA 120, Bayer Corp., Tarrytown, NJ, USA). After collection, blood samples were subsequently centrifuged (2,000 × g) for 30 min at 4℃. The concentrations of IgG and creatinine in the plasma were measured using an automatic biochemistry analyzer (HITACHI 747, Japan). Blood urea nitrogen (BUN) concentration was determined using a spectrophotometric procedure.

Feces and urine were collected on d 42 from 4 pigs per treatment. The urine was collected in a bucket via a funnel below the cage. Samples were kept in sealed containers and were immediately stored at -4℃. After sampling was finished, feces and urine samples were pooled for each pen and each pooled sample was mixed well. The subsamples of slurry (150 g feces and 150 g of urine on a wet weight basis) were taken and stored in 2.6 L plastic boxes in duplicate as described by Cho et al. (2008). Each box had a small hole in the middle of one side wall, which was sealed with adhesive plaster so as to maintain anaerobic condition. The samples were permitted to ferment for 7 days at room temperature (25℃). At 1, 3, 5, and 7 days of the fermentation period, an amount of gas was measured using a Gastec gas sampling pump (model GV-100, Gastec detector tube No. 3 M and 3 La for ammonia and hydrogen sulfide, Gastec Corp., Japan). The adhesive plasters were punctured, and 100 mL of headspace air was sampled approximately 2.0 cm above the feces surface.

Statistical analysis

All data were subjected to statistical analyses as a randomized complete block design using the GLM procedure of the SAS software (SAS Institute, 1996) with the pen as the experimental unit. Orthogonal contrasts were used to test the effects of inclusion of rapeseed meal (SBM vs. RSM). Additionally, orthogonal comparison was conducted using polynomial regression to measure the linear and quadratic effects of increasing concentrations of RSM. Variability in the data was expressed as the pooled standard error (SE). $p < 0.05$ was considered as statistical significance.

Results

Growth performance

Effect of dietary supplementation with RSM on growth performance is shown in Table 2. Supplementation of RSM resulted in no differences in BW, ADG, ADFI, and G/F, as compared with SBM supplementation during the

Table 2. The effects of rapeseed meal on growth performance in growing pigs.

Items[y]	Rapeseed meal				SE[z]	p-value		
	0%	2%	4%	6%		Soybean meal vs. Rapeseed meal	Linear	Quadratic
BW								
Initial (kg)	27.96	27.96	28.02	27.98	0.95	0.983	0.977	0.986
Final (kg)	60.26	60.46	59.43	58.50	1.08	0.529	0.204	0.605
0 to 6 wk								
ADG (g)	769	774	748	727	12.26	0.180	0.010	0.297
ADFI (g)	1711	1693	1679	1670	15.54	0.105	0.060	0.783
G/F (g/g)	0.45	0.46	0.45	0.44	0.01	0.697	0.161	0.319

[y]ADFI: average daily feed intake; ADG: average daily gain; BW: body weight; G/F: gain/feed ratio.
[z]SE: pooled standard error.

experimental period ($p > 0.05$). However, pigs fed with increased dietary RSM had a linear decrease in ADG ($p = 0.01$). RSM supplementation resulted in no significant differences in BW, ADFI, or G/F ratio during the experimental period ($p > 0.05$).

Nutrient digestibility

Effects of dietary supplementation with RSM on ATTD are shown in Table 3. Supplementation of RSM resulted in no differences in DM, nitrogen, and GE, as compared with SBM supplementation during the experimental period ($p > 0.05$). Pigs fed with dietary RSM had a linear decrease in ATTD of nitrogen ($p = 0.036$). No significant differences were observed in DM and GE in response to RSM supplementation during the experimental period ($p > 0.05$).

Blood characteristics

Effects of dietary supplementation with RSM on blood characteristics are shown in Table 4. During the initial phase, supplementation of RSM resulted in no differences in RBC, WBC, lymphocyte, creatinine, BUN, or IgG, as

Table 3. The effects of rapeseed meal on nutrient digestibility in growing pigs.

Items	Rapeseed meal				SE[z]	p-value		
	0%	2%	4%	6%		Soybean meal vs. Rapeseed meal	Linear	Quadratic
Dry matter (%)	76.55	77.49	75.12	74.40	1.39	0.587	0.168	0.556
Nitrogen (%)	77.23	77.68	76.37	73.83	1.16	0.351	0.036	0.210
Gross energy (%)	76.77	77.04	75.23	74.68	1.14	0.402	0.126	0.722

[z]SE: pooled standard error.

Table 4. The effects of rapeseed meal on blood characteristics in growing pigs.

Items[x]	Rapeseed meal				SE[z]	p-value		
	0%	2%	4%	6%		Soybean meal vs. Rapeseed meal	Linear	Quadratic
Initial								
RBC (10^6/μL)	6.69	6.31	6.91	6.87	0.28	0.988	0.377	0.553
WBC (10^3/μL)	16.23	15.88	18.86	16.27	1.51	0.664	0.652	0.466
Lymphocyte (%)	44.83	45.41	45.34	45.71	3.35	0.866	0.865	0.975
Creatinine (mg/dL)	1.42	1.34	1.38	1.38	0.06	0.456	0.803	0.485
BUN (mg/dL)	13.13	12.80	14.47	13.96	0.90	0.560	0.312	0.919
IgG (mg/dL)	356.86	419.14	351.71	388.71	63.16	0.688	0.922	0.843
Final								
RBC (10^6/μL)	6.24	6.61	6.49	6.66	0.23	0.211	0.287	0.669
WBC (10^3/μL)	18.96	18.74	17.44	17.46	1.13	0.419	0.265	0.917
Lymphocyte (%)	34.26	39.76	39.07	36.40	4.22	0.403	0.764	0.343
Creatinine (mg/dL)	1.23	1.43	1.39	1.47	0.07	0.017	0.036	0.380
BUN (mg/dL)	15.14	15.31	15.93	15.16	0.78	0.724	0.853	0.553
IgG (mg/dL)	623	629	618	606	15.50	0.748	0.361	0.561

[x]BUN: blood urea nitrogen; RBC: red blood cells.
[z]SE: pooled standard error; WBC: white blood cell.

compared with SBM supplementation ($p > 0.05$). At week 6, pigs fed an RSM supplementation had increased blood creatinine as compared with SBM supplementation ($p = 0.017$). Additionally, supplementation with increased levels of dietary RSM resulted in a linear increase in blood creatinine at week 6 ($p = 0.036$). Supplementation of RSM had no differences on RBC, WBC, lymphocyte, BUN, or IgG concentrations, as compared with SBM supplementation ($p > 0.05$).

Fecal noxious gas emission

Effects of dietary supplementation with RSM on fecal noxious gas emission are shown in Table 5. Supplementation with RSM had no differences in ammonia and hydrogen sulfide emissioons as compared with SBM supplementation during the experimental period ($p > 0.05$). No significant differences were observed in ammonia and hydrogen sulfide emissions among RSM treatment groups during the experimental period ($p > 0.05$).

Table 5. The effects of rapeseed meal on fecal noxious gas emission in growing pigs.

Items	Rapeseed meal				SE[z]	p-value		
	0%	2%	4%	6%		Soybean meal vs. Rapeseed meal	Linear	Quadratic
NH_3								
d1	11.7	11.4	11.6	11.3	0.49	0.700	0.697	0.977
d3	14.9	14.2	14.3	14.9	0.58	0.494	0.974	0.260
d5	17.3	16.8	17.4	16.7	0.45	0.587	0.594	0.753
d7	16.6	16.0	16.2	15.8	0.59	0.384	0.434	0.820
H_2S								
d1	1.3	1.4	1.7	1.5	0.20	0.345	0.341	0.476
d3	12.7	12.4	13.0	12.2	0.65	0.826	0.752	0.704
d5	21.3	20.5	21.0	20.5	0.61	0.401	0.541	0.791
d7	27.0	26.5	25.9	26.4	0.66	0.376	0.440	0.508

[z]SE: pooled standard error.

Discussion

In the present study, RSM supplementation had no detrimental effects on BW, ADG, ADFI, and G/F, as compared with SBM supplementation. However, the increased dietary RSM resulted in linear decrease in ADG. RSM can be included in pigs' diet with no deleterious effects on their performance (McDonnell et al., 2010; Siljander-Rasi et al., 1996). However, the effect of RSM supplementation is inconsistent according to some reports (Corino et al., 1991; McDonnell et al., 2010; Seneviratne et al., 2010; Siljander-Rasi et al., 1996). Corino et al. (1991) reported that RSM can be included in heavy pig diets with no deleterious effects on growth or carcass characteristics. McDonnell et al. (2010) reported that RSM can be used as a direct replacement for SBM with no associated loss in performance, when formulated on the basis of ileal digestible amino acids and net energy. Siljander-Rasi et al. (1996) reported that RSM can be an alternative to SBM in growing pigs. However, Seneviratne et al. (2010) reported that increasing dietary RSM (0, 7.5, 15, and 22.5%, respectively) linearly decreased ADG and ADFI and linearly increased the G/F ratio. These inconsistent results can be attributed to the different levels of RSM, the different growth phases of pigs, and different quality of RSM used.

In the present study, RSM supplementation had no detrimental effects on nutrient digestibility in pigs, as compared with SBM. However, increasing dietary RSM levels linearly decreased nitrogen contents. The reduced nitrogen digestibility in diets with increasing RSM may result from the increased fiber contents. RSM has high fiber contents that can reduce nutrient digestibility (Fernández and Jørgensen, 1986; Landero et al., 2011). Because of the anti-nutritional factors such as high fiber content, many researchers have attempted to improve the nutrient digestibility of rapeseed (Liu et al., 2014; Sanjayan et al., 2014). Liu et al. (2014) reported that low temperature processed RSM improved apparent ileal digestibility of amino acids, as compared with conventional RSM in pig diets. In addition, pigs fed with multi-carbohydrase in RSM diets improved the ATTD of DM, CP, and GE, as compared to those fed non-multi-carbohydrase supplemented RSM diets (Sanjayan et al., 2014). Sanjayan et al. (2014) suggested that RSM with multi-carbohydrase (supplied 1,400 U of pectinase, 1,600 U of cellulase, 1,600 U of xylanase, 1,200 U of glucanase, 300 U of mannanase, 40 U of galactanase, 1,000 U of invertase, 2,000 U of protease, and 10,000 U of amylase per kg of diet) can be included at up to 25% of weaned pig diets without compromising performance so long as the diets are formulated on a net energy and standard ileal digestible Lys basis. Xie et al. (2012) demonstrated that replacement of 11% SBM by 13% double-low RSM had no negative effects on performance and nutrient digestibility for finishing pigs. In the current study, the levels of RSM were relatively low (2% - 6%), which were perhaps not sufficient to impair nutrient digestibility. Therefore, further work is needed to research the effects of higher concentration of RSM on nutrient digestibility in pigs.

In the present study, RSM supplementation had no detrimental effects on RBC, WBC, lymphocyte, BUN, or Ig G concentrations of pigs as compared with SBM treatment. Also, increased levels of dietary RSM had no detrimental effects on blood characteristics except for creatinine, as compared with SBM. In agreement with the present study, it was reported that a 3% rapeseed meal supplementation had no effect on nutrient digestibility, blood metabolites, fecal volatiles, fatty acids or ammonia-nitrogen of pigs, as compared with maize-SBM based diets (Jo et al., 2012). Consistently, Xie et al. (2012) reported that the replacement of 11% SBM by 13% double-low RSM decreased the concentration of IgG. Additionally, replacement of 11% SBM by 13% extruded double-low rapeseed meal, supplemented with multienzyme significantly decreased the malondialdehyde content in serum (Xie et al., 2012). In the present study, pigs fed with RSM increased the creatinine content of their blood, as compared with those fed with SBM. Little is known about the effects of RSM on the creatinine content of blood, and no direct correlation was found between RSM and creatinine content in blood.

Fecal noxious gas emission is regarded as one of the most important criteria of feed formulation in livestock diets (Aarnink and Verstegen, 2007; Cerisuelo et al., 2012). It has been previously reported that an increase in dietary fiber may reduce ammonia emissions from feces (Bindelle et al., 2009; O'Shea et al., 2010). In the present study, the inclusion of RSM, a relatively high fiber ingredient had no detrimental or beneficial effects on ammonia and hydrogen sulfide emissions, as compared with SBM. Similarly, in a previous report, replacement of decreasing levels of SBM by increasing levels of RSM had no effects on manure ammonia emissions in growing-finishing pigs (McDonnell et al., 2010).

Conclusion

In conclusion, RSM supplementation had no detrimental effects on growth performance, nutrient digestibility, blood characteristics, and fecal noxious gas emission for pigs, as compared with SBM. Thus, RSM is a good, cost-effective alternative to SBM as a protein source in growing pigs' diets.

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