

RECENT ADVANCES IN THE UTILIZATION OF OIL PALM BY-PRODUCTS AS ANIMAL FEED

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Abstract

The rapid expansion of oil palm plantation and production in countries such as Malaysia, Indonesia, Thailand and Nigeria results in large quantities of biomass by-products being produced. These by-products are mostly fibrous in nature although palm kernel meal can be considered a co-product that is valuable as animal feed. With the increase in feed prices and increased use of corn for ethanol production it is imperative that animal feed has to rely on feed materials not utilized by humans. This paper describes the various types of by-product that are potentially available for animal feed. While most of the fibrous by-products need to be processed before it can be fed to animals, palm kernel cake (PKC) can be directly used as a feed ingredient in ruminant feed. As a major producer of palm oil, Malaysia also produces more than 3.0 million tonnes of PKC, much of which is exported. However, its use in poultry is limited due to its high fibre content. In poultry, inclusion rates of 10-20% in the diets are common although higher rates can be achieved when PKC are fermented. Other by-products such as decanter cake, palm oil mill effluent, have been used in the feeding of beef cattle. The old fronds of oil palm removed during the harvesting of fruits have been fed to beef cattle after going through chopping or pelleting. In general, the feeding value of these by-products, with the exception of PKC, is low and to achieve a balanced ration they need to be supplemented with other feed ingredients. Improving the nutritive value of these by-products through fungal and bacterial fermentation has shown some improvements in the nutritive value but the quantum is still small when compared to the costs of the processing. Quite a number of studies have been conducted to increase the utilization of PKC in poultry diets to partially replace corn as an energy source. Solid state fermentation, enzyme treatment and probiotic supplementation have shown positive results.

Keywords: Palm oil by-products - Palm kernel cake - Palm biomass - Oil palm fronds - Nutritive value - Decanter cake.

1.0 Introduction

The oil palm industry is an important agricultural activity that contributes significantly to the GNP of Malaysia. In fact, Malaysia is the world's largest producer of palm oil with more than 5 million ha of land under oil palm. With such an area under cultivation of oil palm, the amount of biomass produced not only at the plantation level but also at the processing mills, is tremendous. It is estimated that 50-70 tonnes of biomass is produced annually from one hectare of plantation. Malaysia has about 4.5 million ha of oil palm and the calculated amount of biomass produced can reach 225 million tonnes per annum. The by-products from milling of palm fruits and extraction of include palm kernel cake, palm pressed fibre, palm oil mill effluent, empty fruit bunches, and decanter cake. In the early days, these by-products were discarded and pose a pollution problem to the environment. The proximate composition of these by-products is shown in Table 1. Among the by-products produced by the oil palm industry, palm kernel cake (PKC) is considered an important feed ingredient in ruminant feeding. Malaysia produces more than 3 million tonnes of PKC much of which are exported to Europe and many other countries.

Table 1: Mean chemical composition (percent in dry matter, except for ME) and nutritive value of oil palm frond and other oil palm co-products

| Co-products | CP | CF | NDF | ADF | EE | Ash | ME (MJ/kg) |
|-------------------------------|------|------|------|------|------|------|------------|
| Palm kernel cake (PKC) | 17.2 | 17.1 | 74.3 | 52.9 | 1.5 | 4.3 | 11.13 |
| Palm oil mill effluent (POME) | 12.5 | 20.1 | 63.0 | 51.8 | 11.7 | 19.5 | 8.37 |
| Palm press fibre (PPF) | 5.4 | 41.2 | 84.5 | 69.3 | 3.5 | 5.3 | 4.21 |
| Oil palm fronds (OPF) | 4.7 | 38.5 | 78.7 | 55.6 | 2.1 | 3.2 | 5.65 |
| Oil palm trunks (OPT) | 2.8 | 37.6 | 79.8 | 52.4 | 1.1 | 2.8 | 5.95 |
| Empty fruit bunches (EFB) | 3.7 | 48.8 | 81.8 | 61.6 | 3.2 | – | – |

Notes: CP = crude protein; CF = crude fibre; NDF = neutral-detergent fibre; ADF = acid-detergent fibre; EE = ether extract; ME = metabolizable energy. *Sources:* Wong and Wan Zahari, 1992; Wan Zahari *et al.*, 2000.

2.0 Palm Kernel Cake (PKC)

PKC is an important by-product of the oil palm industry and is obtained after the extraction of palm kernel oil (PKO) from the kernels of the oil palm fruits. PKC, is 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. In this paper, the term “PKC” is used as PKC is accepted widely in Malaysia and other countries.

Expeller PKC is more common and widely available throughout Malaysia. Solvent extracted PKC has an oil content ranging from 2 - 4% while that of expeller pressed PKC has 6 – 8 % oil. PKC is classified as an energy-feed and its chemical composition is somewhat similar to copra meal, rice bran or corn gluten feed. The ME values for ruminants and poultry are 10.5 – 11.5 MJ/kg and 5.9 – 7.0 MJ/kg, respectively (Yeong, 1985). The ME for swine is generally higher than for poultry with the values ranging between 10.0 – 10.5 MJ/kg. The CP content ranges from 14-18 % and is sufficient to meet the requirement of most classes of ruminants but considered sub-optimal for poultry. A more refined product developed by MPOB (Atil, 2009) had a higher protein content (20%) than the normal screw pressed PKC. This product is obtained after the mechanical removal of fibre, kernel skin and shell contents of the kernel prior to pressing. Expeller PKC also contains high residual fat (about 10 %), carotene and vitamin E (about 0.3 IU/kg). PKC is relatively high in minerals with P and Ca contents of 0.48 – 0.71 % and 0.21 – 0.34 % ,respectively. The Ca:P ratio is rather low and most diets based on PKC need to be supplemented with calcium to meet the requirement of animals. The contents of other minerals such as Mg, K, S, Zn, Fe, Mn, Mo and Se are within acceptable ranges. However, the concentration of Cu in PKC (21 – 29 ppm) is considered high compared to that required by most ruminants. As such there have been reports of copper toxicity in sheep fed high levels of PKC in Malaysia. More than 75% of PKC is cell wall component, which consist of 35.2% mannose, 2.6 % xylose, arabinose 1.1%, galactose 1.9%, lignin 15.1% and ash 5.0% (Cervero et al., 2010).

In Malaysia, PKC is widely used as an ingredient in rations for feedlot cattle, dairy cows and buffaloes. Feedlot beef cattle are sometimes fed diets containing up to 80% PKC with no negative effect provided that the supply of Ca and vitamins (in particular A and E) are sufficient to meet their requirements (Wan Zahari and Alimon, 2003; Alimon, 2004). The level of PKC in diets should not be more than 85% to avoid

occurrence of metabolic diseases such as acidosis. Grass or hay or other long fiber sources, such as grasses and hay, should be mixed at a level between 10 to 15% in the total ration. In addition 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. 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. Quite often, an imbalance of Ca:P ratio can cause urinary calculi in ruminants.

Small ruminants such as sheep and goats can be fed PKC based diets. However, because of the high Cu contents in PKC, care should be taken not to include PKC at high levels. The recommended inclusion level of PKC in goats and sheep rations is 30-50%. Long term feeding of PKC at high inclusion level (> 80%) can induce Cu toxicity in sheep as this species is known to be susceptible to Cu poisoning. Sheep are able to accumulate Cu in the liver, causing liver damage. Addition of 100 ppm of zinc sulphate or 5.2 mg/kg ammonium molybdate together with 440 mg/kg sodium sulphate in the rations can overcome the Cu toxicity problem (Al Kirshi et al, 2011; Alimon et al, 2011). Cu toxicity does not appear in cattle, buffaloes, goats and other animals, although copper levels are reported to be high in the liver and kidneys of animals fed PKC.

PKC in poultry rations

Owing to its high fibre content, non-starch polysaccharides (NSP) and shell content, the use of PKC in poultry rations is very limited. There exist wide variations in the optimum inclusion level of PKC in poultry rations. Main reasons are due to the origin and variations in the oil and shell content of the PKC used. Broiler chicken can tolerate up to 20% PKC in their diets without affecting the growth performance and feed efficiency (Sundu et al., 2006;). In layer rations, PKC can be included up to 25% without any deleterious effects on egg production and quality (Radim *et al*, 1999). However, inclusion of PKC at levels > 20% was reported to reduce egg production and egg quality (Yeong *et al*, 1981) but in another study, reduced egg production was only observed at levels > 40 % (Onwudike, 1988). Bello et al (2011) showed that growing cockerels fed PKC diets showed satisfactory growth even at 40% level. Muscovy ducks can be fed PKE at 30%

level without any deleterious effects on the performance (Mustafa *et. al.*, 2003). Low shell PKC with higher energy and CP contents is important to maximize utilization in poultry. However, the high inclusion levels of PKC require supplementation with high levels of fat, making the rations economically uncompetitive compared to the conventional corn-soya based diet.

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 (Eustace, et al, 2005; Saenphoom *et. Al*, 2010). Broilers can be fed diets containing 30% fermented PKE without any adverse effect on performance (Noraini et. al, 2008; Akpodiete, et al, 2006). 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. (Ramin et al, 2011; Alimon, 2004) *Aspergillus niger* generation until F6 can be used as inoculums for fermentation of PKC (Abdul Rahman et al, 2010).

Feeding Swine

Oluwafemi (2009) reviewed the use of PKC in swine rations in terms of sustainable swine production. In Nigeria, PKC has evolved to be an important ingredient in swine feeding, and inclusion levels of 20 – 25% are suitable for growers and finishers. In Malaysia, PKC is used at lower levels (between 5-10%). It has been suggested that PKC can be fed to swine at levels ranging from 15% to 40% without any negative effects on performance. In a more recent study, Adesehinwa (2007) showed that PKC can replace 50% of the maize in swine diets.

PKC for Aquaculture

The availability of PKC in many tropical countries where aquaculture is practiced has generated much interest in its potential use in fish diets. Earlier studies indicated that

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. PKC pre-treated with commercial feed enzymes resulted in better growth and FCE than those of raw PKC. The fermentation with *Trichoderma koningii*, a cellulolytic fungus, increased the CP content in PKC from 17% to 32% (Ng. *et al.*, 2002; Ng, 2004). It is suggested that 30% is the maximum inclusion level of enzyme-treated PKC in tilapia diets. More research is needed to optimize the use of feed enzymes in PKC-based diets in order to reduce costs of using imported grains as an energy source. **Table 2** shows the recommended levels of PKC in the feeds for beef cattle, dairy cattle, sheep, goats, poultry, swine and fresh water fish.

Table 2. Recommended levels of PKC in livestock feeds.

| Species | Recommended level (%) |
|-------------------|-------------------------|
| Beef Cattle | 30 – 80% |
| Dairy Cattle | 20 – 50% |
| Sheep and Goats | 20 – 50% |
| Poultry – broiler | < 10% |
| Poultry – layer | < 10% |
| Swine | <20% |
| Freshwater fish | <10% |

From Alimon (2004)

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

POME or POS is referred to the liquid colloidal discharge from palm oil extraction in the mill. This 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. Most modern mills have adopted the decanter to complement the clarifier in order to reduce the solids in the waste water before discharging into the ponds. Using the decanter-drier system, a pasty solid by-product is recovered as decanter cake. The average production of POME is 13.60 ton/ha and about 0.67 ton of POME is generated for every ton of FFB processed. In 1997, Malaysia produced about 32 million tons of POME from 290 mills. The material is characterized

by high content of ether extract (11.7%), ash (19.5%) and medium content of CP (12.5%) (**Table 1**). Wide variability in ash content and CP digestibility in POME resulting in widely different feeding values (Gurmit Singh, 1994). The content of CF, cellulose, NDF and GE are 20.1%, 20%, 63% and 8.37 MJ/kg. POME is non-toxic as no chemical is added during the oil extraction process. It is rich in minerals and therefore suitable to be used as an organic fertilizer in crop cultivation. The average concentration of Ca, P, K and Mg are 0.8, 0.3, 2.5 and 0.7%, respectively.

POME as feed for Ruminants

Studies with 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 high level in dairy cattle. In this case, the supplementation with protein, energy and mineral is necessary. The combination of POME and sago meal (40% : 45%) has successfully been used for feeding local sheep with weight gains of 59.1 – 64.0g in the males and 50.5 – 54.3g in the females. In the villages, farmers fed cattle feedlot cattle and pigs a combination POME, PPF and PKC and showed improved LWG. Satisfactory gains of between 0.18 – 0.43 kg/day and 0.47 – 0.78 kg/day for buffaloes and cattle respectively were obtained with POME, PPF and PKC based diets (Dalzell, 1977).

POME as Feed for Non-Ruminants

Most of the studies in poultry utilized dried POME in the raw or in fermented form or in mixtures with other feed materials. Dehydrated POME was used to replace part of the corn in poultry diets. LWG and FCE of birds were significantly lower when the POME was included at a level higher than 15%. Supplementation of lysine and methionine was not able to reverse the situation. Meat to bone ratios was 3.1:1 to 3.4:1 as compared to diets with 20 and 25 % POME (2.6:1 – 2.8:1). In a layer trial, Yeong (1987) showed that the optimum dietary level of inclusion was 10%. 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. It can be

concluded that the optimum POME levels in diets for broilers and layers were 15 and 10%, respectively. Similarly, native and Pekin ducks could only tolerate up to 10% POME in the diet without adverse effect on growth and FCE. Studies by Abu and Ekpenyong (1993) showed that growing rabbits can also tolerate up to 10% dried POME in their diets.

4.0 Oil Palm Decanter cake (OPDC)

Oil palm decanter cake (OPDC) is a brown-blackish paste produced by oil palm mill after the solid fraction is removed from the waste water produced after the extraction of crude oil. The OPDC is produced after passing through a process of decanting, centrifuging and then drying within the machine system. Basically, OPDM is produced by the extraction of solids from palm oil sludge (Utomo and Widjaja, 2004). OPDC consists of 12.63, 7.12, 25.79, 0.03 and 0.003%, of crude protein (CP), ether extract (EE), crude fiber, calcium and phosphorus, respectively. The fatty acids (FA) components of OPDC are usually palmitic, oleic, linoleic, stearic and myristic acids (Afdal et al, 2012). OPDC is also rich in β -carotene and is a source of natural vitamin A with 900 IU g⁻¹. It is a valuable and potential by-product that can be utilized as an alternative energy and protein source for growing goats (Anwar et al, 2012).

5.0 Empty Fruit Bunches (EFB)

Ripe fruit bunches are harvested at intervals of 10 – 14 days throughout the economic life of the palm. Each oil palm bunch usually weighs about 5kg (3 years old) – 50 kg (mature tree) containing about 25 % oil. Empty fruit bunches are the remaining materials of the fruit bunches after the fruits have been stripped and sterilized, following the steaming process at the oil palm mill. It is in the form of stalks with empty spikelets and is commonly used as mulch in the plantation. Empty fruit bunches are separated from the fruits and discarded. The proximate analysis of EFB showed that it is high in the fibre components: NDF, 81.8% and ADF, 61.6 % and lignin, 20%. Although large quantities of EFB are produced yearly, very limited research has been done for livestock feeding.

Treatments by irradiation and substrate culture have met with limited success. Fermented-EFB by inoculating *Pleurotus Sajor-caju* was found to be palatable to beef cattle (Mat Rasol *et. al*, 1993). At present, EFB is widely used as pulp for making paper, bunch ash after incineration, mulch and recycling of nutrients for oil palms, wood composite product and fiber board. Intensive R&D is required to improve its feeding value if EFB is to be utilized as a major ingredient for livestock feeding. EFB is also utilized as substrate for cellulose enzyme production by solid state bioconversion.

6.0 Palm press fiber (PPF)

PPF is a fibrous by-product of crude palm oil extraction from the mesocarp of the oil palm fruit. An estimated 12.2 million tons of PPF is produced annually in Malaysia, at the rate of 2.70 ton/ha/year. PPF has 5.4% CP, 41.2% CF and 26% lignin. Due to its high fibre content, PPF is commonly used as fuel to generate heat for boilers at the oil palm mill, pulp and paper, roof tile and fiber board. Studies on the feeding of PPF to sheep showed that the dry matter intake is low because of poor digestibility (24-30%). In sheep the optimum DMD of PPF was obtained when it was fed at 30% of the diet. Alkali treatments using sodium hydroxide had very little effect in enhancing the digestibility of PPF (Obese *et al*, 2001). Steaming at 15 kg/cm² 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/cm² 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 beef calves produced an average LWG of 117kg per animal during the 251-day feeding. Rations containing 50% PPF and 30% PKC for dairy cattle provided the cheapest source of energy when compared with other cattle pellets based on starch equivalent .

7.0 Fatty Acid Distillate (PFAD)

PFAD is a by-product from refining of CPO at very high temperature (240 – 260°C) under reduced pressure (2-6mmHg). Normally, the refinery mixes all the distillates,

irrespective of whether it is from refining of CPO, crude palm olein or crude palm stearin. The final product is generally called PFAD. 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%). It is used in the animal feed as a source of energy, and in oleo-chemical and soap industries. Vitamin E, squalene and phytosterols can be extracted from PFAD and are of potential value for the nutraceutical and cosmetic industries.

There are several protected fats or calcium soaps based on PFAD that are marketed as by-pass fat or energy. These 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%. Dairy cows fed calcium soaps made from PFAD increased milk production and the total SNF of lactating cows (Farah Nurshahida *et al.*, 2008). The digestibility of fatty acids in hydrogenated distillate was lower than for Ca salts of fatty acids, but intake and production responses were similar or greater for diets containing hydrogenated distillate.

8.0 Spent Bleaching Earth (SBE)

In the process of refining the CPO and PKO, SBE is used to remove color, phospholipids, oxidized products, metals and residual gums from the oil. It also absorbs approximately 0.5% by weight of the oil in the process. The SBE generated annually by Malaysian palm oil refineries is estimated to be approximately 120,000 tonnes. The free fatty acid content of SBE ranges from 14 to 31% with unsaturated: saturated ratio of 46.5: 53.5. The SBE also contains residual water, inorganic acids, organic acids, silicates and active carbon used in the refining process. The content of the output varies greatly, depending on the type of bleaching agents used and the method applied. Ash content is excessively high while the protein content is about 6% (Wan Zahari *et. al.*, 2004). The content of heavy metals is within normal ranges and therefore SBE is considered safe for livestock consumption. There is no published report on the utilization of SBE on ruminant livestock, even though the material is known to be used by small farmers in certain areas in Peninsular Malaysia. Supplementation of protein is required if SBE is to be use as a

main ingredient for ruminants. The high level of residual oil in SBE could be exploited for dairy feeding. Owing to its high Ca content, SBE is suitable to be combined with PKC in order to achieve a better Ca:P ratio. More studies need to be carried out to evaluate the effect of SBE on animal performance, especially on broiler and layer. Apart from blending into animal feed, SBE can also be used as binder in feed processing, especially in high fibrous based diets.

9.0 CONCLUSION

Large quantities of wastes from the plantations and palm oil mills are generated with increasing importance of oil palm as a major vegetable oil in the world. Most of the wastes and residues from the plantations are basically cellulosic and organic biomass with high nutrient content and can be used, after some processing, as animal feed. The availability of these resources will provide avenues for a more practical and a cost-effective feeding system. 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 global livestock industry. Intensive rearing of beef cattle in oil palm plantations also offers tremendous potential for beef production in integrated system. Systems of livestock production and feeding systems need to be established to ensure optimum usage of these by-products in animal production. Guidelines and nutritive values need to be established for these by-products, especially those that have undergone pre-treatments and processing to ensure precise ration formulation for specific classes of livestock. Research should also focus on processing and pre-treatments to produce value added products from these raw materials, hence ensuring a sustainable supply of high nutritive value feed ingredients.

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