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Review Article

Utilisation of Oil Palm Fronds as Ruminant Feed and Its Effect on Fatty Acid Metabolism

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ABSTRACT

Inclusion of oil palm fronds (OPF) pellets (200 g kg^{-1} DM) in a complete animal feed has been found to increase the unsaturated fatty acid content in ruminants. However, given the low-fat content of OPF (21 g kg^{-1} DM), changes in ruminal fatty acid (FA) metabolism will only result in nutritionally relevant differences in animal tissues when OPF enhances conservation of polyunsaturated fatty acid (PUFA) from external sources. Additionally, given the low metabolisable energy value (4.9 to 6.5 MJ (ME) kg^{-1} DM) of OPF, supplementation of OPF with an energy-dense feed compound such as fat is of interest. Thus, this approach could also be used in combination with other dietary fat supplementation strategies to further manipulate fatty acid concentration of ruminant tissues and products for human consumption.

Keywords: Fatty acid, feed, oil palm fronds, ruminant

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INTRODUCTION

Human nutrition is facing sustainability dilemma in ensuring adequate intake of vegetal and animal-based food (Kayouli, 2007). Research is being done to promote the efficient utilisation of non-competitive feed resources from 'marginal areas' not suitable for crop cultivation. In developing and emerging countries, feeding systems based on locally available by-products from the agro-industry represent an important feed resource for animals, as forage land is scarce (Nguyen, 1998). In Indonesia, Thailand and Malaysia, large parts of the land are used intensively for oil palm and rice cultivation. For instance, in Malaysia, 4.69 million hectares is currently under oil palm plantation, representing 60% of the total agricultural land (Ng et al., 2011). In Malaysia, 26.9 million tonnes of oil palm fronds (OPF), the major by-product of palm oil production, is utilised as animal feed, which account for 60% of the total OPF production (Ng et al., 2011). Davendra and Thomas (2002) reported that rice straw is fed to more than 90% of the ruminant livestock in Southeast and East Asia (i.e. China and Mongolia), where between 30% and 40% of the total rice straw production was used as ruminant feed.

Indeed, the use of these abundant agriculture by-products in most of the emerging and developing countries could help reduce the cost of feed.. Animal feed is the largest share of expenses incurred by farmers. Therefore, a strategy to develop the livestock industry is by increasing the use of indigenous feed resources (e.g. agriculture by-products) to reduce the cost of importing animal feed. The use of agricultural by-products as animal feed could also help reduce environmental pollution as the normal practice is to burn agriculture by-products (Dahlan et al., 2000).

AGRICULTURE BY-PRODUCTS FROM OIL PALM INDUSTRY

Oil palm (*Elaeis guineensis*) grows well in wet, humid parts of tropical Asia (mainly in Southeast Asia), Africa and Central and South America. It is characterised as a monocotyledonous plant, with long pinnate leaves, without branches and similar to the coconut palm. The OPF, consisting of leaves and petioles, are found at the top of the trees arranged as a crown. Each palm frond has 20 to over 150 pairs of leaves arranged in two rows along each side of the petiole (Figure 1). The oil palm generally has an economic lifespan of 25 years (Ismail et al., 1990).

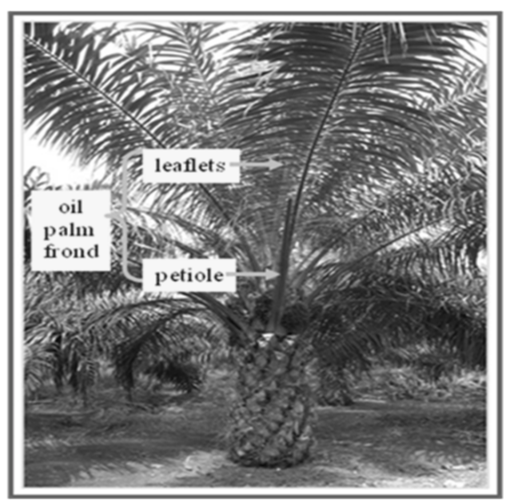

Figure 1. Schematic representation of the oil palm tree

Besides palm oil, massive amounts of oil palm by-products such as oil palm trunks (9%), OPF (30%), empty fruit bunches (22%), palm kernel cake (PKC) (5.5%), palm press fibre (13.5%) and palm oil mill effluent (POME) (9%) are generated each year world-wide with an estimated production of 1.5 to 25 million tonnes of dry matter (DM) at the mill and 10 to 50 million tonnes DM in the plantations (Figure 2). Most of these oil palm by-products are found in Malaysia and Indonesia. It is estimated that the total oil palm by-products from the palm oil industry in Malaysia in 2009 is 77.24 million tonnes DM per year (Ng et al., 2011). The PKC and POME are regularly incorporated into ruminant feed in Malaysia as cattle and goat fattening finisher.

INCLUSION OF OIL PALM FRONDS AS RUMINANT FEED

The OPF, a major by-product of oil palm plantation, are produced during the life cycle of the palm trees upon pruning and replanting (cycles of 25 years). During its productive life, the OPF are continuously pruned as a part of plantation housekeeping to facilitate harvesting of fruit branches. Pruning and felling of oil palm trees are also carried out upon termination of the plant production cycle for replantation. The fronds are typically considered waste products following the pruning practices. In Malaysia, the total production of OPF is estimated at 44.8 million tonnes DM per year (Ng et al., 2011). The abundance of OPF has resulted in major interest in its potential use as livestock feed in Malaysia. Research has shown that the OPF can be used successfully as a viable ruminant forage feed. In addition, these OPF have been extensively processed as pelleted feed for trade and export. For this, the fresh OPF is first trimmed to a length between 1 and 2 cm, sun-dried for 2 to 3 days and processed

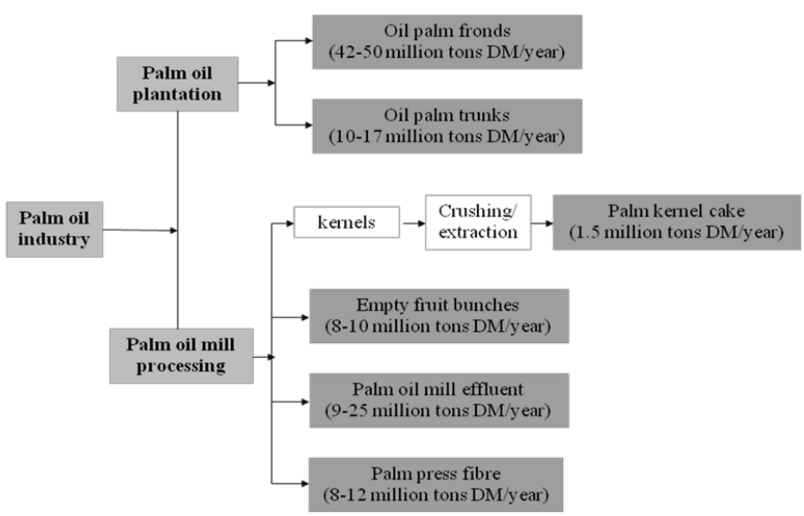

Figure 2. By-products of oil palm production originating during plantation or after processing generated yearly world-wide from palm oil industry (Elbersen et al., 2005)

into pellets or cubes of about 12 mm in size (Figure 3). The process of making OPF pellet and cubes is illustrated in Figure 4.

Figure 3. Picture of oil palm fronds pellet

Toxicity problems have not been reported for OPF (Ishida & Hassan, 1997) and the product seems readily accepted (Dahlan 2000; Rajion et al., 2001) and palatable for cattle, sheep and goat (Asada et al., 1991; Dahlan 2000). Therefore, OPF has been fed to animals as a source of roughage to replace rice straw and other low quality roughages commonly used in ruminant feeding without detrimental effects on livestock production. Besides practical reports illustrating the possibility to include OPF in ruminant diet formulation, some local and technical reports also claimed OPF has increased the unsaturated to saturated fatty acid (SFA) ratio in rumen contents, thereby opening up the possibility of its use to increase the unsaturated fatty acid (UFA) content in ruminant tissues and products.

EFFECT OF FATTY ACIDS IN RUMINANT PRODUCTS ON HUMAN HEALTH

Fatty acids form an essential and integral part of livestock products and influence their

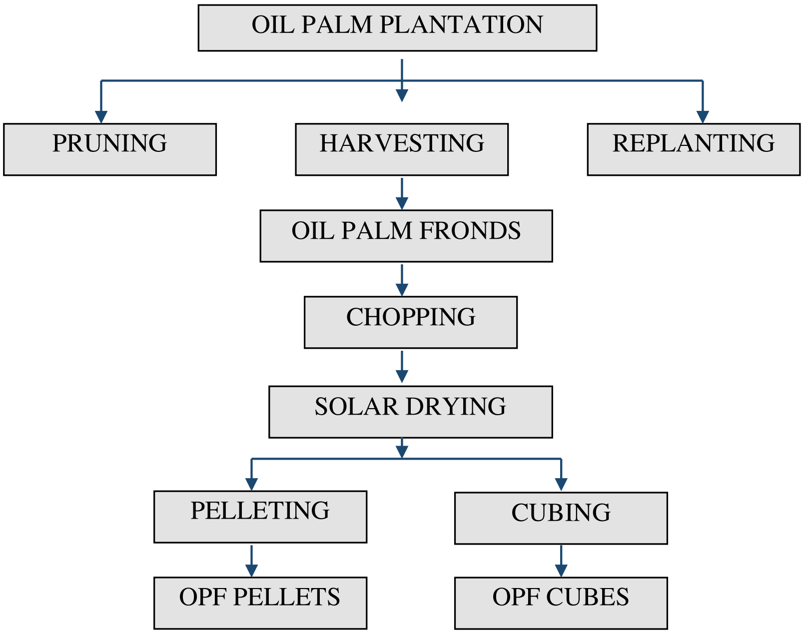

Figure 4. Schematic representation of the process of making OPF pellet and cube (adapted from Mat Daham et al., 2002)

palatability, keeping properties as well as the real and perceived nutritional values (Pariza, 2004). Nutrition and health concerns play a significant role in influencing consumers' food choices. This trend is associated with the perceived relationships between dietary type and amount of fats and fatty acids in animal tissues (Turpeinen et al., 2008). In fact, the human body had not been able to adapt to the recent shifting trends in fat consumption (Newton, 1997). Dietary guidelines published since the early 1980s have proposed reductions in total fat, particularly SFA intake. As recommended by World Health Organization (WHO) total SFA and trans fatty acids should account for between 15% and 30% of one's diet respectively. The SFA should be less than 10% and trans fatty acids less than 1% of dietary energy intake to reduce the prevalence of chronic diseases such as cardiovascular diseases, obesity and diabetes (WHO, 2003). Fatty acids considered beneficial for human health are monounsaturated and polyunsaturated fatty acids (MUFA and PUFA respectively). The most abundant PUFA in ruminant products are linoleic and linolenic acid. Positive health effects attributed to conjugated linoleic acid (CLA) have been shown in many animal studies, e.g. cancer prevention, decreased artheriosclerosis and improved immune response (Whigham et al., 2000; Belury, 2002; Pariza, 2004). In addition, consumption of specific CLA isomers in humans leads to loss of fat and total body weight, reduces plasma concentrations of total and low density lipoprotein (LDL)-cholesterol, and has an anti-inflammatory effect (Gaullier et al., 2007; Close et al., 2007; Turpeinen et al., 2008).

Ruminant products are typically high in SFA, followed by MUFA and PUFA. Red meats, particularly those from ruminant animals, contain more SFA than UFA in terms of ratio compared with meat products from monogastric animals and fishes (Watkins & German, 1998). This is inevitable as the strong reducing conditions in the rumen result in extensive bio-hydrogenation of dietary UFA, leaving only four percent of dietary FA and mostly SFA to be absorbed in the hindgut (Gurr et al., 2002; Jenkins and Thies, 1997). In fact, Dawson and Kemp, (1970) estimated that after normal pasture feeding, the linolenic acid is converted entirely to stearic acid within 10 to 15 hours. Typically, the domesticated ruminant meat has about 45 % total SFA and 55 % UFA, while those from domesticated monogastric animals have only 30% – 35 % fatty acids as SFA (Gurr et al., 2002). These are attributed to the monogastric animals' ability to incorporate dietary fatty acids unchanged (Church & Wood, 1992). Although the rumen seems to be a formidable obstacle for the passage of UFA into the hind gut, it is interesting to note that the muscles of less conventional (buffalo and deer) and wild ruminants (antelope, deer, elk) were found to contain more PUFA than those of range and feedlot animals (Wiklund et al., 2001). In fact, manipulation of the dietary fatty acid composition was shown to modify both plasma and membrane fatty acid profile in human and animal subjects

(Clamp et al., 1997). In the ruminants, modification of the membrane and plasma fatty acid profile occurs via a complex mechanism linked intimately with the rumen functions preceding the absorption and enrichment of fatty acids in both the plasma and membranes (Doreau & Ferlay, 1994). The current study emphasises lipid rumen metabolism in the manipulation of physicochemical events in the rumen for two outcomes. First, the control of the antimicrobial effects of fatty acids which indicate that additional fat can be fed to ruminants without disrupting rumen digestion and fermentation. Second, the regulation of microbial bio-hydrogenation to alter absorption of selected fatty acids that enhance and improve nutritional values of animal food products. The latter had been shown to be possible via both chemical and possible alteration of rumen bio-hydrogenation activity via protozoal activity (Rajion et al., 2001).

It has been demonstrated that it is possible to increase both the milk and tissue fatty acid unsaturation in ruminants by 10-fold if UFA are protected from bio-hydrogenation (Fotouhi & Jenkins, 1992). This is possible since ruminants have higher efficiency to absorb unsaturated fatty acids compared with non-ruminants (Bauchart, 1993). Generally, the intestinal absorption coefficients for individual fatty acids range from 80 % (for SFA) to 92 % for PUFA in conventional diets with low fat content (two to three percent DM) (Bauchart, 1993). These demonstrate that dietary regime, animal husbandry management, dietary habit and preferences have an important role in determining the dynamics of the fatty acid profile within an organism, despite the intrinsic fatty acid metabolism mechanisms in its body (Rajion et al., 2001). Further, these fatty acids form an essential and integral part of fatty acid composition of ruminant products (Pariza, 2004).

Nowadays, consumption of these ruminant products is increasing all over the world and is expected to grow further until 2030, which can lead to excessive fat intake (WHO, 2003). This has led animal scientists to develop strategies to optimise the fatty acid content of ruminant products, particularly by decreasing their SFA to improve the nutritional and health value of ruminant products.

OIL PALM FRONDS AND FATTY ACID CHANGES

Oil palm fronds are characterised by low fat (21 g kg^{-1} DM) and metabolisable energy (4.9 to 6.5 MJ (ME) kg^{-1} DM) content for ruminants, which limit their inclusion in diets of production animals (Dahlan, 2000; Zahari and Alimon, 2005). Therefore, it is important to develop to formulate diets containing OPF which allow optimum growth and productivity for ruminants (Dahlan, 2000). There has been limited scientific research concerning the inclusion of OPF in ruminant diets and only some local and technical reports are available (Dahlan, 2000), promoting relatively high OPF inclusion levels of up to 50% and 30% in beef cattle and dairy cow diets respectively (Ishida & Hassan, 1997). Other reports claimed appropriate formulation of OPF-based diets could allow live weight gain of beef cattle between 0.6-0.8 kg d^{-1} and, for local crossbred dairy cows, milk yields of about 22 litre d-1 (Zahari et al., 2003). Further, reports suggesting that their incorporation (200 g kg^{-1} DM) could enhance the UFA proportion in rumen contents and sheep plasma (Rajion et al., 2001), increased the interest in this product in the context of functional food development, e.g. meat products with greater amounts of UFA. However, the exact mechanisms of how all these phenomena occur remain to be analysed. It is probable that incorporation of oil palm fronds had altered the rumen environment, increasing the availability of UFA either via regulation of rumen bio-hydrogenation or facilitating the continuous availability of dietary UFA by restricting microbial access to these UFA's. Alteration of rumen environment might be through substances in the OPF which potentially modify rumen FA metabolism and bio-hydrogenation as suggested for some plant secondary metabolites (e.g. Benchaar et al., 2007; Lourenco et al., 2008), or due to differences in dietary macronutrient or micronutrient supply through OPF inclusion. Indeed, other research reported that rumen FA metabolism and apparent bio-hydrogenation of C18:2 n-6 and C18:3n-3 was affected in the presence of plant secondary metabolites, e.g. tannins (Vasta et al., 2009), which have been reported in OPF (Sasidharan et al., 2010).

Furthermore, given the low-fat content of OPF, changes in ruminal FA metabolism will only result in nutritionally relevant differences in animal tissues when OPF enhances conservation of PUFA from external sources. Additionally, given the low metabolisable energy value of OPF, from an animal nutrition perspective, supplementation of OPF with an energy dense feed compound such as fat is of interest. Therefore, the potential of OPF to serve as PUFA supplier is low and the origin of the latter observation requires further investigation. Indeed, Hassim et al. (2010) has shown that the inclusion of OPF in a ruminant diet did not affect fatty acid metabolism and the scope to improve fatty acid composition of ruminant products through OPF supplementation seems limited. This indicates challenges to include this agricultural by-product in ruminant diets. Hence, the utilisation and upgrading of this agricultural by-product are important and has attracted much research and development interest. This is understandable due to a rapid and dynamic increase in consumption of livestock products especially in developing and emerging countries.

CONCLUSION

It is clear that oil palm frond-based diet hold promise for ruminant nutrition, especially in countries with vibrant oil palm industries, such as Malaysia and Indonesia. With the current focus on reducing the SFA content of food stuffs for human consumption, it is believed that dietary approaches utilising oil palm fronds could be further developed to improve the availability of UFA in ruminant diets, thereby creating base technology for ruminant products (e.g. milk and meat) that have "healthier" fatty acid composition.

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