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UTILISATION OF OIL PALM BY-PRODUCTS AS RUMINANT FEED IN MALAYSIA

WONG HEE KUM* and M WAN ZAHARI*

ABSTRACT

The main by-products from the oil palm industry are palm kernel expeller (PKE), palm oil sludge (POS), palm pressed fibre (PPF), oil palm fronds (OPF) and oil palm trunks (OPT). The use of these by-products in ruminant feeding systems has been widely reported in Malaysia, and it is estimated that 2.2 million tonnes PKE, 2.2 million tonnes POS, 13 million tonnes of PPF, 35 million tonnes OPF and 9 million tonnes of OPT were available as feeds for ruminants in 2008. This article discusses the utilisation of oil palm by-products as ruminant feed in Malaysia. Studies on the characterisation and digestibility of PKE, PPF, POS, OPT and OPF and their use in practical rations for beef and dairy production have been reported. Factors which can affect nutrient utilisation include the chemical and physical structure of the feeds, feed intake, rate of passage and digestibility of the nutrients. Nutritive value data show that PKE with total digestible nutrients (TDN) of 75.8% and metabolisable energy (ME) of 11.13 MJ kg^{-1} is a high quality feed while POS (TDN 62.5%, ME 8.37 MJ kg^{-1}) is a feed of moderate quality for ruminants. OPF (ME 5.65 MJ kg^{-1}) and OPT (ME 5.95 MJ kg^{-1}) are lower quality feeds and can be sources of roughage for ruminant livestock. The highly fibrous nature of PPF is reflected by its low degradability in the rumen and its low TDN (27.8%) and low ME (4.21 MJ kg^{-1}) values. Due to its huge quantity and availability throughout the year, OPF has been widely used as a roughage source and as a component in complete rations for ruminant livestock. The optimum level of OPF inclusion in rations for ruminant feeding is 30%. Cattle fed OPF-based diets can achieve weight gains of 600-850 g per day.

Keywords: oil palm by-products, nutritive value, ruminant feed, ruminant performance.

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INTRODUCTION

Malaysia's planted area for oil palm was 4 487 957 ha in 2008, and a major by-product of the oil palm industry is the palm kernel expeller (PKE) with a total production of 2 358 732 t (Anon., 2008), of which 95.6% was exported at an export revenue of RM 990 million. PKE is obtained as a by-product from the extraction of palm kernel oil via the mechanical process. The production of PKE involves the grinding of palm kernels followed by screw pressing with or without an intermediary flaking and cooking stages. During the screw pressing stage, the raw palm kernel oil is diverted for clarification and the residual PKE is cooled and stored in a warehouse. Palm kernel cake (PKC) on the other hand, is a by-product from the extraction of palm kernel oil via solvent (hexane) extraction of the ground palm kernels. Palm kernel expeller and PKC are quite similar but have small differences in crude fat and fibre content. The other main by-products from the oil palm industry are palm oil sludge (POS), palm pressed fibre (PPF), oil palm fronds (OPF) and oil palm trunks (OPT). The use of all these by-products in ruminant feeding systems has been widely reported in Malaysia (Sato *et al.*,

* Strategic Livestock Research Centre,
Malaysian Agricultural Research and Development Institute (MARDI), Mail Bag 12301, General Post Office, 50774 Kuala Lumpur, Malaysia.
E-mail: hkwong@mardi.gov.my

2004; Wan Zahari and Alimon, 2004; Zainur Alsmi and Wan Zahari, 2005; Sharif *et al*., 2008), and it is estimated that 2.35 million tonnes PKE, 2.2 million tonnes POS, 13 million tonnes of PPF, 35 million tonnes OPF and 9 million tonnes of OPT were available as feeds for ruminants in 2008 (Sharif *et al*., 2008). The use of PKE in particular in ruminant feeding systems has been widely reported by several researchers (Hutagalung *et al*., 1986; Mustaffa-Babjee *et al*., 1986; Jalaludin *et al*., 1991, Wong and Wan Zahari, 1997, 2002; Noraida *et al*., 2009). PKE contains levels of Cu potentially toxic for sheep (Abdul Rahman *et al*., 1989; Hair-Bejo and Alimon, 1995) but poses no problems for cattle. Due to its abundance and availability, feeding freshly chopped OPF to ruminants has been widely practiced by farmers in Malaysia. The purpose of this article is to discuss the utilisation of oil palm by-products as ruminant feed in Malaysia.

CHEMICAL COMPOSITION OF OIL PALM BY-PRODUCTS

Chemical composition data (*Table 1*) on neutral detergent fibre (NDF), acid detergent fibre (ADF) and crude fibre (CF) show that oil palm by-products are highly fibrous and more suitable as feeds for ruminants than for non-ruminants. The ether extract and ash contents of POS are dependent on the extraction process and on possible soil contamination. The POS is mainly sold as fertilizer, and samples containing up to 30% ash and 19% acid insoluble ash (AIA) have been reported (Wong *et al*., 1991).

NUTRITIVE VALUE OF OIL PALM BY-PRODUCTS

Studies on the characterization of PPF, PKE, PKC and POS in nylon bag degradation and *in vivo* digestion studies in cattle have been reported by Miyashige *et al.* (1987), Wong and Wan Zahari (1992; 1997; 2002) and Wong *et al.* (1992). As the Cu levels in PKE are potentially toxic to sheep, local researchers have used molybdate and ferrous sulphate (Abdul Rahman *et al*., 1989) as well as Zn (Hair-Bejo and Alimon, 1995) supplementation to overcome the effects of Cu toxicity. However, Cu in PKE has no toxic effects in cattle as reported by several studies (Hutagalung *et al*., 1986; Mustaffa-Babjee *et al*., 1986; Wong and Wan Zahari, 1997; 2002). The shell content of PKE has been reported to vary from 5.5%-27.8% (Jalaludin *et al*., 1991), and this can reduce PKE degradation by 18-20 units.

Due to their high crude fibre content and low digestibility, feed intake of PPF, OPT and OPF is very low compared to PKE and POS (*Table 2*). Miyashige *et al.* (1987) reported that extensive chemical and physical processing does not result in much improvement in the feed value of PPF. Studies by Oshio *et al.* (1990a) show that NaOH treatment can significantly improve the feed value of OPT, enabling higher levels of utilization of OPT in rations for steers. With appropriate treatment and supplementation, OPT and OPF can be used in practical ruminant rations.

Several processing techniques have been developed to improve the feeding qualities of OPF, and these include treatments with urea and molasses, preservation as silage, alkali treatment,

TABLE 1. MEAN CHEMICAL COMPOSITION OF OIL PALM BY-PRODUCTS

Feed	Dry matter	Crude protein	Crude fibre	Neutral detergent fibre	Acid detergent fibre	Ether extract	Ash
	Dry matter basis (%)						
PKC (solvent extracted)	89.8	17.2	17.1	74.3	52.9	1.5	4.3
PKE	91.2	16.8	19.7	86.7	45.6	8.1	5.7
PPF	91.2	5.4	41.2	84.5	69.3	3.5	5.3
POS	89.0	12.5	20.1	63.0	51.8	11.7	19.5
OPT	27.3	2.8	37.6	79.8	52.4	1.1	2.8
OPF	25.5	4.7	38.5	78.7	55.6	2.1	3.2

Note: PKE – palm kernel expeller.
PPF - palm pressed fibre.
POS – palm oil sludge.
OPT – oil palm trunks.
OPF – oil palm fronds.
Source: adapted from Wong and Wan Zahari (1992).

TABLE 2. MEAN FEED INTAKE AND NUTRITIVE VALUE OF OIL PALM BY-PRODUCTS BY RUMINANTS

Feed	Feed intake ($g/W^{0.75}$)	TDN (%)	ME* (MJ kg^{-1})
PKE	84.7	75.8	11.13
PPF	30.3	27.8	4.21
POS	58.2	62.5	8.37
OPT	37.8	39.3	5.95
OPF	39.7	37.4	5.65

Note: *ME = metabolisable energy.
TDN – total digestible nutrients.
PKE – palm kernel expeller.
PPF – palm pressed fibre.
POS – palm oil sludge.
OPT – oil palm trunks.
OPF – oil palm fronds.
Source: adapted from Wong and Wan Zahari (1992).

TABLE 4. MEAN APPARENT MINERAL DIGESTIBILITY VALUES (%) OF PKC* BY CATTLE AND SHEEP

Mineral	P	K	Ca	Mg	Na	S
Cattle	64.2	85.7	38.2	48.1	94.8	62.8
Sheep	48.1	77.2	6.8	38.1	78.0	56.2

Note: *Solvent extracted.
PKC – palm kernel cake.
Source: adapted from Wong and Wan Zahari (2002); Wong and Moh Salleh (1989).

steaming under high temperature and pressure, pelletizing and enzymatic degradation (Oshio *et al.*, 1990b).

The optimum level of urea inclusion in an OPF-based diet is 30 g kg^{-1} ration while steaming can increase OPF digestibility. Oshio *et al.* (1990b) also reported that the ADF content in frond leaflets and NDF in stalks tend to increase as the palm grows older. They also reported a TDN range of 34.3% to 46.3% for the whole frond, and the value reported here (*Table* 2) is within this range.

The *in vivo* digestibility of the chemical components in PKC is shown in *Table 3*. The high digestibilities for the PKC components, ranging from 66.7%-83.6%, indicate that PKC is a high quality feed for ruminants.

The nutritive value of PKC for cattle as determined in cattle digestibility trials is 120 g kg^{-1}, 82.5 g kg^{-1}, 13.37 MJ kg^{-1} and 11.0 MJ kg^{-1} for digestible CP, CP retention, digestible energy (DE) and ME, respectively (Wong and Wan Zahari, 1997).

The apparent digestibility of K and Na (*Table 4*) from PKC is very high compared to Ca, which is less digestible. A study by Wong and Moh Salleh (1989) on sheep shows that the apparent digestibility of P, K, Ca, Mg, Na and S is lower in sheep compared to cattle, and these results suggest that Ca supplementation is required for diets high in PKC.

Increases in blood enzyme levels of gamma glutamyl transferase, alkaline phosphatase, glutamic oxalacetic transminase, creatinine and creatine kinase in cattle fed solely on PKC for 125 days were also reported (Wong and Wan Zahari, 2002), but these levels are still within the normal range for cattle.

TABLE 3. MEAN CHEMICAL COMPOSITION AND *in vivo* DIGESTIBILITY VALUES OF CHEMICAL COMPONENTS OF PKC* (% DM basis)

PKC	Composition (%)	Digestibility (%)
Dry matter	91.7	75.8
Organic matter	95.6	77.6
Crude protein	16.5	72.8
Acid detergent fibre	52.7	73.1
Neutral detergent fibre	78.9	76.0
Ether extract	5.2	83.6
Ash	4.3	66.9
Cell content	21.1	66.7
Gross energy (Mcal kg^{-1})	4.256	75.1

Note: *Solvent extracted.
PKC – palm kernel cake.
Source: adapted from Wong and Wan Zahari (1997).

TABLE 5. MEAN DEGRADATION VALUES OF OIL PALM BY-PRODUCTS IN RUMEN OF STEERS

Feed	Time of incubation (hr)			
	8	24	48	72
	Degradation of DM (%)			
PKE	27	46.7	69.3	78.6
PPF	13.8	17.6	19.8	21.8
POS	36.2	58.2	67.0	70.2
OPT	17.6	25.9	39.3	41.1
OPF	12.8	20.2	36.3	38.0

Note: PKE – palm kernel expeller.
PPF – palm pressed fibre.
POS – palm oil sludge.
OPT – oil palm trunk.
OPF – oil palm frond.
Source: adapted from Wong and Wan Zahari (1992).

TABLE 6. MEAN GROWTH PERFORMANCE VALUES OF BRAHMAN-AUSTRALIAN COMMERCIAL CROSS BEEF CATTLE FED VARYING RATIOS OF FRESH CHOPPED PALM FRONDS IN PKE-BASED RATIONS*

Variable	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
OPF	60	50	40	30	20
PKE-based mixture	40	50	60	70	80
No. of animals	24	24	24	24	24
Initial LW (kg)	289.8	279.0	284.4	279.0	278.9
Final LW (kg)	340.2	327.5	343.0	343.5	356.9
ADG (kg per day)	0.64	0.61	0.67	0.75	0.85
DMI (kg per head per day)	6.12	6.02	6.50	7.08	7.56
FCR**	9.56	9.87	9.70	9.44	8.89
Feed cost***	3.09	3.11	3.04	3.45	3.23

Note: PKE – palm kernel expeller. OPF – Oil palm frond.
*Iso-nitrogenous diet (16.4% CP): PKE-based mixture containing soyabean meal, vitamin-mineral premix and urea. All animals were fed palm fatty acid distillates (PFAD) at 3% dry matter intake.
**FCR = feed conversion ratio.
***RM kg^{-1} gain over 86 days .
Source: adapted from Mohd Sukri *et al.* (1999).

DEGRADATION OF OIL PALM BY-PRODUCTS IN THE RUMEN OF STEERS

Studies on the dry matter degradation of oil palm by-products in nylon bags incubated in the rumen of cattle show that PKE and POS have the highest degradability, OPF and OPT are moderately degradable, while PPF has the lowest degradability (*Table 5*). More than 95% of the degradable dry matter is degraded within 48 hr, suggesting that prolonged incubation up to 72 hr does not significantly increase the extent of degradation. The degradation value of 36.2% for POS indicates that a high proportion of the dry matter in POS is rapidly degraded during incubation in the rumen. The degradation rate is comparable for all the feeds as most of the degradable dry matter is degraded after 48 hr incubation in the rumen. Due to the high crude fibre content and low digestibility, feed intake of PPF, OPT and OPF is very low compared to PKE and POS. Wong *et al.* (1992) reported that the yeast *Saccharomyces cerevisiae* increases the initial rate of degradation of OPF and OPT dry matter in the rumen, but degradation is similar at 48-hr incubation for cattle fed the yeast probiotics compared to the control without the yeast. This increase in forage degradation can help enhance feed intake and production levels.

FEEDING TRIALS WITH OIL PALM BY-PRODUCTS

The use of PKE in local ruminant feeding systems has been widely reported. Trials on cattle fed PKE supplemented with mineral and vitamin additives produced growth rates of 0.7-1.0 kg per head per day (Hutagalung *et al*., 1986; Mustaffa-Babjee *et al.*, 1986; Jalaludin *et al*., 1991; Wong and Wan Zahari, 2002). Inclusion of 30% OPT silage or NaOH-treated OPT in Australian Commercial Cross (ACC) cattle rations produced average daily gain (ADG) of 0.66-0.72 kg per head per day (Oshio *et al*., 1990a). ADG of steers fed NaOH-treated OPT was equivalent to that of rice straw-fed steers, indicating that the nutritive value is comparable to that of rice straw.

Feeding freshly chopped OPF to ruminants has been widely used by farmers in Malaysia, and this is attributed mainly to technologies from the extensive R&D on OPF developed by MARDI and the subsequent transfer of technology to the target groups, including small farmers, entrepreneurs and the private sector. The inclusion of 20%, 30%, 40%, 50% and 60% of fresh chopped OPF (*Table 6*) in PKE-based diets produced ADG of 0.85, 0.75, 0.67, 0.61 and 0.64 kg, respectively, in Brahman-ACC cattle (Mohd Sukri *et al*., 1999). These researchers suggested that feeding 40% freshly chopped OPF is the most economical ration.

Inclusion of 50% OPF silage in a PKE diet producing ADG of 0.57 kg in ACC cattle was reported by Ishida *et al*. (1994), and data from the long-term feeding trials using OPF silage in finishing beef cattle are shown in *Table 7*. Feed conversion ratio (FCR) of the cattle fed 50% OPF silage was comparable to the performance of cattle fed 10% and 30% urea-OPF silage.

The potential of OPF silage (Abu Hassan *et al*., 1993) as a roughage source for dairy cows is evident because there were no adverse effects on the animals even when the level of OPF silage was increased to 50% (*Table 8*). Inclusion of 30% and 50% OPF silage in dairy cattle rations produced milk yields of

TABLE 7. EFFECT OF OIL PALM FROND LEVELS ON THE MEAN GROWTH PERFORMANCE AND CARCASS CHARACTERISTIC VALUES OF AUSTRALIAN COMMERCIAL CROSS BULLS

Parameter	Treatment			
	T1	T2	T3	T4
Liveweight (kg)				
Initial weight	229.10	226.50	232.90	229.40
Final weight	396.30	336.40	333.80	357.20
Daily gain (kg per day)	0.75	0.62	0.45	0.57
Feed intake (kg DM per day)	7.02	6.10	5.48	5.58
Feed conversion	9.36	9.84	12.18	9.79
Carcass weight (kg)	237.20	210.20	189.00	195.20
Weight of carcass components (kg)				
Meat	127.80	121.50	107.00	116.70
Fat	76.40	58.10	45.80	46.00
Bone	37.60	33.40	33.20	36.10
% in carcass				
Meat	35.60	58.20	57.20	59.20
Fat	31.60	27.60	24.20	23.70
Bone	16.00	16.10	17.70	18.40

Note: T1: 10% Urea oil palm frond (OPF) silage + 90% palm kernel expeller (PKE)-based concentrate (PKE).
T2: 30% Urea OPF silage + 70% PKE-based concentrate (PKE).
T3: 50% Urea OPF silage + 50% PKE-based concentrate (PKE).
T4: 50% OPF silage + 50% PKE-based concentrate (PKE).
Source: adapted from Ishida *et al.* (1994).

TABLE 8. EFFECT OF FEEDING OIL PALM FROND (OPF) SILAGE ON MEAN MILK PRODUCTION OF SAHIWAL-FRIESIAN LACTATING DAIRY COWS

Item	Dietary treatment		
	T1	T2	T3
No. of cows	9	9	9
Body weight (kg)	417.00	451.00	450.00
Ingredient composition of diet (DM%)			
OPF silage	30.00	50.00	-
Fodder	-	-	50.00
Concentrates*	70.00	50.00	50.00
Feed intake and milk production			
DM intake (kg per day)	6.46[b]	5.86[c]	8.28[a]
Yield of 4% FCM** (kg per day)	6.93	5.73	6.48
4% FCM: ME intake ratio (kg MJ^{-1})	0.109[a]	0.088[b]	0.096[b]

Note: Means with different superscripts differ significantly ($p<0.05$).
*Concentrates contained 24% CP and 11.3 MJ kg^{-1} of ME.
**FCM = fat corrected milk.
Source: adapted from Abu Hassan *et al*. (1993).

6.93 and 5.73 kg daily in Sahiwal-Friesian cattle. Supplementation with 30% OPF silage produced more milk than the fodder- and concentrate-fed cows. As OPF is now extensively used by farmers to feed ruminants in Malaysia, adequate measures to conserve the feed should be encouraged. Besides ensiling, OPF can be processed through drying, size reduction and production of OPF pellets and cubes. An extensive review on the utilization of OPF-based diets for beef and cattle production in Malaysia has been made by Wan Zahari *et al.* (2003).

OIL PALM FROND PELLETS AND CUBES FOR RUMINANT PRODUCTION

Research collaboration between MARDI and the Japan International Cooperation Agency (JICA) led to the development of technologies for the production of OPF pellets and cubes for various classes of ruminant livestock. The success and economics of the production of OPF-based feed depend on the efficiencies in field collection and transportation of OPF, pre-drying and drying systems, and manufacturing into pellet and cube forms. Oshio *et al.* (1990) have reported that grinding and pelletizing of OPF is effective in improving feed intake, but these processes result in a lower OPF digestibility due to the faster rate of passage through the rumen. They suggested that alternative processing methods such as cubing be used to ensure that the digestible value of OPF is maintained at the level of chopped OPF.

CONCLUSION

Extensive research by R&D agencies over the last three decades has shown that practical and cost-effective feeding systems for the local beef, mutton and dairy industries based on feeding with oil palm by-product rations are viable in the local context. This is evident from the extensive use of freshly chopped OPF and PKE-based rations by local ruminant farmers. There is no denying the importance of PKE as a good feed for ruminants in an intensive production system or as a supplement for cattle under the ruminant-oil palm integration system. As 95.6% of PKE produced is exported, the question of using more PKE locally for the growing beef and mutton industries needs to be considered if the country aspires to higher levels of self-sufficiency in these meat products.

The high fibre content in OPF can result in inadequate feed intake. Although particle size reduction can improve feed intake, the consequence is a lower OPF digestibility due to the faster rate of passage through the rumen. However, for the practical reasons of abundance and year-round availability, the use of OPF as the roughage source and PKE as the energy and protein source for ruminants is most suited to the Malaysian situation. Performance trials in cattle show that the optimum level of OPF inclusion in rations for ruminant feeding is 30%, and cattle fed OPF-based diets can achieve weight gains of 600-850 g per day.

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