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The impact of substituting soybean meal with various plant byproducts on the growth performance, nutrient digestibility, and fecal scores of growing pigs

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Abstract

Soybean meal (SBM) is a high-protein plant product commonly used as the primary protein source in pig diets. However, its price has been steadily rising, prompting us to search for cost-effective, high-yield protein sources. This experiment aimed to assess the effects of partial replacing SBM with 6% of palm kernel meal (PKM), lupin kernel (LK), rapeseed meal (RSM), and distillers dried grains solubles (DDGS) on the growth performance, nutrient digestibility, and fecal scoring in growing pigs. A total of 200 (Yorkshire × Duroc) growing pigs with an initial weight of 34.83 ± 1.38 kilograms were utilized in this research for 29 days. All pigs were randomly assigned to one of five dietary treatments based on their gender and initial body weight, Each treatment consisted of 10 replicates with 2 barrows and 2 gilts per pen. The dietary treatments were as follows: control (CON), a corn-SBM-based diet; and basal diet supplemented with 6% of different plant byproducts (PKM, LK, RSM, and DDGS) Adding 6% of RSM to the basal diet showed slightly higher daily gain (2.520 > 2.513) and there was no difference observed on the nutrient digestibilty and fecal score. Replacing soybean meal with different plant byproducts has no adverse effect on growth performance, nutrient digestibility, and fecal score.

Keywords: distillers dried grains solubles, lupin kernel, palm kernel meal, rapeseed meal, soybean meal

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Introduction

Exploring pig feed ingredients has become a hot topic of interest to achieve higher growth performance at lower rearing costs (Yun et al., 2017). Grains and maize become the most fundamental feed ingredient in swine nutrition due to their high nutritional content, providing energy (Zhai et al., 2022). Another primary feed ingredient is soybean meal (SBM), which is a byproduct of soybean oil production. It is often utilized as a main source of protein in pig diets because of its high protein content, generally balanced amino acid profile, and good digestibility (Grabež et al., 2020). Furthermore, the sharp increase in soybean prices has prompted many researchers to seek alternative and cost-effective sources of protein (Park et al., 2016). palm kernel meal (PKM) a byproduct of palm kernel oil extraction, is primarily produced in Southeast Asian regions, with Malaysia and Indonesia being the largest producers (Choi et al., 2021). Due to its favorable price advantage, low risk of fungal toxins, and relatively stable quality, PKM has gained widespread application in animal feed as a substitute for soybean meal (Peng et al., 2018). The inclusion of PKM in pig diets enhance pig growth performance, nutrient digestibility, fecal microbiota, and meat quality, and reduce fecal emissions (Sureshkumar et al., 2022). lupin kernel (LK) is derived from the pods of lupin, and lupin kernels are rich in protein, typically higher in content than soybean meal, making it an excellent source of protein (Lee et al., 2020). rapeseed meal (RSM) serves as another source of protein in growing pig diets due to its high-quality protein content. However, its relatively high fiber and low oligosaccharide content result in lower energy yield, which limits its utilization in the diets of growing pigs (Kim et al., 2017). distillers dried grains solubles (DDGS) are a primary byproduct of distilleries and bioethanol production. It contains a substantial amount of energy and crude protein (CP), making it a potential source of protein for animal feed (Park et al., 2021). It is widely recognized that DDGS can have negative effects on carcass yield and fat quality. As a result, finishing pigs may need to transition from diets containing DDGS to a corn-SBM-based basic diet before marketing. Therefore, using DDGS feed in the early stages of pig feeding can help reduce costs (Lerner et al., 2020). To address the increasing costs associated with SBM, the objective of our current study is to evaluate the effect of different plant byproducts that can partially be replaced with SBM and to evaluate their impact on growth performance, nutrient digestibility, and fecal scores.

Materials and Methods

Ethical statement

This study was conducted in accordance with the study protocol (DK-1-2208) and animal ethics guidelines approved by the Animal Care and Use Committee of Dankook University, South Korea.

Experimental design, animals, housing, and diets

A total of 200 crossbred pigs ([Yorkshire × Landrace] × Duroc) with an average body weight (BW) of 34.83 ± 4.38 kg were used in the 29-day trial. The pigs were assigned to one of five dietary treatments in a complete randomized blocks design, with each treatment consisting of 10 replicates per pens. In each pen, there were 4 pigs (2 barrows [castrated males] and 2 gilts [females]), and these pigs were arranged based on their initial body weight and sex. Dietary treatments included control (CON): maize-SBM-based diet and basal diet with SBM partially replaced by 6% (each) of different plant byproducts (PKM, LK, RSM, and DDGS).

All diets were formulated to meet or exceed the nutritional requirements as outlined in the National Research Council (NRC) guidelines from 2012 (Table 1). The pigs were accommodated in a regulated environment featuring slatted plastic flooring and mechanical ventilation within a climate-controlled facility dedicated to their welfare. Each pen was equipped with a self-feeder and a nipple drinker to provide the pigs with ad libitum access to feed and water throughout the experimental period.

Table 1. Ingredient composition of experimental diets as-fed basis.

Item	Grower				
	Corn-soybean meal	DDGS	Palm kernel meal	Lupin kernel	RSM
Ingredient (%)					
Corn	75.13	71.55	69.51	73.75	72.41
Soybean meal (48%)	18.90	16.10	18.00	14.27	14.62
DDGS	-	6.00	-	-	-
Palm kernel meal	-	-	6.00	-	-
Lupin kernel	-	-	-	6.00	-
RSM	-	-	-	-	6.00
Tallow	2.29	2.65	2.84	2.22	3.46
MDCP	1.54	1.44	1.45	1.58	1.36
Limestone	0.72	0.78	0.75	0.72	0.71
Salt	0.30	0.30	0.30	0.30	0.30
Methionine (99%)	0.06	0.06	0.07	0.08	0.06
L-lysine (78%)	0.48	0.55	0.50	0.52	0.53
Threonine (99%)	0.10	0.10	0.10	0.10	0.10
Tryptophan (99%)	0.05	0.04	0.05	0.03	0.02
Vit/mineral premix[z]	0.40	0.40	0.40	0.40	0.40
Choline (25%)	0.03	0.03	0.03	0.03	0.03
Total	100.00	100.00	100.00	100.00	100.00
Calculated value					
CP (%)	15.50	15.50	15.50	15.50	15.50
ME (kcal/kg)	3,300	3,300	3,300	3,300	3,300
Fat (%)	5.15	5.85	5.48	5.26	6.18
Ca (%)	0.70	0.70	0.70	0.70	0.70
P (%)	0.60	0.60	0.60	0.60	0.60
LYS (%)	1.10	1.10	1.10	1.10	1.10
MET (%)	0.31	0.31	0.31	0.31	0.31

DDGS, distillers dried grains solubles; RSM, rapeseed meal; MDCP, mono dicalcium phosphate; CP, crude protein; ME, metabolizable energy; LYS, lysine; MET, methionine.

[z] Provided per kg of complete diet: 16,800 IU vitamin A; 2,400IU vitamin D_3; 108 mg vitamin E; 7.2 mg vitamin K; 18 mg Riboflavin; 80.4 mg Niacin; 2.64 mg Thiamine; 45.6 mg D-Pantothenic; 0.06 mg Cobalamine; 12 mg Cu (as $CuSO_4$); 60mg Zn (as $ZnSO_4$); 24 mg Mn (as $MnSO_4$); 0.6mg I (as Ca $(IO_3)2$); 0.36mg Se (as Na2SeO_3).

Sampling and measurements

Individual pig body weight (BW) and feed consumption were recorded at the beginning and end of a day 29- to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain to feed ratio (G : F) Seven days prior to fecal collection pigs were provided with a diets containing 0.2% chromic oxide (Cr_2O_3, 0.2%; Samchun, Korea) as an indigestible markerto determine apparent total tract digestibility (ATTD) of dry matter (DM), gross energy (GE), and nitrogen. At 29 Day, faecal samples were collected from 10 pigs in each treatment group via rectal massage. All faecal and feed samples were placed in an icebox, transported to the laboratory, stored at -20℃, and dried until final analysis. Prior to analysis, all specimens were dried in an oven at 70℃ for three days. The collected ground specimens were then sieved through a 1-mm screen sieve. Chromium was analyzed using UV absorption spectro-photometry (Shimadzu UV-1201, Shimadzu, Japan). Energy was determined by using an oxygen bomb calorimeter (Parr 6100, Parr instrument Co., USA). Nitrogen was determined (Kjectec 2300 Nitrogen Analyzer; Foss Tecator AB, Sweden). The digestibility was calculated using the following formula:

$$\text{ATTD (\%)} = [1 - \{(\text{Nf} \times \text{Cd}) / (\text{Nd} \times \text{Cf})\}] \times 100 \quad (1)$$

where, Nf indicated concentration in faeces (% DM), Nd indicated nutrient concentration in diets (% DM), Cf indicated chromium concentration in faeces (% DM), and Cd indicated chromium concentration in diets (% DM).

The fecal score was determined by the average value of five pigs of each pen by using a 5-grade score system (Hu et al., 2012). The standard of this system is as following: 1 = hard, dry pellets in a small, hard mass; 2 = hard, formed stool that remains firm and soft; 3 = soft, formed and moist stool that retains its shape; 4 = soft, unformed stool that assumes the shape of the container; 5 = watery, liquid stool that can be poured. Scores were recorded on a pen basis following observations of individual pigs and signs of stool consistency in the pen.

Statistical analysis

All experimental data were analysed as a randomized complete block design using the general linear model procedure of SAS version 9.4 (SAS Institute Inc., USA). The pen was used as the experimental unit. Orthogonal contrasts were used to the effect of treatments: CON vs. TRT1, TRT2, TRT3, and TRT4. Variability in the data was expressed as the pooled standard error of the mean (SEM), and $p \leq 0.05$ was considered statistically significant.

Results

The effects of replacing part of soybean meal with different plant extract on growth performance of growing pigs is

Table 2. The effects of replacing part of soybean meal with 6% PKM, 6% LK, 6% RSM or 6% DDGS on growth performance in growing pigs[z].

Item	Dietary treatment					SEM	p-value			
	CON	TRT1	TRT2	TRT3	TRT4		CON vs. TRT1	CON vs. TRT2	CON vs. TRT3	CON vs. TRT4
Body Weight (kg)										
Initial	34.83	34.82	34.83	34.84	34.83	0.02	0.9951	0.9958	0.9924	0.9965
Finish	55.44	55.06	54.86	55.29	55.02	0.37	0.7992	0.6997	0.9244	0.7823
Overall										
ADG (g)	711	698	691	705	696	13	0.5121	0.3086	0.7879	0.4639
ADFI (g)	1,781	1,743	1,722	1,773	1,730	20	0.2342	0.0728	0.7977	0.1176
G : F	2.513	2.502	2.501	2.520	2.488	0.043	0.8681	0.8290	0.9338	0.6781

ADFI, average daily feed intake; ADG, average daily gain; G : F, gain : feed ratio; SEM, pooled standard error of the mean; CON, basal diet; TRT1, 6% palm kernel meal (PKM); TRT2, 6% lupin kernel (LK); TRT3, 6% rapeseed meal (RSM); TRT4, 6% distillers dried grains solubles (DDGS).

[z] For growth performance n = 10 for each treatment.

shown in (Table 2). During the overall experimental period, TRT 2 group pigs showed slightly increased ADG compared to CON but there were no significant differences found on the body weight, ADFI, and G : F until day 29. Moreover, there was no differences found observed between the treatments for the apparent total tract digestibility (ATTD) for dry matter (DM), gross energy (GE), and nitrogen (Table 3) and fecal score (Table 4).

Table 3. The effects of replacing part of soybean meal with 6% PKM, 6% LK, 6% RSM or 6% DDGS on nutrient digestibility in growing pigs[z].

Item (%)	Dietary treatment					SEM	p-value			
	CON	TRT1	TRT2	TRT3	TRT4		CON vs. TRT1	CON vs. TRT2	CON vs. TRT3	CON vs. TRT4
Finish										
Dry matter	76.51	76.06	75.41	76.27	75.73	1.18	0.7929	0.5178	0.8885	0.6488
Nitrogen	74.35	73.79	73.28	73.95	73.74	1.14	0.7417	0.5247	0.8135	0.7194
Gross energy	75.28	74.86	74.27	74.94	74.67	1.16	0.8126	0.5592	0.8473	0.7223

SEM, pooled standard error of the mean; CON, basal diet; TRT1, 6% palm kernel meal (PKM); TRT2, 6% lupin kernel (LK); TRT3, 6% rapeseed meal (RSM); TRT4, 6% distillers dried grains solubles (DDGS).

[z] For nutrient digestibility n = 10 for each treatment.

Table 4. The effects of replacing part of soybean meal with 6% PKM, 6% LK, 6% RSM or 6% DDGS on fecal score in growing pigs[y].

Item	Dietary treatment					SEM	p-value			
	CON	TRT1	TRT2	TRT3	TRT4		CON vs. TRT1	CON vs. TRT2	CON vs. TRT3	CON vs. TRT4
Fecal score[z]										
Initial	3.27	3.26	3.26	3.26	3.27	0.04	0.6867	0.3985	0.8559	0.7931
Finish	3.21	3.23	3.24	3.22	3.23	0.03	0.9253	0.7606	0.6228	0.9439

SEM, pooled standard error of the mean; CON, basal diet; TRT1, 6% palm kernel meal (PKM); TRT2, 6% lupin kernel (LK); TRT3, 6% rapeseed meal (RSM); TRT4, 6% distillers dried grains solubles (DDGS).

[y] Fecal score = 1 hard, dry pellet; 2 firm, formed stool; 3 soft, moist stool that retains shape; 4 soft, unformed stool that assumes shape of container; 5 watery, liquid that can be poured.

[z] For fecal score n = 10 for each treatment.

Discussion

There are numerous alternative feed additives available on the market that can enhance pig immunity and reduce side effects by modulating the gut microbiota (Liu et al., 2020). PKM can serve as a substitute protein source for corn-soybean meal, given its high protein content. With an increasing level of PKM, feed costs significantly decrease, Based on animal performance, PKM can be considered a satisfactory alternative (Peng et al., 2018). PKM is very abundant in many tropical countries but scarce in temperate countries where they are sometimes imported. PKM is a by-product of vegetable oil byproduct, Nigeria ranks as a leading producer of potential livestock feed and at least 75% of her annual tonnage is exported to countries where it is used mainly for the manufacture of industrial goods (Babatunde et al., 2010). As reported in earlier studies, high levels of PKM have been found to result in a linear decrease in ADFI, as well as in the digestibility of crude protein and crude fiber (Jang et al., 2020). pigs fed the PKM diet exhibited diminished growth rates, poorer feed-to-gain ratio, lower protein efficiency ratio, and reduced feed. Therefore, it is important to avoid excessive PKM supplementation solely for the purpose of cost reduction (Huang et al., 2020). This is in contrast to our experimental results where feeding added 6% PKM did not adversely affect the growth performance of growing pigs in this study, possibly because we added only 6% PKM. This variation could stem from discrepancies in palm kernel varieties, which may evolve over time, as well as variances in the processing techniques employed in palm plantations to procure PKM despite containing anti-nutritive phytases and non-starch polysaccharides, lupines provide valuable nutrition and are sustainable nitrogen-fixing plants suitable for cultivation in temperate regions, including Europe (Garcia-Santos, 2021). As early as 2015, Glencross, B. and others predicted the protein and energy digestibility of LK using near-infrared reflectance spectroscopy. Their findings confirmed that LK is indeed a high-protein plant extract (Glencross et al., 2015). High doses of LK have been reported to reduce animal growth performance, whereas reducing amino acid supply to less than 15% of the recommended level does not seem to affect animal performance, and LK can be added at up to 12.5% to be used as a source of protein without negatively affecting animal performance, as long as the supply of essential amino acids is balanced under the specific conditions of organic farming (Nørgaard and Fernández, 2010). It has also been reported that When 25% of the soybean meal was replaced with LK in the corn-soybean meal diet, growth rates and feed gain ratios did not change; however, pigs fed corn as well as an equal amount of soybean meal and the LK-added diet gained 16% slower and required 9% more feed per unit of gain compared to pigs fed the control diet, but feed conversion ratios for both diets were similar (Hale and Miller, 1985). This is in general agreement with our findings that the addition of 6% LK had no significant effect on growing pigs and that the addition of 6% LK did replace some of the soybean meal in the diet. It is well known that RSM has a high fiber content, which affects nutrient digestibility. Many researchers have attempted to enhance the nutrient digestibility of RSM by improving processing methods and adding enzymes, including carbohydrates, to reduce the fiber content and anti-nutritional factors in RSM (Yun et al., 2017). According to reports, supplementing with RSM did not have adverse effects on weight, ADG, ADFI, and G/F compared to supplementing with SBM (Kim et al., 2017). It is possible that the experiment did not observe significant differences due to the relatively low concentration of RSM used. It's also possible that the processing temperature of RSM and its source, including genetic background and growth conditions, could play a role in the observed effects on pig growth (Liu et al., 2016). These factors can indeed contribute to variations in the impact of RSM on pig performance. Further research and detailed investigations are essential to understand these complex interactions. Also, other reports indicate that increasing the inclusion of RSM in the diet (at levels of 0, 7.5, 15, and 22.5%) led to a linear decrease in ADG and ADFI, while linearly increasing the G/F (gain-to-feed) ratio. In the present study, the addition of 6% RSM did not result in a significant decrease in ADG and ADFI. If a linear relationship is to be considered, more detailed experiments with varying RSM concentrations need to be conducted. According to Caine et al. (2008), CP and amino acids were significantly lower in growing pigs fed RSM-supplemented diets compared to pigs fed SBM-supplemented diets (Caine et al., 2008). McDonnell et al. (2010) also reported that nutrient digestibility declined linearly with increasing levels of RSM in the diets when RSM was used in place of SBM at different levels (McDonnell et al., 2010). Whereas in the present study, the use of 6% RSM partially replacing SBM did not adversely affect nutrient digestibility, these inconsistent results could be attributed to the use of different levels of RSM and the different growth stages of the pigs. It has been reported that DDGS derived from legume seeds, rapeseed, and corn can effectively replace SBM. DDGS is favored as a non-conventional feed ingredient due to its high nutritional value, ready availability, cost-effectiveness, and the ease of absorption of its protein and fiber content, all while maintaining low levels of anti-nutrients (Garavito-Duarte et al., 2023). Other studies indicate that while excess fiber in DDGS decreases dry matter (DM) digestibility and increases fecal excretion, adding 4 - 15% DDGS to the diet does not significantly affect digestibility or the growth performance of growing pigs (Biswas and Kim, 2022). This is in general agreement with our experimental results, where the addition of 6% DDGS to replace some of the SBM in the diet did not adversely affect growth performance and nutrient digestibility in this study. Conversely, augmenting the proportion of corn DDGS in broiler chicken rations can improve the apparent digestibility of DM (Damasceno et al., 2020). These different results may be influenced by factors such as animal species, palatability, grain quality, and the dose of DDGS added to the diet.

Conclusion

This study demonstrated that partial replacement of SBM in diets with 6% PKM, 6% LK, 6% RSM or 6% DDGS, respectively, did not adversely affect the growth performance, nutrient digestibility or faecal scores of growing pigs. Therefore, it was concluded that these plant byproducts could replace some of the soybean meal in growing pig diets, thereby reducing feed costs.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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