UNIVERSITI PUTRA MALAYSIA

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

KONIMBA BENGALY

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By

KONIMBA BENGALY

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Chairman: Associate Professor Dr. Liang Juan Boo

Faculty: Agriculture

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

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.

Abstrak disertasi yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MENINGKATKAN PENGGUNAAN PELEPAH KELAPA SAWIT (*ELAEIS GUINEENSIS*) MELALUI RAWATAN STIM DAN SUPLEMENTASI NITROGEN DALAM RUMINAN

Oleh

KONIMBA BENGALY

Jun 2002

Pengerusi: Prof. Madya Dr. Liang Juan Boo

Fakulti: Pertanian

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 terhadam 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 amaun substrat yang tersedia daripada rangsum asas dan daripada suplementasi yang digunakan untuk membetulkan kekurangan nutrien.

Dalam satu siri eksperimen dengan mengambilkira 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 keatas fraksi serat dan penguraian *in situ* telah diselidiki. Tiga kumpulan sampel rawatan telah diperolehi daripada pelepah yang baru dipotong, iaitu tanpa rawatan (UT), rawatan

stim dalam bentuk segar (FT) dan dilayukan kepada kandungan kelembapan 24 –30% (DT) sebelum rawatan stim 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 stim telah meningkatkan kelarutan air OPF ($p<0.001$), menghasilkan penurunan dalam fraksi serat detergen neutral (NDF), khususnya hemiselulos 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 stim pada 10 kg cm^{-2} selama 20 minit dan perlu dilayukan kepada kandungan kelembapan 25 – 30% .

Eksperimen 2 direkabentuk untuk menyelidik paras yang optima bagi supplementasi N boleh fermentasi OPF yang dirawat stim (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 pembaikan 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 pengambikan 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 dedicate this work to my lovely wife Ramata Traoré for her patience and long suffering during the past four years of absence. I owe her a great debt.

I certify that an Examination Committee met on 14th June 2002 to conduct the final examination of Konimba 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

ABD. RAZAK ALIMON, PhD
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

LIANG JUAN BOO, PhD.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

HO YIN WAN, PhD.
Professor
Faculty of Science and Environmental Studies
Universiti Putra Malaysia
(Member)

ZAINAL AZNAM BIN MOHD. JELAN, PhD.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

ONG HWEE KENG, PhD.
Malaysian Agricultural Research and Development Institute
(Member)

EGIL ROBERT ØRSKOV, PhD.
Professor
International Feed Resource Unit
Macaulev Land Use Research Institute
Scotland, UK
(Independent Examiner)

SHAMSHER MOHAMAD RAMADILI ,PhD.
Professor / Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date

This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfillment of the requirements for the degree of Doctor of Philosophy. Members of the Supervisory Committee are as follows:

LIANG JUAN BOO, PhD.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Chairman)

HO YIN WAN, PhD.
Professor
Faculty of Science and Environmental Studies
Universiti Putra Malaysia
(Member)

ZAINAL AZNAM BIN MOHD. JELAN, PhD.
Associate Professor
Faculty of Agriculture
Universiti Putra Malaysia
(Member)

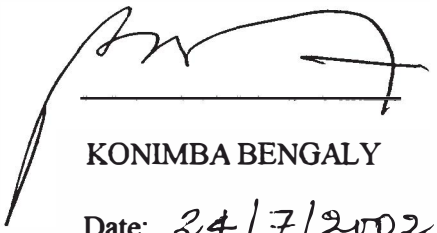
ONG HWEE KENG, PhD.
Malaysian Agricultural Research and Development Institute
(Member)

AINI IDERIS, PhD.
Professor / Dean,
School of Graduate Studies
Universiti Putra Malaysia

Date: 12 SEP 2002

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

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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.

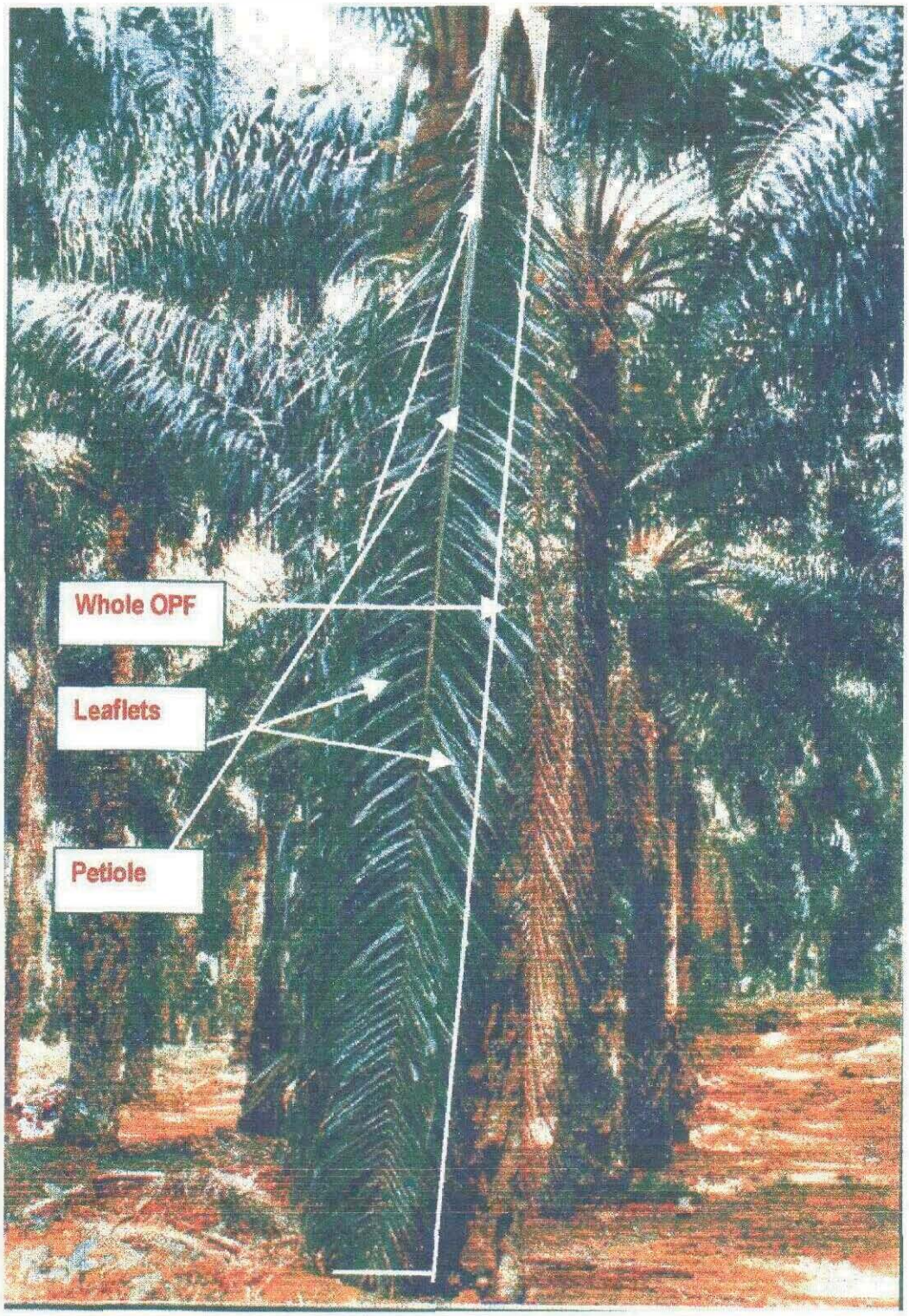

Plate 1: View of oil palm frond on a tree (Adapted from Islam, 1999)

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 (NH_3) 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 inbalance between the amount of rumen degradable N (RDN) and the readily fermentable carbohydrates so that the microbial capture of NH_3-N produced in the rumen is incomplete. The excess NH_3 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