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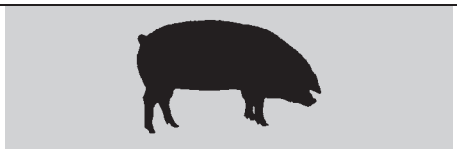

Effects of using copra meal, palm kernel expellers, or palm kernel meal in diets for weanling pigs

N. W. Jaworski, J. Shoulders, J. C. González-Vega, and H. H. Stein,[1] PAS
Department of Animal Sciences, University of Illinois, Urbana 61801

ABSTRACT

Three experiments were conducted to evaluate effects of including copra meal, palm kernel expellers (PKE), and palm kernel meal (PKM) in diets for weanling pigs from approximately 9 to 20 kg of BW. A total of 128, 128, and 160 pigs were used in the experiments with copra meal, PKE, and PKM, respectively. In each experiment, pigs were randomly allotted to 4 dietary treatments with 4 or 5 pigs per pen and 8 replicates per treatment. The control diet was based on corn, soybean meal, and 4% fish meal. Three additional diets were formulated by including 5, 10, or 15% copra meal, PKE, or PKM at the expense of corn and soybean meal. Diets were formulated to contain equal quantities of digestible AA and P, and ME. Pigs were fed experimental diets for 20 or 21 d, and ADG, ADFI, and G:F were calculated. Results indicated that pigs fed increasing levels of copra meal had a linear reduction ($P < 0.05$) in final BW, overall ADG, and ADFI, but overall G:F was unaffected. Pigs fed increasing levels of PKE had a linear reduction ($P < 0.05$) in final BW and overall ADG, but overall ADFI and G:F were not influenced. No differences were observed in growth performance if PKM was used. In conclusion, if diets are formulated based on digestible nutrients and ME, diets for weanling pigs may include up to 15% PKM without affecting overall growth performance, but if copra meal or PKE is used, pig performance may be reduced.

Key words: copra meal, palm kernel expellers, palm kernel meal, pig

INTRODUCTION

Replacing corn and soybean meal (**SBM**) with less expensive coproducts in swine diets has become economically important due to the increasing cost of corn and SBM. Copra meal, palm kernel expellers (**PKE**), and palm kernel meal (**PKM**) are coproducts from the vegetable oil industry and may potentially replace some corn and SBM in weanling pig diets. Copra meal is a coproduct of the coconut-oil industry and is often fed to poultry and pigs in subtropical and tropical countries where it is readily available (Février et al., 2001). Palm kernel expellers are produced after the fruits of oil palm are de-oiled using mechanical extraction, whereas PKM is produced after solvent extraction of the oil from the oil palm. Use of copra meal, PKE, and PKM in weanling pig diets is of interest because these ingredients contribute both protein and energy to the diets (Agunbiade et al., 1999). However, because these ingredients are produced in subtropical and tropical countries, the cost of transportation needs to be taken into account when evaluating the economic value of these ingredients in the United States swine industry.

Variable effects on growth performance of growing-finishing pigs fed these coproducts have been reported (Lekule et al., 1986; Rhule, 1996; O'Doherty and McKeon, 2000; Kim et al., 2001), but it is possible that the reason for the variable results is that diets were not formulated to contain sufficient quantities of digestible nutrients and energy. However, recently values for DE, ME, and standardized ileal digestibility (**SID**) of AA and the digestibility of P were determined in copra meal, PKE, and PKM (Almaguer et al., 2011; Sulabo et al., 2013). Therefore, the objective of this experiment was to test the hypothesis that copra meal, PKE, or PKM may replace some corn and SBM in diets fed to weanling pigs from approximately 9 to 20 kg of BW without negatively affecting pig performance if diets are formulated to contain equal quantities of ME, SID AA, and digestible P.

MATERIALS AND METHODS

The protocols for 3 experiments were reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illi-

[1] Corresponding author: hstein@illinois.edu

nois. All experiments were conducted in environmentally controlled rooms at the University of Illinois at Urbana-Champaign, and pigs were housed in 1.4 × 1.4 m pens with fully slatted floors. A feeder and nipple drinker were provided in each pen, and feed and water were provided on an ad libitum basis throughout the experiments. All pigs used in these experiments were the offspring of G-Performer boars mated to F-25 females (Genetiporc, Alexandria, MN).

Each experiment used pigs weaned at approximately 20 d of age. Pigs were fed a common phase 1 diet for 14 d after weaning. In Exp. 1, 128 pigs (initial BW = 9.2 ± 1.2 kg) were randomly allotted to 4 diets that were fed for 20 d. The control diet contained corn, SBM, and 4% fish meal (Table 1). Three additional diets were formulated by including 5, 10, or 15% copra meal in the diets at the expense of corn and SBM. All diets were formulated to contain equal quantities of ME, SID AA, and standardized total-tract digestible (**STTD**) P. Soybean oil and crystalline Lys, Met, Thr, and Trp were added at the expense of corn and SBM as copra meal was included in the diet to maintain equal quantities of ME and SID AA in the diets. Values for ME, SID AA, and STTD of P in corn, SBM, and fish meal were from NRC (2012), whereas values for ME and SID AA in copra meal were from Sulabo et al. (2013) and the values for STTD of P in copra meal were from Almaguer et al. (2011). There were 4 pigs per pen and 8 replicate pens per treatment. An attempt was made to keep the barrow:gilt ratio equal among pens within a replicate. Individual pig BW was recorded at the start of the experiment, on d 10, and at the conclusion of the experiment. Daily feed allotments were recorded, and feed left in the feeders were recorded on the same day as pigs were weighed. At the conclusion of the experiment, data were summarized to calculate ADG, ADFI, and G:F for each pen and treatment group.

In Exp. 2, 128 pigs (initial BW = 9.8 ± 1.0 kg) were randomly allot-

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

	Copra meal				Palm kernel expellers				Palm kernel meal			
Ingredient, %	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
Corn	63.55	59.40	55.29	51.12	63.55	59.42	55.30	51.12	63.36	58.15	52.75	47.36
Soybean meal, 48%	28.00	27.00	26.00	25.00	28.00	26.50	25.00	23.50	28.25	27.55	27.05	26.50
Fish meal	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Soybean oil	2.00	2.14	2.25	2.40	2.00	2.60	3.20	3.80	2.00	2.90	3.80	4.70
Copra meal	—	5.00	10.00	15.00	—	—	—	—	—	—	—	—
Palm kernel expellers	—	—	—	—	—	5.00	10.00	15.00	—	—	—	—
Palm kernel meal	—	—	—	—	—	—	—	—	—	5.00	10.00	15.00
Limestone	0.79	0.83	0.90	0.92	0.79	0.80	0.75	0.75	0.77	0.76	0.77	0.80
Dicalcium phosphate	0.55	0.50	0.40	0.35	0.55	0.50	0.50	0.50	0.57	0.54	0.50	0.45
L-Lys HCL	0.28	0.30	0.32	0.35	0.28	0.32	0.36	0.40	0.16	0.19	0.20	0.23
DL-Met	0.06	0.06	0.07	0.07	0.06	0.07	0.09	0.10	0.10	0.11	0.12	0.13
L-Thr	0.07	0.07	0.07	0.08	0.07	0.09	0.10	0.13	0.09	0.10	0.11	0.12
L-Trp	—	—	—	0.01	—	—	—	—	—	—	—	0.01
Salt	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin–mineral premix[1]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

[1]The vitamin–micromineral premix provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2,204 IU; vitamin E as DL-α tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamine as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

Table 2. Analyzed and calculated composition of experimental diets (as-fed basis)

	Copra meal				Palm kernel expellers				Palm kernel meal			
Item	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**	**0%**	**5%**	**10%**	**15%**
Analyzed composition												
DM, %	89.07	89.32	89.31	89.48	90.15	90.42	90.66	90.79	87.85	88.31	88.33	89.23
Ash, %	4.81	5.16	5.08	5.80	5.15	5.15	5.62	5.09	5.00	5.57	4.71	5.52
GE, kcal/kg	4,038	4,065	4,069	4,148	4,082	4,170	4,253	4,289	3,948	4,036	4,099	4,205
CP, %	20.05	20.74	21.25	21.29	20.83	21.26	20.63	19.83	20.66	20.69	22.01	20.78
AEE,[1] %	5.11	5.63	5.95	6.01	5.17	5.85	6.42	8.04	5.12	6.52	6.53	7.17
ADF, %	3.19	4.29	5.72	6.86	2.73	4.50	6.88	8.80	2.80	5.29	7.32	9.80
NDF, %	10.44	13.66	15.41	18.05	10.38	12.83	16.84	20.00	10.28	14.29	17.62	21.39
Calculated composition												
ME, kcal/kg	3,389	3,389	3,388	3,389	3,389	3,389	3,389	3,388	3,472	3,473	3,474	3,474
SID[2] AA, %												
Arg	1.24	1.26	1.28	1.29	1.25	1.25	1.26	1.27	1.31	1.33	1.35	1.37
His	0.50	0.49	0.49	0.48	0.50	0.48	0.46	0.45	0.53	0.52	0.50	0.49
Ile	0.76	0.76	0.76	0.76	0.76	0.75	0.73	0.71	0.81	0.79	0.79	0.78
Leu	1.57	1.55	1.54	1.52	1.57	1.52	1.47	1.43	1.67	1.62	1.58	1.54
Lys	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.20	1.20	1.20	1.20
Met	0.38	0.38	0.39	0.39	0.38	0.39	0.40	0.41	0.45	0.45	0.46	0.46
Phe	0.88	0.88	0.88	0.88	0.88	0.86	0.84	0.81	0.93	0.91	0.90	0.89
Thr	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.74	0.78	0.78	0.78	0.78
Trp	0.22	0.22	0.22	0.22	0.22	0.21	0.21	0.20	0.22	0.22	0.22	0.22
Val	0.84	0.85	0.85	0.86	0.84	0.83	0.81	0.80	0.88	0.87	0.87	0.86
Ala	0.92	0.92	0.92	0.91	0.92	0.90	0.87	0.85	0.93	0.91	0.89	0.87
Asp	1.75	1.74	1.74	1.73	1.75	1.70	1.65	1.60	1.76	1.74	1.72	1.71
Cys	0.28	0.27	0.27	0.27	0.28	0.27	0.26	0.25	0.28	0.27	0.27	0.26
Glu	3.17	3.18	3.18	3.19	3.17	3.10	3.03	2.96	3.19	3.15	3.13	3.10
Gly	0.77	0.78	0.78	0.79	0.77	0.76	0.75	0.74	0.78	0.77	0.77	0.76
Pro	1.32	1.30	1.29	1.27	1.32	1.27	1.23	1.18	1.33	1.28	1.24	1.20
Ser	0.86	0.85	0.85	0.84	0.86	0.83	0.81	0.79	0.86	0.85	0.84	0.83
Tyr	0.58	0.57	0.57	0.56	0.58	0.56	0.54	0.53	0.58	0.57	0.57	0.56
STTD[3] P, %	0.33	0.33	0.33	0.33	0.33	0.32	0.33	0.33	0.35	0.35	0.35	0.35

[1]AEE = acid hydrolyzed ether extract.

[2]SID = standardized ileal digestible.

[3]STTD = standardized total-tract digestible.

ted to 4 diets. This experiment was similar to Exp. 1 with the exception that 0, 5, 10, or 15% PKE, rather than copra meal, was included in the diets and the diets were fed for 21 d (Tables 1 and 2).

Experiment 3 was also similar to Exp. 1 with the exception that 0, 5, 10, or 15% PKM was used (Table 1). Also, a total of 160 pigs (initial BW = 8.4 ± 1.3 kg) were allotted to the 4 treatment diets with 5 pigs per pen and 8 replicate pens per treatment.

In each experiment, a blood sample (10 mL) was collected from one barrow and one gilt with a BW closest to the pen average on the first day and the last day of the experiment. Because pigs for bleeding were selected based on BW, it was not always the same pig that was bled at each bleeding. Blood samples were analyzed for plasma urea nitrogen (**PUN**).

Copra meal and PKM used in this experiment were previously analyzed for nutrients and energy. But, the PKE used in this experiment was an equal mix of the 2 sources of PKE from Costa Rica and Indonesia that were previously used (Almaguer et al., 2011; Sulabo et al., 2013; Table 3).

Bulk density and water-binding capacity (**WBC**) of copra meal, PKE, PKM, and all diets were determined. Bulk density was measured by pouring samples into a 250-mL beaker, leveling off the top, and weighing the sample. This procedure was performed in triplicate, and a mean weight was determined (Cromwell et al., 2000). Water-binding capacity was determined by weighing 1 g of sample into a centrifuge tube and mixing the sample with 30 mL of distilled water, and after the samples settled, they were centrifuged for 20 min at 3,000 rpm. The supernatant was removed, and sample weights were recorded. Values for WBC were expressed as the amount of water retained by the pellet (g/g; Urriola, 2010). All diets and ingredients were analyzed for DM (Method 930.15; AOAC International, 2007), ash (Method 942.05; AOAC International, 2007), ADF (Method 973.18; AOAC International, 2007), NDF (Holst, 1973), and CP (Method 990.03; AOAC International, 2007). Acid hydrolyzed ether extract (**AEE**) was determined in all diet and ingredient samples by acid hydrolysis using 3 *N* HCl (Sanderson, 1986) followed by crude fat extraction using petroleum ether (Method 2003.06, AOAC

Table 3. Nutrient composition of ingredients (as-fed basis)[1]

	Ingredient		
Item	Copra meal	Palm kernel expellers[2]	Palm kernel meal
DM, %	92.9	91.9	91.9
Bulk density, g/L	502.4	634.1	401.0
Water-binding capacity, g/g	4.18	1.83	2.17
GE, kcal/kg	4,445	4,482	4,250
CP, %	22.0	14.3	13.6
AEE,[3] %	1.9	6.9	1.3
NDF, %	54.8	70.6	77.9
ADF, %	26.9	43.0	49.4
Insoluble dietary fiber, %	41.4	60.9	68.7
Soluble dietary fiber, %	5.5	2.6	2.2
Total dietary fiber, %	46.9	63.5	70.9
Ash, %	6.0	3.9	3.8
Ca, %	0.04	0.31	0.20
P, %	0.52	0.52	0.54
Phytate P, %	0.22	0.37	0.32
Indispensable AA, %			
Arg	2.08	1.53	1.36
His	0.35	0.20	0.17
Ile	0.66	0.47	0.41
Leu	1.20	0.82	0.71
Lys	0.42	0.37	0.36
Met	0.27	0.25	0.22
Phe	0.79	0.53	0.47
Thr	0.55	0.37	0.33
Trp	0.15	0.12	0.05
Val	0.97	0.65	0.57
DE, kcal/kg	3,430	2,893	2,669
ME, kcal/kg	3,248	2,786	2,542
STTD[4] P, %	70.6	40.4	57.9
SID[5] indispensable AA, %			
Arg	91.2	90.4	88.3
His	82.5	83.6	80.8
Ile	81.6	83.5	80.4
Leu	81.6	82.4	79.7
Lys	72.8	76.5	71.1
Met	85.5	85.0	82.2
Phe	84.5	84.6	82.2
Thr	76.7	77.2	73.9
Trp	88.4	89.4	87.5
Val	79.0	81.0	77.2

[1]Values from Almaguer et al. (2011) and Sulabo et al. (2013).

[2]Palm kernel expellers used in this experiment are a mixture of palm kernel expellers from Costa Rica and Indonesia.

[3]AEE = acid hydrolyzed ether extract.

[4]Standardized total-tract digestible.

[5]Standardized ileal digestible.

International, 2007) on a Soxtec 2050 automated analyzer (FOSS North America, Eden Prairie, MN). The concentration of GE was determined in all diet and ingredient samples by using an adiabatic bomb calorimeter (model 6300, Parr Instruments, Moline, IL). Benzoic acid was the standard for calibration. Ingredients were also analyzed for Ca, total P, phytate, AA, total dietary fiber, insoluble dietary fiber, and soluble dietary fiber. Calcium and total P were analyzed by inductively coupled plasma spectroscopy (Method 985.01 A, B, and C; AOAC International, 2007) after wet ash sample preparation [Method 975.03 B(b); AOAC International, 2007]. Phytate was analyzed as phytic acid (Ellis et al., 1977). Amino acids were analyzed on a Hitachi Amino Acid Analyzer (Model L8800, Hitachi High Technologies America Inc., Pleasanton, CA) using ninhydrin for postcolumn derivatization and norleucine as the internal standard. Before analysis, samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C [Method 982.30 E (a, b, c); AOAC International, 2007]. Methionine and Cys were analyzed as Met sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis. Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C. Total dietary fiber, insoluble dietary fiber, and soluble dietary fiber were analyzed according to Prosky et al. (1992).

Data were analyzed using the MIXED procedure of SAS (SAS Institute Inc., Cary, NC). The model consisted of treatment as the fixed effect, and replicate was included as a random effect. The UNIVARIATE procedure was used to verify normality and to test for outliers, but no outliers were identified. Treatment means were calculated using the LSMEANS statement in SAS. Linear and quadratic effects of including increasing levels of copra meal, PKE, or PKM were determined using orthogonal CONTRAST statements. Pen was the experimental unit for all calculations, and an α level of 0.05 was used to assess significance among means.

RESULTS AND DISCUSSION

Effects of Using Copra Meal (Exp. 1)

No differences in BW, ADG, ADFI, and G:F were detected during the initial 10 d when weanling pigs were fed experimental diets (Table 4). However, ADG, ADFI, and G:F from d 10 to 20 and final BW decreased linearly ($P < 0.05$) with increasing concentrations of copra meal in the diets. Cumulative ADG and ADFI also decreased linearly ($P < 0.05$) with increasing levels of copra meal in the diets, but overall G:F and PUN were not affected by addition of copra meal to the diets.

The apparent total-tract digestibility of GE in copra meal is less than in corn and SBM (Sulabo et al., 2013), and thus, soybean oil was increased in diets as copra meal increased. This is demonstrated by the increased GE and AEE in the diets as concentrations of copra meal in the diets increased.

Table 4. Growth performance and PUN[1] of weanling pigs fed increasing levels of copra meal

	Inclusion rate of copra meal					*P*-value	
Item	0%	5%	10%	15%	SEM	Linear	Quadratic
BW, kg							
d 0	9.23	9.23	9.22	9.22	0.46	0.79	0.99
d 10	13.11	12.84	12.85	12.81	0.59	0.16	0.40
d 20	19.48	19.05	18.88	18.49	0.82	<0.01	0.92
ADG, g/d							
d 0–10	387	362	363	360	25	0.16	0.39
d 10–20	638	622	604	568	26	<0.01	0.53
d 0–20	512	491	483	464	23	<0.01	0.95
ADFI, g/d							
d 0–10	537	500	505	502	84	0.19	0.33
d 10–20	994	990	966	940	50	0.04	0.58
d 0–20	765	744	735	721	36	0.04	0.83
G:F							
d 0–10	0.85	0.86	0.88	0.88	0.13	0.44	0.87
d 10–20	0.65	0.64	0.64	0.61	0.03	0.05	0.53
d 0–20	0.67	0.66	0.66	0.64	0.01	0.06	0.68
PUN, mg/dL							
d 0	8.94	8.38	8.56	8.56	0.54	0.70	0.61
d 20	8.81	9.00	9.19	8.44	0.47	0.66	0.33

[1]PUN = plasma urea nitrogen.

Table 5. Bulk density and water-binding capacity of experimental diets

	Copra meal				Palm kernel expellers				Palm kernel meal			
Item	0%	5%	10%	15%	0%	5%	10%	15%	0%	5%	10%	15%
Bulk density, g/L	702.8	695.7	679.7	678.7	711.7	705.7	704.8	697.1	695.3	668.1	650.1	623.9
Water-binding capacity, g/g	1.47	1.59	1.69	1.81	1.37	1.47	1.50	1.49	1.37	1.41	1.45	1.56

Neutral detergent fiber and ADF increased as levels of copra meal increased in the diets, and increased fiber in the diets decreased the bulk density, despite the addition of fat to the diets (Table 5). High concentrations of dietary fiber in pig diets increases bulk in the gut, thus, feed intake is reduced (Kyriazakis and Emmans, 1995). Also, WBC increased as concentrations of copra meal increased in diets because of the capacity of fiber in copra meal to bind water. Soluble fiber has a greater capacity to bind water than insoluble fiber, and the copra meal used in this experiment contained 5.5% soluble fiber, which increases digesta viscosity and slows rate of passage, thereby reducing pig feed intake. The increased WBC and decreased bulk density that were observed as concentrations of copra meal increased in the diets are good indicators that fiber, especially the soluble dietary fiber, from copra meal is a major impediment to pig feed intake, and because of decreased ADFI, pigs had a decrease in ADG. Copra meal contains 42.2% nonstarch polysaccharides of which 29.4% is mannose (Bach Knudsen, 1997). The presence of mannose, glucose, and galactose indicates the presence of gluco- and galactomannans, and these carbohydrates may have antinutritional properties if provided in large quantities to weanling pigs, which may also have contributed to the reduced performance. However, the fact that G:F was not affected by dietary copra meal indicates that the ME value for copra meal is accurate. There were also no differences in PUN among pigs fed experimental diets, which indicates that diets were balanced for SID AA. It was, therefore, expected that there would be no difference in PUN, indicating that values for SID AA used in diet formulations were accurate.

To our knowledge, no data have been reported on the use of copra meal in weanling pig diets. However, results of studies using growing-finishing pigs indicated that inclusion of copra meal in growing-finishing diets reduced growth performance, and growth-performance data from this experiment are in agreement with these observations (Creswell and Brooks, 1971; Thorne et al., 1988, 1990).

In conclusion, recently published values for ME and SID of AA in copra meal appear to be accurate and can be used in diet formulation. Inclusion of copra meal in diets fed to weanling pigs does not decrease G:F if diet formulations are based on ME, but increased ADF, NDF, WBC, and soluble dietary fiber in copra meal will result in decreased ADFI, which decreases ADG.

Effects of Using PKE (Exp. 2)

No differences in ADFI or G:F were observed as pigs were fed increasing levels of PKE (Table 6). However, d-10 BW, d-21 BW, d-0 to d-10 ADG, and cumulative ADG decreased linearly ($P < 0.05$) with increasing concentrations of PKE in the diets. Plasma urea nitrogen on d 21 was linearly ($P < 0.05$) decreased with increasing levels of PKE.

Gross energy and AEE increased in the diets as concentrations of PKE increased because soybean oil was added because of the lower apparent total-tract digestibility of GE in PKE compared with corn and SBM (Sulabo et al., 2013; Table 2). Also, NDF and ADF increased in the diets as levels of PKE increased. However, the reduction in PUN that was observed as concentrations of PKE in diets increased was unexpected because diets were balanced for SID AA, and this observation indicates that values for SID AA used in diet formulations may be inaccurate for PKE. The main reason for the inaccuracy may be the fact that Sulabo et al. (2013) determined SID of AA in PKE from Costa Rica and Indonesia and in this experiment those 2 sources were mixed and average values for SID AA were used in diet formulation.

As levels of NDF and ADF increased in diets, ADFI of pigs was not affected, which is in contrast to Exp. 1. It is possible that reduced WBC of diets containing increasing

Table 6. Growth performance and PUN[1] of weanling pigs fed increasing levels of palm kernel expellers

	Inclusion rate of palm kernel expellers					*P*-value	
Item	0%	5%	10%	15%	SEM	Linear	Quadratic
BW, kg							
d 0	9.79	9.74	9.75	9.78	0.39	0.82	0.08
d 10	13.03	12.65	12.96	12.36	0.52	0.04	0.52
d 21	20.29	19.61	19.92	19.15	0.69	0.03	0.89
ADG, g/d							
d 0–10	323	292	322	260	20	0.05	0.39
d 10–21	727	696	696	679	26	0.21	0.78
d 0–21	525	494	509	470	19	0.04	0.80
ADFI, g/d							
d 0–10	569	521	563	513	32	0.25	0.95
d 10–21	1,118	1,041	1,070	1,038	47	0.16	0.50
d 0–21	844	781	816	775	37	0.13	0.66
G:F							
d 0–10	0.57	0.56	0.58	0.51	0.02	0.09	0.17
d 10–21	0.65	0.67	0.65	0.66	0.01	0.93	0.68
d 0–21	0.63	0.63	0.63	0.61	0.01	0.19	0.21
PUN, mg/dL							
d 0	8.44	7.69	8.88	8.19	0.49	0.84	0.95
d 21	9.25	9.00	8.50	7.44	0.58	0.03	0.49

[1]PUN = plasma urea nitrogen.

concentrations of PKE compared with diets containing increasing concentrations of copra meal is the reason for this observation. These observations indicate that WBC may be more detrimental to ADFI than diet bulk because bulk density of PKE-containing diets was similar to bulk density of copra meal–containing diets. Also, the fiber composition of PKE is different from the fiber composition of copra meal, which may also have contributed to these results. Copra meal contained 5.5% soluble dietary fiber, which binds water, increasing digesta viscosity, and slows rate of passage, thereby reducing pig feed intake. In contrast, PKE contained much less soluble dietary fiber (2.6%) and greater amounts of insoluble dietary fiber (60.9%), which does not bind water well, in turn accelerating rate of passage, allowing for greater feed intake. However, the accelerated rate of passage may have reduced nutrient and energy digestibility causing PUN, overall ADG, and overall BW to decrease as concentrations of PKE increased in diets. The fact that G:F was not affected by increasing concentrations of PKE in diets indicates that the ME value for PKE that was used in diet formulation is accurate. In conclusion, recently published values for ME in PKE appear to be accurate and can be used in diet formulation. Inclusion of PKM in diets fed to weanling pigs does not decrease G:F if diets are based on ME, but BW and ADG are decreased possibly because of an accelerated rate of passage.

Effects of Using PKM (Exp. 3)

Day-10 BW, d-10 ADG, and d-10 G:F decreased linearly ($P < 0.05$) with increasing concentrations of PKM in the diets (Table 7). However, no differences in BW, ADG, ADFI, and G:F were detected on d 20 and cumulatively when weanling pigs were fed diets containing increasing levels of PKM. Concentrations of PUN on d 20 decreased linearly ($P < 0.05$) with increasing levels of PKM in the diets.

Dietary GE and AEE increased as concentrations of PKM increased because of addition of soybean oil to compensate for the decreased apparent total-tract digestibility of GE in PKM compared with corn and SBM. Concentrations of ADF and NDF also increased in diets as levels of PKM increased, and as a result, bulk density of diets decreased as levels of PKM increased despite the fact that fat was added to the diets along with PKM. However, the increased ADF and NDF and decreased bulk density of diets containing increasing concentrations of PKM did not affect pig feed intake, further indicating that diet bulk does not affect ADFI. Also, there is a low amount of soluble dietary fiber in PKM (2.2%) and a much greater amount of insoluble dietary fiber (70.9%), further indicating that soluble dietary fiber is more of an impediment to feed intake in weanling pigs than insoluble dietary fiber. The fact that overall G:F was not affected indicates that the ME value for PKM is accurate. Although PUN decreased as concentrations of PKM increased in diets, overall pig ADG and BW were unaffected, indicating that diets were balanced for SID AA.

To our knowledge, no data have been published on the effects of

Table 7. Growth performance and PUN[1] of weanling pigs fed increasing levels of palm kernel meal

	Inclusion rate of palm kernel meal					*P*-value	
Item	0%	5%	10%	15%	SEM	Linear	Quadratic
BW, kg							
d 0	8.41	8.44	8.43	8.37	0.46	0.07	0.03
d 10	11.04	10.93	10.70	10.67	0.11	0.01	0.70
d 20	16.71	16.50	16.24	16.23	0.26	0.16	0.70
ADG, g/d							
d 0–10	263	252	231	226	11	0.01	0.83
d 10–20	515	506	508	507	17	0.78	0.82
d 0–20	395	387	373	375	12	0.20	0.68
ADFI, g/d							
d 0–10	451	444	432	436	17	0.45	0.72
d 10–20	826	836	819	844	41	0.84	0.86
d 0–20	647	649	652	650	23	0.92	0.94
G:F							
d 0–10	0.59	0.58	0.54	0.52	0.02	0.02	0.78
d 10–20	0.63	0.61	0.65	0.60	0.03	0.88	0.66
d 0–20	0.61	0.60	0.58	0.58	0.01	0.09	0.65
PUN, mg/dL							
d 0	8.44	8.06	8.00	8.81	0.63	0.71	0.36
d 20	11.25	10.69	9.63	9.63	0.65	0.04	0.65

[1]PUN = plasma urea nitrogen.

including PKM in diets fed to weanling pigs. However, results of studies with growing pigs indicate that PKM may be included by up to 20% in grower diets and 30% in finisher diets without negatively affecting growth performance (Rhule, 1996), and data from this experiment indicate that inclusion of at least 15% PKM in diets for weanling pigs does not negatively affect growth performance. In conclusion, these results indicate that recently published values for ME and SID of AA in PKM appear to be accurate and can be used in diet formulation.

IMPLICATIONS

Results from these experiments demonstrate that if diets are formulated based on SID AA, STTD P, and ME, diets for weanling pigs may include up to at least 15% PKM without affecting overall growth performance. However, if diets contain up to 15% copra meal or PKE, pig ADG will be slightly reduced, but G:F will not be affected. The cost effectiveness of using copra meal or PKE, therefore, depends on the importance of ADG in a production system. The overall economic value of these ingredients also depends on the location of the production facility because transportation costs may make the ingredients uneconomic in some parts of the world.

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