OIL-PALM BY-PRODUCTS AS FEEDS FOR LIVESTOCK IN MALAYSIA

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ABSTRACT

Oil palm fronds (OPF), oil palm trunks (OPT), palm press fiber (PPF), palm kernel cake (PKC) and palm oil mill effluent (POME) are the main by-products from the oil palm industry which can be used as ingredients for livestock feeding. Many of the field residues and processing mills are high fibrous materials which need further processing for better utilization in ruminant animals. OPF has been widely utilized as feedstuff either in the form of freshly chopped, silage, or processed into pellets and cubes. Optimum inclusion level in beef and dairy animals is about 30 %. Ensiled OPT produced reasonably good live-weight gain (LWG) of about 0.7 kg/day in beef cattle when fed at levels between 30 – 40 %. PPF on the other hand, has a lower digestibility, which limits its inclusion in ruminant diets to less than 20 %. PKC is a high energy source and is a cost-effective ingredient to be utilized in ration formulations for various livestock species. High content of fiber and shell can limit its utilization in poultry and aquaculture. With biotechnological treatments, inclusion levels of PKC can be increased for poultry and aquaculture feeding. Palm fatty acid distillates (PFAD) from oil palm refineries are often used for supplementing non ruminant animals and aquaculture. The experience by the CK Agrifeed Sdn Bhd in the development of complete feeds based on these products is highlighted.

(Keywords: Oil Palm By-Products, Ruminants, Utilization, Feeding, Feed mill)

INTRODUCTION

The revenue from palm oil industry plays an important role in Malaysia's economic development. Oil palm plant has an economic life of about 25 years and bears about 10 fruit bunches, each weighing approximately 20 kg. Crude palm oil (CPO) and palm kernel oil (PKO) are the end products when the fresh fruit bunches (FFB) are processed. The by-products are obtained from residues in the plantations and from palm oil milling. The former produced two major by-products, i.e. oil palm trunks (OPT) and oil palm fronds (OPT) whereas the latter produced empty fruit bunches (EFB), palm kernel cake (PKC), palm oil mill effluent (POME), palm press fiber (PPF) and shell. The availability of various types of residues in the oil palm environment has been reviewed (Zin 2000). The yield of OPF, PKC, POME and PPF are estimated 0.62, 0.04, 0.96 and 0.23metric tones/ha/year (Devendra, 2006). Not all of the residues are suitable to be used as feedstuff for livestock.

FIELD RESIDUES

Oil Palm Fronds (OPF)

Oil palm fronds are obtained during harvesting or pruning and felling of palms for replanting. About 24 fronds are pruned per palm tree per year. About 30 million tons of OPF is produced per year on a dry matter (DM) basis during the pruning and replanting activities. About 70% of the DM in the OPF is from the petiole and the rest from leaves and rachis. The leaves contain a higher percentage of crude protein (CP) than the petioles. The chemical composition of OPF in comparison with other oil-palm by-products is shown in **Table 1.**

Several processing techniques have been used to improve the feeding values of OPF. These include urea and molasses treatments, preservation as silage, alkali treatment, steaming under high temperature and high pressure, pelletizing and enzymatic degradation. Urea and molasses treated OPF can almost meet the maintenance requirements of ruminants for energy and protein. The optimum level of urea inclusion in the OPF based diet was 30 g/kg ration and steaming was reported to increase OPF digestibility. Increasing the level of urea in the steamed OPF resulted in reduced dry matter intake (DMI) and dry matter digestibility (DMD). Microbial fermentation of OPF mixed with rice bran and rice husk through microbial fermentation of Japanese *koji* had enhanced the feeding value by improving the CP content, reducing the neutral detergent fiber (NDF) and improving the DMD of the feed, particularly with *Aspergillus awamori* (Ramli *et. al*., 2010).

Freshly chopped OPF has been extensively used by local farmers for feeding beef and dairy cattle in Malaysia. The growth performance and carcass composition of Brahman-Australian Commercial Cross (ACC) beef cattle fed iso-nitrogenous diet based on freshly chopped OPF and palm kernel cake (PKC) - based mixture is shown in **Table 2.** Feeding 40% OPF: 60% PKC based mixture (Diet 3) was the most economical as indicated by feed cost per weight gain value. Better feed conversion efficiency (FCE) and average daily gain (ADG) were obtained by diet 5 (20% OPF: 80% PKC based mixture), but it was not economical in terms of cost. Moreover, there were higher percentages of fat in the carcass. Carcass weight and dressing percentage improved with increasing levels of OPF in the diet.

Whole OPF can be chopped (about 2 - 3 cm in length) and conserved as silage for feeding livestock. Good quality silage could be produced without using any additives, provided that OPF is ensiled under anaerobic conditions. Urea addition at the rate of 1 - 2% prevented mould growth. Inclusion of more than 3% of urea reduced the nutritive value of the silage **(Table 3).** *Lactobacillus plantaram*, heterofermentative lactic acid bacteria, is the best isolate from OPF silage based on its ability to decrease pH faster and attained the lowest pH as compared to the other isolates (Hussin and Wan Mohtar, 2010). Digestibility studies conducted using mature Kedah-Kelantan (KK) bulls indicated a DMD value of about 45% for

OPF silage. It was significantly reduced when urea was included at 6 % of the total diet (Ishida and Abu Hassan, 1992)**.** Further long-term feeding trials were conducted on growing and finishing beef cattle, and lactating cows (Abu Hassan *et al.*1993, Ishida *et al*., 1994). In the former trial, the feed required for LWG and lean meat production was reduced with the higher inclusion levels of OPF silage. This is reflected in a reduction to the feed cost. The cows fed 30% OPF silage produced more milk than those fed 50% OPF silage.

The effects of varying levels of OPF pellet on intake and growth performance of local beef cattle has been reported (Oshibe *et. al.,* 2000) **(Table 4).** Over the 172 days feeding period, the LWG achieved were 0.50, 0.52, 0.30 and 0.44 kg/day respectively when the animals were fed 10, 12, 14 and 15% CP respectively. The respective mean DMD of the diets were 55.7, 68.6, 56.8 and 52.7. The LWG obtained were comparable to those raised on 30% roughage and 70% concentrate. Provision of 12% CP has improved the DMD by about 23% as compared to those fed 10% CP. Distended rumen was reported in beef heifers fed pellets made from ground OPF at 30% inclusion level (Wan Zahari *et al.,* 2002). This is associated with the rapid rate of passage of finely ground materials from the pellet which is not favorable for optimum rumen fermentation. Longer particle size (>15 mm) should be considered for making complete diets based on OPF. One option is by making OPF cube, a process which does not require grinding. Small particle size of the diet was also known to depress the population of protozoa in the rumen. The LWG of Brahman X KK male cattle fed diets containing 70% OPF: 30% cassava fodder was significantly less compared to those fed 70% OPF: 30% concentrate or 70% OPF: 15% cassava fodder: 15% grain concentrates (Tung *et al.,* 2001). The values for DMI (kg/head/day), N retention (% of N intake) and LWG (g/head/day) for the respective treatments were 4.01, 4.78 and 4.66; 15.49, 19.04 and 17.93 and 277.8, 412.7 and 373.0 respectively.

A study was conducted to evaluate ground OPF based diets (containing 30% OPF) as a complete ration for lactating Sahiwal-Friesians dairy cows (Abu Bakar *et. al.,* 2001). Milk yields of cows ranged from 11.1 to 20.3 liters/day. The highest 28-day period of milk yield recorded was 609 liters which translated into an average daily yield of 21.75 liters **(Table 5).**

Oil palm trunks (OPT)

OPT is only available after oil palms are felled for replanting at an age of about 25 years. The biomass consists mainly of vascular bundles and parenchyma tissues. The nutritive value of OPT is similar to PPF and it contains about 3% CP. The vascular bundles contain less lignin than the parenchyma tissues and in digestibility studies with sheep; the parenchyma tissue had higher DM and organic matter values. OPT can be processed into chips (about 2 – 3 cm) and preserved in the form of silage. The use of OPT silage resulted in an excellent fermentation due to low pH (3.2) and good production of lactic acid. Without any treatment, the DM digestibility of OPT is comparable to rice straw. OPT silage produced better FCE than rice straw, with good rate of growth and eating quality (Oshio *et. al.,* 1991). The parenchyma is an excellent source of roughage for beef cattle in feedlots. The biomass was readily consumed by the animals even at 50% level. The nutritive value of the material can be further enhanced by physical, chemical or biological treatment. OPT based ration can be formulated for feeding large ruminant animals and the maximum level of inclusion is suggested at 30%.

Palm Kernel Cake (PKC)

PKC is produced after the extraction of PKO from the kernels of the oil palm fruits. It also known as palm kernel meal (PKM) or palm kernel expeller (PKE). Two types of oil extraction process are employed, namely the screw press (expeller) and solvent extraction.

The oil milling industry differentiates PKC as the solvent extraction type while PKE is the screw pressed type. The PKE is subjected to heat damage during screw pressing. The solvent extracted PKC have a lower oil content ranging from 1.2% - 5.0% while the expeller pressed PKC has 4.5% - 17.3% (Tang, 2000). PKC can be classified as an energy-feed and its chemical composition is similar to copra meal, rice bran or corn gluten feed **(Table 6)**. The ME values for ruminants and poultry are 10.5 – 11.5MJ/kg and 5.9 – 7.0MJ/kg respectively (Yeong, 1985). The ME for swine is generally higher than for poultry with the values between 10.0 – 10.5 MJ/kg. Limiting amino acids are lysine, methionine and tryptophan. The protein quality of the MPOB-Q-PKC, recently introduced by the MPOB is superior than the existing PKC (Atil, 2009). PKC also contains high residual fat (about 10 %), carotene, and vitamin E (about 0.3 IU/kg), which can act as a natural antioxidant. Its low content of unsaturated fatty acids also reduces the rancidity problem. PKC is high in minerals with P and Ca contents of 0.48 – 0.71 % and 0.21 – 0.34 % respectively. The Ca:P ratio is very low (about 0.36:1) and diets based on PKC need to be supplemented with Ca to meet the requirement. Cu content in PKC (21 – 29 ppm) is higher than required by ruminants. More than 75% of PKC is cell wall component, which consist of 58% mannan, 12% cellulose and 4% xylan (Mohd Jaafar and Jarvis, 1992). **Table 7** shows the average digestibility coefficients of nutrients in PKC based on studies on sheep and cattle. The digestibility values for ADF and NDF are much higher in cattle than in sheep, suggesting that sheep is less efficient than cattle in digesting fibre.

In Malaysia, feedlot cattle are normally fed diets containing up to 80% PKC with LWG of 0.6 – 0.8kg/day and 1.0 – 1.2 kg/day for local KK cattle and crossbred cattle respectively (Wan Zahari *et. al,* 2000). It is a common practice in Malaysia to produce complete feed based on PKC, either in the form of pellet, cube or as total mixed ration (TMR) (Wan Zahari *et. al.*, 2009). Owing to its small particle size, the level of PKC in diets should not be fed at more than 85% to beef cattle to avoid occurrence of metabolic diseases like acidosis and kidney stones. Grass or hay or other long fiber sources should be mixed at least 10 to 15% in the total ration. Addition of grasses or other forages will reduce the rate of passage of PKC in the gastro-intestinal tract of the animals in order to increase retention and digestibility of nutrients (Wan Zahari *et. al.,* 2002). Moreover, when feeding PKC at high level, it is important to ensure that the ratio of Ca: P in the rations is within 1:1 to 3:1 in order to overcome skeletal deformities and mineral imbalances.

In dairy cattle rations, PKC is used as a source of energy and protein at the inclusion level of 30 – 50%. The grass to concentrate ratio are fed between 50 – 70%: 30 – 50%. Recommended inclusion level of PKC in sheep rations is 30%. Long term feeding of PKC at high inclusion level (> 80%) can cause Cu toxicity in sheep as sheep is known to be very susceptible to Cu poisoning (Hair Bejo *et. al,* 1995) Owing to its high fibre content, non-starch polysaccharides (NSP) and shell content, the use of PKC in poultry rations is very limited. Broiler chicken can tolerate up to 20% PKC in their diets without affecting the growth performance and FCE (Yeong, 1980). In layer rations, PKC can be included up to 25% without any deleterious effects on egg production and quality. The inclusion of PKC at levels > 20% was reported to reduce egg production and egg quality (Yeong *et al, 1*981). Muscovy ducks can be fed PKC at 30% level without any deleterious effects on the performance (Mustafa *et. al*., 2002). Low shell PKC with higher energy and CP contents is important to maximize utilization in poultry.

Current research are focused at enhancing the nutrient content of PKC for poultry. These include enzyme treatment and solid state fermentation (SSF) of the PKC. Enzymic depolymerization of PKC releases digestible sugars that will be fully absorbed and metabolized by poultry. Supplementation with specific enzymes can improve nutrient digestibility and worked efficiently to breakdown mannans in PKC (Mohd Jaafar *et. al.*, 1997, Noraini *et al.*, 2002, Saenphoom *et. al,* 2010). Broilers can be fed diets containing 30%

fermented PKE without any adverse effect on performance (Noraini *et. al,* 2008). The fermentation with *Aspergillus niger* was reported to increase the true metabolisable energy (TME) of PKE from 5.5 MJ/kg to 8.1 MJ/kg. *Aspergillus niger* generation until F6 can be used as inoculums for fermentation of PKC (Abdul Rahman *et. al,* 2010). Chemical treatment using sodium hydroxide and formaldehyde have also been investigated but with variable results. Further research is required to enhance the nutrient content of PKC for poultry (Wong *et. al*., 2009). PKC is also suitable for swine at the inclusion level between 20 – 25% for growers and finishers. PKC can be tolerated up to 30 % in Catfish *(Clarias gariepinus)* and 20 % in Tilapia (*Oreochromis niloticus)* rations with no deleterious effects on growth and performance (Sukkasame; 2000) The fermentation with *Trichoderma koningii,* a cellulolytic fungus, increased the CP content in PKC from 17% to 32% (Ng. *et. al.,* 2002). At 40% feeding level of PKC, rate of growth was reduced and this was not rectified with the addition of 1.2% dietary L-methionine (Ng, 2006). It is suggested that 30% is the maximum inclusion level of enzyme-treated PKC in tilapia diets.

Palm oil mill effluent (POME) / Palm oil sludge (POS).

In 1997, Malaysia produced about 32 million tons of POME from 290 mills. POME is the residue left from the purification of the crude palm oil (CPO) and includes various liquids, dirt, residual oil and suspended solids, mainly cellulosic material from the fruits. When fresh, it is thick brownish yellow colloidal slurry of water (95%) with average pH about 4.7 and BOD of 25,000 mg/l. (Ma, 2000). The material is characterized by high content of ether extract, ash and medium content of CP **(Table 1).** Wide variability in ash content and CP digestibility in POME resulting in widely different feeding values.

An assessment of feeding value using sheep indicated that up to 40 % POME can be used either alone in molasses urea-based diets or when combined in equal proportions with

PPF. Retardation in rate of growth and skeletal mineralization had been observed when POME was fed at 100% level in dairy cattle. Dehydrated POME was used to replace part of the protein and energy sources in poultry diets. LWG and FCE of birds were significantly lower when the POME level in the diet was above 15%. In a layer trial, the optimum dietary level of inclusion was 10% (Yeong, 1983). The average percent egg production, total egg mass and feed / gain ratio were 76.4%, 8.9 kg and 2.77:1 respectively as compared to 77.9%, 9.2 kg and 2.52:1 respectively for maize-soy control diet. Inferior results were apparent in those birds fed diets above 10% POME. The optimum POME levels in diets for broilers and layers were 15 and 10% respectively. The levels have also been confirmed with studies on pigs. Local and Pekin ducks could utilize 10% POME efficiently without exhibiting any adverse effect on growth and FCE.

Palm press fiber (PPF)

PPF is a fibrous by-product of crude oil extraction of the mesocarp. More than 12.2 million tons of PPF is produced annually in Malaysia, at the rate of 2.70 ton/ha/year. Being a highly lignified and fibrous, intake by the animal is low because of the poor digestibility (24-30%). Based on balance trials on sheep, optimum DMD of PPF was obtained when it was fed at 30% level of inclusion. Alkali treatments via sodium hydroxide and calcium hydroxide had no effect in enhancing the digestibility of PPF. Steaming at 15 kg/cm^2 for 10 minutes improved the organic matter digestibility (OMD) of untreated PPF from 15% to 42%. Higher OMD were achieved by explosive depressurization at 30 kg/cm^2 for 1 minute (OMD 51.6%). Other researchers found no benefit of sodium hydroxide treatment and steaming in improving the digestibility of PPF. Formulated feedlot ration containing 30% of PPF fed to LID X Red Dane male calves produced an average LWG of 117kg per animal during the 251-day feeding. The widespread use of PPF is still constrained by its low digestibility and the potential problem of rumen impaction. Farmers operating in the vicinity of oil palm mills could utilize PPF, either in the fresh form or silage in order to reduce cost of feeding. Further research on chemical and physical treatments, are necessary to improve its utilization in livestock.

Palm Fatty Acid Distillate (PFAD)

PFAD is a by-product from refining of CPO. It is a light brown solid at room temperature, melting to a brown liquid on heating. PFAD is composed of free fatty acids (81.7%), glycerides (14.4%), squalene (0.8%), vitamin E (0.5%), sterols (0.4%) and other substances (2.2%). The majority of today's market for by-pass fats consumption is the dairy cow. There are several protected fats based on PFAD or calcium soaps which are marketed worldwide under various trade names. Most of the products are in the form of hydrogenated triglyceride with energy content of about 9000 Kcal/kg and a digestibility above 90%. The products can be absorbed in the small intestine and has a very low stearic acid (C-18:0) content between 1 to 5%.

Experience in ruminant feed manufacturing

CK Agrifeed Sdn Bhd is one of the pioneers in the production of ruminant feeds in Malaysia. Oil palm by-products are often utilized as the main components in these feeds. Among others, the ingredients include PKC, OPF, POME and PFAD. New approaches have been utilized to improve the quality of the raw materials and finished products. Apart from making use of locally available ingredients to reduce cost of production, attempts have been made to produce more value-added feeds aiming at improving overall digestive system, growth performances and health status of the ruminants. One of the main issues related to consumer preferences, is the continuous demand for "high quality-low cost" feeds, which is a major challenge when agricultural-by products are used in feed manufacturing.

SUMMARY

Large quantities of waste from the palm oil field and mill are generated from the industry. Most of the resources can be used as feeds for livestock. At the plantation site, potential feedstuffs include OPF and OPT. The by-products from the milling and refining activities include PPF, PKC and POME. A significant development in the processing of these feedstuffs, either as an ingredient for TMR or as a complete and balanced feeds can encourage further growth of the local goats, sheep, beef and dairy industry. Intensive rearing of beef cattle in oil palm plantations also offers tremendous potential for beef production in view of the availability of OPF, PKC and POME to be utilized as feedstuffs. Due to some changes in the livestock production systems, i.e. towards semi-intensive and fully intensive systems, the demand for feed production is growing in Malaysia. Growth of the local livestock sector is aimed at meeting the self sufficiency level for beef and milk over the next decade and this creates further demand for feed.

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TABLE 1. MEAN CHEMICAL COMPOSITION AND NUTRITIVE VALUES OF OIL PALM FRONDS AND OTHER OIL-PALM BY-PRODUCTS (% IN DRY MATTER)

By-products	CP	CF	NDF	ADF	EE	Ash	ME (MJ/kg)
Palm kernel cake	17.2	17.1	74.3	52.9	1.5	4.3	11.13
Palm oil mill effluent	12.5	20.1	63	51.8	11.7	19.5	8.37
Palm press fibre	5.4	41.2	84.5	69.3	3.5	5.3	4.21
Oil-palm fronds	4.7	38.5	78.7	55.6	2.1	3.2	5.65
Oil-palm trunks	2.8	37.6	79.8	52.4	1.1	2.8	5.95

Notes: CP: crude protein, CF: crude fibre, NDF: neutral detergent fibre, ADF: acid detergent fibre, EE: ether extract and ME: metabolisable energy.
Source: Wong and Wan Zahari (1992); Wan Zahari *et al.* (2000)

TABLE 2. GROWTH PERFORMANCE AND CARCASS COMPOSITION OF BRAHMAN-AUSTRALIAN COMMERCIAL CROSS BEEF CATTLE FED VARYING RATIOS OF FRESH CHOPPED OIL PALM FRONDS (OPF) AND PALM KERNEL CAKE (PKC) BASED MIXTURE*

Variables	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
OPF	60%	50%	40%	30%	20%
PKC-based mixture	40%	50%	60%	70%	80%
No of animals	24	24	24	24	24
Initial LW (kg)	289.8	279	284.4	279	278.9
Final LW (kg)	340.2	327.5	343	343.5	356.9
ADG (kg/day)	0.64	0.61	0.67	0.75	0.85
DMI (kg/head/day)	6.12	6.02	6.5	7.08	7.56
FCR	9.56	9.87	9.7	9.44	8.89
Feed cost+	3.09	3.11	3.04	3.45	3.23
Carcass composition					
Dressing %	54	56.3	54.8	57.8	57.2
Meat:Bone	2.9	2.57	2.88	3.03	2.85
Meat (% carcass weight)	66.6	57	59.3	55.7	55.6
Bone (% carcass weight)	22.7	21.9	20.9	18.7	19.5
Fat (% carcass weight)	9.6	14.2	14.7	17.2	17.2

Note:
* Iso-nitrogenous diets (containing about 16.4 % CP). PKC based mixture contained soya bean meal, vitamin-mineral premix and urea. All animals were fed palm fatty acid distillates (PFAD) at 3 % of DMI for energy source.
+ RM/kg gain over 86 day's experimental period (1 US: RM 3.8).
CF % of diet 1, 2, 3, 4 and 5 were 31.5, 28.6, 25.6, 22.2 and 19.2% respectively. The respective total digestible nutrient (TDN) values were 58.2, 60.2, 62.3, 65.3 and 67.3 %.

DMI: Dry matter intake
FCR: Feed conversion ratio

Source: Mohd. Sukri *et al.*
(1999).

TABLE 3. EFFECT OF UREA LEVEL AT ENSILING ON CHEMICAL COMPOSITION, FERMENTATION CHARACTERISTICS, VOLUNTARY INTAKE AND DIGESTIBILITY OF OIL PALM FROND SILAGE

Items	Urea level (% in DM)		
	0	3	6
Chemical composition			
Dry matter (%)	30.1^{ab}	30.7^{a}	28.6^{b}
Percentage of dry matter			
Crude protein	6.7^{c}	11.4^{b}	17.2
Organic cell contents	20.8^{a}	20.0^{ab}	13.0^{c}
NDF	73.2^{b}	73.9^{b}	80.3^{a}
Fermentation characteristics			
pH value	3.78^{a}	4.89^{b}	7.81^{c}
Total acids (DM %)	3.68^{b}	4.76^{b}	8.96^{a}
Composition of acids (%)			
Lactic acid	91.0^{a}	37.4^{b}	13.0^{c}
Acetic acid	6.1^{c}	25.8^{b}	72.9^{a}
Propionic acid	0.1^{b}	3.8^{a}	0.8^{b}
Butyric acid	0.9^{c}	30.9^{a}	6.7^{b}
Ammonia (DM %)	0.0^{c}	0.6^{b}	1.1^{a}
Voluntary DM intake (g/day)	39.9^{a}	32.1^{a}	24.0^{b}
Digestibility (%)			
Dry matter	45.3	46.8	35.7
Organic cell contents	100	91.7	86.1
NDF	29.1	37.5	30.2
TDN (DM %)	45.5	49.2	37.5

DM: dry matter, NDF: neutral detergent fibre, TDN: total digestibility nutrients.

^{a,b,c} means with different superscript differ ($p<0.05$).

Source: Ishida and Abu Hassan (1992).

TABLE 4. INTAKE AND GROWTH PERFORMANCE OF BEEF CATTLE RAISED ON OPF PELLET BASED DIET

Treatment	Mean DMI (kg/day)	Dry matter digestibility (%)	Initial LW (kg)	Final LW (kg)	LWG	Mid abdomen (cm)
10 % CP	6.4	55.7	242.5	328.5	0.5	181 - 214
12 % CP	5.94	68.6	234.8	324	0.52	172 - 226
14 % CP	5.88	56.8	231.5	283.4	0.3	182 - 192
15 % CP	5.94	52.7	236.6	312.6	0.44	171 - 212

Note: DMI, dry matter intake; LWG, live weight gain; CP, crude protein

Source: Wan Zahari *et al*. (2000) and (2002)

TABLE 5. EFFECTS OF OIL PALM FRONDS (OPF) BASED PELLETS ON MILK YIELD AND MILK COMPOSITION

Rations	Milk yield (Liters/28 days)	Milk fat (%)	Milk protein (%)	Weight change (kg)
30 % OPF pellets	366	3.5	3.5	22.5
30 % OPF pellets + LG	375	3.5	3.5	16.5

Notes:
LG: Un-chopped guinea grass hay given at 100 g/cow/day as long fiber supplement. Four Sahiwal - Friesian cows per group, assigned to a treatment sequence in a 4 x 4 Latin square design involving four 28 day measurement periods following a 2-week adjustment period. Daily ration fed to each cow was limited to 14 kg/day.

Source: Abu Bakar *et al.* (2001)

TABLE 6. CHEMICAL COMPOSITION AND NUTRITIVE VALUE OF PALM KERNEL CAKE

Parameters	
Dry matter (DM as %)	88.0 – 94.5
Chemical composition (% in DM)	
Crude Protein (CP)	14.5 – 19.6
Crude Fibre (CF)	13.0 – 20.0
Ether extract (EE)	2.0 – 8.0
Ash	2.0 – 10.0
Nitrogen Free Extract (NFE)	46.7 – 75.8
Neutral Detergent Fiber (NDF)	66.8 – 78.9
Oil content (%) +	4.5 – 17.3
Shell and dirt	3.6 – 21.4
Metabolizable Energy (ME) (MJ/kg)	
Ruminants	10.5 – 11.5
Poultry	6.5 – 7.5
Swine	10.0 – 10.5

+ Adapted from Siew (1989)

TABLE 7. THE DIGESTIBILITY COEFFICIENTS OF NUTRIENTS IN PALM KERNEL CAKE

Nutrient	Sheep	Cattle
Dry matter	0.70	0.76
Crude Protein	-	0.78
Ether extract	0.91	0.84
Ash	-	0.67
Neutral detergent fiber	0.52	0.76
Acid Detergent Fiber	0.53	0.73

Source: Wong and Wan Zahari (1997)