ENHANCING THE UTILIZATION OF OIL PALM (ELAEIS GUINEENSIS) FROND BY STEAM TREATMENT AND NITROGEN SUPPLEMENTATION IN RUMINANTS

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By

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The overall objective of this study was to investigate the possibility of improving the feeding value of oil palm frond (OPF) by steaming-process. Animal performance is a function of intake of digestible nutrients and the efficiency of their utilization. From a review of literature, the potential intake of fibrous crop residues can only be realized if microbial activities were not limited, allowing the slowly fermented structural carbohydrates, to be degraded in the rumen. It is apparent that the efficiency of N utilization in poor quality roughages with low N is closely related to the amount of available substrates from the basal diet and from the supplement being used to correct its nutrient deficiencies.

In a series of experiments the above factors were considered. It was assumed that steam treatment would make more energy available from OPF and that strategic supplementation could be used to further improve steam-treated OPF utilization by ruminants.

The first experiment was designed to establish optimum steaming conditions for OPF. The effects of steam pressure and moisture content of OPF on fibre fractions and in situ degradability were investigated. Three treatment groups of samples were obtained from newly harvested fronds, namely, untreated (UT), steam treated as fresh (FT) and

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predried to 25-30% moisture (DT) before steam treatments at pressures: 10 kg cm\(^{-1}\) for 20 min, 12.5 kg cm\(^{-2}\) for 7 min, and 15 kg cm\(^{-2}\) for 4 min. Steam treatment increased water solubility \((P < 0.001)\) of OPF, resulting in a decrease in the neutral detergent fibre (NDF) fractions, particularly the hemicellulose and an increase in acid detergent lignin (ADL) content. The increments in potential degradability (PD) compared to UT were: 31.7 – 55.3% (FT), 31.7 – 59.1% (DT). It was concluded that in considering the energy economy, the optimal treatment conditions of OPF were a steaming pressure of 10 kg cm\(^{-2}\) for 20 min and the material should be pre-dried to 25-30% moisture content.

Experiment 2 was designed to investigate the optimum level of fermentable N supplementation of steam-treated OPF (SOPF). Eight lambs weighing 10 to 20 kg were used in a replicated 4 x 4 Latin square design. The SOPF was mixed with molasses, Dicalcium phosphate and supplemented with graded levels of urea, namely, 0 (U0), 8 (U8), 16 (U16) or 24 g / kg OPF (U24). When the lambs were fed the above dietary treatments, all the parameters for intake and digestibility (DM, OM, NDF, and N) increased linearly \((P = 0.001)\) up to the level of U16. No further benefit was obtained in adding more urea. It was concluded that U16 would be optimal for SOPF supplementation.

In Experiment 3, cassava foliage (CF), cassava leaves (CL) and soybean meal (SM) were incubated in the rumens of cattle receiving SOPF or untreated OPF pellets (OPFP) in order to choose the supplement which would be more suitable for SOPF. The results showed that increasing the rate of outflow of particulate matter resulted in a greater disappearance of N from CF than from CL and SM. Because of its relative faster rate of degradation, CF in addition of providing NH\(_3\) in the rumen, may contribute easily fermentable cellulose and hemicellulose to SOPF-based diets.
In Experiment 4 the effect of supplementation of SOPF at the optimum rate of urea inclusion together with graded levels of CF on N balance in lambs was investigated. Pelleted cassava foliage was fed in amounts equivalent to 0% (CO), 20% (C20) or 40% (C40) of DM intake of SOPF to 9 lambs weighing 15 to 20 kg in randomized block design. The animals responded positively to CF supplementation in terms of total intake and digestibility, except for NDF digestibility, which was identical across dietary treatments. No further improvement in efficiency of N utilization occurred beyond the first increment of CF supplementation.

It was concluded that steam-treated OPF supplemented with adequate amount of urea (i.e. 16 g / kg) and small quantities of pelleted CF (e.g. 200 g / kg DM) would significantly increase total DM intake without any depressive effect on intake of OPF. Steam treatment improved the nutritive value of OPF and could serve as an alternative to enhance utilization of OPF.
Meningkatkan penggunaan pelepah kelapa sawit (Elaeis guineensis) melalui rawatan stim dan suplementasi nitrogen dalam ruminan

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Objektif keseluruhan kajian ini ialah untuk menyiasat kemungkinan memperbaiki nilai pemberian makanan pelepah kelapa sawit (OPF) melalui proses rawatan stim. Prestasi haiwan ialah fungsi pengambilan nutrien terhadap dan kecekapan penggunaannya. Daripada sorotan bahan bertulis, potensi mengambilan sisa tanaman berserat hanya boleh dicapai jika aktiviti mikrobial tidak terhad, membenarkan struktur karbohidrat difermentasi secara perlahan, untuk diuraikan didalam rumen. Adalah jelas bahawa efisiensi penggunaan N dalam bahan berkualiti rendah adalah berkait rapat kepada amalan substrat yang tersedia daripada rangsum asas dan daripada suplementasi yang digunakan untuk membetulkan kekurangan nutrien.

Dalam satu siri eksperimen dengan mengambilkan faktor-faktor diatas. Adalah dianggapkan bahawa rawatan stim boleh menjadikan ketersediaan tenaga daripada OPF dan pemberian makanan tambahan yang strategik boleh digunakan untuk memperbaiki lagi penggunaan OPF rawatan stim oleh ruminan.

Eksperimen pertama direkabentuk untuk memgujudkann keadaan pengewapan yang optima bagi OPF. Kesan tekanan wap dan kandungan kelembapan OPF ke atas fraksi serat dan penguraian in situ telah diselidiki. Tiga kumpulan sampel rawatan telah diperolehi daripada pelepah yang baru dipotong, iaitu tanpa rawatan (UT), rawatan
stirn dalam bentuk segar (FT) dan dilayukan kepada kandungan kelembapan 24 –30% (DT) sebelum rawatan stirn pada tekanan 10 kg cm\(^{-2}\) selama 20 minit, 12.5 kg cm\(^{-2}\) selama 7 minit, dan 15 kg cm\(^{-2}\) selama 4 minit. Rawatan stirn telah meningkatkan kelarutan air OPF (p<0.001), menghasilkan penurunan dalam fraksi serat detergen neutral (NDF), khususnya hemiseluloso dan peningkatan dalam kandungan lignin detergen asid (ADL). Peningkatan potensi penguraian (PD) berbanding dengan UT adalah: 31.7 – 55.3% (FT), 31.7 0 59.1% (DT). Adalah disimpulkan bahawa dalam mengambilkira ekonomi tenaga, keadaan rawatan yang optima adalah tekanan stirn pada 10 kg cm\(^{-2}\) selama 20 minit dan perlu dilayukan kepada kandungan kelembapan 25 – 30%.

Eksperimen 2 direkabentuk untuk menyetelik paras yang optima bagi supplementasi N boleh fermentasi OPF yang dirawat stirn (SOPF). Lapan ekor bebiri dengan berat 10 ke 20 kg telah digunakan dalam 4 replikasi dengan rekabentuk segi empat latin 4 X 4. SOPF telah dicampurkan dengan molasses, Dikalsium fosfat dan disuplemen dengan paras gred urea iaitu 0(U0), 8(U8), 16(U16) atau 24 g/ kg OPF (U24). Apabila bebiri diberi makan rawatan rangsum diatas, semua ukuran untuk pemgambilan makanan dan penghazaman (DM, OM, NDF dan N) telah meningkat secara linear (p = 0.001) sehingga ke paras U16. Tiada kebaikan tambahan diperolehi dengan menambah lebih urea. Adalah disimpulkan bahawa U16 adalah paling optima bagi suplementasi SOPF.

Dalam Eksperimen 3, fodder ubikayu (CF), daun ubikayu (CL) dan mil kacang soya (SM) telah dieramkan dalam rumen lembu yang diberi makan SOPF atau OPF yang dipeletkan tanpa rawatan (OPFP) dalam usaha untuk memilih bahan suplemen yang lebih sesuai bagi SOPF. Keputusan menunjukkan peningkatan kadar pengaliran keluar bahan dihasilkan dalam kehilangan besar N daripada CF lebih daripada CL.
dan SM. Disebabkan kadar penguranan relatif yang lebih cepat, penambahan CF menyediakan NH$_3$ didalam rumen, mungkin menyumbang kepada fermentasi mudah selulos dan hemiselulos dalam rangsum berasas SOPF.

Dalam Eksperimen 4, kesan suplementasi SOPF pada kadar urea yang optima bersama dengan paras tertentu CF keatas keseimbangan N dalam bebiri telah diselidiki. Pellet fodder ubikayu telah diberi makan dalam amaun bersamaan 0\% (C0), 20\% (C20) atau 40\% (C40) pengambilan bahan kering SOPF kepada 9 ekor bebiri dengan berat badan 15 hingga 20 kg dalam rekabentuk blok rawak. Haiwan tersebut telah bergerakbalas secara positif kepada supplementasi CF dalam pengambilan keseluruhan dan penghadaman, kecuali untuk penghadaman NDF, dimana ia adalah sama bagi semua rawatan. Tiada perbaikan seterusnya dalam kecekapan penggunaan N berlaku diluar peningkatan pertama supplementasi CF.

Adalah disimpulkan bahawa pelepah kelapa sawit yang dirawat stim dan ditambah dengan amaun urea yang mencukupi (i.e. 16g/ kg) dan sejumlah kecil pelet CF (e.g. 200g/ kg DM) semasa pemberian makanan asas, boleh meningkatkan pengambilan bahan kering tanpa kesan buruk terhadap pengambilan OPF. Rawatan stim telah memperbaiki nilai pemakanan OPF dan ia adalah pendekatan yang dicadangkan untuk penggunaan OPF secara efesien.
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I certify that an Examination Committee met on 14th June 2002 to conduct the final examination of Konomba Bengaly on his Doctor of Philosophy thesis entitled. “Enhancing the Utilization of Oil Palm (Elaeis guineensis) Frond by Steam Treatment and Nitrogen Supplementation in Ruminants” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations, which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

KONIMBA BENGALY

Date: 24/7/2002
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CHAPTER 1

INTRODUCTION

The population of ruminant livestock may increase, in tandem with a growing human population, and an increased demand for animal products in Malaysia (Chin et al., 1998). Consequently, an increased demand for animal feeds coupled with a high number of animals per unit area of available land will result in a shortage of forages. Current trends toward a developing manufacturing and industrial sector with its drawback to decreased available land for grazing or fodder production, may increase the attractiveness of alternative feed resources for ruminants. Meanwhile, Malaysia leads the world in palm oil production and 24.4 million metric tons (dry matter basis) of oil palm frond (OPF) (the petiole plus the leaflet) (see Plate 1) are harvested annually from its 2.5 million ha of oil palm plantation (Islam, 1999). The oil palm tree like other perennial crops, offers the advantage of yielding an important biomass, which is available throughout the year. The current post-harvest management of OPF, consisting of piling the biomass in the inter-rows for soil conservation (Plate 2), also provides a potential breeding ground for snakes and other pests, which may be a management constraint in the plantation. As the demand for direct human use of palm oil increases, in addition to an increasing utilization of imported feed ingredients (corn, soybean and fish meal) in the poultry and swine sectors (Abu Hassan et al., 1996), OPF and other perennial crops (e.g. cassava, sugar cane, sweet potatoes, multi-purpose trees) will be used increasingly in the ruminant livestock production enterprise. Moreover, perennial crops are more environmentally friendly or
sustainable because of the protection they provide against soil erosion associated with less pesticides and fertilizer required for their production (Jung and Allen, 1995; Preston, 1996). But the lack of sufficient available nutrients from OPF limits its utilization by rumen microbes and consequently by the host animal.

The extent of microbial degradation of specialized plant material varies generally with the stage of maturity of the plant. As plant cells mature, their cell walls thicken and the concentration of hemicellulose and lignin increases, reducing degradability.

To improve the nutritive value of agricultural fibrous residues for livestock feeding, some form of processing is generally required. The purpose of processing is to increase degradability of high-fibre feeds to the microbes, thus increasing daily feed intake, and to enhance rate or extent of digestion, thus increasing nutrient availability (Nicholson, 1981; Fahey et al., 1993). For most processing techniques, the cost often exceeds the value of the improvement in terms of animal productivity (Satter, 1983), however, and the difference may be larger due to the extra protein or energy supplementation required to achieve a completely balanced diet (Fahey et al., 1993). Nevertheless, because of the steady availability of OPF in Malaysia, extensive processing to maximize microbial digestion and utilization by the animal may be easy to justify. Furthermore, the use of locally available protein or energy sources to supplement processed OPF may be more attractive than reliance on imported feed ingredients for ruminant animals.
Plate 1: View of oil palm frond on a tree (Adapted from Islam, 1999)
Plate 2: Post-harvest management of oil palm fronds piled in inter-row space of the plantation for decomposition (Adapted from Islam, 1999).
Steam treatment has been shown to be a valuable processing technique for improving the nutritive value of low-quality roughages. The treatment generally increases the amount of available energy resulting from the solubilization of the structural carbohydrates, cellulose and hemicellulose (Oji and Mowat, 1978; Hart et al., 1981). Klopfenstein and Bolsen (1971) reported that both rate and extent of digestion of roughages are improved following steam treatment.

Nutritional management of livestock has traditionally aimed at maximizing meat and milk production by use of concentrate diets. However, recent concerns about manure disposal, ammonia (NH₃) emission into the atmosphere, ground water quality, and the need for nitrogen (N) economy, have increased interest in the effective utilization of dietary N. Nitrogen utilization by ruminants is greatly affected by the extent of microbial fermentation of feed carbohydrates and the quantity and quality of crude protein (CP) in the diet. Faecal N losses and negative N balance occur when low-protein diets contain highly digestible carbohydrates (Van Soest, 1994) with the resulting increased passage of potentially digestible carbohydrates to the small intestine (Ørskov et al., 1972). Bacterial matter may account for more than 80% of the total faecal N (Van Soest, 1994). Increased urinary N losses result from an imbalance between the amount of rumen degradable N (RDN) and the readily fermentable carbohydrates so that the microbial capture of NH₃-N produced in the rumen is incomplete. The excess NH₃ is absorbed from the rumen and small intestine, and converted back to urea by the liver (Satter and Roffler, 1975). A low percentage of the urea is recycled, but the majority is excreted in urine. Tamminga (1996) suggested that the most effective option for reducing N losses is to improve ruminal
digestibility of the organic matter (OM) resulting in more substrate being available for microbial protein synthesis with simultaneous reduction in the amount of dry matter (DM) passing through the small intestine.

The improvement of the nutritive value of oil palm by-products by processing and supplementation has received considerable attention in Malaysia (see Oshio et al., 1990; Kawamoto et al., 2001). But very few feeding trials have been conducted to delineate the relationships between processing, supplementation and animal performance in the context of optimising N utilization. Additionally, understanding and overcoming the barriers to microbial fermentation of OPF cell wall through for instance steam treatment may greatly improve the feeding value of OPF.

The inaccuracy of describing the feeding value of a resource solely based on the gross chemical composition was reiterated by Ørskov and Reid (1989). The authors suggested that the in situ degradation data either alone or in combination with the chemical composition of the feed would be a more reliable approach. Jung and Deetz (1993) also suggested that because of the restrictions in time and economics, more emphasis should be placed upon the relationships between forage cell wall degradability data and chemical composition. On the other hand, Van Soest (1994) reported the physicochemical characteristics such as buffering capacity, cation exchange capacity (CEC) and water holding capacity, which greatly affect the quality of dietary fibre, may not be at all related to the chemical composition.
The overall objective of this study was to assess the nutritive value of OPF after steam treatment and its supplementation for use as basal diet for ruminants.

The specific objectives were:

1. To investigate the optimum steaming conditions of OPF.
2. To examine the changes in OPF cell wall composition and the physicochemical characteristics after treatment and relate those changes to the pattern of OPF degradation in the rumen.
3. To investigate the merits of locally produced energy and protein supplements for the utilization of steam-treated OPF.
4. To assess the performance of animal and N balance on steam-treated OPF-based diets.
CHAPTER 2

REVIEW OF LITERATURE

2.1 Digestion and Metabolism in Ruminants

The important aspects of digestion and metabolism are discussed here. However, feeding the rumen microorganisms is the number one priority for an efficient utilization of low quality feeds by ruminants (Leng, 1986; E. R. Ørskov, pers. comm).

2.1.1 The Digestive tract of ruminants

The ruminant digestive tract is dominated by a large fermentative unit known as the forestomach comprising three compartments: reticulum, rumen and omasum. These are located before the abomasum which is equivalent to the stomach of the monogastric animal. The first two compartments are usually considered as a single organ, the reticulorumen, because there is no sphincter between them (Forbes and France, 1993).

The reticulorumen accommodate and mixes ingested food during prolonged microbial fermentation, and selectively propels either back to the month for further chewing (rumination) or onward through the reticulo-omasal orifice. According to the theory of the sieving action of the reticulorumen (Bruining and Bosch, 1992) and the theory of