



Effects of Palm Kernel Expellers on Growth Performance, Nutrient Digestibility, and Blood Profiles of Weaned Pigs

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ABSTRACT: This experiment was conducted to investigate the effects of palm kernel expellers on growth performance, nutrient digestibility, and blood profiles of weaned pigs. A total of 88 weaned pigs (6.94±0.76 kg body weight [BW]; 28 d old) were randomly allotted to 2 dietary treatments (4 pigs/pen; 11 replicates/treatment) in a randomized complete block design (sex as a block). The dietary treatments were a typical nursery diet based on corn and soybean meal (CON) and CON added with 20% of palm kernel expellers (PKE). Pigs were fed for 6 wk using a 3-phase feeding program with declining diet complexity and with phases of 1, 2, and 3 wk, respectively. Blood was collected from randomly selected 2 pigs in each pen before weaning and on d 7 after weaning. Pigs were fed respective dietary treatments containing 0.2% chromic oxide from d 29 to 35 after weaning. Fecal samples were collected from randomly selected 2 pigs in each pen daily for the last 3 days after the 4-d adjustment period. Measurements were growth performances, digestibility of dry matter, nitrogen and energy, white and red blood cell counts, packed cell volume, and incidence of diarrhea. The PKE increased average daily gain (ADG) (246 vs 215 g/d; $p = 0.06$) and average daily feed intake (ADFI) (470 vs 343 g/d; $p < 0.05$) and decreased gain-to-feed ratio (G:F) (0.522 vs 0.628 g/g; $p < 0.05$) during phase 2 compared with CON, but did not affect growth performance during phase 1 and 3. During overall experimental period, PKE increased ADG (383 vs 362 g/d; $p = 0.05$) and ADFI (549 vs 496 g/d; $p < 0.05$) compared with CON, but did not affect G:F. However, no differences were found on digestibility of dry matter, nitrogen, and energy between CON and PKE. The PKE reduced frequency of diarrhea (15% vs 25%; $p = 0.08$) for the first 2 wk after weaning compared with CON. Similarly, PKE decreased white blood cells (8.19 vs 9.56×10³/μL; $p = 0.07$), red blood cells (2.92 vs 3.25×10⁶/μL; $p = 0.09$), and packed cell volume (11.1% vs 12.6%; $p = 0.06$) on d 7 after weaning compared with CON. In conclusion, addition of 20% palm kernel expellers to nursery diet based on corn and soybean meal had no negative effects on growth performance, nutrient digestibility, and blood profiles of weaned pigs. (**Key Words:** Blood Profiles, Diarrhea, Growth Performance, Nutrient Digestibility, Palm Kernel Expellers, Weaned Pigs)

INTRODUCTION

Antibiotics are growth promoters and powerful in disease control (Cromwell, 2002; Gaskins et al., 2002), but

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the use of antibiotics in swine production has been changing (Pettigrew, 2006; Stein and Kil, 2006) to more restricted use of in-feed antibiotics because of potential safety issues of use of antibiotics for livestock animals (Pluske et al., 2002; Adjiri-Awere and van Lunen, 2005). In addition, the cost of conventional feed ingredients such as corn or soybean meal has markedly increased, resulting in increased use of cheaper co-products to replace partially them in swine diets (Wachenheim et al., 2006; Hoffman and Baker, 2011). Due to the above two main issues, swine production industry has increasingly considered the use of all kinds of alternatives not only to reduce feed cost but also to improve pig performance and health (Pluske et al., 2002; Pettigrew, 2006; Stein and Kil, 2006).

The palm kernel co-products such as palm kernel expellers and meals are co-products from the kernels of oil palm fruits after oil removal by chemical or mechanical extraction (Sulabo et al., 2013) and contain low energy density, poor amino acids profiles, and high fiber containing relatively high soluble fiber, such as β -mannans and glucomannans that may affect animal gut health (Pluske et al., 2002), compared with conventional feed ingredients (Balasubramaniam, 1976; Daud and Jarvis, 1992; Dusterhoft et al., 1991; NRC, 2012).

These co-products have been primarily used in ruminant (Singhania et al., 2008) and poultry diets (Ravindran and Blair, 1992) and evaluated for growing (Son et al., 2012, 2013, 2014; Sulabo et al., 2013) or finishing pigs (Kim et al., 2001; Ao et al., 2011), but no information for nursery pigs is available. Therefore, the objective of this experiment was to investigate the effects of addition of 20% palm kernel expellers in a typical nursery diet based on corn and soybean meal on growth performance, nutrient digestibility, and blood profiles of weaned pigs.

MATERIALS AND METHODS

The experimental protocol for this study was reviewed and approved by the Animal Care and Use Committee of Dankook University.

Experimental design, animals, and diets

A total of 88 weaned pigs (Duroc \times [Landrace \times Yorkshire]; 6.94 \pm 0.76 kg of average body weight [BW]; 28 d old) were used in this experiment. Pigs were moved from lactation crates to nursery pens equipped with a feeder and waterer in an environmentally controlled room and randomly assigned to 2 dietary treatments with 4 pigs per pen and 11 replicated pens per treatment in a randomized complete block design. Each pen had same sex of pigs as a block and each treatment had an equal number of barrows and gilts. The dietary treatments were a typical nursery diet based on corn and soybean meal (CON) and CON added with 20% palm kernel expellers (PKE) and were formulated to meet or exceed the NRC (2012) estimates of nutrient requirements of weaned pigs and to have similar metabolizable energy, crude protein, and lysine levels (Table 1). The 3-phase feeding program with declining diet complexity was used during experimental period for 6 wk. Each of dietary treatments consisted of a series of 3 diets for pigs of increasing age and was fed for these periods after weaning: phase 1 (wk 1), phase 2 (wk 2 and 3), and phase 3 (wk 4 to 6). Pigs were allowed free access to diets and water at all times.

Data and sample collection

Pig BW as a pen weight was weighed at the beginning

and end of each phase. Amount of dietary treatments provided per pen were recorded during each phase and feed refusals were weighed at the end of each phase. Daily presence of diarrhea from each pen was checked visually and recorded with two scales: presence of diarrhea or not. Frequency of diarrhea was calculated by counting pen days with presence of diarrhea.

Pigs were fed respective dietary treatments containing 0.2% chromic oxide as an indigestible marker from d 29 to 35 after weaning. Fecal samples were collected from randomly selected two pigs in each pen daily by rectal palpation for the last 3 days after the 4-d adjustment period. The collected samples were pooled and stored at -20°C until analysis. Diet samples were also collected from each batch of manufactured feed and stored at -20°C until analysis. Whole blood samples were collected from a jugular vein of randomly selected 2 pigs in each pen using ethylenediaminetetraacetic acid tubes (Becton Dickinson Vacutainer Systems, Franklin Lakes, NJ, USA) with anticoagulant before weaning and on d 7 after weaning.

Sample analyses

Fecal samples were dried in a forced-air drying oven at 60°C and ground through a cyclone mill (Foss Tecator Sycotec 1093, Hillerød, Denmark) before analysis. Diet and fecal samples were analyzed for dry matter (method 930.15; AOAC, 2000), nitrogen (method 988.05; AOAC, 2000), gross energy using a bomb calorimeter (Parr 1281 Bomb Calorimeter, Parr Instrument Co., Moline, IL, USA), and chromium content using an absorption spectrophotometer (Hitachi Z-5000 Absorption Spectrophotometer, Hitachi High-Technologies Co., Tokyo, Japan) based on the report by Williams et al. (1962). Whole blood samples were analyzed for total white blood cell (WBC) and red blood cell (RBC) counts as well as packed cell volume (PCV) using a multiparameter, automated hematology analyzer calibrated for porcine blood (scil Vet abc hematology analyzer, scil animal care company, F-67120 Altorf, France).

Statistical analyses

Data were analyzed using the PROC MIXED procedure of SAS (SAS Inst. Inc., Cary, NC, USA) in a randomized complete block design. The experimental unit was the pen and block was the sex. The statistical model for growth performance, nutrient digestibility, and blood profiles included effects of dietary treatment as a fixed effect and sex as a random effect. The χ^2 test was used for the frequency of diarrhea. Results are given as means \pm standard error of the mean. Statistical significance and tendency were considered at $p < 0.05$ and $0.05 \leq p < 0.10$, respectively.

RESULTS AND DISCUSSION

No differences were found on growth performance

Table 1. Composition of experimental diets for weaned pigs (as-fed basis)¹

Items	Phase 1		Phase 2		Phase 3	
	CON	PKE	CON	PKE	CON	PKE
Ingredient (%)						
Corn	39.60	22.50	44.95	27.85	54.80	37.70
Soybean meal, 48%	10.00	7.00	18.00	15.00	24.00	21.00
Palm kernel expellers ²	-	20.00	-	20.00	-	20.00
Dried whey	22.00	22.00	16.00	16.00	10.00	10.00
Spray dried plasma	8.00	8.00	4.00	4.00	-	-
Fish meal	10.00	10.00	9.00	9.00	6.00	6.00
Lactose	6.00	6.00	3.00	3.00	-	-
Soybean oil	3.00	3.00	3.00	3.00	3.00	3.00
Limestone	0.60	0.60	0.55	0.55	0.70	0.70
Dicalcium phosphate	-	-	0.30	0.30	0.60	0.60
Zinc oxide	0.50	0.50	0.50	0.50	-	-
Salt	-	-	0.40	0.40	0.40	0.40
Vitamin premix ³	0.15	0.15	0.15	0.15	0.15	0.15
Mineral premix ⁴	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine-HCl	-	0.10	-	0.10	0.20	0.30
Total	100	100	100	100	100	100
Calculated energy and nutrient contents						
ME (Mcal/kg)	3.57	3.51	3.51	3.44	3.47	3.41
CP (%)	23.10	23.70	23.00	23.50	21.10	21.70
Crude fat (%)	2.84	4.45	2.92	4.53	2.94	4.54
Crude fiber (%)	1.21	4.10	1.62	4.51	2.04	4.93
NDF (%)	4.43	13.92	5.57	15.06	6.96	16.45
ADF (%)	1.67	8.48	2.24	9.06	2.85	9.66
Calcium (%)	0.83	0.88	0.83	0.88	0.81	0.86
Phosphorus (%)	0.72	0.76	0.73	0.76	0.67	0.71
Lysine (%)	1.60	1.62	1.48	1.50	1.37	1.39

ME, metabolizable energy; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; GE, gross energy; DM, dry matter.

¹Phase 1 = wk 1 (7 days), phase 2 = wk 2 to 3 (14 days), phase 3 = wk 4 to 6 (21 days). CON, control diet based on corn and soybean meal; PKE, CON+ 20% palm kernel expellers.

²The analyzed energy and nutrient contents of palm kernel expellers are 4,492 kcal/kg GE, 94.3% DM, 16.9% CP, 9.0% ether extract, 13.3% crude fiber, 4.5% ash, 53.9% NDF, and 26.9% ADF.

³Provided per kilogram of diet: vitamin A, 12,000 IU; vitamin D₃, 2,500 IU; vitamin E, 30 IU; vitamin K₃, 3 mg; D-pantothenic acid, 15 mg; nicotinic acid, 40 mg; choline, 400 mg; and vitamin B₁₂, 12 µg.

⁴Provided per kilogram of diet: Fe, 90 mg from iron sulfate; Cu, 8.8 mg from copper sulfate; Zn, 100 mg from zinc oxide; Mn, 54 mg from manganese oxide; I, 0.35 mg from potassium iodide; Se, 0.30 mg from sodium selenite.

during phase 1 and 3 when weaned pigs fed either CON or PKE (Table 2). However, feeding PKE to weaned pigs tended ($p = 0.06$) to increase average daily gain (ADG), increased ($p < 0.05$) average daily feed intake (ADFI), and decreased ($p < 0.05$) gain-to-feed ratio (G:F) during phase 2 compared with CON. During overall experimental period, feeding PKE to weaned pigs also tended ($p = 0.05$) to increase ADG and increased ($p < 0.05$) ADFI, but did not affect G:F. One of the most important points in the management program of weaning pigs is the fast adaptation of solid feed of nursery diets from liquid feed of sow milk as well as the fast increase amount of feed intake after weaning because it can directly influence their growth performance and health (Lalles et al., 2007). In addition, previous studies showed palm kernel co-products in

finishing pig diets reduced growth performance (Kim et al., 2001; Ao et al., 2011). The data from present experiment cannot be directly compared with the data from previous studies described above because the data from present experiment is for weaned pigs rather than finishing pigs. However, the present experiment did not show any adverse effects on ADFI and ADG when weaned pigs fed PKE during overall experimental period.

There were no differences on apparent total tract digestibility of dry matter, nitrogen, and energy when weaned pigs fed either CON or PKE (Table 3). Previous studies reported that the increased fiber contents in swine diets contribute to the decrease nutrient digestibility (Noblet and Le Goff, 2001) and that palm kernel co-products in growing or finishing pig diets reduced nutrient digestibility

Table 2. Growth performance of weaned pigs fed dietary treatments¹

Item	Treatments ²		SEM	p-value
	CON	PKE		
Phase 1				
Initial BW (kg)	6.87	7.02	0.24	0.67
Final BW (kg)	7.27	7.46	0.25	0.59
Feed intake (kg)	4.11	4.15	0.10	0.78
ADG (g/d)	57.14	63.86	10.32	0.65
ADFI (g/d)	146.79	148.21	3.60	0.78
G:F (g/g)	0.384	0.439	0.070	0.59
Phase 2				
Initial BW (kg)	7.27	7.46	0.25	0.59
Final BW (kg)	10.28	10.90	0.29	0.15
Feed intake (kg)	19.20	26.36	0.63	<0.05
ADG (g/d)	215.19	245.67	10.81	0.06
ADFI (g/d)	342.84	470.75	11.19	<0.05
G:F (g/g)	0.628	0.522	0.022	<0.05
Phase 3				
Initial BW (kg)	10.28	10.90	0.29	0.15
Final BW (kg)	22.09	23.10	0.45	0.13
Feed intake (kg)	60.00	61.79	0.89	0.17
ADG (g/d)	562.14	580.67	16.68	0.44
ADFI (g/d)	714.29	735.54	10.65	0.17
G:F (g/g)	0.786	0.792	0.022	0.87
Overall				
Initial BW (kg)	6.87	7.02	0.24	0.67
Final BW (kg)	22.09	23.10	0.45	0.13
Feed intake (kg)	83.31	92.30	1.19	<0.05
ADG (g/d)	362.33	382.87	7.09	0.05
ADFI (g/d)	495.89	549.39	7.09	<0.05
G:F (g/g)	0.731	0.698	0.014	0.11

SEM, standard error of the mean; BW, body weight; ADG, average daily gain; ADFI, average daily feed intake; G:F, gain-to-feed ratio.

¹ Values are presented as the least squares mean of 11 replicates (4 pigs/replicate). One pig in the CON diet was died at the end of week 6. Phase 1 = wk 1 (7 days); phase 2 = wk 2 to 3 (14 days); phase 3 = wk 4 to 6 (21 days); overall = wk 1 to 6 (42 days).

² CON, control diet based on corn and soybean meal; PKE, CON+20% palm kernel expellers.

compared with conventional ingredients (Son et al., 2012; Sulabo et al., 2013). However, the present experiment did not show any negative effects on nutrient digestibility when weaned pigs were fed PKE. The reason for this observation is unclear and no corresponding information is available.

Feeding PKE to weaned pigs tended ($p < 0.10$) to reduce frequency of diarrhea for the first 2 wk after weaning and WBC, RBC, and PCV on d 7 after weaning compared with CON (Table 3). However, no differences were found on WBC, RBC, and PCV before weaning between CON and PKE. In addition, only one pig fed CON was died during overall experimental period and thus there was no information about postweaning mortality. Generally, the weaning is a stressful event and thus the first week after

Table 3. Apparent total tract digestibility and blood profiles of weaned pigs fed dietary treatments¹

Item	Treatments ²		SEM	p-value
	CON	PKE		
Apparent total tract digestibility				
Dry matter (%)	73.88	74.24	1.03	0.81
Nitrogen (%)	69.90	70.25	1.62	0.88
Energy (%)	73.73	75.06	1.13	0.41
Frequency of diarrhea (%) ³	24.7	14.7	-	0.08
Number of white blood cells ($\times 10^3/\mu\text{L}$)				
Before weaning	9.50	9.18	0.67	0.74
d 7 after weaning	9.56	8.19	0.51	0.07
Number of red blood cells ($\times 10^6/\mu\text{L}$)				
Before weaning	2.70	2.61	0.14	0.64
d 7 after weaning	3.25	2.92	0.12	0.09
Packed cell volume (%)				
Before weaning	11.30	10.72	0.64	0.52
d 7 after weaning	12.61	11.06	0.56	0.06

SEM, standard error of the mean.

¹ Values are presented as the least squares mean of 11 replicates (2 pigs/replicate).

² CON, control diet based on corn and soybean meal; PKE, CON+20% palm kernel expellers.

³ Frequency of diarrhea = frequency of diarrhea of weaned pigs for the first 2 weeks after weaning, (number of diarrhea/number of pen days) $\times 100$. Data was analyzed by the χ^2 test.

weaning is a very important period for weaned pigs that have immature digestive tract and immune system (Pluske et al., 2002; Lalles et al., 2007). In addition, the post-weaning diarrhea is one of main causes for mortality of weaned pigs (NAHMS, 2008). Due to those reasons, blood samples were collected at different time points (before weaning and d 7 after weaning) to check the changes of blood profiles after weaning, especially WBC which can be used as an indicator of inflammation (Gordon-Smith, 2009; Liu et al., 2013). The palm kernel co-products contain greater fiber contents which mainly consist of β -mannans compared with conventional feed ingredients as well as other oilseed co-products (Balasubramaniam, 1976; Daud and Jarvis, 1992; Dusterhoft et al., 1991). The increment of fiber contents in nursery diets may improve gastro-intestinal environment. Gerritsen et al. (2012) reported that the supplementation of insoluble nonstarch polysaccharides (wheat straw and oat hulls) reduced *E. coli* concentration in the ileum and colon digesta and stimulated the physical adaptation of the gastro-intestinal tract. Previous studies also showed that mannan-oligosaccharides in swine diets affected immune system and growth and productive performances positively (Miguel et al., 2004; Che et al., 2011). Although the present experiment did not show the improvement of postweaning mortality of pigs fed PKE compared with CON, the PKE reduced frequency of diarrhea, WBC, RBC, and PCV. The reason for this observation may be related to relatively greater β -mannan

contents in PKE compared with CON, which may contribute to the reduced incidence of diarrhea of pigs after weaning. Furthermore, energy saved from this reduced diarrhea may contribute to growth and health of pigs fed PKE.

To our knowledge, the present experiment is the first to show the effects of palm kernel expellers in nursery diets and thus there are little corresponding data to discuss our findings critically. Therefore, more research is needed to determine effects of palm kernel expellers in nursery diets and to verify its assumed mechanisms in growth performance and health standpoints that were not determined in the present experiment.

CONCLUSION

In conclusion, addition of 20% palm kernel expellers in nursery diets based on corn and soybean meal had no negative effects on growth performance, nutrient digestibility, and blood profiles of weaned pigs.

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