Effect of Processing Method on the Quality of Palm Kernel Cake: Chemical Composition and Nutrient Utilization in Enzyme Supplemented Diets

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Abstract. The feed value of palm kernel cake (PKC) from two expeller sites and two hydrothermal production facilities were assessed using 30 laboratory rats as a model. Following chemical analysis, the PKC were incorporated at 0% (control, CON) or 35% (w/w) into isonitrogenous maize-based diets (2.9% N, DM basis) and fed to individually caged albino rats for 28 day. All PKC diets included 0.5% (w/w) Alzyme Vegpro (Alltech Canada, Guelph, ON). PKC from expellers (E1, E2) contained more fatty acids (FA) and less crude protein (CP) than did PKC from hydrothermal production (H1, H2), averaging 15.8% vs 7.7% FA and 13.3% vs. 19.7% CP (DM basis), respectively. Lauric, oleic, myristic and palmitic acids were predominant in PKC, accounting for 84% of total FA. E1 and E2 had higher essential amino acid contents (average 67.1% of total AA) than did H1 or H2 (average 64.1%). Gain and feed efficiency (FE; feed/gain) were similar between rats fed E1 or E2 diets and those fed CON (2.1 and 2.2 g/d vs. 2.2 g/d; 4.7 and 4.3 g/d vs. 5.3, respectively), but were reduced in rats fed H1 or H2 diets (1.5 and 1.3 g/d gain; 7.1 and 7.0 FE) compared with CON. This study indicated that expeller-produced PKC could potentially be included in maize-based starter diets for pigs at up to 35% with no adverse effects on growth.

Key words: Amino acid, fatty acid, expeller, hydrothermal

Abstrak. Nilai pakan PKC dari dua expeller dan dua fasilitas produksi hidrotermal diukur menggunakan 30 mencit sebagai model. PKC dianalisa secara kimiawi dengan kadar 0% (kontrol, CON) atau 355 (w/w) ke dalam pakan berbahan dasar jagung isonitrogen (2.9% N, BK) dan diberikan kepada mencit albino yang dikandangkan secara individu selama 28 hari. Semua pakan PKC mencakup 0.5%(w/w) Alzyme Vegpro (Alltech Canada, Guelph, ON). PKC expeller (E1, E2) mengandung lebih banyak asam lemak (FA) dan lebih sedikit protein kasar (PK) daripada PKC dari produksi hidrotermal (H1, H2), dengan kisaran 15,8% vs 7,7% FA dan 13,3% vs 19,7% PK (berdasarkan BK). Asam laurat, oleat, miristat dan palmitat mendominasi PKC, mencakup 845 dari total asam lemak. E1 dan E2 mempunyai kandungan asam amino esensial (rata-rata 67,1 dari total asam amino) daripada H1 dan H2 (rata-rata 64,1%). Efisiensi pakan dan pertumbuhan (FE; pakan/bijian) sama antara tikus yang diberi pakan E1 atau E2 dengan yang diberi CON (2,1 dan 2,2 g/hari vs. 2,2 g/hari; 4,7 dan 4,3 g/hari vs. 5,3), namun berkurang pada tikus yang diberi pakan H1 atau H2 (1,5 and 1,3 g/hari; 7,1 dan 7,0 FE) dibandingkan dengan CON. Penelitian ini menunjukkan bahwa PKC expeller berpotensi disertakan dalam pakan berbahan dasar jagung untuk babi hingga kadar 35% tanpa berpengaruh buruk terhadap pertumbuhan.

Kata kunci: Asam amino, asam lemak, expeller, hidrotermal

Introduction

The increasing demand for grains as raw materials in the production of high-value commodities (biofuel) is driving food and feed prices higher than ever recorded in history. It becomes apparent that the future of feeding livestock on high-grain diets is increasingly threatened so greater attention should be focused on finding alternative energy feedstuffs for pigs and other monogastric animals. Many attempts have been made in this regard and one approach, which has proven successful over the years, is the incorporation of agro-industrial by-products (AIBP) in monogastric diets (Osei et al., 1991; Atuahene et al., 2000). Palm kernel cake (PKC) is one of such potential feedstuffs which is available in large quantities

and cheaper price (Ng et al., 2002; Orunmuyi et al., 2006).

PKC is by-product of palm kernel oil extraction from African oil palm fruit (*Elaeis guineensis, jacq.*). Boateng et al. (2008) described two processes in the extraction of palm kernel oil in Ghana; expeller press and an indigenous local technique that employs hydrothermal techniques to extract the oil. Nutritional evaluation of palm kernel cake (PKC) have been reported by Hutagalung et al. (1982); Yeong et al. (1983) and Iluyemi et al. (2006). However, the chemical analyses revealed wide variations in chemical composition attributed to, among others, the source, the extent and method of oil removal (Rhule, 1996; Carvalho et al., 2005).

Although it is commonly known that heat is involved in all commercial methods of palm kernel oil extraction (directly or indirectly), little or no attention has been given to the effect of amount of heating used in the extraction process has on the nutritive value of the palm kernel cake. The objective of this study was therefore to explore the effect the extraction process on chemical composition of palm kernel cake and its subsequent effect on nutrient utilization in monogastric diets when supplemented with exogenous enzymes.

Materials and Methods

Sources of samples. Two of the samples were collected from Ghana Oil Palm Development Corporation (GOPDC) – Kwae in the Eastern Region of Ghana (E1) and Golden Web Oil Mills in Kumasi (E2) where the method of extraction is by the expeller press whilst the other two "hydrothermal" (H1 and H2) were collected from processing centres at Oforikrom and Ayigya, all suburbs of Kumasi.

Chemical analyses. Dry matter was determined by drying samples in forced air oven at 105^{o} C for 24 hours. Total nitrogen (N) was determined by combustion (AOAC, 1990) and crude protein (CP) was calculated as Nx6.25. Neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined according to Goering and van Soest (1970) and hemicellulose estimated by difference. Ether extract was determined by extracting PKC samples with petroleum ether using the Soxhlet method (AOAC, 1990). Ash was determined by combustion at 550 8C for 16 h. Mineral analyses were carried out by atomic absorption on a spectrophotometer according to standard AOAC method (AOAC, 1990). Fatty acid methyl esters were quantified by a gas chromatograph (Hewlett Packard GC System 6890; Mississauga, ON) equipped with a flame ionization detector (SP-2560 fused silica capillary column (100m with 0.2 mm film thickness; Supelco Inc., Oakville, ON). The EZ: faast amino acid analysis kit (EZ: Faast™ - Phenomenex, Torrance, CA, USA) was used to identify amino acids following the hydrolysis of PKC samples with 6N HCl overnight at 110°C. Derivatized amino acids were analyzed by gas chromatography.

Feeding trial. Five groups of weanling albino rats (balanced by weight and sex) were randomly allocated to 5 iso-nitrogenous diets; control (0 PKC, D0) and diets containing 35% (w/w) of PKC derived from E1, E2, H1 and H2 (D1, D2, D3 and D4) and their growth performance monitored for 28 days (n=6 treatment). All but the control diet were supplemented with a protease-cellulase enzyme cocktail at 500g/1000kg of diet (Allzyme Vegpro, containing protease 7500 HUT/g) and cellulose 44 CMCU/g as given by the manufacturer). The animals were individually housed in plastic containers measuring 53.34x40.64x15.24 cm and fitted with glass nipples to supply water. All the animals had unrestricted supply of feed and water**.**

Data collection and statistical analysis. Average daily intake and average daily gain were obtained from weekly feed intake and

weekly weight gain respectively and feed efficiency calculated as (F:G) at 7-d intervals as g gain/g intake. Economy of gain was computed as the cost of feed per unit gain after feed cost per kilogram had been calculated from the market price of the individual ingredients. At the end of the 28-day trial period, all the 30 rats were anesthetized by chloroform asphyxiation, each carcass was opened up and the heart, kidney, liver, lungs and spleen removed for examination for onset and/or presence of pathological conditions and weighing. The weight of each of the organs was expressed as a percentage of live body weight to ensure uniformity in comparison. Data collected were analyzed using the PROC MIXED models of SAS (1996) for process-effect and significance was declared at P≤0.05. Where significant, data was further analysed for location-effect.

Results and Discussion

Chemical analysis (Table 1) yielded results similar to those reported in literature (O'Mara et al. 1999; Alimon, 2004; Ezieshi and Olomu, 2007), reflecting the influence of the extraction process on chemical composition. The difference is clearly shown by the higher (P<0.05) crude fat with lower (P<0.05) CP, NDF and hemicellulose content observed in the expeller samples (Table 1). This is in agreement with the results obtained by O'Mara et al. (1999). The high level of fat in these products (D1 and D2) may have contributed to the lower level of CP observed in the oil-laden factory-type PKC. This is consistent with report by Ezieshi and Olomu (2007). Rhule (1996) also reported of a source-dependent variability in the chemical composition (protein, fibre and lipids).

A critical evaluation of the local/traditional hydrothermal process may liken it to the conventional solvent extraction process; in that the hot water (solvent) used in the extraction has the ability to penetrate the cell wall and also reduce viscosity of the oil causing its rapid release.

The amino acid compositions are reported in Table 2. Levels observed are within the range of figures reported by other researchers (Yeong 1983; Hutagalung et al., 1982). Lysine, methionine, cysteine and tryptophan have been described as the limiting amino acids in PKC. However, the lysine content of E1 (0.68%) was higher than those reported in literature but decreased from E2 (0.55%), H1 (0.38) to H2 (0.37%). Threonine and serine also followed a similar pattern decreasing amongst H1 and H2. Loss of cystine, lysine, arginine, threonine and serine as a result of heat treatment was reported by Papadopoulos, (1988) and this explains the decline in lysine, threonine and serine levels from E1 to H2, contrary to levels of phenylalanine, histidine, tyrosine, glycine, valine, leucine and isoleucine. This is an indication of their stability under heat reported by Papadopoulos (1988).

Table 1. Chemical composition of PKC from two different processing methods (% DM)

Sample	Expeller		Heat	
	E1	E2	H1	H2
DM	94.47^{b}	96.90^{a}	93.08^{c}	92.75^{c}
CP	15.9^{b}	13.2^{b}	19.4^{a}	19.8^{a}
EE	19.19^{a}	12.42^{b}	7.48^{c}	7.94^{c}
ADF	45.36^{a}	38.72^{b}	45.18^{a}	46.32^{a}
NDF	64.22^{c}	62.66^{d}	74.15^{b}	77.01^{a}
HEM	18.86^{c}	23.94^{b}	28.98^{a}	30.69^{a}
OM	95.78^{b}	96.24^{a}	95.445^{c}	95.69^{b}

Values bearing different superscript within rows show significant difference (P<0.05)
Eastern Region of Ghana (E1) and Golden Web Oil Mills in Kumasi (E2); the method of extraction is by the expeller press whilst the other two "hydrothermal" (H1 and H2)

Results from Table 3 shows that the major fatty acids in the PKC samples were lauric (C 12:0), oleic (C 18:1), myristic (C 14:0) and palmitic (C 16:0), with lauric acid being the most abundant, a trend observed by Iluyemi et al. (2006). Lauric acid ranged from 23.08 to 45.37, oleic acid 16.54 to 28.43%, while myristic acid was between 15.35 to 18.05% and plamitic, 8.8 to 15.37%. Fatty acid content was

Table 2. Amino acid composition of PKC from two different processing methods (%)

Amino acid	Expeller		Hydrothermal		Significance
	E1	E2	H1	H2	
ALA	0.60^{b}	0.66^{ab}	0.78^{ab}	0.88^{a}	
GLY	0.59^{b}	0.69^{ab}	0.69^{ab}	0.79^{a}	
VAL	0.70^{b}	0.81^{ab}	0.91^{ab}	1.01^{a}	
LEU	0.94^{c}	1.07^{bc}	1.23^{ab}	1.38^{a}	
ISOLEU	0.49^{b}	0.52^{ab}	0.59^{ab}	0.66^{a}	
THR	0.41	0.40	0.34	0.39	NS
SER	0.51	0.55	0.35	0.38	NS
PRO	0.56^{b}	0.62^{ab}	0.64^{ab}	0.79^{a}	
ASP	0.99	1.10	1.03	1.14	NS
METH	0.21	0.25	0.27	0.25	NS
HYP	0.060^{ab}	0.055^{b}	0.080^{a}	0.055^{ab}	
GLU	2.28	3.33	3.37	3.60	NS
PHE	0.59^{c}	0.68^{b}	0.73^{b}	0.81^{a}	
LYS	0.68^{a}	0.56^{a}	0.37^{b}	0.38^{b}	
HIS	0.28	0.30	0.28	0.31	NS
TYR	0.36	0.40	0.44	0.41	NS

Values bearing different superscript within rows show significant difference (P<0.05)
Eastern Region of Ghana (E1) and Golden Web Oil Mills in Kumasi (E2); the method of extraction is by the expeller press whilst the other two "hydrothermal" (H1 and H2); ns: means within row are not significantly (P>0.05) different

Table 3. Fatty acid composition of the PKC samples

Weight % F.A		Expeller		Hydrothermal	
		E1	E2	H1	H2
	Saturated fatty acids (SFA)				
Caproic	C6:0	0.05	0.26	0.00	0.00
Caprylic	C8:0	0.66	3.30	0.27	0.14
Capric	C10:0	0.75	3.08	1.32	0.37
Lauric	C12:0	23.08	45.37	35.98	31.21
Tridecanoic	C13:0	0.00	0.00	0.05	0.00
Myristic	C14:0	18.00	15.35	16.27	18.05
Palmitic	C16:0	15.37	8.88	12.23	12.77
Behenic	C22:0	0.21	0.00	0.10	0.12
Stearic	C18:0	6.64	4.35	5.77	5.83
Heptadecanoic	C17:0	0.07	0.00	0.08	0.00
Arachidic	C20:0	0.24	0.15	0.21	0.20
Total		65.07	80.74	72.28	68.69
	Monounsaturated fatty acids (MUFA)				
Palmitoleic	C16:1 (cis)	0.06	0.00	0.07	0.08
Elaidic	C18:1(trans-9)	0.00	0.00	0.13	0.17
Oleic	C18:1(cis-9)	28.43	16.54	22.84	26.23
cis-11-Eicosenoic	C20:1	0.10	0.09	0.16	0.16
Total		28.59	16.63	23.20	26.64
	Polyunsaturated fatty acids (PUFA)				
Linoleic	C18:2 (c,c)	5.20	2.54	3.96	4.19
gamma-Linolenic	C18:3 (gamma)	0.08	0.00	0.00	0.00
Linolenic	C18:3	0.22	0.00	0.00	0.00
Eicosapentaenoic	C20:5 (EPA)	0.38	0.00	0.17	0.26
Total		5.88	2.54	4.13	4.45

influenced by extraction process with wide variations between E samples. PUFA contents were 6.33, 2.54, 4.22 and 4.6 for E1, E2, H1 and H2 respectively. Caponio et al. (2003) stated that regardless of the heat type (microwave or conventional) both mono-unsaturated and polyunsaturated fatty acid contents undergo a marked decrease a finding they attributed to the oxidative degradation of the oil. In the extraction of E2, the kernels were also subjected to heat pre-treatment so the increased level of saturation is not unlikely. What remains unexplained however is extremely high level of saturation in E2 compared to H which extraction was entirely based on heat.

Mineral composition of the PKC is reported in Table 4. There is an indication that Ca, Mg, K and P are the most abundant minerals in the samples analysed. Significantly higher levels of Ca, P, Mg, Na, Mn, Cu, Zn and S were recorded for the hydrothermal samples. This explains their slightly lower organic matter content. Ca and P were higher than the results of Alimon (2004). However, the ratio of calcium to phosphorus was very low and diets based on PKC will thus, need to be supplemented with calcium to meet the requirements of most animals.

Chemical compositions of the diets are presented on Table 5. The addition of PKC to the diets increased the fibre level of the PKC diets to about twice that of the control diet. The cottage types PKC were generally darker and pulverized compared to those from the industry. Regardless the type, rats on PKC diets consumed less feed (P>0.05) than the control (Table 6). Average daily gain was however lower (P>0.05) for the H group compared to the E-PKC and the control maize-based diet. Efficiency of feed utilization was significantly (P>0.05) better for the Control (D0) and expeller-type PKC diets (D1 & D2) compared diets D3 and D4 which contained heat-extracted PKC. The lower (P<0.05) feed cost per unit gain was as a result of better utilization of a relatively cheap diet (Table 6).

Table 4. Mineral composition of PKC from two different processing methods

Mineral	Expeller		Hydrothermal		Significance
	E1	E2	H1	H2	
%					
Ca	0.25^{b}	0.25^{b}	0.37^{a}	0.37^{a}	
P	0.61^{b}	0.63^{b}	0.81^{a}	0.84^{a}	
Mg	0.3^{b}	0.33^{b}	0.38^{a}	0.41^{a}	
K	0.62^{a}	0.52^{b}	0.34^{d}	0.45^{c}	
S	0.19^{b}	0.21^{b}	0.27^{a}	0.29^{a}	
ppm					
Na	41^{c}	44^{c}	160^{b}	222^{a}	
Al	11^{d}	245^{a}	233^{a}	211^{c}	
Mn	172^{d}	198^{c}	252^{a}	222^{b}	
Cu	25.1^{b}	27.1^{b}	34.9^{a}	37.1^{a}	
Zn	42^{d}	47.6^{c}	71.8^{a}	67.4^{b}	
Ni	1.74^{b}	2.73^{a}	1.2^{c}	1.71^{b}	
Cr	1.95^{a}	0.66^{c}	0.89^{b}	1.7^{a}	
Bo	3.5^{d}	9.9^{a}	6.23^{b}	5.07^{c}	
Mo	0.32	0.39	0.51	0.56	NS
Pb	1.2	0.89	1.7	1.86	NS
Cd	0.09^{a}	0.07^{a}	0.1^{ab}	0.17^{b}	

Values bearing different superscript within rows show significant difference (P<0.05)
Eastern Region of Ghana (E1) and Golden Web Oil Mills in Kumasi (E2); the method of extraction is by the expeller press whilst the other two "hydrothermal" (H1 and H2); NS: means within row are not significantly (P>0.05) different

Table 5. Composition of experimental diets

Ingredients	D0	E1	E2	H1	H2
PKC$^{\psi}$	0	35	35	35	35
Maize	58	40	40	40	40
Wheat bran	23.5	8	10.5	14	13.5
Soyabean	11.5	10.5	8	4	4.5
Fishmeal	5	5	5	5	5
Vit-Min. premix$^{\phi}$	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Oyster shell	1	0.5	0.5	1	1
Dical	0.5	0.5	0.5	0.5	0.5
Total	100	100	100	100	100
Calculated analyses					
CP (%)	18.02	18.00	18.04	18.04	18.06
DE (Kcal/kg)	3195.04	3100	3100	3055.41	3056.45
CF (%)	4.15	8.42	8.46	8.42	8.55
Ca (%)	0.83	0.71	0.70	0.88	0.88
P (%)	0.80	0.73	0.72	0.79	0.81

$^{\phi}$The vitamin and mineral premix provide the following quantities per kilogram of diet: vitamin A, 5,500 IU; cholecalciferol, 1,100 IU; vitamin E, 11 IU (dl-α-tocopheryl); vitamin K3, 1.5 mg; riboflavin, 9.0 mg; niacin, 26 mg; D-calcium pantothenic acid, 12 mg; choline chloride, 220 mg; vitamin B12, 0.01 mg; folic acid, 1.5 mg; manganese, 55 mg; zinc, 50 mg; iron, 30 mg; copper, 5 mg; iodine, 1.5 mg; selenium, 0.1 mg; and antioxidant, 125 mg.

$^{\psi}$ All PKC diets were upplemented with Alzyme Vegpro® (protease 7500 HUT/g) and cellulose 44 CMCU/g as given by the manufacturer) was added at 500g/1000kg of diet.

Table 6. Effect of PKC type on growth and economy of gain (source)

	D0	D1	D2	D3	D4
ADI, g	11.82^{a}	9.23^{b}	9.47^{b}	8.54^{b}	10.42^{ab}
ADG, g	2.22^{a}	2.08^{a}	2.19^{a}	1.25^{b}	1.50^{b}
FCR	5.34^{c}	4.65^{bc}	4.32^{b}	6.98^{a}	7.07^{a}
Cost/gain, ¢*	16.84^{b}	14.25^{c}	12.84^{c}	19.38^{a}	19.5^{a}

Values bearing different superscript within rows show significant difference (P<0.05); * ¢100 is equivalent to US ¢1.07; Control (0 PKC, D0) and diets containing 35% (w/w) of PKC derived from E1, E2, H1 and H2 (D1, D2, D3 and D4) and their growth performance monitored for 28 days (n=6 treatment).

The differences between the two PKC may be ascribed to heat damage of some of the essential amino acids as reported by Sundu and Dingle (2005). Mauron (1981) also reported that excessive heat during process can lead to destruction of amino acids resulting in the formation of amino acid-carbohydrate complexes which are biologically unavailable. Accordingly, even though H-PKC had higher CP, the protein may not be in an available form, but rather in a complex with carbohydrates; limiting the availability of carbohydrates as well.

Conclusion

The fact that rats on two of the enzyme supplemented PKC diets performed equally well as those on the control diet indicated the suitability of expeller PKC as monogastric feed ingredient. PKC also reduced feed cost and increased feed cost per gain.

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