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NUTRITIONAL EVALUATION AND UTILISATION OF OIL PALM (ELAEIS GUINEENSIS) FROND AS FEED FOR RUMINANTS

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ABBREVIATIONS

The following abbreviations are used in the thesis with or without definition

AA	Amino acids
^{0}C	Degree Celsius
AD	Apparent digestibility
ADF	Acid detergent fibre
ADFI	Average daily feed intake
ADG	Average daily gain
ADIN	Acid detergent insoluble nitrogen
ADL	Acid detergent lignin
AIA	Acid insoluble ash
ANOVA	Analysis of variance
ARDOM	Apparent rumen degradable organic matter
BW	Body weight
Ca	Calcium
cc	Cubic centimetre
CEL	Cellulose
CF	Crude fibre
CHO	Carbohydrate
cm	Centimetre
Co	Cobalt
CP	Crude protein
Cu	Copper
CV	Coefficient of variation
CWC	Cell wall content
d	Day
DAFI	Digestible acid detergent fibre intake
DCP	Digestible crude protein
DCPI	Digestible crude protein intake
DDMI	Digestible dry matter intake
DE	Digestible energy

df	Degree of freedom
DM	Dry matter
DNDFI	Digestible neutral detergent fibre intake
DOMD	Digestible organic matter in dry matter
DOMI	Digestible organic matter intake
DP	Digestible protein
EE	Ether extract
EFA	Essential fatty acids
g	Gram
GLC	Gas liquid chromatography
GLM	General Linear Model
h	Hour (s)
ha	Hectare
HC	Hemicellulose
HPLC	High performance liquid chromatography
I	Iodine
i.m.	Intra-muscular
in sacco	In bag
in vitro	In glass
in vivo	In animal
IVDMD	*In vitro* dry matter digestibility
K	Potassium
Kg	Kilogram
l.s.d.	Least significant difference
LW	Live weight
m	Metre
MADF	Modified acid detergent fibre
ME	Metabolisable energy
Mg	Magnesium
N	Nitrogen
NDF	Neutral detergent fibre
NE	Net energy

NH_3	Ammonia
NH_3N	Ammonia nitrogen
NH_4	Ammonium
NIR	Near-infrared radiation
NPN	Non-protein nitrogen
OM	Organic matter
P	Phosphorus
PD	Potential digestibility
RSD	Residual standard deviation
S	Sulphur
SD	Standard deviation
SE	Standard error
SED	Standard error of the mean deviation
SEM	Standard error of the mean
TDN	Total digestible nutrients
VFA	Volatile fatty acids
$W^{0.75}$	Metabolic body weight

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NUTRITIONAL EVALUATION AND UTILISATION OF OIL PALM (*ELAEIS GUINEENSIS*) FROND AS FEED FOR RUMINANTS

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Use of plant residues as ruminant livestock feed has been suggested to reduce the feed-cost and recycle the biomass. Physical and chemical characteristics of oil palm (*Elaeis guineensis* Jacq.) frond (OPF) and utilisation of OPF by ruminant were studied in a series of experiments.

The yield of different fractions (leaflets, petiole and midribs) and segments (basal, middle and top) of OPF from different aged palms were measured. Results showed that the yield of OPF from matured (≥21 years) palm was 13.4 kg, where basal, middle and top segments constituted 53%, 27% and 20%, respectively. The estimated annual yield of petiole, leaflets and midribs were 21.70, 5.51 and 1.59 ($DM.t.ha^{-1}$) respectively. The whole OPF contained 418.6, 960.8, 65.3, 740.1, 529.5, 210.6, 218.5, 878.8 and 138.8 ($g.kg^{-1}$) of dry matter (DM), organic matter (OM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), cellulose (CEL), hemicellulose (HC), total carbohydrates (TC) and non-fibre carbohydrates (NFC), respectively. Calcium (Ca), phosphorus (P), sodium (Na), potassium (K), magnesium (Mg) contents of the OPF were 0.530, 0.108, 0.049, 0.697 and 0.18 $g.100g^{-1}DM$, respectively. Copper (Cu), zinc (Zn), manganese (Mn), iron (Fe) and sulphur (S) contents of the OPF were 2.71, 11.17, 44.66, 106.7 and 0.096 $mg.kg^{-1}DM$,

respectively. The *in sacco* DM degradation value of the OPF at 48h incubation was 37.32 g.100g^{-1}. The *in vivo* digestibility of DM, OM, CP and ADF of OPF were 52%, 56%, 43% and 26%, respectively. Results of the rumen fermentation trials showed that OPF could support an efficient rumen function when used ≤50% is included in the diet.

Results of effects of different levels of urea and /or molasses on the preservation qualities of OPF and *in sacco* digestion characteristics showed that mixing molasses reduced the pH of the preserved OPF, while mixing urea increased the pH. The lowest pH (3.98) was observed in molasses (200 g.kg^{-1}DM) mixed OPF and the highest pH (8.65) was in the urea (60 g.kg^{-1}DM) mixed OPF. Mixing of 20, 40 and 60 g.kg^{-1}DM urea with OPF increased the CP level of the preserved OPF by 25%, 38% and 96%, respectively. Mixing molasses and/or urea showed increased digestion characteristics. The pelleting of OPF increased DM, OM, CP, cell content and decreased the cell wall contents of the OPF. Ensiling and pelleting both reduced ($P>0.05$) slightly the fibrous components (CEL, HC, lignin and silica) of OPF. Moreover, pelleting and ensiling increased ($P<0.05$) the rapidly disappearing value, extent and rate of digestion of OPF.

Determination of digestible nutrient intake of fresh, ensiled and pelleted OPF and its effects on body weight gain of goats were measured. Results indicated that the pelleting of OPF increased the nutrient intake, digestibility, digestible nutrient intake and reduced refusals. The pelleting of OPF mixed with 4% urea, 15% molasses and 2% fishmeal increased the digestible DM and OM intake by 80% and 63%, respectively which resulted in an increased body weight gain of the goats.

Based on these studies, it can be concluded that OPF is a potential alternative roughage that can be used as a basal ingredient in the diet of ruminants. Fresh, chopped or ensiled OPF can be used up to 50% in the diet and mixing of either urea or molasses can increase the portion of OPF. The results of this study suggest that pelleting is the best way to conserve and handle OPF where almost no refusal can be observed. Moreover, the use of the pellets is convenient and pre-treatments can be easily incorporated during pelleting. Finally, it is suggested that mixed complete pellet can be made by correcting for the nutrients lacking (protein and minerals) in OPF and the use of the mixed pellet would maximise the utilisation of OPF.

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PENILAIAN PEMAKANAN DAN PENGGUNAAN PELEPAH KELAPA SAWIT (*ELAEIS GUINEENSIS*) UNTUK MAKANAN RUMINAN

Oleh

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Penggunaan sisa tumbuhan sebagai makanan ternakan dipercayai boleh mengurangkan kos makanan disamping pengitaran semula biomas. Beberapa siri eksperimen telah di jalankan ke atas pelepah kelapa sawit bagi mengkaji paggunaan dan ciri-ciri fizikal dan kimianya.

Bahagian pelepah yang berlainan (anak daun, petiol dan urat tengah) dan setiap segmen (bawah, tengah dan atas) pelepah yang matang (≥ 21 tahun) menunjukkan pengeluaran sebanyak 13.4 kg dengan 53% daripada bahagian bawah, 27% bahagian tengah dan 20% bahagian atas. Pengeluaran tahunan ($DM.t.ha^{-1}$) bagi petiol, anak daun dan urat tengah ialah 21.70, 5.51 dan 1.59 masing-masing. Keseluruhan OPF mengandungit 418.6 DM, 960.8 bahan organik (OM), 65.3 protin kasar (CP), 740.1 NDF, 529.5 ADF, 210.6 selulos (CEL), 218.5 hemiselulos (HC), 878.8 jumlah karbohidrat (TC) dan 138.8 ($g.kg^{-1}$) karbohidrat bukan fiber (NFC). Kandungan mineral utama, Ca, P, Na, K dan Mg (g.100g-1DM) ialah 0.530, 0.108, 0.049, 0.697 dan 0.18 masing-masing. Mineral mikro seperti Cu, Zn, Mn, Fe dan S ($mg.kg^{-1}$) ialah 2.71, 11.17, 44.66, 106.67 dan 0.096 masing-masing. Nilai cerna bahan kering (*in sacco*) OPF ($g.100g^{-1}$) pada 48 jam ialah 37.32. Pencernaan *in vivo* DM, OM, CP dan ADF masing-masing ialah 52%, 56%, 43% dan 26%.

Keputusan daripada fermentasi rumen menunjukkan OPF boleh menampung fungsi rumen bila digunakan pada ≤50% dalam diet.

Kesan penggunaan tahap urea dan/atau molases yang berbeza keatas kualiti penyimpanan OPF dan ciri-ciri pencernaan secara *in sacco* menunjukkan bahawa percampuran molases menurunkan pH, manakala percampuran urea meningkatkan pH penyimpanan. Percampuran molases memberikan pH terendah (3.98) manakala urea pH tertinggi (8.65). Percampuran 20, 40 dan 60g.kg^{-1} DM urea dengan OPF meningkatkan tahap protin kasar sebanyak 25%, 38% dan 96% masing-masing. Percampuran kedua-dua bahan meningkatkan sifat pencernaan OPF. Pembuatan pelet OPF meningkatkan DM, OM, CP, kandungan sel dan menurunkan kandungan dinding sel OPF. Pemeraman (silage) dan pembuatan pelet menurunkan ($P > 0.05$) kandungan gentian (CEL, HC, lignin dan silika) OPF. Ia juga meningkatkan ($P < 0.05$) nilai kehilangan, degradasi dan kadar pencernaan OPF dengan cepat.

Pengambilan makanan OPF yang segar, diperam dan diproses untuk dibuat pelet dikaji kesannya keatas peningkatan berat badan kambing. Keputusan menunjukkan pembuatan pelet OPF meningkatkan pengambilan makanan, pencernaan, pengambilan makanan terhadam dan mengurangkan baki makanan. Pelet OPF yang dicampur dengan 4% urea, 15% molases dan 2% fishmeal meningkatkan pencernaan bahan kering (DM) dan pengambilan bahan organik pada 80% dan 63% masing-masing. Ini memberikan peningkatan ke atas berat kambing.

Berdasarkan kajian ini, boleh disimpulkan bahawa OPF berpotensi sebagai alternatif kepada serat yang boleh digunakan sebagai diet asas ruminan. OPF ynag segar, dipotong atau diperam boleh digunakan sehingga 50% di dalam diet dan percampuran dengan urea atau molases boleh mengesankan lagi penggunaannya. Pembuatan pelet adalah cara terbaik untuk penyimpanan OPF kerana hampir tiada baki makanan diperhatikan. Selain itu, penggunaannya adalah mudah. Akhir sekali, adalah dicadangkan supaya pelet OPF yang lengkap atau campuran boleh di gunakan atau dibuat dengan menambahkan kandungan nutrien yang kurang. Ini kerana pelet campuran boleh memaksimakan penggunaannya.

CHAPTER I

GENERAL INTRODUCTION

The livestock population in Peninsular Malaysia is estimated at 675,428 cattle, 83,271 buffaloes, 197,531 goats and 216,850 sheep in the year 1998 and the forages for these livestock are derived from natural vegetation and natural pastures (Chin et al., 1998). This livestock population is small to meet the rising animal protein demand in Malaysia. Self sufficiency in animal protein especially from beef, mutton and milk by the year 2020 is difficult to achieve mainly because of the shortage of feed resources for ruminant livestock. Although much effort is geared towards improving the ruminant industry, the availability of feeds and fodders for ruminants is still a major limiting factor (Raghavan, 1992; Alimon, 1993; Raghavan, 1998).

Feed Shortage

Feed quality and quantity are the primary constraints of an efficient and sustainable production of ruminant livestock. This sector has been suffering for the inability to produce the required feed resources for ruminants. The limited areas of pasture and diminishing communal grazing areas have discouraged the entrepreneurs for investing in livestock production in the South Asian and the South East Asian countries. Japan and Korea also have shortages of fibrous feeds for ruminant production. Innovative feeding systems with low cost alternative feeds are needed to produce a sutainable ruminant productin system. Coupled with these, development strategies are urgently required that can stimulate large-scale identification of primary feedstuff for ruminants.

In most of the developing countries including Malaysia, the livestock feed industry is also based on agricultural by-products, crop and plant residues. Among these, rice straw is the staple feed for ruminants in many parts of the world particularly in Asia. The rapid increase in the use of straws has created a critical feed shortage for ruminants especially the fibrous feed. The land under natural pastures and developed improved pastures are decreasing rapidly. The reason is most likely that growing pasture does not give a good return. This has led to a critical shortage of fibrous feed for ruminants. Increased natural calamities such as floods and droughts increase the biomass losses and contribute towards the feed crisis.

The total production of by-product for feeds in Malaysia was about 783,630 tonnes in 1978, where palm kernel cake (PKC) and oil palm sludge (OPS) represent 50% of the total (Hutagalung, 1981). These days the production of by-product for feeds have been increased and was 1.77 million tonnes in 1991 (Alimon, 1993) where PKC, rice bran, broken rice and wheat bran represent the major share. These feed ingredients are used as parts of concentrate mixture in most of the diet for ruminants. Malaysia also produces 3.67 million tonnes of fibrous feed where rice straw and palm press fibre constitute 79% of the total (DVS, 1982; as cited by Jelan and Jalaludin, 1983). Alimon (1993) reported that the estimated rice straw production was 825,000 tonnes and these days it has been increased. He also reported that the bulk fibrous materials that are needed for ruminants are still scanty and it is almost impossible to sustain a ruminant industry using imported fibrous feed.

Competition for Existing Feed Resources

Researchers have always shown a great interest to utilise agricultural by-products in livestock feeding. During the last decades the interest has become more important due to the increase in the new food-feed competition (Yotopoulos, 1987) and the increased cost of feed. Animal production is a primary source of high quality food, textiles and leisure activities. Animals contribute to the well being and quality of life for humankind. The increase in population and urbanisation increase the demand for and the values of food from animal origin (meat and milk) particularly in the developing countries (FAO, 1977; Kim and Han, 1998). The increase in population and food-feed competition (FAO, 1974) affects the animal production tremendously (Gupta, 1988; Khush et al., 1998). Moreover, the feed-feed competition with poultry affects the price of agricultural crop residues, rice and wheat bran, and pulse bran which are commonly used in the poultry industry in Asian countries (Gupta, 1988). Thus, it is desirable to find new feed resources, particularly those ingredients that are not being used for human consumption, to meet this rising demand of animal protein (FAO, 1977; Kim and Han, 1998).

Feed Converted to Food

Animal production is currently facing challenges from many directions where feed shortage tops the list (NFF, 1992). At present, the producers of animal products and feeds, are in a unique position in the world. They are consumers as well as producers of agricultural and agro-industrial by-products, crops and plant residues. Sustainable crop residues and waste utilisation have become priorities to the producers during this time, when the natural resources have become increasingly scarce. Unless properly utilised, fibrous residues can pose a problem of disposal and consequently there is a need for research in the utilisation of fibrous residues which might increase their usefulness, augment the income of livestock entrepreneurs and minimise environmental pollution (Castillo, 1981). Animal researchers have to find a satisfactory way to convert fibrous materials to quality and valuable food products. Since the last decade it has become more important in Asia due to the pressure of increasing population (Gupta, 1986).

Cost of Feed

The estimated feed cost of feeding livestock amounts to 50 to more than 70% of the total production cost of livestock (Alimon, 1993), thus research efforts need to be directed to increase livestock production by minimum costs. By utilising the agro-industrial by-products and the wastes, the cost of feeding for increased livestock productivity could be reduced. As such, during the last two decades, much research on agricultural by-products (ABP) was carried out over the world. The results have shown that ABP or the fibrous crop residues (FCR) and fibrous plant residues (FPR) could play a major role in the animal feed industry in the near future. These by-products especially tree by-products can also play an important nutritional and economical role when utilised at high levels (Saadullah, 1989).

Waste Utilisation

Waste is a raw material in the wrong place (Braun, 1978). Effective waste and by-products utilisation are inevitable because of economic and ecological pressure. As an example, oil palm frond is a lignocellulosic waste of oil palm. It may be returned to the organic matter cycle in nature. This can also play an important role in the plant ecosystem. Nowadays, the utilisation of cellulolytic and lignocellulosic wastes represents an unlimited scope of regeneration (Castillo, 1981) and the possibility of use of this waste for ruminant feeding is very important from a biological point of view (Braun, 1978). Development of least cost techniques of rumen manipulation, for efficient utilisation of fibrous residues by the ruminants thus becomes the current priority. This could be achieved by supplying enough N, ATP and readily soluble CHO with minerals (Leng, 1987; Boda, 1990; Leng, 1990). Now the ruminants are considered a valuable converter of secondary products of the present ecosystem (Steg et al., 1985).

Environmental Pollution

The present global environmental pollution has become more critical. Waste recycling has been advanced as a method of preventing environmental decay and increasing food supplies. The potential benefits from a successful recycling of fibrous crop residues are enormous. It may be the only low cost method for large-scale animal protein production that does not require a concomitant increase in energy consumption. In addition, recycling of fibrous residues could be the most effective method for producing animal feed from lignocellulosic materials that has little nutritive value and are therefore, used as fuel or used in mulching. Feeding of waste for ruminants can help to diminish environmental pollution (Braun, 1978).

Livestock Production under Plantation Area

Vegetation under tree plantations has the potential to support a substantial number of ruminants with a marked impact for livestock development in the South Asian region. The shortage of grazing land has directed the producers to find alternative livestock production systems. The integration of livestock under plantation crop offers the greatest potential in Malaysia since there are more than three millions ha of land under the major commodity crop (rubber, oil palm, coconut and fruit orchard). Rubber and oil palm offer the best option for ruminant production in Malaysia by extensive grazing in the plantation (Tajuddin and Wan

Zahari, 1992). Ani Arope et al. (1985) reported that small ruminants are efficient biological weed killers in the plantation sector and could increase the efficiency of land utilisation by reducing the weed cost by 15 to 25%. Thus, ruminant livestock production with this plantation crop has become an important system in Malaysia.

Integration of ruminant livestock in the oil palm plantation has been successfully tried with cattle (Chen and Othman, 1983; Dahlan, 1989; Chen, 1992), sheep (Rajion et al., 1994a; 1994b) and buffaloes (Nordin and Abdullah Sani, 1996) but the existing herbages under plantations do not provide the required nutrients even for the maintenance requirement of sheep (Wattanachant et al., 1997). They also reported that the quality and quantity of the herbages under the older palm are generally reduced. Thus there is a need to provide supplementary feed to the animals in the plantation system and by-product feeds can be used as the supplementary feed to feed the ruminants in plantations.

Shrubs, bushes and tree fodders can play an important role as feeds in ruminant production as they have the potential to grow rapidly and the leaves contain high protein. They also have the advantage over grasses in sustaining through dry season. Thus tree leaves, shrubs and bushes have been widely considered as feeds for ruminants in many parts of the world (Hutagalung, 1981; Devendra, 1988; Saadullah, 1989; Islam et al., 1991; Islam et al., 1995). In the South East Asian countries and Africa, oil palm is a major crop. In the oil palm plantation, palm leaves can also play an important role when incorporated in the ruminant diets. Hutagalung (1981) reported that in this tropical environment abundant by-products derived from tree crops could contribute to increase food production through animal production especially ruminant production. Ruminants can exploit these by-products which are cellulose rich products through the action of ruminal microorganisms. Moreover, the ruminant has the unique ability to convert non-edible fibrous feed (such as leaf, root and stem) to human food (milk and meat). Now, the researchers and the planners all over the world are exploiting this ability of ruminants to produce more food. There is a need therefore to maximise the utilisation of inedible crops or plant residues that are increasingly made available in the crop production processes for use as ruminant livestock feeds.

Oil Palm Frond

Oil palm frond (OPF) is a fibrous plant residue, which comes from oil palm (*Elaeis guineensis* Jacq.). Presently, oil palm is the second largest agricultural crop in Malaysia next to rubber (Ch'ng, 1988). The oil palm frond (leaf of the oil palm) is a readily available by-product of oil palm plantations produced throughout the year from the pruning of senescence and felled palm during re-plantation after the terminal growing production (Dahlan, 1993a). Oil palm generally has an economic life span of 25 years. During re-plantation a large quantity of these lignocellulosic raw materials as trunk and frond are also generated (Ismail et al., 1990).

Presently, OPF is a waste product in the oil palm plantation. The total production of this felled and pruned OPF is estimated at 24.4 million metric tonnes dry matter per year (Dahlan, 1996). During the harvesting of fresh fruit bunches, this OPF is felled in between the inter rows of the oil palm plant. The only reason to fell this OPF is to use it as decomposed fertiliser. Shredding followed by burning and palm poisoning followed by chain saw felling usually remove these products from the oil palm plantation. The disposal cost involving these two methods is about RM 1200/ha (Shredding) and RM 599/ha (poisoning) for trunks (Husin et al., 1986) and to dispose the trunk from a hectare of oil palm plantation costs about RM 950 (Osman and Yusuf, 1984). Similarly, to dispose a ton of OPF costs about RM 15.00 (Akmar et al., 1996). Furthermore, the decaying of fibrous material provides an ideal breeding environment for snakes and rats. These create problems in the management of operations in the oil palm plantation.

In Malaysia, there are 42 feed mills producing compound feeds where 3.7 to 4.0 million tonnes of feed are produced per year (Raghavan, 1998). He also reported that only 30 to 40% local feed ingredients are used in the feed mills where the rest are imported. The local ingredients are used mostly agro-industrial by-products where palm oil industry contributed the most. Most of the by-products of palm oil industry (e.g. palm kernel cake, palm press fibre, palm oil mill effluent) are considered as potential livestock feeds (Alimon, 1993; Dahlan, 1996). However, the huge green biomass of OPF is still under-utilised. The major reasons for this under-utilisation include the requirement for an initial capital outlay and hence high cost of processing, failure to appreciate the potential value of the product; difficulty of supply and high cost in collection and a relatively lower nutritive value. This under-utilisation is due to a lack of appropriate guidelines for their effective utilisation (Hutagalung, 1981). A strategy that needs to be taken to exploit the oil palm feed, with other feed resources in the country in meeting production targets of the feed industry (Jalaludin et al., 1991) is to utilise effectively the available agricultural by-products and plant residues.

Taking into account the non-seasonal availability of OPF, efforts should be directed towards finding the possible better uses of the OPF. Research work have been conducted to assess the feeding value of OPF as a ruminant livestock feed (Oshio et al., 1989; 1990; Asada et al., 1991; MARDI, 1991; Dahlan, 1992a; 1992b; Ishida and Abu Hassan, 1992a; Dahlan et al., 1993a) and a feed for nonruminant herbivores such as the rabbit (Dahlan et al., 1994). The results showed that OPF contained moderate levels of crude protein (<70 $g.kg^{-1}DM$) and soluble carbohydrate. The high biomass, year round availability, moderate CP content and a high soluble carbohydrate content make OPF a potential roughage source for ruminant livestock. However, this OPF has not been used in the feed industry yet (Raghavan, 1998). This is due to the fact that the reported information on OPF is so little to suggest that OPF can be used as a feed for ruminants or in the feed industry.

The economic viability of utilising OPF as ruminant feed depends on the strategic utilisation of OPF. However, information on the characterisation, thorough nutritive evaluation, degradability values and rumen fermentation parameters in animals fed OPF have not been well documented yet. Evaluation of OPF during the post-harvest period in the plantation needs to be determined to maximise the utilisation of OPF. In addition, the problems of harvesting and handling of OPF, storage and obtaining the materials in a form that make it palatable, are constraints for the effective utilisation of OPF. Information on the storage and processing techniques are required to maximise the nutrient availability and reducing the transportation costs of a bulky feed such as OPF. Furthermore, production parameters of fractions of OPF, long-term feeding effects and optimum levels of OPF to be used are required for diet formulations of ruminants.

It is essential to establish a thorough nutritive profile of OPF to justify its potential as an alternative roughage source for ruminants. There is a need to study the basic parameters and characterisation of OPF. The information on yield, productivity, and actual availability of nutrients (per hectare of oil palm), effects of long term feeding on growth and production have to be determined. Improving the nutritive quality and increasing the keeping qualities of OPF are also priority areas. Determinations of nutrient contents and nutritive value with different preservation and processing techniques are also needed. The effects of different levels of OPF in the diets on the rumen environment are also important to assess to provide the fibre digestion pattern of OPF. It is also essential to determine the rumen pH and NH_3N

concentration to know whether the OPF can support an efficient rumen function. Hence, this project was conducted to answer these questions and have the objectives listed below.

Specific Objectives of the Study

1. To determine the biomass yield, production parameters and nutrient content of different fractions of oil palm frond in different palm age categories.

2. To determine the biomass yield and nutrient content of different fractions of oil palm frond in different segments of OPF.

3. To determine the nutrient content of the fractions of freshly harvested OPF and changes during post-harvest period.

4. To determine the *in sacco* and *in vivo* digestibility of fresh OPF and their fractions after subjecting to different forms of processing.

5. To determine the rumen fermentation parameters in animals fed different levels of OPF based diet.

6. To develop preservation techniques of fresh and dried OPF to increase nutrient content, nutrient intake and nutritive value.

7. To determine the effects of different processing techniques to improve the nutrive value, keeping quality and forms of feeding OPF.

8. To determine the nutrient intake of different types of fresh and processed OPF to ruminants.

9. To determine the effects of different types of OPF based diets on digestible nutrient intake and live weight gain of goats.

CHAPTER II

REVIEW OF LITERATURE

Introduction

The world livestock industry is now under threat due to increasing food-feed competition. It is a difficult task to face this challenge for the planners and animal scientists all over the world. This situation is particularly acute in Asia, where chronic animal feed deficits and increasing animal population are common. By-products from plant origin that produce high biomass are taken into consideration to meet the emerging demand for feed.

Oil palm is one of the plants, which produces many by-products besides palm oil. Oil palm by-products are produced more abundantly than any other crops as the cultivated areas are rapidly increasing in the South East Asian countries like Malaysia and Indonesia. Currently, Malaysia's production area of over 2.5 million ha (in 1995) is the highest in the world overtaking the dominating position previously held by Nigeria, Congo and Indonesia (Dahlan, 1996).

The rapidly increasing livestock population in Asia makes the feed shortage more acute (Kim and Han, 1998). The development of the ruminant sector in Malaysia has been arrested due to a lack of sustainable feed resources both in terms of quality and quantity (Devendra, 1977; 1986). Concentrate feeds prices are increasing. Even the price of fibrous agricultural by-products which form the staple feed (mainly rice straw, wheat straw, rice bran and wheat bran) in Asia have also increased during the last years. Not only that the listed roughages cannot meet the demand in Asia but also during the last decades the feed crisis had worsened and researchers are engaged to find alternative sources.

The OPF is produced in abundance compared to the other by-products of palm oil industry. The huge biomass yield available all the year round makes OPF a top ranked roughage and some research work have been carried out to determine the nutrient content and the utilisation of OPF in ruminants and herbivores (Dahlan, 1992a; Dahlan et al., 1993a; Dahlan et al., 1994; Ishida et al., 1994; Dahlan, 1996). This review presents the reported results of OPF as a feed for ruminant and the priority area for further research.

Production Parameters of Oil Palm Frond

The Oil Palm

The oil palm is a monocotyledonous plant without branches, somewhat similar to the coconut palm in having long pinnate leaves (Onwudike, 1996). The leaves are arranged usually at the top of the plant as a crown. This tree is monoecious bearing both male and female flowers in the same plant. Fruit bunches which contain thousands of fruits, are held in the axils of the leaves and are arranged in a rosette around the crown. The African oil palm belongs to the order, *Palmales*, family, *Palmaceae,* sub-family, *Cocoideae*. The Latin name of oil palm is *Elaeis guineensis.* This palm contains numerous products than other oil-providing palms apart from the coconut (Rehm and Espig, 1991).

Oil palm is widely believed to be a native of tropical Africa and the Congo basin. It was first carried from Africa and planted in Bogor Botanical Garden, Java, Indonesia in 1948 (Gray, 1995). This exotic species was later taken to the Singapore Botanical Garden in 1870 and spread to all over Malaysia, as well as other neighbouring countries. Now the palm oil (oil extracted from oil palm fruit) industries are the leading industry as the foreign exchange earning source in Malaysia.

Oil palm grows to a height of 9 m or more, with a stout stem, covered with semi-persistent leaf bases on which epiphytes often grow. The stem may be 30 to 38 cm in diameter, with progressive thickening towards the base. On older palms, the stem is punctuated with conspicuous and regularly arranged leaf scars and the stem terminates in a handsome growth of leaves (fronds). The crown may contain up to 40 or more fronds. The frond is paripinnate with a prominent petiole (0.9 to 1.5 m long). The petiole often broadens at the base to form a clasper round the stem. Each palm frond bears from 20 to over 150 pairs of leaflets arranged in more or less two rows along each side of the flattened rachis with the longest pinnae varying up to 120. The pinnae are parallel veined (Opeke, 1982).

There are many palms grown in the tropical countries. Sago palm is one of them. There are a few species of sago naturally grown in Malaysia. The main one is *Metroxylon* sago and the others are *Corypha, Arenya, Eugeissona* and *Caryota* (Ruddle et al., 1978). The great advantage of the oil palm, as with other tropical perennial crops, is the capacity to produce a high total biomass in a form which can easily be categorised into low and high fibre fractions (FRIM, 1991). It has also been reported that no other palm in the world is of such economic importance as the oil palm (FRIM, 1991).

Oil Palm Production Areas

Oil palm is cultivated abundantly in the South East Asian countries and Africa. The countries, which cultivate oil palm, include Indonesia, Malaysia, Nigeria, Congo, and recently

India (Rao and Mani, 1996). In Bangladesh, oil palm has also been introduced during the recent years. In Malaysia, emphasis has been placed in oil palm production since late 1960s. The oil palm industry is the major revenue earning industry in Malaysia and oil palm is the second biggest crop next to rubber (Ch'ng, 1988).

There is numerous information on the oil palm production areas in Malaysia. Nordin and Abdullah Sani (1996) and Weng (1996) reported that the oil palm plantations cover about 2.6 million ha. The total plantation rose to 2.51 million ha from 2.41 in 1994 and 2.3 million in 1993 and the industry continued to grow. During the recent years the plantation areas have increased and this could be 2.9 million ha by the year 2000 (Dahlan, 1996; Weng, 1996).

Oil Palm Frond

Oil palm frond is the leaf like part of the oil palm (*Elaeis guineensis* Jacq.) which is produced continuously by pruning and senescence of the palm. The OPF grows in tightly clustered bunches or heads. This is a readily available by-product of oil palm plantations, that are cut down during harvesting of fresh fruit bunches, senescence and felled palm during re-plantation (Dahlan, 1992b). OPF is available in oil palm plantations throughout the year.

Harvesting Method of Oil Palm Frond

To get the fresh fruit bunches from the oil palm usually 2 to 3 OPF are cut as the fresh fruit bunches (FFB) are compactly packed and hidden in the leaf axils. In order to cut off the fruit bunches and OPF on old, tall palms, curved knives fastened to bamboo poles are used. Simple instruments are used to cut this namely, cutlasses, axes, chisels and the Malaysian knife (Adetan and Adekoya, 1995).