THE USE OF *LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT FORAGE AS A FEED SUPPLEMENT FOR DAIRY GOATS

BY

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ABSTRACT

THE USE OF *LEUCAENA LEUCOCEPHALA* (LAM.) DE WIT FORAGE AS A FEED SUPPLEMENT FOR DAIRY GOATS

Six experiments were conducted to evaluate *Leucaena leucocephala* (LL) as protein supplement for dairy goats. In Experiments 1 and 2 an appropriate feeding level of dry LL leaves as substitute for cotton seed cake (CSC) fed to lactating does was investigated. A total of 82 does randomly allocated to four treatments with LL inclusion at levels of 0 (treatment 1), 180 (treatment 2), 360 (treatment 3) and 540g (treatment 4) substituting cotton seed cake at levels of 300, 200, 100 and 0 g per day of the concentrate. Basal ration contained elephant grass and Rhodes grass hay *ad libitum*, supplemented with maize bran. Daily milk yield was sampled twice a week for chemical analysis. Fourtnight body weights and daily feed intake were recorded.

In Experiment 3 comparison between fresh LL and CSC on milk yield and composition was made. Twenty eight does were subjected to four treatment diets as follows: No LL and No CSC (treatment 1), restricted CSC (treatment 2), restricted LL (treatment 3) and LL offered *ad libitum* (treatment 4). The basal ration composed of *Hyparrhenia rufa* hay *ad libitum* supplemented with maize bran.

Milk and FCM yields, fat, protein, total solids, solid not–fat, ash and mineral contents did not differ significantly ($P>0.05$) between treatments in Experiments 1, 2 and 3.

In Experiment 4 a total of 20 males and 20 females (weaner goats) were randomly allocated to four treatments. Dry LL inclusion levels varied from 0 (treatment 1), 100 (treatment 2), 200 (treatment 3) and 300g (treatment 4) of feed whilst those for CSC were 150, 100, 50 and 0 g per day for their respective four treatments. Basal diets included 5% urea treated maize stover sprinkled with molasses and supplemented with maize bran. Weekly body weights and daily feed intake were recorded. Liveweight changes were not significantly ($P>0.05$) different between treatments.

Two *in sacco* experiments were carried out to measure the degradability and rumen parameters (pH, NH_3–N, VFA) of the feed components used in Experiments 1, 2, 3 and 4 in the rumen of bucks fed a standard diet (Experiment 5) and treatment diets (Experiment 6). The fitted exponential equation ($P=a+b(1-e^{-ct})$) was used to calculate the degradation kinetics. Results of Experiment 5 showed that maize meal was most degraded followed by maize bran, CSC, dry LL leaves and *Chloris gayana*. Results of Experiment 6 showed that when the bucks were fed treatment diets from Experiments 1 and 2 protein solubility of LL (intercept) was highest ($P<0.05$) for treatment 3 followed by treatments 2, 4 and 1. The potential degradability of DM (b) was highest ($P<0.05$) for CSC in treatment 2 followed by treatments 3, 4 and 1.

It is recommended from these studies that up to 32% of dry LL and 17% of fresh LL of total diet can be offered to dairy goats. Areas of further research are suggested.

DECLARATION

I, Edith Eliakim Ndemanisho, do hereby declare to the Senate of Sokoine University of Agriculture that the thesis presented here is my own original work and that to the best of my knowledge this work has not been submitted to any other University for a degree award.

Signature.....

Date.....2/4/'96

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To all I say God Bless you.

DEDICATION

Dedicated to my mother

Phoebe

My Heavenly Father through His Son Jesus Christ has endowed me with knowledge and perserverance throughout my study. I could hear whispers of His invaluable Love as He Himself sacrificed His Only Son to die for us. "Not that we are sufficient of ourselves to think of anything as being from ourselves, but our sufficiency is from God" 2 Corinthians 3:5

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ABBREVIATIONS

AAT	–	Total amino acids absorbed in the intestine
PBV	–	Protein Balance in the Rumen
ADL	–	Acid detergent lignin
ARC	–	Agricultural Research Council
BF	–	Butter Fat
CF	–	Crude fibre
cm	–	Centimetre
CP	–	Crude protein (Nx6.25)
CWC	–	Cell Wall Content
d	–	Day
DCHO	–	Digested carbohydrate
DCP	–	Digestible crude protein
DHP	–	3–hydroxy–4(IH)–pyridone
DM	–	Dry matter
DMD	–	Dry Matter Digestibility
DMI	–	Dry Matter Intake
ED	–	Effective degradability
EE	–	Ether extract
FAO	–	Food and Agriculture Organization
Fe	–	Iron
FCM	–	Fat Corrected Milk
g	–	gramme
h	–	hour
I	–	Iodine
IVOMD	–	*In vitro* organic matter digestibility

ABBREVIATIONS CONTINUED:

IVDMD	–	*In vitro* dry matter digestibility
kg	–	kilogramme
LL	–	*Leucaena leucocephala*
ME	–	Metabolizable Energy
mg	–	milligramme
MJ	–	Mega–joule
ml	–	milliliter
mm	–	millimetre
MPS	–	Microbial Protein Synthesis
MS	–	Untreated maize stover
NDF	–	Neutral Detergent Fibre
NPN	–	Non Protein Nitrogen
NRC	–	National Research Council
NS	–	Not significant
OM	–	Organic matter
OMD	–	Organic matter digestibility
PD	–	Protein degradability
PDI	–	Protein digested in the small intestine
P/E	–	Protein/energy ratio
pH	–	Acid concentration
RDP	–	Rumen degradable protein
SEM	–	Standard error of the means
S	–	Sulphur
SNF	–	Solid Non Fat
TS	–	Total Solids
Tshs	–	Tanzanian shillings
		(1 US $ = 350 Tsh in 1992)
UMS	–	5% urea treated maize stover without molasses
UMSM	–	5% urea treated maize stover sprinkled with molasses

SYMBOLS

(P<0.05)* Significant at the 5% level of probability

(P<0.01)** Significant at the 1% level of probability

(P<0.001)*** Significant at the 0.1% level of probability.

CHAPTER 1.0

INTRODUCTION

According to the Livestock census of 1984, there are more than 6,000,000 goats in Tanzania mainland (MALD, 1988). Most of the goats are indigenous and kept for meat production. Blended goats from a three – way cross (composed of 55% Kamorai, 30% Boer and 15% indigenous goats) are being introduced for dairy production (Das, 1989). Total lactation yield of the blended goats averages 120 kg for an average lactation length of about 270 days giving an average daily milk yield of about 450 g/day (Das, 1989). Madsen *et al.* (1990) reported on a successful introduction of Norwegian Landrace x Upgraded Tanzanian dairy goats into a rural area in Morogoro region, in a village in Mgeta division, where the climate is temperate and feed resources are adequate. Milk yield per doe averages 1.3 liters per day for an average lactation length of four months. It can be deduced from the two pilot studies that milk production can be significantly increased through the introduction of suitable dairy goats in some areas of the country. Goats have various advantages over dairy cattle, in that they are able to convert the widest range of plants because they are more selective; they reach sexual maturity and become productive at an earlier age; the space required for handling and feeding goats is much less compared to cattle (Devendra and McLeroy, 1987; Madsen *et al.* 1990). In developing countries therefore, it has been realized that imported cows of high genetic value are not the only possible solution to the milk deficit and that goats can be especially useful in making up this deficit owing to their ability to make good use of locally available fodder (Morand–Fehr, 1991).

Dairy goat keepers in Tanzania are faced with difficulties in coping with the current increasing prices of commercial feeds which includes supplementary livestock feeds from agricultural products and agroindustrial by–products. There is therefore, an urgent need to look for cheap locally available alternative sources. *Leucaena leucocephala* (Lam.) de Wit (leucaena or LL, Plate 1) has been found to be a good source of protein, energy, some minerals and vitamins for ruminants throughout the year (Jones, 1979). The protein content of the leucaena leaves can be up to 34% on dry matter basis and the *in vitro* and *in vivo* digestibility of its forage material is estimated to be in the range of 50 – 80% (Upadhyay, *et al.* 1974; Jones, 1979 and Meulen et al. 1979).

There has been a lot of interest at the Sokoine University of Agriculture, Morogoro to include this leguminous tree in agroforestry studies (Lulandala, 1991). This is because leucaena species have several advantages in many agricultural systems. Leucaena can be used as a renewable source of energy, wood fuel, building material and fertilizer. The LL tree can also be used as a windbreak and provide shade for livestock and crops such as coffee. Furthermore it can supply materials for the pulp and paper industry. It has been used extensively for soil restoration programmes (Jones and Bray, 1982; Benge, 1983, Pound and Martinez, 1983; Lulandala, 1991; National Academy of Sciences, 1984; NFTA, 1985 and Perera, 1990). This leguminous plant is evergreen throughout

Plate 1: Leucaena leucocephala (Lam.) de Wit (Leucaena or LL) grown in Morogoro

the year and seems to offer great possibilities as a supplement feed, especially during the dry season when other forage materials are scarce in Tanzania.

Cotton seed cake as a protein supplement to ruminants' diets has been utilized successfully for many years (McDonald *et al.* 1991). Recently, the prices of cotton seed cake has been rising continuously. The hypothesis behind this study was that LL could substitute cotton seed cake used in the country as an animal feed supplement. Thus the work was carried out to investigate the possibility of using leucaena leaves in meeting the nutritional requirements of dairy goats. It is expected from this study that proper and safe levels of feeding leucaena will be established for use by farmers raising goats in Tanzania.

CHAPTER 2.0

LITERATURE REVIEW

2.1 Overview

It has been projected that livestock production in Africa should increase by 4.7% annually between 1980 and 2000 to meet the needs of the rapidly growing human population (FAO, 1979). Wise use of forage (grazed and preserved) and of crop and agro-industrial by-products will contribute immensely in achieving this goal. Strategies must be formulated that will foster the increase of food production to feed the population in a sustainable manner, support the economic development of the region, raise incomes, promote the welfare of rural people and protect the environment (Winrock International, 1992).

Various studies have been carried out to try and overcome some underlying grassroot level problems of animal feed shortage in the tropics. Research work carried out in East Africa (Lwoga, 1981) shows that when legumes are mixed with pastures they improve the quality of the forage, help to increase the DM yield of natural grasslands and extend the grazing period into the dry season during which time the crude protein content of the grasses is at its lowest (Mkiwa, 1990; Rukanda and Lwoga, 1981). More research work in Tanzania on the use of good quality leguminous forages and shrubs, as a source of supplementary protein is being carried out at SUA, Mpwapwa and other parts of the

country to bridge the gap between protein and energy supply for ruminants.

Small ruminants, especially goats have risen faster in numbers than any other livestock species in the world's herds over the past one decade (Morand-Fehr, 1991). Research has recently and widely extended the knowledge on goat keeping for milk and meat. World wide average milk production from goats is approximately 50 kg per doe per lactation if one-third of all goats have milk producing capability (Morrison *et al*, 1980). When selected they have greater potential for much greater productivity.

The constraints to livestock production in the tropics and East Africa can be summarized (Winrock International, 1983 and MALD, 1990) as follows:-

1. Technical constraints.
   - Nutrition - water, feed
   - Animal diseases and health
   - Livestock genotype - production and adaptation traits
   - Improper animal management
   - Predators

2. Socio-economic constraints
   - Traditional objectives of the producer

- Land tenure and land use
- Labour availability
- Management skills
- Consumer taste / preference

3. Support service constraints

- Poor veterinary services
- Ineffective extension services
- Poor input delivery system
- Lack of effective credit facilities
- Poor market and transport services
- Low disposable income

4. Ecological

- overlaps with no. 2 on land use
- Climate

According to Winrock International (1983), it would be feasible with well - designed strategies to resolve all these constraints, which will in turn have major impact on small ruminant production. For instance, the possibilities of using dietary intervention to improve or increase goat milk yield have received extensive studies over the years. Nevertheless, feed supply is the most pervasive constraint to livestock production

(Winrock International, 1983). It is directly dependent upon the production of plant biomass, natural pastures, improved pastures / legumes and browses with emphasis on chemical composition, intake and digestibility.

2.2 Leguminous trees and shrubs with their values to livestock

Trees and shrubs occupy a significant niche in the lives of the people in tropical forests and savannas of Asia, Africa, and the Pacific (Skerman, 1977; Le Houérou, 1980; Kaitho et al. 1993). The importance of browse increases with climatic aridity; in Africa over 250 million head of domestic animals live in arid and semi-arid and montane zone where browse is an important qualitative component in livestock diets (Le Houérou, 1980).

When compared with herbaceous crops, tree and shrub legumes have received relatively little attention in search for productive and persistent forage sources in the tropics (NAS, 1979). However, in the last decade success with leucaena has prompted the search for other legume tree and shrub species suitable for introduction to grazing land including cut and carry system in sustainable agriculture (Norton, 1994).

Majority of the leguminous trees or shrubs are classified under Multipurpose Tree Species (MPTS), and are represented as tree species which can be used to produce variety of uses as wood and fuelwood for domestic purposes, food for people, fodder for animals, ingredients for drugs and medicines, organic matter for soil fertility improvement,

materials for housing, fencing and handcrafts, live barriers for soil erosion control and as windbreaks.

Many researchers world over are now encouraging the multi-discipline way of tree use. These disciplines were initiated under Agroforestry systems (Weerawardena 1990 and Kløvstad, 1991).

The term Agroforestry is a "collective name for land use systems and practices in which woody perennials are deliberately combined on the same land management unit with herbaceous crops techniques and or animals or both in some spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economic interactions among the different components" (Lulandala, 1991). The aim of these land use systems is to optimise production per unit area of land while at the same time reversing some of the problems of land degradation and sustain good yields.

There are a wide range of tree legumes in use as multipurpose species throughout the tropical and subtropical regions of the world. More than 200 species of leguminous trees are reported to be used for fodder worldwide (Norton, 1994) with most of these species being tropical or sub - tropical in origin. Some of the important tree species in Tanzania are summarized in Appendix 2.1. Several studies in Tanzania (Jumbe, unpublished; Temu, R.P.C. personal communication, 1993) have shown that livestock keepers are well aware of the MPTS around them and are experts in identifying the ones suitable for

animal fodder (Appendix 2.1). The native MPTS reported for Tanzania are just some of the many naturalized and indigenous MPTS. Owing to their perennial nature, MPTS could provide valuable fodder to animals throughout the year, especially during the dry season. It is apparent therefore, that if the potentials of these MPTS are properly identified and managed, they could optimize benefits derived from them.

Goats depend on tree and shrub fodders as the main sources of feed. Being browsers goats have special ability of selectively utilizing a wide variety of shrubs, woody plants, and weeds given the chance to feed in the bushes. Studies done elsewhere have documented that animals grazing under trees is an old practice (Perera, 1990). In tree crop farming systems, the ruminants can easily be intergrated to utilize the loppings of the tree crops and the undergrowth whether cultivated or natural herbage. The animals can be used as biological weeders. The grazing animals recycle nutrients in the available forms to the tree crop system at a faster rate through their urine and dung than the normal process of decomposition of tree litter biomass. Therefore, intergration of livestock, especially ruminants can be complementary for both the livestock and crop component (Perera, 1990).

2.3 Background information on leucaena species

Leucaena leucocephala (Lam.) de Wit., formerly known as *L. glauca*, became pantropical in the 17th century from its native region in Central America and the Yucatan

Peninsula of Mexico where its fodder value was recognized over 400 years ago by the Spanish conquistidors. They carried along with them leucaena feed and seed on the galleons to the Phillipines to feed their stock (Brewbaker et al, 1985). From there it spread to most countries of the tropical world as colonialists made use of leucaena as a shade plant for various plantain crops (NAS, 1984; Brewbaker and Sorensen, 1990). By twentieth century other species had attracted interest. Today more than 13 species are recognized in the genus and others are expected to be validated (NFTA, 1990; Shelton and Jones, 1994).

In addition to *Leucaena leucocephala*, there are *L. collinsii (COLL.), L. diversifolia (DIVE.), L. esculenta (ESCU.), L. greggii (GREG.), L. lanceolata (LANC.), L. macrophylla (MACR.), L. pallida (PALL.), L. pulverulenta (PULV.), L. retusa (RETU.), L. trichodes (TRIC.). LEUC., PALL* and one subspecies of *DIVE* are polyploid (104 chromosomes), while the other species are diploid (52 or 56 chromosomes) (NFTA, 1990).

Leucaenas vary widely in leaf and tree shape, ranging from shrubs to stately trees. *LEUC.* and tetraploid varieties of *DIVE* are self - pollinating, while all others are outcrossing. More than 100 cultivars of leucaena are recognized and fall into three broad types or forms, namely:

Hawaiian (common); is small and bushy with a rounded crown, growing to a maximum

height of 8 metre (m), highly flowering, greyish and pubescent shoots.

Salvador (Giant); is a tall, slender tree with limited branching from a main stem that reaches up to 20 m in height and 40 cm in diameter. This type includes all the selections of giant leucaena cultivars in the K (accessions) series (for instance, K8, K2 and K67) coded at the University of Hawaii. The giants are the best wood producers and can be very effective forage producers when managed properly. It begins flowering at 8 to 12 months and continues at yearly intervals.

Peru; multi-branched, leafy, medium height (5 - 15 m) flowering initially at 6 to 12 months and subsequently once a year (Brewbaker et al, 1972; NAS, 1984; Oakes, 1968 cited by Lulandala and Hall, 1991). In Australia, a new variety, Cunningham, was derived from crossing Salvador and Peru - type varieties and is reported to produce up to 50% more edible dry matter (DM) than other forage varieties (Lulandala and Hall, 1991). The great diversity within species can easily comfound farmers, but provides a large potential for selection in plant breeding.

Leucaena thrives on deep, well drained neutral or calcerous soils. It is not suited to very acidic soils (pH < 5), with low calcium levels, or poorly drained sites. The big taproot reaches water and nutrients in deep soil layers and allows the plant to tolerate a wide array of soil conditions. Unlike many other tropical legumes, leucaena is adapted to clay soils (Jones, 1982); but not water logged areas (Shelton and Jones, 1994). It grows in areas

with annual rainfall ranging from 650 to 3,000 mm. It has been known to produce edible forage with yields ranging from 3 to 30 t DM /ha/year depending on soil fertility, row spacing, rainfall, temperature and psyllid attack (Shelton and Brewbaker, 1994). At high altitudes in the tropics growth is slow due to cool nights. From some research findings, it has been observed (Jones, 1982) that in the sub-tropics leucaena could be damaged by frost but that it was less affected than Siratro or Desmodium. During favourable weather conditions leucaena regrowth was rapid, and sprouted from the base of the plant following extreme damage to stems from frost or fire (Jones, 1982).

The genus of leucaena is considered an interbreeding complex, and breeding efforts are concentrated in producing interspecific hybrids. *LEUC.* has been crossed successfully with all other species except *GREG.* Such hybrids might be used to expand the range of leucaena to colder and more acid sites. Among new varieties of crossing are K340 and K743 (NFTA, 1985; Shelton and Jones, 1994).

Over 50 species hybrids are now under study in Hawaii for growth, form, psyllid resistance, cold tolerance and fodder quality (NFTA, 1990). Many hybrids have high commercial potential, notably in cooler climates and on certain acid soils where LEUC. is an economic failure. New varieties are increasingly available from breeding stations in Hawaii (NFTA, 1990), Australia, Taiwan and Indonesia (NFTA, 1990).

Like in many other countries where leucaena had been introduced, this leguminous plant in Tanzania gained popularity as a potential animal feed quite fast. The Hawaiian type was introduced to the Usambara Mountains (Lulandala and Hall, 1991), though there are no reports which give reasons for selecting certain types for given areas. The more productive Salvador type has continuously been planted in reforestation programmes throughout mainland Tanzania, but especially in the low-rainfall areas of the central, northern and western plateaus, large parts of which are not much above 1000m elevation – and other lowland areas (Lulandala and Hall, 1991).

2.4 Chemical composition of *Leucaena leucocephala*

The chemical composition of leucaena varies considerably as reported by different authors (Table 2.1). The factors which influence the composition of plant parts most are: crop management, the portion of the plant under analysis, variety, and processing and postharvesting treatment techniques. Values may also differ according to the assay

Table 2.1. Mean values for the chemical composition of *Leucaena leucocephala*

DM	CP	EE	CF	Ash	Ca	P	K	Mg	Na	Fe	Reference Year
g/kg	g/kgDM										
Dry LL											
-	-	-	-	-	15.3	3	28.3	3.1	0.6	-	Jones and Megarrity 1983
-	259	-	-	-	23.6	2.3	-	-	-	-	Pound and Martinez 1983
-	224	39.8	124	97.8	23.7	1.9	-	4.2	0.2	-	Pound and Martinez 1983
-	222	32.9	258	97.0	18.5	2	2.8	3	-	-	Wahyuni *et al.* 1983
950	227	34.5	156	64.2	12.1	2.2		5.3	0.1	-	Ngaiza 1985
896	230	45.0	151	89.2	-	-	-	-	-	-	Shoo 1986
883	210	60.0	113	80.0	12	3	-	-	-	-	Shirima 1986
938.9	199	73.7	114	106	24.6	2.2	18	12.1	-	0.2	Swai 1987
935	300	35.0	180	108	16	2.3	-	-	-	-	Muhikambele and Urio 1988
910	209	34.0	114	82.9	-	-	-	-	-	-	Ngaiza 1988
904	224	32.2	165	96.4	6.6	2.8	-	-	-	-	Luziga 1993
910	225	46.5	153	94.6	-	-	-	-	-	-	Ocran 1993
Fresh LL											
-	224	64.0	96	108	-	-	-	-	-	-	Gnatt 1953
345	215	65.0	143	82.8	27	1.7	-	-	-	-	Upadhyay *et al.* 1974
-	258	-	-	110	-	-	-	-	-	-	NAS 1977
-	259	26.0	118	110	19	2.2	-	-	-	-	D'mello and Taplin 1978

Table 2.1 continued:

-	291	47.0	89	70	18	2.5	-	-	-	-	D'mello and Frazer 1981
307	242	27.0	242	89	-	-	-	-	-	-	Gohl 1981
-	269	-	-	-	11	2.6	22.5	-	0.2	0.1	Jones and Megarrity 1983
282	232	28.0	276	64.0	-	-	-	-	-	-	Jotee 1984
-	203	55.0	183	93.0	-	-	-	-	-	-	Brewbaker 1986
300	220	69.0	196	44.0	5.5	1.3	-	3.4	-	-	Devendra 1986
301	174	38.0	305	46.0	3	1.4	-	7.1	-	-	Devendra 1986
-	294	34.0	73	104	23	2.5	-	-	-	-	D'mello and Acamovic 1989
-	249	77.0	90	145	26	2.3	-	-	-	-	Sunaria and Sagar 1989

method used, and caution is thus necessary when interpreting the analysed data (Pound and Martinez, 1983). The values on the leucaena composition, showing higher fibre, lower ether extract, lower crude protein, were from samples of mature forage (Pound and Martinez, 1983). The authors did not report the stage at which these plants were assessed. Dry matter content were between 282 and 345 g/kg for fresh and 883 and 950 g/kg for dry leucaena.

Ash content of the forage varies according to the amount of woody material in the sample. This view is supported by D'mello and Fraser (1981), who showed that the ash content increased from 5.3 g/kg DM in semi–open leaves, to 90 g/kg DM in mature leucaena leaves.

The wide variation in crude fibre content is probably due to the variation in the amount of twigs included in the sample. The lowest fibre content recorded was from fresh leucaena, 73 g/kg DM (D'mello and Acamovic, 1989). Fibre content as high as 434 g/kg DM have been recorded (Pound and Martinez, 1983).

Crude protein (Nx6.25) is dependent on the leaf:twigs ratio of the sample. The values reported by various authors in Table 2.1 vary from 174 for the fresh and 300 g/kg DM for the dry leucaena, CP components as high as 340 g/kg DM of dry sample have been reported elsewhere (NAS, 1979; Meulen *et al.* 1979). Pound and Martinez (1983) cautioned on the possibility of exaggerated CP contents, which could be over–estimated

Table 2.2. Amino acids composition in soyabean, fishmeal, alfalfa and leucaena (mg/16 g N)

Amino acid	Soyabean	Fishmeal	Alfalfa	Leucaena	Leucaena (SUA)
	1	2	3	4	5
Cystine	106	69	77	67	97
Aspartic acid	756	625	-	864	682
Methionine	88	175	96	98	140
Threonine	244	269	269	266	346
Serine	331	256	-	279	368
Glutamic acid	1138	813	-	640	854
Proline	300	244	-	305	376
Glycine	275	400	-	278	385
Alanine	275	394	-	311	433
Valine	300	325	356	311	465
Isoleucine	294	256	290	244	253
Leucine	488	475	494	444	638
Tyrosine	238	-	232	208	124
Phenylalanine	319	256	307	283	403
Lysine	388	500	368	339	490
Histidine	181	-	139	123	233
Arginine	463	375	357	277	449

Sources: 1: Degussa (1973); 2: Pound and Martinez (1983); 3: Hegarty (1977)
4: Meulen *et al.* (1979); 5: Swai (1987)

by the mimosine present in the plant during the analysis. Amino acid composition of leucaena is similar to that of alfalfa (*Medicago sativa*) and is also comparable to soyabean even fishmeal (Table 2.2). It is however deficient in S–containing amino acids, and for efficient rumen microbial–synthesis supplementation of sulphur would be recommended (Pound and Martinez, 1983). Quantity greater than 1.5 g/kg DM or N:S ratios less than 15:1 are considered adequate. A wide variation in essential amino acid content between different types and sources of leaf meal of the same cultivar have been recorded (D'mello and Frazer, 1981).

Values for gross energy content have been found to be rather consistent, at around 19–20 MJ/kg DM (Pound and Martinez, 1983). Metabolizable energy recorded for 5 week old chicken were rather low, 2.67 MJ/kg DM and an N–corrected value of 2.98 MJ/kg DM (D'Mello and Acamovic, 1989). The same authors attributed the low values to high fibre content and to the presence of tannins, mimosine and 3–hydroxy–4(1H)–pyridone (DHP) in the leaves. In Malaysia, values obtained for ruminants ranged from 7.1 to 10.4 MJ/kg DM (Devendra, 1982) which was considered low in regard to its low fibre content (D'mello and Acamovic, 1989). Sodium (Na) has been reported to be quite low, ranging from 0.1–0.3g/kg DM (Jones, 1979; Jones and Megarrity, 1983), lower than the recommended requirement for Na in ruminant diets which is about 0.7 g/kg DM. The level of iodine is usually quite low 33–90 mg/kg DM (Jones, 1979) compared to the

Table 2.3. Nutrient contents of foliage of different leucaena species (g/kgDM)

Species	N	P	K	Mg	Ca	Ash
L. leucocephala K 636	33.7	1.76	8.21	8.70	37.10	138.7
L. pallida K 376	34.3	1.61	9.47	2.28	13.32	82.0
L. collinsii	31.5	1.88	8.42	5.39	23.45	97.4
Hybrid K x 1	32.9	1.56	6.85	4.13	15.24	86.2
Hybrid K x 2	30.0	1.75	6.03	4.27	20.84	97.7
Hybrid K x 3	29.1	2.14	7.67	5.63	13.09	70.4
L. diversifolia K 156	37.6	2.22	9.07	2.70	10.88	97.2
L. diversifolia * 46568	34.0	1.52	8.8	2.78	23.91	105.1
L. diversifolia * 33820	25.5	1.65	5.16	4.57	16.77	95.2
L. leucocephala K 8	31.8	2.43	13.29	4.79	14.39	111.6
L. diversifolia K 785	32.1	2.75	12.14	4.59	13.71	102.6
L. esculenta	30.5	2.1	6.82	4.08	12.23	73.5
G. sepium	30.5	2.45	13.32	8.56	26.66	137.6

Source: Gunasema et al. (1990)

800 mg/kg DM required by ruminants (ARC, 1990). Leucaena is quite adequate in calcium (Ca) and phosphorus (P), though they may vary from location to location; it should be recalled here that Ca and P are closely associated in the bone formation, and a Ca:P ratio of 2:1 is usually recommended for ruminant diets (Norton, 1994). The Ca:P ratio of leucaena plants ranges from 1.12 to 15.9 (Table 2.1). Fourteen other leucaena species (Table 2.3) have been reported to have N ranging from 25.5 to 37.6; P, 1.5 to 2.8; K, 5.2 to 13.3; Mg, 2.3 to 8.7; Ca, 10.9 to 37.1 and ash, 70.4 to 138.7 g/kg DM respectively. Magnesium and K are seldom a limiting factor in ruminants (Norton, 1994). It is now confirmed that leucaena is a valuable source of carotenoids for the pigmentation of egg yolks and a precursor for vitamin A metabolism (Pound and Martinez, 1983). The high carotenoid levels shown in Table 2.4, are responsible for imparting a yellow colouration to the fat of cattle consuming high levels of leucaena (Takahashi and Ripperon, 1949 cited by Pound and Martinez, 1983) and for the yellowing of milk of dairy cattle eating leucaena several hours before milking (Henke, 1958). Leucaena leaf meal is said to have approximately twice the carotene level and twice as much Riboflavin and vitamin K as alfalfa meal (NAS, 1977). Studies carried out in Malawi, using sun-dried leucaena leaf meal (cv. Peru) showed carotene and Xanthophyll concentration values of 446 mg/kg and 865 mg/kg respectively (Pound and Martinez, 1983). Warm air drying (60^0C) or hot air drying (145^0C) caused considerable losses of xanthophyll. Severe losses of carotenoids also occured during blanching in water or ferrous sulphate solution.

Table 2.4. Carotenoid content of pinnules of 3 cultivars of leucaena grown at Mpemba, Malawi[3] (mg/kg)

	Cultivar		
Carotenoid	"Cunningham"	"Hawaiian Giant" (K8)	"Peru"
B-carotene	248	227	245
"	398	310	315
Xanthophyll	766	741	741
"	873	653	609
Lutein	529	530	557
Zeaxanthin	146	132	110

Source: Pound and Martinez (1983)

Storage losses of carotenoids from leucaena treated in this way ranged from 19–40 mg/kg/month and of xanthophylls from 29–55 mg/kg/month at 16–20^{0}C (Pound and Martinez, 1983). Removal of mimosine using the latter method might require addition of vitamin A (to such animal meals). In another study, Castillo (1978, cited by Pound and Martinez, 1983) gave carotene values in leucaena leaf meal as 518.3 mg/kg and total xanthophyll of 762.4 mg/kg. Fifty percent loss of carotene over a ten day conservation period (731 mg/kg to 367 mg/kg) were reported (Castillo *et al.*1978, cited by Pound and Martinez, 1983). These figures are far more than the ones reported for the Malawi study. However, the addition of an antioxidant was reported to significantly reduce such high losses of carotene and xanthophyll, but not when the leaf meal was stored in a partial vacuum or in an inert gas such as carbon dioxide or nitrogen (Castillo *et al.* 1978, cited by Pound and Martinez, 1983). All the leucaena species studied were found to be good sources of vitamin K, which was approximately twice per unit DM as other legume feeds (D'mello and Taplin, 1981; NAS, 1984 and Gunasema et al. 1990).

2.5 Strategies for utilization of leucaena in agriculture

When fed to ruminants consuming poor quality fibrous diets such as straw or chopped sugar cane, even relatively small quantities of the green forage can stimulate rumen activity and lead to higher intakes, which in turn improve animal performance (Preston, 1982; Pound and Martinez, 1983). A pure diet of leucaena gives poor results; animals

Table 2.5. The effects of supplementing dried (D) and fresh (F) *Leucaena leucocephala* leaves on the intake of low quality forages in cattle, sheep, goats and buffalo (offered in percent of DM).

		Intake(g)		Diet		
Animal species	Basal diet	basal	LL leaves	DMD%	Reference	Year
Cattle	Natural	20.2	-	42.0	Wayuni *et al.*	
	grass	26.1	5.2D	44.0		1982
Cattle	Rice	18.3	-	37.6	Moran *et al.*	
	Straw	15.9	6.8D	40.3		1983
Buffalo	Rice	18.4	-	36.6	Moran *et al.*	
	Straw	17.1	7.4D	38.6		1983
Goats	Spear	10.8	-	47.3	Baumalin *et*	1984(a)
	grass	15.3	4.3F	55.5	*al.*	
Sheep	Spear	12.2	-	50.5	Baumalin *et*	1984(b)
	grass	12.3	3.2F	49.3	*al.*	
Goats	Maize	10.3	-	46.0	Banda and	
	stover	10.3	5.5D	51.0	Ayoade	1986
Sheep	Sorghum	24.6	-	41.7	Goodchild	1990
	stover	32.8	5.9D	46.7		

may either maintain or gain weight initially but subsequently lose it (Pound and Martinez, 1983). However, given as a supplement to the ration, or as a complement to pastures, good results have been obtained (Table 2.5). Norton (1994) expresses the levels of supplementation as ranging from 10 to 33% of DMI.

Leucaena is used in cropping and "alley cropping" systems. Contour strips of this plant have been employed for many years in Timour, Indonesia and Phillipines for erosion control on steep slopes and mulching of the leucaena foliage into the soil to enhance yields of inter-crops (Gutteridge and Shelton, 1994). On some islands of Eastern Indonesia, thickets of leucaena are regularly burnt prior to planting crops in an advanced form of "slash and burn" agriculture. The plant is capable of producing a large volume of a medium - light hard wood for fuel (specific gravity of 0.75) with a high heating value, and makes excellent charcoal, producing little ash and smoke (Brewbaker *et al.* 1985). It can also be used for posts, props and frames for various climbing crops. The low seeding varieties are used for providing shade for cacao and coffee and a support for climbers such as pepper and vanilla (Brewbaker *et al.* 1985). The leucaena hedges are useful as windbreaks and firebreaks, the latter due to the suppression of understorey grass growth. Other uses are aesthetics and include production of necklaces from seeds and the use of young leaf and seeds as vegetables for humans (Gutteridge and Shelton, 1994). Leucaena is palatable to most stock including wildlife, fish and some insects (psyllid). This can lead to a distinct disadvantage when establishing the crop.

The strategies of utilization of leucaena in agriculture can be summarized into advantages and disadvantages (Jones, 1994). The advantages are:

i) It is a very persistent legume under cutting or grazing. Planted on appropriate sites and given reasonable management, plants can survive for decades (Jones and Harrison, 1980).

ii) Its productivity is frequently higher than that of alternative legumes.

iii) Leucaena recovers rapidly from defoliation.

iv) Leucaena has a high quality forage with the exception of the problems associated with mimosine, and is readily eaten.

v) Leucaena is grazed with minimal losses due to trampling or fouling and plants are not unduly damaged by grazing animals.

vi) Leucaena grown in rows combines well with companion grasses grown in the inter-row.

The disavantages are:

i) Slow establishment of the plant

ii) Intolerance of water logging and acid soils

iii) Presence of mimosine in the plant

iV) Susceptibility to pysllids (Jones, 1994)

iii) and iV) will be discussed in detail under section 2.6.

2.6 Problems of leucaena as livestock feed

Toxic problems that exist within the leucaena plants are comparable to those of many other leguminous plants like clover species, lucerne and some agroindustrial by products. In the past decade fears of mimosine's effects as a barrier to leucaena's wide use as a forage had been dispelled with a better understanding of its pharmacology, brought about by the discovery of the rumen microbes, *Synergistes jonesii* (Jones, 1979; Jones *et al.*1985).

Leucaena's popularity has recently been affected by the attack of the insect, pysllid which has caused a tremendous decline in the leucaena production worldwide. Solution to this problem will be discussed under section 2.7.

Antinutritional factors found in most non– conventional feedstuffs in livestock feeds may be defined as substances which by themselves, or through their metabolic products arising in the system, interfere with feed utilization and affect health and production of animals. These deleterious substances, (also known as anti–quality factors) can be divided into four groups based on their effects on livestock:

– Those affecting protein utilization and depressing digestion (protease inhibitors, tannins, saponins, and lectins).

- Metal ion scavengers (oxalates, phytates, gossypol pigments, glucosinolates).

- Antivitamins

- Mycotoxins, mimosine, cyanogens, nitrates, alkaloids, photosensitizing agents and isoflavones (Makkar, 1993).

In his review, Makkar, (1993) has emphasized more on the listed polyphenolic compounds, as this class of antinutritional factor is the most widespread in non-conventional feedstuffs, such as agroindustrial and forestry byproduct. Effective utilization of these non-conventional feeds form the main area of research in the developing countries due to shortages of conventional feeds (Akbar and Gupta, 1985; Meulen *et al.* 1984; Ndemanisho *et al.* 1989; Makkar, 1993). Mimosine composition in leucaena plants has been extensively studied (Acamovic and D'mello, 1981; Jones and Megarrity, 1983; Megarrity and Jones, 1983; Jones and Megarrity, 1986; Ngaiza, 1988; Quirk *et al.* 1988; Sunaria and Sagar, 1989; Adeneye, 1991; Pratchett *et al.* 1991). Mimosine is a nonprotein, unbound amino acid with the following chemical name: B – [N – (3–hydroxy – 4 oxopyridyl] (– a –aminopropionic acid. Using C^{14} lysine, Hylin (1964, cited by Pound and Martinez, 1983) found that the radioactive mimosine was formed rapidly when lysine was given to plants, suggesting that lysine is an important precursor for mimosine. The radioactivity was almost exclusively located in the pyridone ring. Ninenty five percent of this activity was carried over into the DHP isolated following pyrolysis of mimosine (Pound and Martinez, 1983).

The structure of mimosine (Fig. 1) is very similar to that of tyrosine, and Lin *et al.* (1964, cited by Pound and Martinez, 1983) suggest that mimosine acts as a tyrosine analogue or antagonist, inhibiting protein biosynthesis. Although mimosine is directly toxic, DHP is only indirectly so through its goitrogenic action. Megarrity and Jones (1983) found that the goitrogenecity of DHP is only partly responsible for the toxicity of leucaena to ruminants, and that the low feed intakes and low liveweight gains are related to other effects of DHP. Thus, animals which can break down the mimosine to DHP tolerate higher dietary levels of leucaena than do other animals, and animals that can degrade DHP can have higher tolerance levels (for instance, up to 100%

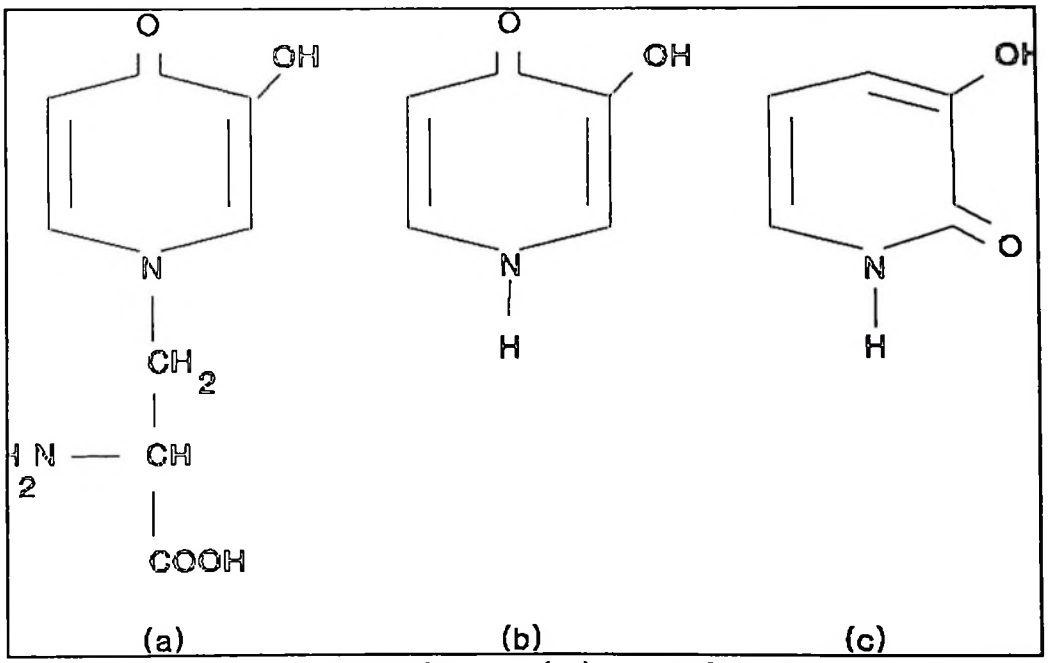

Figure 1: -Mimosine (a) and its ruminal degradation products, 3-hydroxy-4(1H)-pyridone (3,4-DHP [b]) and 2,3-DHP (c)(Source: Hammond *et al.* 1989)

leucaena for the animals having the detoxifying microbes). It is recommended that diets for pigs, poultry and rabbits should contain less than 10% Leucaena (Jones, 1979).

It has been known over a decade that in areas where leucaena is an indigenous plant (e.g. in South and Central America; Asia), ruminants consuming leucaena appear to be able to degrade the ruminal metabolite of DHP to harmless end products (Jones and Megarrity, 1986). This capacity is associated with a specific bacterial population in the rumen of these adapted animals. Scientists have now been able to name the DHP – degrading bacteria, as *Synergistes jonesii* named after the discoverer – R.J. Jones (Shelton and Jones, 1994). They are known to be anaerobic gram negative short rods (1.2 x 0.6 μ) (Pratchett *et al.* 1991; Jones, 1994). However, where leucaena has been introduced to ruminant populations without this adaptation, symptoms of toxicity are observed and have been reported from Papua New Guinea (Holmes *et al.* 1981); Australia (Hegarty *et al.* 1976; Jones, 1979); Kenya (Semenye, 1990) and Tanzania (Eik, L.O. personal communication, 1994). The severity of toxicity is related to the level of mimosine (leucaena) consumed, and diets containing less than 30% or less than 1.0 g/kg $DM^{0.75}$ mimosine are considered safe for ruminants (Jones, 1979; Perera, 1990; Adejumo and Ademosun, 1991 and Pratchett, *et al.* 1991). Mimosine occurs in all parts of the leucaena plant (Table 2.6) and their different contents among strains have been reported (Carangal and Catindig 1955; Brewbaker and Hylin, 1965; Jones, 1979; Lowry *et al.* 1993; Adeneye, 1991)

Table 2.6. Concentration (% fresh weight) of mimosine in various parts of cv "Peru" and two leucaena accessions (K 55 and K 65)

Plant part	Peru	K55	K65
Shoot tips	1.56	1.82	2.88
First expanded leaf	1.12	1.18	2.15
Third expanded leaf	0.81	0.83	1.72
Fifth expanded leaf	0.69	0.79	1.32
Ninth expanded leaf	0.54	0.43	1.05
Fifteenth expanded leaf	0.23	0.21	0.34
Third stem internode	0.35	0.57	0.90
Fifth stem internode	0.16	0.21	0.41
Ninth stem internode	0.10	0.10	0.17
Fifteenth stem internode	0.11	0.10	0.07
Flower heads	0.87	1.34	1.57
Young pods	1.07	1.12	1.43

Source: Wong and Devendra (1982)

with content ranging from 2 to 5% (DM basis and equivalent to 0.9 to 2.9% fresh basis). Higher contents have been found in West Nigeria, the DM of edible parts ranging from 0.5% in the empty green pod to 12.3% in the yellow cotyledon (Adeneye, 1991). Mature seeds were twice (6.2 and 3.2%) as rich in mimosine as young seeds, respectively, but the reverse was true of leaves (2.6 versus 5.1 %). Young and mature leaflets were higher in mimosine than the corresponding petioles, rachis and rachillae or entire leaves. The green and brown seed coats had no mimosine (Adeneye, 1991).

The effect of cutting interval on mimosine content in the leaf and young stems (< 5 mm diameter) has also been studied (Guevarra *et al.* 1978, cited by Wong and Devendra, 1982). Mimosine levels were found to decline generally with increased time between cutting. Tables 2.6 and 2.7 show variability in mimosine content between workers, ranging from 0.7 to 145 g/kg DM. These variability between authors could have been due to many factors including the variety of leucaena, age of the plant, parts under study and laboratory technique used to determine the mimosine content.

2.6.1 Mode of Mimosine and DHP toxicity

Mimosine acts by interfering in cellular mitosis, and it could act as an amino acid antagonist intefering with the metabolism of phenylalanine, tyrosine or cystine. Lin *et al.* (1964) hypothesized that mimosine probably acts as a tyrosine analogue or

tyrosine antagonist which inhibits protein biosynthesis in the living body and causes toxic symptoms including retardations of growth. The symptoms of toxicity are alopecia, inappetance, reduced weight gain, excessive salivation, hair loss, incordination of gait, enlarged thyroid glands (low serum thyroxine), and reduced fertility (Jones, 1979). Further investigation in Florida revealed that inoculation with 3,4 – DHP – degrading ruminal bacteria also resulted in ruminal ability to degrade 2,3 – DHP (Fig. 1) in heifers that did not have this ability initially. In this study, ruminal microorganisms that degraded 2,3 – DHP and not 3,4 – DHP were also found (Hammond *et al.* 1989; Pratchett, *et al.* 1991).

Another mode of action was proposed by Tsai and Ling (1973). They suggested that the metal chelating power of mimosine could disturb the action of metal–containing enzymes, especially those containing iron cations. The chelating properties of mimosine was thus suggested as a possible detoxification method employing ferrous sulphate ($FeSO_4$). In other words mimosine is chelated by $FeSO_4$ and hence not easily absorbed in the gastrointestinal tract, and is excreted mainly in the faeces (Tsai and Ling, 1973; El Harith *et al.* 1979; Meulen *et al.* 1979). The recommended rate of $FeSO_4$, to rations containing leucaena leaf meal is 1–2%. One study observed that rats on a 25% leucaena diet supplemented with 2% $FeSO_4$ gave weight gains intermediate between those of the control (a standard rat ration) and those of unsupplemented diet (El Harith *et al.* 1979).

Mice fed on diets containing 3,4 – DHP developed hyperplastic goitres with enlarged

vesicles deficient in colloids and lined by enlarged epethelial cells. The hyperplastic changes in the thyroid of goitrous cattle resembles those produced in mice. The evidence strongly suggested that the goitres in cattle were associated with absorption of 3,4 – DHP (Hegarty *et al.* 1976). This may depend on geographical location (NFTA, 1990). For instance, rumen micro–organisms of cattle and goats in Hawaii hydrolyse mimosine into 3,4 – DHP so efficiently and rapidly that even when the animals are fed on a diet rich in leucaena, their blood, meat and milk are quite free from mimosine. In Australia, cattle and goats (at different occasions) on the all leucaena diets became hypothyroid after only 3 weeks of feeding. Thyroid glands were enlarged and there was erosion of the oesophageal mucosa and reticulo– rumen (Jones and Megarrity, 1983). The researchers noted that excretion of DHP in the urine was related to the mimosine intakes, with recoveries of about 86%. In marked contrast, goats fed on leucaena in Hawaii exhibited no clinical signs of toxicity and excreted less than 1% of the mimosine intake as DHP in the urine. No degradation of DHP occured *in vitro* with rumen fluid from Australian goats, whereas 71% of the added DHP was degraded after 5 h with rumen fluid from goats in Hawaii. The results support the hypothesis that the differences observed are attributable to a different microbial metabolism of mimosine and DHP in ruminants in Hawaii (Jones and Megarrity, 1983).

It has been found that sheep do not hydrolyse mimosine into 3,4 – DHP as efficiently as those of cattle (Meulen *et al.* 1979). Consequently some mimosine is absorbed and enters the blood stream (Ruskin, 1977). High intakes (above 25%) of

leucaena by sheep have been shown to cause remarkable shedding of fleece within 7–10 days (Hegarty *et al.* 1976). This method has been used as a potential cheap way of shearing sheep (CSIRO, 1983). Wool growth starts again 3–4 days after shearing (CSIRO, 1983).

2.6.2 Antinutritive factors

It is likely that legume forages rich in tannins will be superior as sources of bypass protein since tannins link with proteins during mastication and appear to reduce microbial degradation of plant proteins (Reid *et al.* 1973; Preston, 1986). Perera (1990) reported that, tannins if in low levels serve a beneficial effect by 'protecting' the protein from microbial attack. These protected proteins escape to the small intestine and are digested in the presence of proteolytic enzymes. Species of browse which contain tannins will provide both rumen degradable protein (RDP) and undegradable rumen protein (UDP) and will be a more effective source of supplemental N for ruminants (Norton, 1994). This phenomenon is challenged by that of Rodriguez and Borges, (1989), where the 40% degradable part of leucaena in the rumen was found to provide insufficient NH_3–N and due to low availability of energy within the rumen as shown by the low efficiency of bacterial synthesis (2.24 plus or minus 0.23 g microbial N/100 g OM digested in the rumen). He thus suggested that leucaena should be used with sources of rumen degradable N and energy for proper ruminant feeding (Rodriguez and Borges, 1989). It has been stipulated that even when consumed in excess these tannins contained in LL for

instance do not cause bloat in ruminants. This can be contrasted to alfalfa (lucerne) which when consumed in excess, causes bloat due to lack of tannin content. The presence of tannins, trypsin inhibitors, galactomannan gums, saponins and flavonols (Table 2.7) may reduce nutritive value for all the monogastrics (D'mello and Acamovic, 1989).

Table 2.7: Antinutritional components of *Leucaena leucocephala*

	Concentration (g/kgDM)	
Component	Leaf	Seed
Mimosine	10–120	33–145
DHP	5–8	Not detected
Tannins	13–44	7.1
Trypsin inhibitors	Weak activity	Strong activity
Galactomannan gums	46	320
Saponins	2–11	2–11
Flavonols	30–60	Not detected
Haemagglutonins	Not tested	Low activity

Source: D'Mello and Acamovic (1989).

The ideal concentration of tannin in the feed has been found to be in the range of 20–40 g/kg DM. Higher levels, 70–90 g/kg DM were reported to be detrimental (Barry and Manley, 1985; Perera, 1990). Some species of browse materials

including leucaenas (Norton, 1994) contain as much as 50 per cent phenolic compounds in the organic matter (Backlund and Bellskog, 1991). Protein precipitation present in the tannins contributes to plant defence mechanism that deters predation by herbivores and insects, probably through astringent sensation induced in grazing animals (McLeod, 1974; Backlund and Bellskog, 1991;). Thus many plants increase their tannin content under stress, for instance drought and intensive grazing. Two types of soluble tannins exist in majority of plant species. They are the hydrolysable tannins (HTS) and the non–hydrolysable (condensed – proanthocyanidins) tannins (CTS) (Gutteridge and Shelton, 1994). HTS are characterised by a central carbohydrate core with a number of phenolic carboxylic acids bound by ester linkages (Backlund and Bellskog, 1991). The condensed tannins are by far the most common type in browse plants including leucaenas. Backlund and Bellskog (1991) report further that the hydrolysable tannins may form complexes with protein at rumen pH, but these complexes are readily split and the protein utilized in the lower acidic digestive tract. The condensed tannins however, form stable complexes with protein and the bound protein is lost with faeces. Tannins also act as antimicrobial agents, but under certain conditions, the microbes may adapt (Robbins et al. 1975). Hoffman (1985, cited by Backlund and Bellskog, 1991) is of the opinion that animals adapt to high levels of tannins in feed by enhancing their mucin production from the salivary glands. This adaptation was observed in goats and deer (Hoffman, 1985, cited by Backlund and Bellskog, 1991). Tannins may have either beneficial (increase bypass protein, decrease ammonia loss) or detrimental effects (depress palatability, decrease rumen ammonia, decrease post

ruminal absorption). It has also been shown that the leaves of species which do not have tannins such as Albizia, Enterlobium, Samanea and Sesbania are rapidly degraded in the rumen (RDP), providing high levels of rumen ammonia, much of which will be ultimately wasted by excretion as urinary urea (Norton, 1994). Although the topic of tannins is said to be extensively reviewed, the significance of tannins in browse is only poorly understood (Woodward, 1988; Norton, 1994).

In situations where the fermentable N requirement can be met from other sources (urea or animal excreta) there is a need to reduce rumen degradability of the legume protein so as to increase its bypass characteristics. This can be achieved when these forages are artificially dried or pelleted (Preston and Leng, 1987).

2.6.3 Psyllid attack to *Leucaena leucocephala*

The leucaena psyllid (*Heteropsylla cubana* Crawford) is a small sucking insect, an aphid (Plate 2), which feeds on the shoots and new leaves of leucaena (Plate 3). It is a tiny insect (1–2 mm) in the family Psyllidae (Hemoptera), eggs are yellow, found primarily on young terminal leaves, and hatch in 2 to 3 days. Nymphs, which resemble aphids, undergo five instars over eight to nine days. Adults are two to

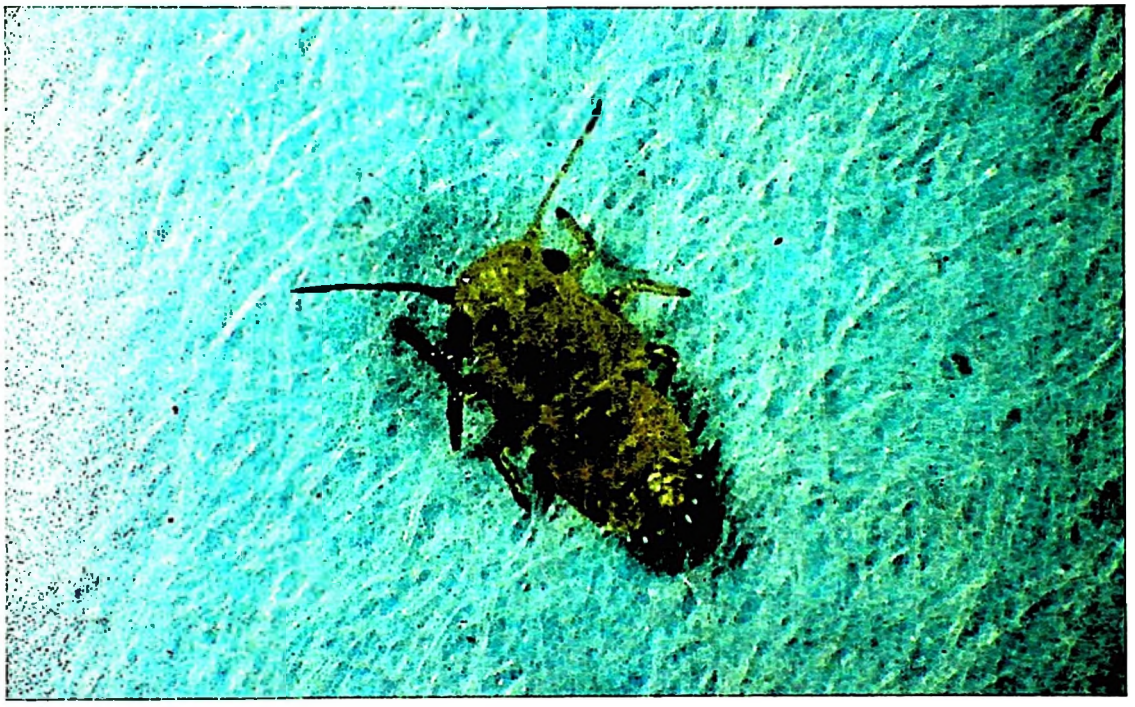

Plate 2: Leucaena psyllid (Heteropsylla cubana)

Plate 3: Leucaena leaves infested with psyllid insects

three times the size of the largest nymphal instar. Their reported color has ranged from green to brown to whitish, which gives it an appropriate comouflage to the plant. They use their stout legs to jump before taking flight when disturbed. Females begin laying eggs 1 to 3 days after becoming adults (NFTA, 1988). The leucaena psyllid has caused a severe damage to leucaena plants in tropical and subtropical areas outside their native range in the Americas since late 1982 (NFTA, 1988). They arrived in Hawaii in 1984 by wind or on aircrafts. By 1986, they were reported in Australia, the Pacific Islands and Southeast Asia (Thailand, Malaysia, Indonesia, Philippines). In 1987 they arrived in Sri Lanka, making their way to Burma, China and India in 1988. They had not landed on the African continent by then (NFTA, 1988), but was first reported in Mombasa, Kenya, in August, 1992 (Van Den Beldt and Napompeth, 1992) which simultaneously affected Tanzania via Tanga (Mulangila, R.C.T. personal communication, 1994). When in large numbers, psyllid can cause defoliation and death of the tree (Plate 4). The onset of psyllid infestation in a given location is characterized by a sudden and dramatic decline or dieback of the LL host. Typically this phase continues for about a full year, but amounts to a decline of the pest with time (Fig. 2). This could be attributed to the fact that during the rainy season the psyllid nymphs die, reducing the number of aphids. In Thailand the psyllid was first noticed at Chachoengsao in September 1986. Infestation was severe throughout the cool season, from November to

Plate 4: Leucaena plant dried up due to leaf defoliation caused by psyllid attack

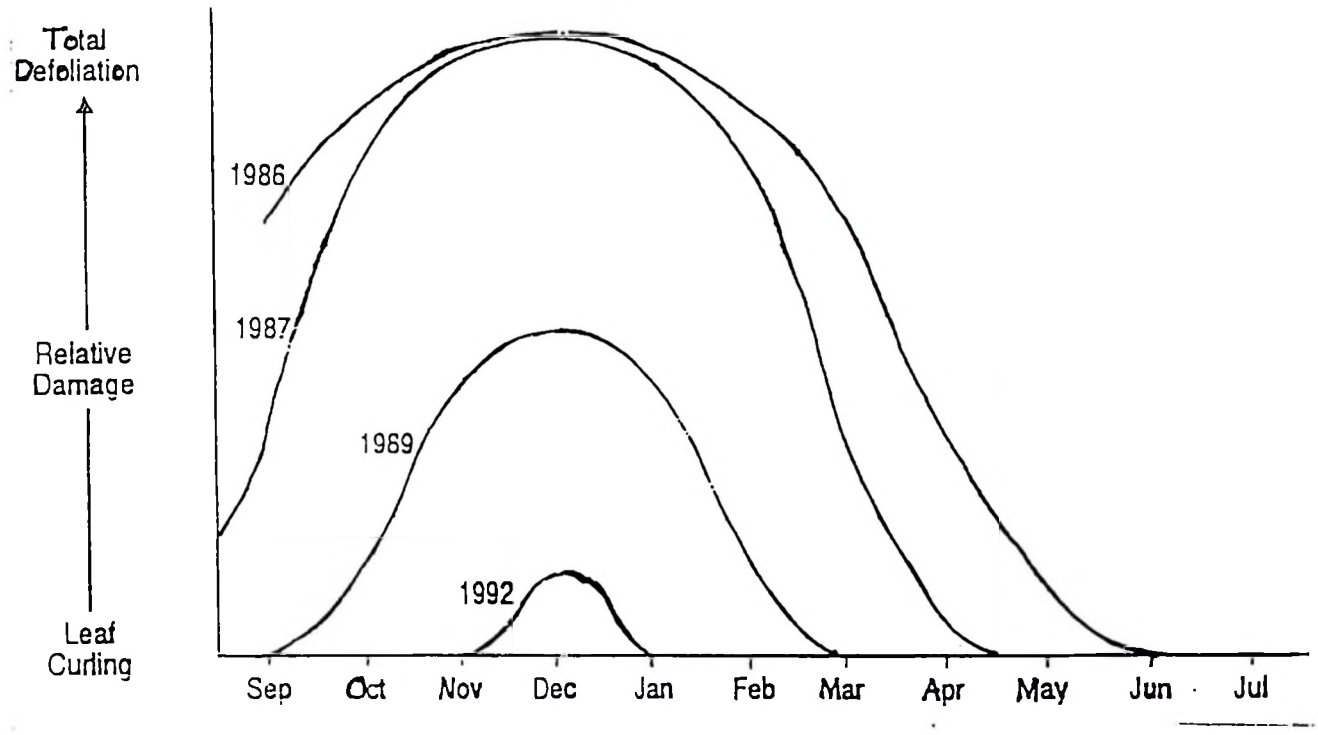

Figure 2. Schematic diagram of leucaena pysllid infestation in Thailand over six-year period (Source Van Den Beldt and Napompeth, 1992)

February, but by May 1987, at the start of the hot season, the pest had disappeared. Based on the Asian experience, Africa has a lot to learn as is suggested by Van den Beldt and Napompeth (1992). Experience in Australia has also shown that the psyllid is not a serious pest in subhumid regions (600–800 mm) and commercial plantings are still widespread (Wildin, 1993).

2.7 Overcoming the constraints of leucaena plant

The most successful method to overcome mimosine toxicity at present is that of inoculating a ruminant animal with the bacterial cultures obtained from ruminants that have the microbes (*Synergistes jonesii*) which degrade the 3,4, DHP in the rumen (Jones, 1994; Shelton and Jones, 1994). With increasing knowledge of the structure of antinutritive compounds and the likely degradation pathways it may be possible to genetically engineer bacteria with specific enzymes to detoxify chemical compounds (Jones, 1994). However, several other methods of detoxifying or reducing the mimosine are in existence and need to be practised in areas where the rumen microbes are not available. Detoxification *per–se* using chemicals or any form of biochemical process is rather expensive. The following cost–effective means of minimizing mimosine effect have been proposed ((Jones, 1994; Shelton and Jones, 1994):–

i) Breeding of varieties of leucaena low in mimosine. This is a long and complicated process (Shelton and Jones, 1994) and it has been found difficult to

combine high vigour with low mimosine content (Jones and Bray, 1982). For intance if leucaena is bred for low mimosine then the leaf yield becomes poor and vice versa (Jones, 1994).

ii) Pre-wilting of the leaf material and leaching with flowing water. Protein content of the leaf is only slightly affected by this method (Szyszka *et al.* 1983). Although boiled water has been tried on fresh leucaena (Lowry *et al.*1983), it was envisaged that the remaining DHP factor would have deleterious effects, chiefly by reducing intake (Tangendjaja *et al.* 1984).

iii) Addition of metal ions and polyethylene glycol (PEG) to diets containing leucaena leaf meal (LLM) have been found to bind mimosine and protect the intestinal walls of the animal from being eroded (Acamovic and D'mello, 1981).

iv) Ensiling leucaena will reduce mimosine concentration (Lyon, 1985; Shelton and Jones, 1994). The use of *Synergistes jonesii*, though not yet tested may be incoporated during ensiling to degrade the DHP (Shelton and Jones, 1994).

The best and less costly measures that have been taken against the leucaena psyllid are selection and use of other accessions of leucaena plant. In other parts of the world like Asia and Australia other accessions resistant to the pest such as K 636, *Leucaena pallida*, *Leucaena diversifolia*, *Leucaena collinsii* and *Leucaena esculenta*

have been propagated (Shelton and Jones, 1994). Secondly use of other alternative multipurpose species like Acacia tortilis, Albizia lebbek, Tamarindus indica, Gliricidia sepium and Sesbania species. In Kenya, the *Leucaena revoluta* (Plate 5) has proved resistance to the psyllid attack.

2.8 Rumen environment

Feed proteins are digested in the rumen to provide for microbial protein synthesis (Norton, 1994). The microbial population in the rumen requires a minimum level of ammonia of 50 – 70 mg N/l to support optimum activity. Levels less than these are indicative of nitrogen (N) deficiency (Preston, 1982; Barry and Manley, 1984; Norton, 1994). This is found in some grasses containing less than 6% protein. Microbial activity in rumen with such low proteins diets is depressed by lack of sufficient nitrogen (Milford and Minson, 1966). Since most browse species provide protein levels higher than 6%, they may be considered adequate in protein. Leucaena supplementation to poor quality roughages has been found to increase rumen ammonia concentration, stimulate microbial synthesis in the rumen (1.6 to 2.9 g/d) and increase the amount of plant protein available for absorption (Norton, 1994). He further found that protein degradability of leucaena were approximately 66% for fresh and 40% for dried. Degradation of dietary protein contributes significantly to the ruminal NH_3 pool.

Plate 5: Leucaena revoluta has proved resistance to leucaena psyllid (Kenya)

It is thus essential that degradability of feed proteins be known to meet the animal's protein requirements efficiently and economically (Poos–Floyd *et al.* 1985).

AAT–PBV (amount of amino acids truly absorbed in the small intestine and the protein balance in the rumen respectively) system developed by the Nordic countries (Madsen, 1985; NKJ protein group, 1985) has become a useful tool for protein evaluation in ruminants. AAT is important for the animal's body while PBV is important for the microorganisms. Reported production experiments for cows and goats indicate that the new system gives better prediction of the milk production than the digestible crude protein system (NKJ protein group, 1985).

The energy available to the micro–organisms in the rumen is obtained anaerobically, and their end products are the VFAs. (Preston and Leng, 1987). The latter are absorbed directly from the rumen into the host animal's portal system and serve as a major source of energy while undergoing further, oxidative, degradation. Considerable research has been conducted to study the dietary factors which influence the volatile fatty acids (VFAs), resulting from ruminal fermentation (Ørskov and Oltjen, 1993; Hume, 1970; Sutton and Morant, 1978; Van Soest, 1983; Nolan *et al.* 1986; Leng, 1987; Bergman, 1990; Flachowsky and Tiroke, 1993; Khorasani *et al.* 1993).

VFAs are produced along with small amounts of other organic compounds, such as

methane, carbon dioxide, lactate and alcohol. VFAs are produced in several parts of the gastrointestinal tract of ruminants through the processes of microbial fermentation. Acetic, propionic and butyric acids are the predominant VFAs and are produced mainly from the fermentation of plant materials, such as cell walls, starches and sugars. The branched – chain VFAs are reported to be essential for some cellulolytic rumen bacteria and which in turn influence feed intake (Ørskov and Oltjen, 1993). Because ruminants do not produce enzymes that are able to split long–chain structural carbohydrates, microbial fermentation is of great advantage to the body. The concentration of VFA in the rumen are highly variable, but the total amounts usually range between 60 and 150 mM (Bergman, 1990). Exceptionally high values (200 mM) may occur when animals graze on fresh grass or when offered starch rich diets (Bergman, 1990). Commonly, molar ratios of acetate to propionate to butyrate are found to vary from 75:15:12 to 40:40:20 (Bath *et al.* 1978; Preston and Leng, 1987; Bergman, 1990; Ørskov and Ryle, 1990). VFAs are absorbed from the rumen in proportion to their molar proportions in rumen liquor (Leng, 1970 cited by Nolan *et al.* 1986) which are typically 70:20:10 for animals on roughage–based diets, and 60:30:10 for animals on concentrate diets (Nolan *et al.* 1986). The proportion produced is affected by pH indirectly via the diet consumed by the host (Ørskov *et al.* 1974; Mould and Ørskov, 1984), and the status of the methanogenic population in the rumen (Van Soest, 1987). Overall, VFA production represents nearly 75% of the energy content of the carbohyrate; the remaining 25% is used by the microbes for growth or lost as hydrogen and methane (Bergman, 1990; Ørskov and Ryle, 1990). The fermentation of carbohyrate is by far the most important

source of energy for the rumen anaerobes and fulfill important biosynthetic functions in ruminants (Bondi, 1987). The capture of carbohydrate energy into metabolites useful to the host animal is much greater when propionic acid is produced compared to acetic acid. The generation of methane – a waste product is greatest when acetic acid is formed (Bergman, 1990; Ørskov and Ryle, 1990).

Production rates of VFAs vary diurnally as a consequence of eating patterns. The pattern following a meal shows a rise of VFAs and a drop in pH, followed by a slow recovery to original conditions (Ørskov and Ryle, 1990). This is because when a ruminant animal is fed there is an extensive fermentation of carbohydrates in the rumen resulting in production of acetate, propionate and butyrate (VFAs) as the main products (Hvelplund, 1990). A rise in VFAs may induce slight increase in acidity, especially when the diet comprises a higher proportion of concentrate in relation to forage and this in turn depresses pH. The pH is usually in the range of 5.8–6.8, but a rapid fermentation can lower the pH to <5.0. When recovery of pH is delayed, growth of organisms that produce both propionate and lactate is encouraged (Bergman, 1990). Peak of fermentation is at about 4h after feeding on hay diet, but occurs sooner with concentrate based diets. The maximum quantity of cellulose digested for a meal occurs between 6 and 18h after ingestion, depending on the rate of digestion and rate of passage (Ørskov and Ryle, 1990; Hvelplund and Madsen, 1990).

Rations that contain high proportions of forages and other roughage–type feeds favour the production of acetate in the rumen. Generally in all mammals, irrespective of species differences, acetate is used principally by peripheral tissues, especially fat and muscle (Bergman, 1990). Acetate contributes greatly to the synthesis of milk. When the percentage of propionate is increased relative to the other fatty acids, a depression in the percentage of milk fat often occurs, accompanied by an increase in body weight as a result of the deposition of fat in the ruminant (Bath *et al.*1978; Van Soest, 1983). The preferred pathway for synthesis of milk fat within the mammary cell uses B–hydroxybutyrate as the primer, which is converted back to the 4 – carbon VFA butyrate, and by successive addition of 2 – carbon units it forms the SCFA of various lengths (Bath *et al.* 1978 and Bergman, 1990). The conversion of butyrate to acetate seems to be advantageous for microbial metabolism, since there is a net gain of ATP (Bergman, 1990).

2.9 Nutrient requirements of dairy goats

The daily nutritional requirements of growing and lactating dairy goats are presented in Table 2.8.

Table 2.8: Nutrient requirement for maintanance, growth and lactation of dairy goats

Body weight	Metabolizable Energy (MJ)	Total Protein (g)	Ca (g)	P (g)	Vitamin A (1000 I.U.)	Vitamin D (I.U.)
10	2.38	22	1	0.7	0.4	84
20	4.02	38	1	0.7	0.7	144
30	5.44	51	2	1.4	0.9	195
40	6.74	63	2	1.4	1.2	243
50	7.99	75	3	2.1	1.4	285
Additional requirement for growth - weight gain at 50 g /d						
	1.51	10	1	0.7	0.3	54
Additional requirement for growth - weight gain at 100 g/d						
	3.01	20	1	0.7	0.5	108
Additional requirements for milk production per kg at different fat percent						
(% Fat)						
2.5	5.02	59	2	1.4	3.8	760
3.0	5.06	64	2	1.4	3.8	760
3.5	5.15	68	2	1.4	3.8	760
4.0	5.23	72	3	2.1	3.8	760
4.5	5.27	77	3	2.1	3.8	760
5.0	5.36	82	3	2.1	3.8	760

Source: NRC (1989)

2.9.1 Energy and protein requirement of dairy goats

The energy and protein requirements of goats are affected by age, body size, pregnancy, lactation, and milk composition. Quantitatively, energy is the most important item in an animal's diet (Kearl, 1982). The energy requirement for milk production is based on the energy content of milk which is approximately about 186.4 kJ/kg for milk with a fat content of 4%. The efficiency of metabolizable energy (ME) for lactation is around 70% which are similar to cows (Devendra and McLeroy, 1987). Limitations in energy intake can occur from inadequate feed intake, low quality of the diet and from forages with high water content. Energy requirement for weight gain is on the average 7.25 kcal ME/g of gain (NRC, 1989).

Protein accretion has priority over fat deposition in general, and more so in growing animals with high protein requirement (Hadjipanayiotou *et al.* 1991). Performance may be inhibited by the absence of adequate dietary amino acid and uptake of amino acids by the host animal. When fed in excess of the animals' needs, however, protein can have a negative effect in that the host's DMI decreases (Bruce, 1989). On the other hand metabolizable energy of a food will vary according to whether the amino acids it supplies are retained by the animal for protein synthesis, or are deaminated and their nitrogen excreted in the urine as urea. If some amino acids have to be synthesized while others undergo deamination, efficiency will be considerably less and the observed efficiency of protein synthesis is generally much lower than the observed effiency of fat synthesis (McDonald *et al.* 1991) Protein

can also be fed to goats as non-protein nitrogen (NPN) due to the ability of the rumen microflora to synthesize required amino acids for the host.

2.9.2 Mineral

Requirements of minerals are important in that they give rigidity and strength to the skeletal structures as constituents of the bones and teeth, organic compounds like proteins and lipids that make up the muscles, organs, blood cells and other soft tissues in the animal's body. They are significant in enzyme activation and serve various functions as soluble salts in the body (Maynard *et al.* 1984). It was reported that a lactating goat yielding 600 kg milk per year excreted in the milk twice the quantity of minerals in her body (Morand-Fehr, 1981).

In addition to the elements in organic matter (oxygen, nitrogen, carbon and hydrogen) seven major and nine minor minerals are considered dietary essentials for livestock (NRC, 1989). The major minerals that must be fed in relatively large amounts are calcium, phosphorus, sodium, chlorine, magnesium, potassium and sulfur. Minor or trace minerals, required in small amounts, include iron, iodine, copper, molybdenum, zinc, manganese, cobalt, selenium and fluorine. Most of these minerals occur naturally in feedstuffs (NRC, 1989).

2.9.3 Vitamin

Pasture and range plants usually contain adequate levels of vitamins to maintain healthy animals (Kearl, 1982). Pen–fed goats and high producing animals may need supplemental vitamin supply. The aim for grazing goats to search out for palatable green parts is to meet their requirement in vitamin A. Deficiencies of vitamins D, E and K are rare in adult animals (Maynard *et al.*, 1984). Some of the vitamins such as vitamins B and C are not dietically essential for adult goats as these are synthesised by microorganisms.

2.9.4 Water

In the tropics goats are adapted to water shortages; they have often low turnover rates and the ability to resist desiccation (Devendra and McLeroy, 1987). Factors affecting free water intake include lactation level, environmental temperature, water content of forage consumed, feed quality, and activity of the animal.

It has been suggested (NRC, 1989) that 3.5 kg of water is consumed for each kilogram of milk produced by dairy goats under temperate conditions. French recommendations are 145.6 g water per W $kg^{0.75}$ for maintanance and 1.43 kg water per kilogram of milk as a production requirement (NRC, 1989). Increased water intake can accelerate the rate of food passage through the gastro–intestinal tract. It dilutes the rumen contents including the rumen microorganisms (Kearl, 1982). This

effect can hinder or greatly reduce the time required for optimum substrate – enzyme contact, thus reducing the digestibility of crude fibre protein and other nutrients.

2.10 Performance of ruminants fed *Leucaena leucocephala* as a supplement.

2.10.1 Effect of leucaena inclusion on feed intake, feed efficiency and growth rate

There appears to be little work done on leucaena intake in lactating goats (Kishore *et al.* 1989; Richards *et al.* 1994ab) compared to meat goats (Jotee, 1984; Banda and Ayaode, 1986; Eys *et al.* 1986; Adejumo, 1987; Ademosun *et al.*, 1988; Reynolds, 1989; Vadiveloo, 1989; Mtenga and Shoo, 1990; Girdhar *et al.* 1991).

Comprehensive studies have been carried out using cattle and sheep, with enough data to quantify on this subject (Henke and Work, 1940; Alvarez *et al.*, 1975; Jones *et al.* 1976; Jones, 1979; Saudeco *et al.* 1980; Holmes 1981; Teeluck *et al.* 1981; Jones and Megarrity, 1983; Reynolds, 1989; Pound and Martinez, 1983; Reddy *et al.* 1989; Lemma, 1992 and Muinga *et al.* 1992). Saudeco *et al.* (1980) recorded higher liveweight gains from cows and calves grazing the grass pasture supplemented with leucaena. However, other studies have found insignificant differences in relation to both digestiblity and degradability of leguminous plants when fed to

digestiblity and degradability of leguminous plants when fed to cattle, sheep and goats (Tisserand *et al.* 1991).

2.10.2 Effect of leucaena on milk production and weight gain

The effect of feeding sababul hay (*Leucaena leucocephala*) on the milk production and its composition in goats, was carried out in India (Kishore *et al.* 1989). In this experiment a concentrate mixture (T1; wheat bran/groundnut cake/gram husk 45:40:12) was replaced at 50 (T2) and 100% (T3) levels with sababul hay (leaves + soft twigs) for the formulation of 3 isonitrogenous feeds for 18 lactating goats; gram straw was offered *ad–lib*. Milk yield, milk fat, protein, total solids and solids–not–fat contents did not differ significantly in both the trials. The findings suggested the possibility of economical raising of lactating goats in their last stage of lactation on sababul as protein source, supplemented with gram straw. For goats in early lactation, 50% replacement of concentrate mixture with sababul hay could be considered (Kishore *et al.* 1989). The results of experiments where lucaena has been fed to dairy cows are summarized in Table 2.9. The average increase of milk obtained from feeding leucaena was 14% (range of 2–33%). There was usually an increase in fat and protein percent of milk as well. Milera and Santana (1989) found that the main advantage of leucaena was in the reduction of concentrate fed to the animals. Saurez *et al.* (1987 cited by Jones, 1994) recorded a 33 percent increase in milk production from feeding leucaena, as compared with a 57 percent increase through feeding 6 kg of concentrate per cow per day.

Table 2.9.Increases in milk production achieved in experiments where leucaena was fed as a supplement to pure grass pastures

Grass species	N rate (kg/ha/yr)	Increase in milk production %	Experimental details
Cynodon plectostachyus	200	2	3-4 hr. leucaena grazing
Chloris gayana	115	7	leucaena fed in pens
Panicum maximum	150	12	Morning grazing of leucaena
Cynodon dactylon	-	16	6 hr. leucaena grazing
Digitaria decumbens	239	33	2 hr. leucaena grazing

Source: Jones (1994).

When the intake of leucaena was measured it was less than 0.82 kg DM/ cow/day (Jones, 1994). Reddy *et al.* (1989) reported that DM intake and average daily weight gain were higher when subabul leaves together with ground maize were supplemented to chopped elephant grass and fed to weaned lambs. Feed conversion efficiency and digestibility of nitrogen-free extract were better in supplemented than unsupplemented treatments.

It is evident that when cattle consumed more than 60% leucaena they started loosing weight from 590 to 310g over a period of ten weeks (Table 2.10). Best performances observed for all animals, irrespective of the basal roughages offered was at 60% level of leucaena supplementation. Other researchers (Plucknet, 1970 and Stobbs, 1972) have summarised reports on milk yields from cows whose grazing or main feed supply was confined to leucaena/grass pastures or to straight leucaena pasture. Stobbs (1972) reported 6300 kg of milk and 272 kg fat per hectare from Jersey cows grazing a leucaena/green panic (*Panicum maximum*) pasture. In Hawaii, Plucknett (1970) reported that Friesian cows grazing leucaena/guinea grass pastures, with supplement but with leucaena pastures as the main feed, produced 9780 kg milk/ha. Henke and Morita (1954) reported production of 5130 kg of milk per cow on a 305 day lactation basis, from cows that were fed an average of 28.5 kg fresh leucaena a day with an additional low protein supplement. Henke (1958) compared the financial returns from milk yield of cows fed leucaena or nitrogen fertilized elephant grass, where the leucaena was not grazed but 'cut and carried'. Benefits from feeding leucaena have been obtained where

Table 2.10. The effect of increasing levels of *Leucaena leucocephala* (LL) on digestibility and weight gain in cattle, sheep and goats.

Animal species	Basal diet	LL level DM%	Intake g/kg$W^{0.75}$	Diet DMD%	Weight change (g)	Reference
Cattle	Natural	0.0	20.2	42.0	-20.0	Wahyuni *et al.*
	grass	20.0	26.1	44.0	290.0	1982
		40.0	28.8	46.0	540.0	(Indonesia)
		60.0	28.8	44.0	590.0	
		100.0	22.0	51.0	310.0	
Goats	Maize stover	0.0	10.3	46.0	-	Banda and
		35.0	15.8	51.0	-	Ayoade 1986
		51.0	20.8	48.0	-	(Malawi)
		59.0	21.5	54.0	-	
Goats	Rhodes grass	0.0	15.0	55.0	20.0	
		25.0	17.3	56.7	23.0	
		40.0	21.0	55.5	29.0	
		60.0	21.0	66.1	30.0	
Sheep	Poor hay	0.0	-	-	-9.0	ILCA (1987)
		15.0	-	-	15.0	(Ethiopia)
		27.0	-	-	37.0	
		45.0	-	-	53.0	
		59.0	-	-	65.0	

protein levels of the grass have been around 18 percent (Flores *et al.* 1979). Flores *et al.*(1979) attributed this to the fact that protein in leucaena is to some extent protected against degradation in the rumen. Hence the benefits of feeding leucaena are, in part, similar to those which can be achieved from feeding protected protein such as formaldehyde–casein. Moreover, supplementation with leucaena provide higher intake of digestible energy when fed together with other undegradable protein, such as cotton seed cake (Flores *et al.* 1979: Muinga, 1993, Getachew *et al.* 1994).

In Kenya Muinga *et al.*(1992) carried out a study to evaluate dairy cow performance from an alley cropping system, where elephant grass was intercropped with *Leucaena leucocephala*. Supplementation with leucaena significantly increased total daily DM intake (7.8, 9.3 and 10.4 kg), reduced daily live–weight loss (560, 235 and 174g), and increased daily milk yield (7.3, 7.7 and 8.3 kg). Their results showed that reasonable dairy performance in the tropics could be achieved by supplementing an elephant fodder basal diet with leucaena forage, and highlighted the importance of the stage of harvesting of the elephant grass.

In the same experiment some fistulated steers were offered *ad libitum* elephant grass alone (N) or supplemented on dry matter basis with 1kg leucaena (LL), 2kg leucaena (HL) or 2kg leucaena and 1kg maize bran (LM) (Muinga, 1993). The rumen ammonia concentrations tended to increase on supplementation (152, 181, 202 and 252 mg/l, for

N, LL, HL and LM respectively). Feeding maize bran increased the molar proportion of butyrate, reduced acetate and tended to increase proprionate in the rumen. Muinga (1993) concluded that supplementing elephant grass basal diet with leucaena forage was effective in increasing milk yield of crossbred cows. She found that feeding 1kg maize bran in addition to 2kg leucaena increased milk yield significantly, but leucaena alone had no significant effect.

2.10.3 Leucaena supplementation on crop residues and other poor quality roughages

Crop residues or by-products represent an abundant, but underutilized feed resource. They are a part of several non-conventional feed resources whose characteristics have aroused immense research interests over the last six decades (Sundstøl *et al.* 1978; Preston and Leng, 1987; Ndlovu and Manyame, 1989). The by-products are end products that have not been used, recycled or salvaged. Often the cost of collection and transformation for use of crop residues is higher than the value of conventional feedstuffs and consequently they are discarded as waste. Most crop by-products are bulky, of poor quality, biochemically low in protein, vitamins and minerals (Schiere and Ibrahim, 1989). As sole feed for ruminants they are limited by their severe nutritional deficiencies and by having high lignocellulose contents, which lead to low digestibility and voluntary intakes (Said and Wanyoike, 1987; Oji *et al.* 1977). In order to improve their digestibility, chemicals such as urea, ammonia biuret including strong alkalis such as sodium hydroxide (NaOH) and

calcium hydroxide (CaOH) to remove the crusting substances (Cellulose, hemicellulose and lignin) have been employed (Sundstøl, 1983/84; Wanapat *et al.* 1985). Soaking in water is common in some places (Ndlovu and Manyame, 1989). Other techniques would be physical, for instance chopping and grinding. Biological methods have also been advocated (Schiere and Ibrahim, 1989). The crop residues and agro-industrial by- products may however; complement well with tree forages (Preston and Leng, 1987), which are increasingly becoming important as protein supplements to crop redidues, particularly during the dry season.

Animals on fibre-based diets appear to utilize absorbed nutrients, such as acetate and amino acids, less efficiently than animals given concentrates (Nolan *et al.* 1986). Less glucogenic precursors, such as propionate, starch and amino acids, are available to these animals so they may not synthesize adequate amounts of glucose. This leads to reduced NADPH (nicotinamide - adenine dinucleotide phosphate) that enables acetate to be converted to LCFAs and fat; their inability to clear acetate may lead to an increase in blood acetate concentration that could inhibit feed intake. Growing animals are known to have a very high requirement for amino acids for tissue synthesis and glucose for oxidation in specific tissue such as brain. In addition, considerable amounts of glucose must be oxidized to provide the NADPH required to synthesize fat from acetate (Preston, 1986). It is imperative to recognize that high growth rates cannot be supported on the products of fermentative digestion and that bypass protein supplements are essential to take advantage of the VFA energy absorbed.

It has been reported that the nutrient content and digestibility of maize stover is generally higher than that of many straws and that it can be used successfully with minimum supplementation to maintain pregnant cows (Sundstøl, 1988; Dias-da-Silva *et al.* 1988). It is a common practice, in tropical farms for livestock to be herded into crop fields (*in situ*) to graze the stubble of various cereal crop such as maize, millet, sorghum, paddy and others (Table 2.11). Sisal waste (not listed) also accounts for a large crop residue in Tanzania (Gohl, 1981 and Biwi, 1984).

Table 2.11: Field crop residues estimated annually in tons

Principal crop	Farmed area (ha)	Field residue	Estimated amount produced
Maize	1 626 460	Maize stover	813 230
Sorghum	416 380	Sorghum	104 095
Paddy	351 190	Rice straw	351 190
Millet	308 170	Millet stover	154 085
Wheat	56 880	Wheat straw	28 440
Cassava	21 900	Cassava leaves	21 900
Sweet potatoes	191 840	Vines	383 680
Pubes	545 420	Straw	272 710

Source: MALD (1990).

Annual and perennial crops in Tanzania generate large quantities of residues (Table 2.11) and their importance is immense.

It has been observed elsewhere that when an ammonia treated straw is properly supplemented, it can be fed to beef cattle as a sole source of roughage (Urio, 1981). Ammonia treated straw, when supplemented with some amounts of concentrates, minerals and vitamins, can support an average growth rate of 400g/d for growing steers (Sundstøl, 1983/84).

In a study where maize stover and *Hyparrhenia rufa* grass were treated with levels of Na_2CO_3 ranging from 0 to 10g/100g of roughage DM, *Hyparrhenia rufa* grass responded comparatively better to the chemical treatment than maize stover (Urio, 1981). According to Urio (1981) however, addition of herring meal resulted in a marked improvement in the digestibility of both roughages. This is in consistency with the findings of Madsen (1985) that fishmeal provides rumen undegradable dietary protein which increases the amount of total amino acid (AAT) that is absorbed in the small intestine. A higher response in IVOMD was observed for the maize stover than for *Hyparrhenia rufa* grass after the addition of the herring meal (Urio, 1981).

In Malawi, Banda and Ayoade (1986) supplemented leucaena leaf hay to goats fed chopped maize stover. With increasing levels of leucaena hay supplementation, daily water intake, total dry matter and daily crude protein intake increased, whilst daily dry

matter intake from maize stover was significantly decreased. Similarly Mtenga and Shoo (1990) reported an increase on water intake (expressed as g/day, and % of liveweight) with increasing levels of leucaena in the diet. However, when water was expressed as g/kg DM intake, differences were nonsignificant.

Cochran *et al.* (1984) conducted an experiment using 32 Peruvian male goats and randomized them among four diets containing 10, 20, 30, or 40% *Leucaena leucocephala* with the balance supplied by maize stover. In their finding, Cochran *et al.* (1984) reported that withering height was not influenced by treatment. A trend was however apparent in which height at the withers increased as the level of leucaena in the diet increased. Body length measurement were not significantly affected by levels of leucaena in the diet. These authors concluded that leucaena offered at levels of 30 to 40% may be of potential benefit to growing kids subsisting on low quality materials such as maize stover.

Kimambo *et al.* (1992) measured the effect of different levels of leucaena supplementation on the DM intake and degradation of maize stover and rumen ammonia concentration of sheep fed maize stover as a basal diet. They observed an increase in total DM intake, increase in rumen ammonia and DM degradability of maize stover with increasing level of leucaena from 0 to 6 g/kg liveweight per day of leucaena. The findings of this experiment supports the findings of Muinga (1993). At 48 hours incubation period OM and DM degradability differed significantly between

supplemented and unsupplemented rations. Norton (1994), reported that leucaena supplements at a rate of 0.6% liveweight (16% in DM) were effective in converting a weight loss to a significant weight gain in both sheep and cattle.

2.11 Studies involving cotton seed cake as protein supplement in ruminants

Cotton seed cake (meal) is a good protein supplement in combination with leucaena in ruminants' diets, but has the disadvantage of having a low content of cystine, methionine and lysine, the latter being the first limiting amino acid (McDonald *et al.* 1991). The calcium content is low (having the calcium to phosphorus ratio of about 1:6) and thus deficiencies of calcium may easily arise. It is a good source of thiamin, but is a poor source of carotene (McDonald *et al.* 1991). Since leucaena leaves are rich in carotene, vitamins and the minerals calcium and phosphorus, it may complement cotton seed cake when formulated together in rations (Ndemanisho *et al.* 1992). Addy and Thomas (1977) reported non–significant differences, between cotton seed cake and leucaena when they were fed with maize bran at the same levels of crude protein to beef cattle.

Decorticated cotton seed cake is lower in crude fibre content than undecorticated one and has an important effect in improving the apparent digestibility of the other constituents (McDonald *et al* 1991). Undecorticated cotton seed cake is only suitable for feeding adult ruminants. They are not produced nowadays due to poor economic returns.

Cotton seeds may contain from 0.3 to 20 g/kg DM of a yellow pigment known as gossypol. Gossypol is a polyphenolic aldehyde which is an antioxidant, a polymerisation inhibitor and toxic to simple–stomached animals. The general symptoms of gossypol toxity are depressed appetite and loss of weight; death usually results from circulatory failure (McDonald *et al*, 1991). The free gossypl content however, decreases during processing and varies according to the methods used. The limitations on effective utilization of cotton seed meal in rations for swine and poultry are of minor significance for ruminant animals (Göhl, 1981).

2.12 Feed evaluation techniques in relation to the present study

Effective feed evaluation systems are necessary for describing or predicting the performance of farm animals (Garnsworthy and Cole, 1990). These systems are always oriented on the energy and protein values of the feed (Bickel, 1988). Secondly, distinction between animal species and type of production have to be taken into consideration.

2.12.1 *In vitro* digestibility

Digestibility is commonly estimated by *in vitro* rumen systems that simulate the rumen environments outside the animal, in the laboratory (McDonald *et al*. 1991; Van Soest, 1983). The success of any rumen *in vitro* system depends on the degree to which it

reflects rumen events and the sequential processes of the ruminant digestive tract. These values may be used to rank feeds in quality but usually underestimate digestiblity *in vivo*. Although the *in vitro* rumen digestion technique (Tilley and Terry, 1963) has its shortcomings, it is still the most common procedure. Although the *in vitro* and *in vivo* techniques have managed to ease the work on evaluating feeds for ruminants, evaluation *in vivo* is still preferred for comparison purposes (Mehrez and Ørskov, 1977).

2.12.2 *In sacco* digestibility

The method *in sacco* technique involves putting raw materials in a polyester bag in the rumen of fistulated animals. The *in sacco* technique also referred to as *in situ* technique is because the test is conducted at the actual site of protein degradation, that is – in the retuculo – rumen. This method is efficient to predict both potential digestibility and rate of digestion, and it has been shown that voluntary feed intake can be explained from degradation profiles of dry matter or neutral detergent fibre (NDF) (Weisbjerg and Hvelplund, 1993). This method is given first priority for researchers as the most appropriate tool for providing information on the nutritive value of a feed for ruminants and the efficacy of the rumen ecosystem (Preston, 1986). However, the technique will depend on the ability of the relevant research stations to maintain fistulated animals. The method generates useful information from the point of view of both the carbohydrate and protein status of a feed; and the degree to which it will be digested in the rumen or escape to the intestine (Schneider and Flatt, 1975 and Ørskov, 1976).

The rate of breakdown of carbohydrates is an important determinant of voluntary intake in ruminants (Mehrez and Ørskov, 1977) and the degradation of protein in the rumen influences the protein supply for the host animal and the N available for the rumen micro-organisms (Mehrez and Ørskov, 1977). *In sacco* technique has been used with varying success over the past three decades due probably to rumen and feed variation in regard to different geographical location and season (Ørskov *et al.* 1990; Kibon and Ørskov, 1993). Possibility of applying it to determine protein degradability values for new protein system was recently identified by Mehrez and Ørskov (1977). The advantage of the technique, is that larger numbers of raw materials can be processed than with traditional *in vivo* methods (Wilson and Brigstocke, 1983) and it avoids the details of the *in vitro* technique (Preston, 1986). One disadvantage of *in sacco* digestibility may be that it has a tendency of overestimating the *in vivo* digestiblity values (Norton, 1994).

2.12.3 Summary of the evaluation techniques

In vitro, in sacco and *in vivo* values of leucaena are shown in Table 2.12. They are known to differ markedly between fresh and dry state (Norton, 1994). *In sacco* values are said to be underestimated by 2–7% due the presence of mimosine, reducing the activity of the cellulolytic bacteria (Pound and Martinez, 1983). The *in vitro* value was quite high and *in vivo* values as high as 71.4 have been recorded for goats (Pound and Martinez, 1983). The authors also recorded low value (54.8) of *in vivo* in cattle and this was attributed to the fact that the values were obtained when leucaena was given as part of a mixture, and the digetibility calculated by difference, whereas the highest value was obtained when goats were fed on sole diet of leucaena. The general degradability of fresh leaves has been recorded to range from 65.0 to 83.3 % and 54.8 to 82.1% for DM and N respectively (Norton, 1994), supporting the values shown in Table 2.12. The N and DM degradability of leucaena leaflets using nylon bag technique were 31 and 69% respectively, from the results obtained by Preston and Leng (1987). The DM degradability value obtained by Garcia *et al.* (1987) was 41.32%. Athough high degradability (> 78%) has been associated with non–tannin browses (Norton, 1994), leucaena with 3–5% tannins has shown moderate degradability (64–84%) suggesting that the high palatability and intakes of this plant could be overiding the amount of tannin contained in it (Norton, 1994). A study was carried out where shoots of *Leucaena leucocephala, Calliandra calothyrsus* and *Calliandra surinamensis* were incubated for12, 24, 36, and 48 h in nylon bags suspended in the rumen of a steer

Table 2.12. Some values for *in vitro, in sacco* and *in vivo* digestibility and voluntary feed intakes of ruminants given fresh *Leucaena leucocephala*

	Digestibility percent					
Animal	*In vitro*	*In sacco*		*In vivo*		Voluntary intake
species	DM	DM	N	DM	N	(g/kg LW)
Goats				68.0		35.6
Sheep				63.2		31.9
		82.1	83.3			
Goats		52.7				
	68.8					
Cattle				54.8	65.0	-

Source: Norton (1994)

(Jones *et al.* 1992). Leucaena had much faster rates of loss of NDF after 48 h than *C. surinamensis* (46.4 vs 10.3%). The authors concluded that *C. calothyrsus* and *C. surinamensis* may not be suitable alternatives to leucaena as a ruminant feed. These findings may not act as a guide to feed intake and contrasts Norton's (1994) view on browses' digestibility rates. Another degradation experiment carried out in Mpwapwa, Tanzania (Kabatange and Shayo, 1991) were in agreement with findings by Jones *et al.* (1992) experiment. After 24 hours incubation, more than 75% of the degradable fraction had been fermented in the supplemented diets, while only about 50% was degraded in the control diet. This implied faster rate of passage and hence more feed intake for the leucaena supplemented rations.

Since there are no known techniques which predicts palatability and intake, the overall nutritive value (voluntary feed intake x dry matter degradability) of browse species can only be accurately determined by feeding trials (Norton,1994). Feeding trials, have the added advantage of providing information on animal health and productivity.

Although there has been an extensive work on feeding of LL and cotton seed cake to ruminants, there is yet scanty information on feeding of these protein supplements to dairy goats in Tanzania. Dairy goats are being raised in some research institutions, and distributed extensively to farmers (Ministry of Agriculture, Livestock Development and Cooperatives, 1991). Good feed quality, especially protein supplement has been a major problem to these ruminants. Review of literature shows clearly that there is limited

information of LL as a feed supplement to lactating and growing dairy goats. Leucaena which grows well in nearly all parts of Tanzania was selected to try and replace the expensive cotton seed cake as protein supplement to dairy goats' diets. This study was therefore undertaken with the specific objectives as outlined in section 2.13.

2.13 Objectives of the study.

1. To find the effect of substituting dry LL for cotton seed cake as a source of nitrogen to diets fed to dairy goats on milk yield and growth of weaner goats.

2. To study the effect of supplementing fresh LL versus cotton seed cake as sources of nitrogen to diets fed to dairy goats on milk yield.

3. To determine the nutritional value of dry LL versus cotton seed cake as a supplement to feeds fed to the dairy goats, by estimating amino acid absoption in the small intestine and protein balance in the rumen (AAT –PBV).

4. To study the rumen environment of the goats fed the different diet combinations used in all these experiments.

5. To determine mimosine or 3–hydroxy–4(1H)–pyridone (DHP) contents of LL and of urine from goats fed different levels of LL leaves.

CHAPTER 3.0

MATERIALS AND METHODS

3.1 Milk production experiments

3.1.1 Introduction

Zero grazing is the most viable option for keeping dairy goats in high population density areas. It requires appropriate diet such as dairy meals to ensure adequate supply of nutrients. Conventional feed supplements are both expensive and scarce. LL can be a cheap alternative supplement to the oil cakes such as cotton seed, sunflower, kapok and groundnut cakes. But no information is available that explicitly specifies the safe level of LL inclusion in diets of lactating small ruminants. It is imperative that studies are made to establish suitable and safe levels of inclusion of LL in dairy diets.

Three lactation experiments were therefore set up to establish an appropriate feeding level of LL to dairy goats and recommend such safe and productive level to goat keepers. LL was fed so as to substitute cotton seed cake in four different treatments. Both were dietary sources of nitrogen which were aimed at creating an optimum rumen environment, enabling a better qualitative comparison of their supplementary effect.

Experiments 1 and 2 were set up for the dry LL with two different roughages, namely, elephant grass (*Pennisetum purpureum*) and Rhodes grass (*Chloris gayana*) hay while in experiment 3 the lactating goats were fed different levels of fresh LL with one type of roughage, *Hyparrhenia rufa* grass hay.

Degradability, rumen environment and *in vitro* digestibility experiments were carried out to elucidate further on the findings from Experiments 1 to 3.

3.1.2 Materials and methods common to all milk production experiments

3.1.2.1 Research site

The research work was conducted at Magadu Research Unit (MRU) of Department of Animal Science and Production (DASP) of Sokoine University of Agriculture (SUA) Morogoro. MRU is situated at an altitude of 526m above sea level and 6^0 50'S, 37^0 38'E.

3.1.2.2 Source of experimental animals and management

Between 1983 and 1984, 63 goat kids of the breed Norwegian Landrace were imported from Norway to SUA. The main purpose of importing goats was to crossbreed between Tanzanian and Norwegian goats, to produce cross-breds with ability to produce both milk and meat under the Tanzanian conditions. The experimental animals were selected from

this herd.

A total of 110 lactating Norwegian x Upgraded (crosses of Saanen, Boer, Kamorai and Tanzanian Small East African small types) Tanzanian goats were used in lactation experiments (Experiments 1 to 3). The does had mean average initial weight of 33.3±1.30 kg. The animals were bred in January/February and the experiments started in June/July of every year (for 5 years) when the females kidded.

The does were weighed fourtnightly (weekly for Experiment 3) during the experiment, with a weighing cradle after overnight fasting. That is they were not allowed access to water or any feed before weighing, and each goat was weighed individually.

3.1.2.3 Experimental design and treatments

The experiments were carried out over five different years, that is in 1986, 1987, 1990, 1991 and 1992. The does were assigned to their appropriate treatments by allocating them randomly to the four pens as they kidded. Replication of the treatments was not carried due to lack of adequate number of animals in all the experiments. In all the three experiments(1 to 3) feeding regimes were carried out involving 4 treatment diets (Tables 3.1, 3.2, 3.3, and 3.4). The selected does were all stall fed to facilitate recording of feed intake.

In Experiments 1 and 2, the experimental animals were initially subjected to a preliminary period of 4 weeks in which the animals received similar diet; followed by experimental period of 8 weeks in which the animals received the experimental diet. The four weeks were used so as to adjust the animals to their new environment of confinement, and to new feeds.

In Experiment 3, the animals were initially subjected to a preliminary period of 2 weeks (offered same diet) followed by experimental period of 6 weeks (offered experimental diet). Experiment 3 took shorter time than Experiments 1 and 2 due to shortage of the purchased roughage materials.

Table 3.1 Layout of the milk production Experiments 1 to 3

T[2]	Expt	No of animals	Basal diet *ad-lib*	Supplementary[1]: *Leucaena leucoc ephala* (%)	Cotton seed cake (%)	Maize bran/ Maize meal (%)
1	1A	4	*Pennisetum*	0	36.5	60.2
2		4	*purpureum*	19.9	22.2	55.0
3		4	(PP) grass	36.6	10.2	50.5
4		4		50.8	0	46.7
1	1B	3	PP grass	0	36.5	60.2
2		3		19.9	22.2	55.0
3		3		36.6	10.2	50.5
4		3		50.8	0	46.7
1	2A	7	*Chloris*	0	33.0	64.0
2		7	*gayana*(CG)	18.1	20.2	59.0
3		6	hay	34.0	9.4	54.6
4		6		46.9	0	50.8
1	2B	7	CG hay	0	33.0	64.0
2		7		18.1	20.2	59.0
3		7		34.0	9.4	54.6
4		7		46.9	0	50.8
1	3	7	*Hyparrhenia*	0	0	96.0
2		7	*rufa*(HR)	0	31.5	65.5
3		7	hay	13.4	0	82.9
4		7		27.9	0	69.0

[1]Compounded supplementary diet were based on percent of DM in concentrate. The diets, were formulated according to dairy goats' requirements using the NRC tables (NRC, 1989).

[2] Treatment

3.1.2.4 Management before the experiment

One week before the commencement of each of the experiments, all the goats were dewormed with either Fenbendazole™ (Experiments 1A and 1B) or parasitol™ injection (Experiments 2A and 2B) or seponver™ boluses (Experiment 3) depending on the availability and the effectiveness of the drug from the SUA Veterinary Clinic.

Ticks, lice and other external parasites were controlled by hand spraying Toxaphane™ acaricide. Floors, pens, feed troughs and feeding containers were thoroughly scrubbed with water and a disinfectant. These activities were done around the same time as for deworming.

3.1.2.5 Feeds and feeding

Maize bran (MB) was purchased from National Milling Company (NMC), at Mzizima branch in Dar es Salaam.

Leucaena was harvested at podding stage from Magadu plots (SUA) dried on a concrete floor under the sun for two days, threshed to separate leaves from the twigs. The dried leaves with pods, and some flowers were put into dry sacks (Plate 6) and stored in a dry place ready for feeding. Cotton seed cake was purchased from Morogoro Oil Producing

Plate 6: Dried leucaena leaves kept into dry sacks ready for storing

Company (MOPROCO). It was ground with a tractor mounted mill, bagged ready for being compounded with other feeds. Mineral mixture, Maclik Super™ was purchased from Tanzania Farmers Association (TFA) in Arusha or Dar es Salaam. Mineral mixture were given at the rate of 25g per animal per day and had the following composition (g/kg):-

CaO, 286; P_2O_5, 275; NaCl, 261; Ca/P ratio, 1.7:1; Ca, 205; P, 120; Na, 103; Cl, 158; Mg, 20; Cu, 2; Co, 0.2; Fe, 5; K, 0.06; I, 0.2; Zn, 5; Mn, 4; S, 3; Se, 0.01.

The diet mixtures were compounded every two weeks and stored in 300 l clean, plastic containers and covered with lids. The formulated diets (calculated in g/animal/d) were isonitrogenous (except in experiment 3).

Feeding of the animals was done in two periods (Preliminary and Experimental) as explained under materials and methods specific to each experiment. Concentrates including dry leucaena leaves (Plate 7) were weighed and individually fed while roughages were group fed. Concentrate feeds were offered to the animals twice a day in two equal quantities during milking times at 0700 and 1630h. Roughages and fresh water were given *ad-libitum* to the animals.

3.1.2.6 Feed offered

Feed intake (difference between feed offered and refusal) of the animals was recorded

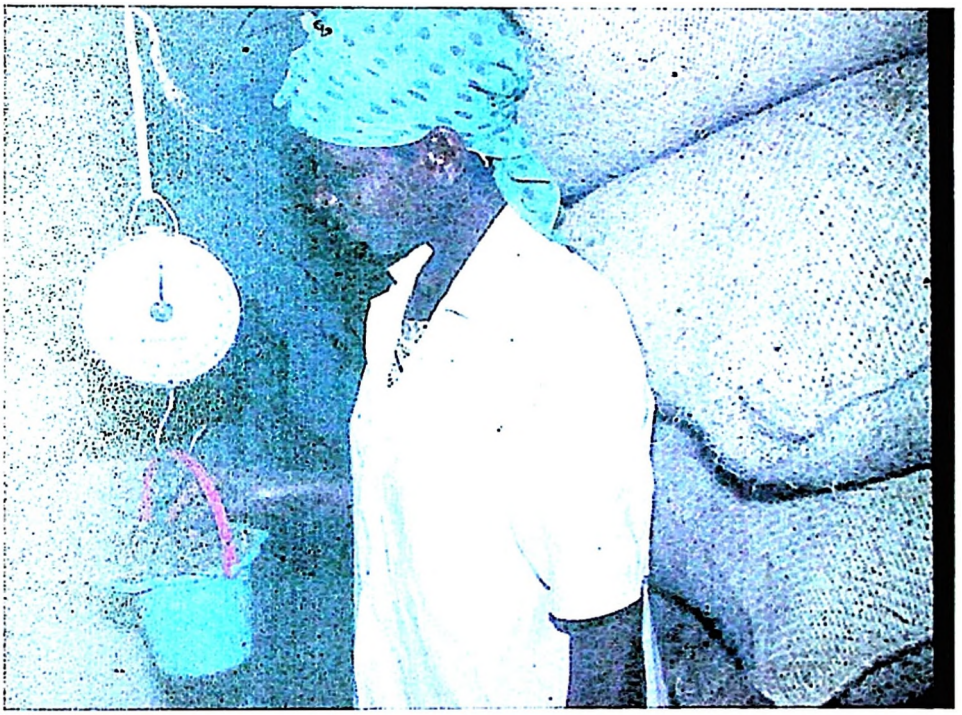

Plate 7: Dry leucaena leaves being weighed ready for feeding

daily. There were no refusals from the concentrate offered neither during the preliminary nor during the experimental periods for Experiments 1 to 3. However, there were some refusals from the roughage materials offered and these were recorded daily in the mornings before next feeding.

3.1.2.7 Milking and milk sampling

The does were hand milked every morning and evening in their pens and milk produced recorded in litres (Plates 8 and 9). A day's sample of milk was taken in the morning and evening (100 ml each) for two consecutive days on Tuesday and Wednesday of every week. The sample was preserved with potassium dichromate and stored in stoppered sample bottles (Plate 10) and sent to the dairy laboratory for analysis. Fat content analysis was done before the rest of the milk was deepfrozen in tightly capped plastic bottles. Later on the milk was thawed in water bath with constant temperature of 40^{0}C; thereafter chemically analysed for crude protein and mineral content.

3.1.2.8 Chemical analysis

All chemical analyses were carried out at the DASP laboratory unit, SUA, Morogoro except for the VFA analyses (under the rumen metabolism experiments) which were done in the Department of Botany at the University of Dar es Salaam.

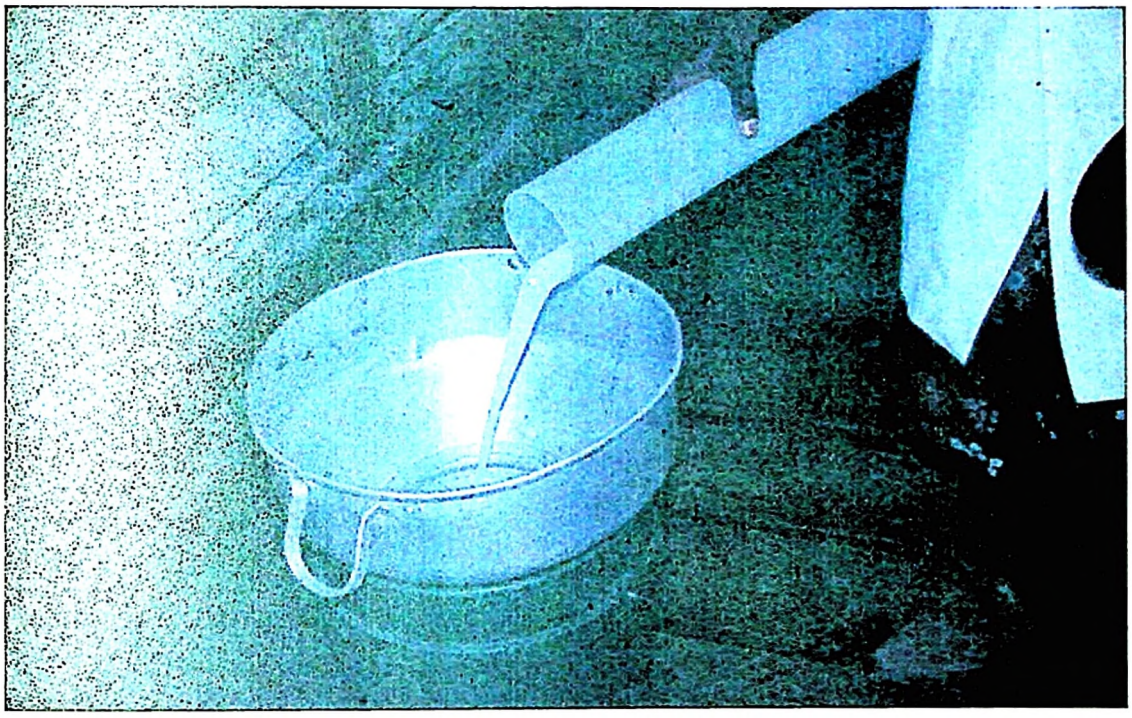

Plate 8: Goat milk produced was measured volumetrically

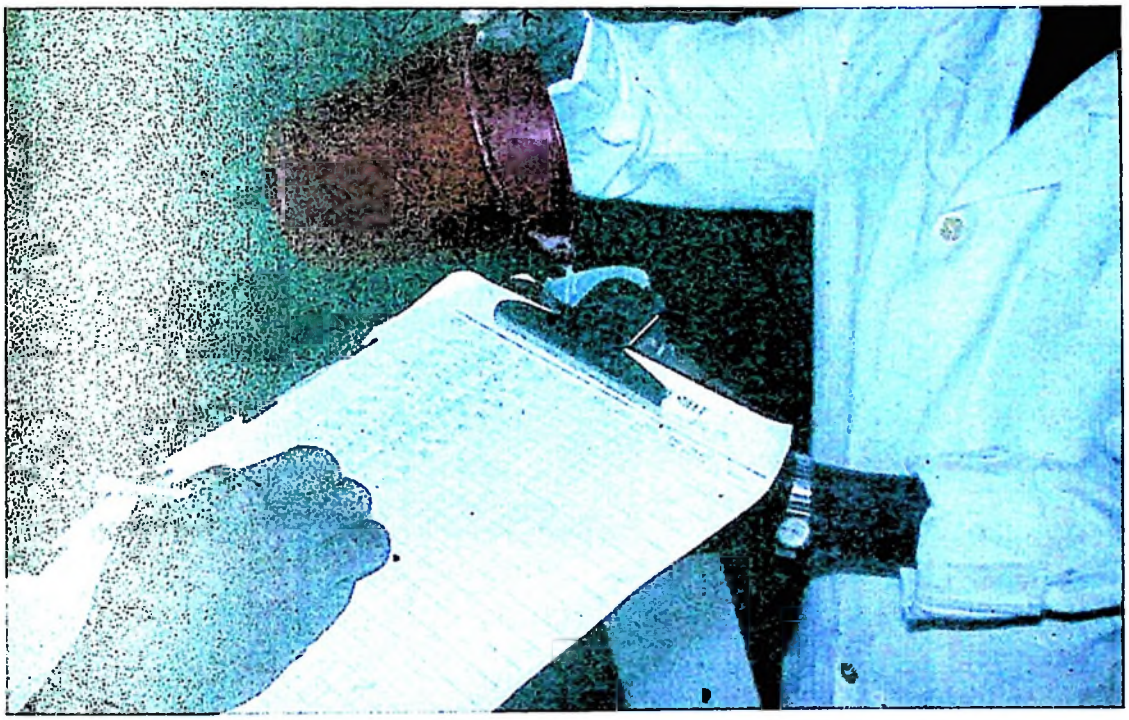

Plate 9: Goat milk recorded in "weekly byre sheet"

Plate 10: Milk samples in tight stoppered plastic bottles to be stored in a deep freezer

All the dried samples of feeds and refusals were ground through a 1 mm screen in a Christy and Norris 20 cm laboratory hammer mill before they were analysed. The samples were then analysed for contents of dry matter (DM), crude protein (CP), crude fibre (CF), Crude fat (EE), ash, calcium (Ca), Phosphorus (P), Sodium (Na) and Potassium (K) in accordance with A.O.A.C (1975 and 1991).

a) Milk fat

Milk fat content was analysed by Gerber method (British Standard Institution B.S.I 696, (1955) and Ling (1982).

b) Fat Corrected Milk

The 4 per cent fat corrected milk used in the present experiment was calculated according to the following (described by Maynard *et al.*(1984):-

FCM = (Milk x 0.4) + Milk x B.F. X 0.15.

c) Milk crude protein

Crude protein content of the milk was analysed by Kjeldahl method as outlined by A.O.A.C (1975 and 1991).

d) Total solid and ash contents

The total solids content in the milk samples were analysed according to the method outlined by Ling (1982) and ignition of the total solids in the muffle furnace (550^0C) as

the ash content.

e) Milk minerals

Milk minerals (Ca, P, Na and K) were analysed by the methods outlined by A.O.A.C (1975 and 1991).

f) Solid non-fat (derived)

The solid non-fat in the milk was obtained by difference between the concentration of the total solids and fat content.

g) Energy value of the compounded feeds

Energy was calculated according to Alderman (1985), using the following formula:-

ME(MJ/kg DM) = 0.012CP + 0.031EE + 0.005CF + 0.014NFE.

3.1.2.9 Statistical analyses

Data obtained in experiments 1 to 3 were subjected to the SAS GLM procedure (SAS, 1990). Least Square Means for treatments were compared with respect to milk yield and other variables. All animals were on a common treatment during the first 4 weeks (2 weeks for Experiment 3) of the experiments and measurements of milk yield, milk composition obtained in these preliminary periods were used as covariates in the analysis of the data measured in the next 8 and 6 weeks of lactation in Experiments 1-2, and 3

respectively. In Experiment 2, two animals which did not complete the experiment due to diarrhoea were excluded from analyses.

The model used to study effects of different levels of leucaena on milk yield, milk composition and body weights was as follows:

$Yijk = \mu + Ai + Bj + (AB)ij + b(Xijk - M) + eijk$ where,

Yijk is the record (milk, milk composition and body weights) of the k^{th} goat assigned to the j^{th} level of leucaena in the experimental period of the i^{th} year.

μ is the overall mean.

Ai is the effect of the i^{th} year (i= 1 and 2).

Bj is the effect of the j^{th} treatments (j= 1,2,...4).

(AB)ij = interaction between i^{th} year and j^{th} treatment.

b is the regression coefficient of experimental period

performance on preliminary period variable.

Xijk is preliminary period performance (milk yield, milk

composition, and body weight), of the k^{th} goat assigned to the j^{th} treatment for the i^{th} year.

M is mean of the preliminary period for all goats in the experiment.

eijk is residual effect (associated with the yield or

performance of each goat).

Since year effects appeared to be non-significant for most of the traits considered the data for Experiment 1A and that for Experiment 1B were pooled to make Experiment 1, while those for Experiment 2A were pooled with the data for Experiment 2B to make Experiment 2. The pooled data were then analysed according to the model:

$Yij = \mu + Ai + b(Xij - M) + eij$

μ is the overall mean.

Yij = effect on the j^{th} goat of i^{th} treatment

Ai = effect of i^{th} treatment

b is the regression coefficient of experimental period

performance on preliminary period variable.

Xij is preliminary period performance (milk yield, milk composition, and body weight), of the j^{th} goat assigned to the i^{th} treatment.

M is mean of the preliminary period for all goats in the

experiment.

eij is residual effect (associated with the yield or performance of each goat).

3.1.3 Materials and methods specific to each experiment

3.1.3.1 Experiment 1: Effect of substituting dry *Leucaena leucocephala* leaves for cotton seed cake fed to lactating goats using fresh Pennisetum purpureum as basal roughage.

a) Introduction

The initial plans of the study was to use Rhodes grass hay as the basal roughage but it was not available. Elephant grass which was available at the time of the experiment was therefore used. The other problem that showed up was number of animals used for this experiment which was lower (section 3.1.3.1.2) than initially planned. It was planned to use a minimum of 48 lactating goats, but unfortunately their conception rate was low and a few had aborted. The main aim of this experiment was to find the best substitution level of dry LL to cotton seed cake.

b) Animals

Sixteen lactating Norwegian x Upgraded Tanzanian goats were used in Experiment 1 A and distributed (randomly) into 4 animals per treatment; while in Experiment 1 B (Table 3.1) there were 12 lactating goats of the same breed and were divided (randomly) into 3 animals per treatment.

c) Feeds and feeding

The germplasm of the elephant grass native in Morogoro is *Pennisetum purpureum* (cultivar local, hairy type) and varies from location to location. The goats were consuming it with difficulty, probably due to the hairs. Their dry matter content were analysed on as–fed basis and used for calculating total feed intake per animal.

The does were offered the following diet combination (on as – fed basis per individual animal) throughout the preliminary period:–

500g maize bran, 150 g cotton seed cake, 270 g dried LL leaves,
Fresh elephant grass, *ad–lib*, 25 g mineral mixture

During the experimental period the animals in Experiment 1 were grouped into treatments as shown in Table 3.2.

Table 3.2: Experimental diets offered (g/d as fed) to lactating goats (Experiment 1)

Treatment	Maize bran	Cotton seed cake	Dried LL leaves	Elephant grass
1	500	300	0	*Ad-lib*
2	500	200	180	*Ad-lib*
3	500	100	360	*Ad-lib*
4	500	0	540	*Ad-lib*

3.1.3.2 Experiments 2: Effect of substituting dry *Leucaena leucocephala* leaves for cotton seed cake fed to lactating goats, using Rhodes grass hay as basal roughage

a) Introduction

Bales of Rhodes grass hay were made available from some parastatal (organized) farm called Molomo in West Kilimanjaro. Though the quality of the hay was poorer than that of the elephant grass, the quantity of hay purchased was sufficient and

more uniform for the whole experimental period. The main aim in this experiment was to collect enough data to corroborate findings in Experiment 1.

b) Animals

Experiment 2A was composed of 26 lactating Norwegian x Upraded Tanzania goats (Table 3.1) which were distributed into 7 animals per treatment, except in treatments three and four in which only 6 animals per treatment were available. Experiment 2B had 28 lactating goats of the same breed which were distributed into 7 animals per treatment. Distribution of animals into pens were as explained under Experimental design and treatments (section 3.1.2.3).

c) Feeds and feeding

Whole maize grain was purchased from the Morogoro NMC and ground into maize meal (MM) through an animal feed mill at SUA. Maize meal was added into the concentrate in these experiments after it was observed that the feeds offered in the previous experiments were deficient in energy for milk yield. The rest of the feeds are as explained ealier (section 3.1.2.5).

The goats were offered the following diet combination (on as fed basis per individual animal) throughout the preliminary period:–

300g Maize bran + 300g Maize meal, 150 g cotton seed cake

270 g dried leucaena leaves, Rhodes grass, *ad-lib*, 25 g mineral mixture

During the experimental period the animals in Experiment 2 were grouped into treatments as shown in Table 3.3.

Table 3.3: Experimental diets offered (g/d as fed) to lactating goats (Experiment 2)

Treatment	½ maize bran+ ½ maize meal	Cotton seed cake	Dried LL leaves	Rhodes grass hay
1	600	300	0	*Ad-lib*
2	600	200	180	*Ad-lib*
3	600	100	360	*Ad-lib*
4	600	0	540	*Ad-lib*

3.1.3.3 Experiment 3: Milk production experiment using fresh *Leucaena leucocephala* (leaves + twigs) as a supplement and *Hypparhenia rufa* as a basal roughage.

a) Introduction

Feeding of fresh LL would be appropriate where grazing or the cut and carry systems are being practised. Grazing is usually carried out in controlled, fenced and low density population areas while the cut and carry is done mainly where land is a constraint. The latter method is quite expensive in terms of labour, fuel and time, thus becomes less economic than grazing. There is paucity of information on comparative data between fresh and dry LL on performance of domesticated livestock especially the lactating animals. Experiment 3, though not directly on comparative basis between fresh and dried LL, was set up solely to investigate the quality of fresh LL in comparison to CSC and MB on milk yield from the cross-bred lactating goats.

b) Feeds and feeding

Cut and carry system was practised. LL grown as a hedge – row around MRU was cut daily in the morning, fetched by a tractor; thereafter stored under a shade for

morning and evening feeding. Two well trained attendants separated the leucaena rachis from the twigs by plucking by hand. It was subsequently weighed and offered (Plate 11) to each goat individually. *Hyparrhenia rufa* grass hay was weighed and offered to the animals twice a day. The hay was fed *ad–libitum* by allowing 15–20% refusals to ensure that these animals had continuous access to the hay. Source of the rest of the experimental feeds were as described earlier (section 3.1.2.5), except for *Hyparrhenia rufa* grass hay which was purchased from the Mpwapwa LPRI (Livestock Production Research Institute) about 400 km away from Morogoro town. Diet combination offered (on as fed basis per individual animal) during the preliminary period were as follows:–

600g maize bran, 150 g cotton seed cake, 300 g fresh leucaena leaves, *Hyparrhenia rufa* grass hay *(ad–lib)* and 25 g mineral mixture

During the experimental period the animals were grouped into their appropriate treatments as shown in Table 3.4.

Table 3.4: **Experimental diets offered (g/d as fed) to lactating goats (Experiment 3)**

Treatment	Maize bran	Cotton seed cake	Fresh LL leaves	*Hyparrhenia rufa* grass hay
1	600	0	0	*Ad-lib*
2	600	300	0	*Ad-lib*
3	600	0	300	*Ad-lib*
4	600	0	Ad-lib	*Ad-lib*

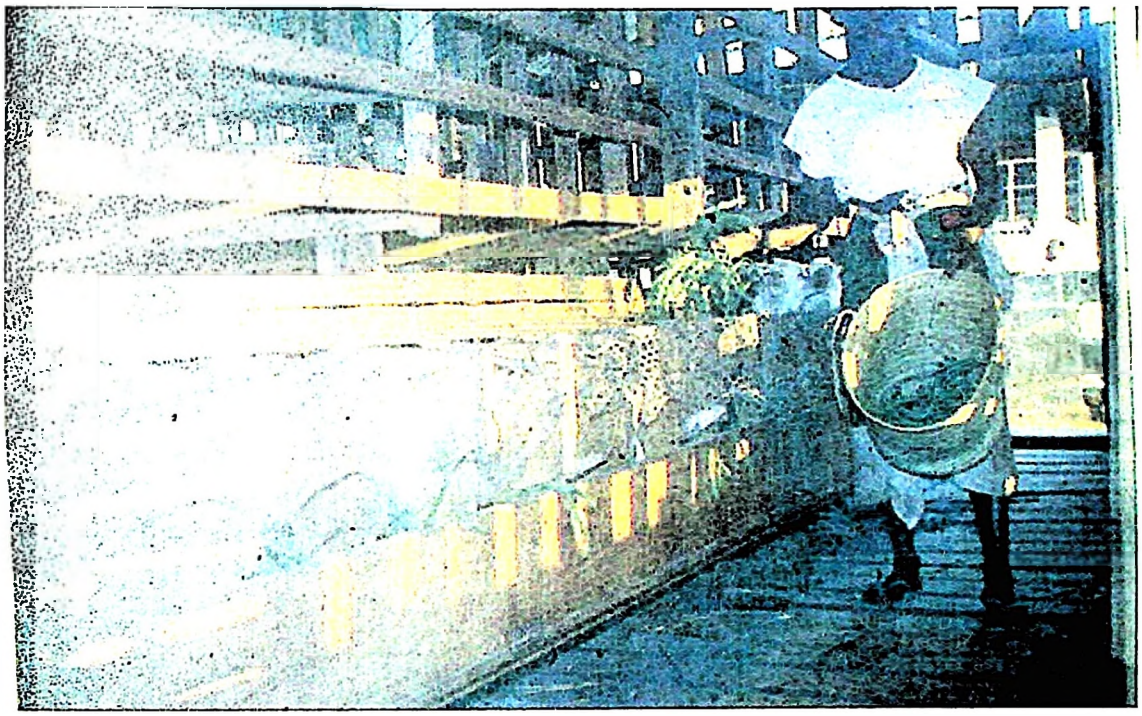

Plate 11: Individual feeding of fresh leucaena to dairy goats

3.2 Growth experiment

3.2.1 Experiment 4: Effect of substituting dry *Leucaena leucocephala* leaves for cotton seed cake using urea treated maize stover as basal roughage for weaner goats.

3.2.1.1 Introduction

Studies done elsewhere (Preston and Leng, 1987; Preston 1986; FAO, 1986; Ndlovu and Manyame, 1989) have shown that the N available from the urea treated crop residues is not enough to meet the complete nutrient requirements by small ruminants. This is partly due to the protein degraded in the rumen. To quantify this statement some leguminous plants or animal protein like fishmeal have been supplemented to urea treated roughages to provide by–pass protein (Preston, 1986; Mgheni *et al.* 1993). When supplements of bypass protein nutrients are given, productivity may increase (Ørskov, 1987).

In ruminants receiving high roughage rations, a high acetate entry rate and adaptation to acetate metabolism will compensate for low glucose concentrations. Elevation of plasma FFA (free fatty acid) concentrations is an important factor in adaptation to other nutritional conditions resulting from glucose deficiency and will also compensate to a certain extent for decreased glucose availability in muscular supply (Riis, 1983). Therefore, plasma FFA concentration may be used as an indicator of

the adequacy of feed energy supply, because FFA increases if energy supply is insufficient and *vice versa*. Furthermore, plasma glucose concentration is another parameter that can aid in evaluating the ability of an animal to adapt to different nutritional conditions as it directly affects the secretion of hormones (insulin/glucagon) which regulate the energy metabolism (Riis, 1983). This experiment was designed to study the effect of dry LL substitution level on cotton seed cake as a protein supplement to urea treated maize stover on performance of weaner goats.

Degradability, rumen environment and *in vitro* digestibility experiments were also carried out to try to explain changes occuring in growth experiments (section 3.3.3.2).

3.2.1.2 Housing

Same facilities as those for experiment 3 were used.

However, some modification and reconstruction by partitioning and blocking into smaller cubicles to the pens were done.

3.2.1.3 Experimental design and treatments.

Fourty weaners (20 entire males and 20 females), aged four months and weighing 10.5±0.1, at the start of the experiment were used. The weaner goats were separated by sex and within each sex the animals were randomly allocated to four treatments, each being replicated five times (Steel and Torrie, 1980). The mean initial age of the animals was four months, implying uniformormity among the animals.

3.2.1.4 Source of experimental animals and their management.

All the weaner goats were crossbreds of Norwegian x Upgraded Tanzanian. Some of them were offsprings of the lactating goats used in the production Experiment 3, while the rest came from other lactating goats which kidded at this period but were not selected for Experiment 3.

Animals in this experiment were properly identified by distinct plastic eartags so their numbers could be read without restraining the animals.

Ticks, lice and other external parasites were controlled by hand dipping the animals in water baths treated with Toxaphane ™ acaricide. The animals were dewormed with the doses of seponver™ boluses, a broad–spectrum antihelmintic. Faecal samples were taken from each individual animal a month later in order to check for

eggs of internal parasites. Thereafter, a second deworming and treatment was carried out against coccidiosis for some of the affected weaners. The drug used against coccidiosis was Davisol™.

3.2.1.5 Feeds and feeding

Maize stover used in this experiment was collected from the University farm, immediately after maize harvest, chopped and treated with 5% urea using the procedure described by Schiere and Ibrahim, (1989).

Dry LL leaves were thus fed so as to substitute CSC as dietary sources of nitrogen at same percentage levels as those in Experiments 1 and 2. 5% urea treated maize stover (50 g urea per 1 kg stover) was sprinkled with 5% molasses per kg DM of maize stover according to Preston and Leng, (1987) and fed to the weaners *ad–lib.*

3.2.1.6 Feed offered during preliminary and experimental periods

A preliminary period of 4 weeks was allowed for all animals during which they were all given similar diet, to adjust them before actual experimental diets were offered. The diet offered was as follows (g as fed basis per animal):–

270g maize bran, 75g CSC, 150g LL, 15g mineral mixture, 38mg vitamins *ad–lib.*, urea treated maize stover sprinkled with 5% molasses, 15g mineral mixture & 38 mg

vitamins.

During this period two male and two female weaners succumbed to diarrhoea, thus were replaced by some reserved weaner goats.

Treatment diets offered during the experimental period were as presented in Table 3.5.

Table 3.5: Experimental diets offered (g/d as fed) to growing kids (Experiment 4)

Treatment	Maize bran	Cotton seed cake	Dried leucaena leaves	Urea-treated maize stover
T1	250	150	0	*ad-lib*
T2	250	100	100	"
T3	250	50	200	"
T4	250	0	300	"

3.2.1.7 Mineral supplements

In addition to the Maclik Super™, Super – vita mino™ whose composition is shown in Table 3.6 containing the essential vitamins and trace elements were also included. The recommended amount of the Super –Vita™ mino inclusion in the feed was at the rate of 800 g per 1000 kg (38 mg/ animal/d) which catered adequately for the vitamin and trace mineral requirements by the growing animals. The purpose behind this was to improve growth and alleviate the stressful condition during confinement and increase resistance to infection of the weaners.

3.2.1.8 Feed sampling

Samples collected for all the urea treated maize stover (with and without molasses), and refusal were analysed for DM at 105^0 C for 24 hours to constant weight to ensure proper calculation of the roughage intake once a week. The values were then used to estimate daily DMI of roughages.

3.2.1.9 Growth performance measurements

The animals were weighed at the start of the experimental period (using the spring weighing balance) for two consecutive days at the beginning and two other weights were taken at two consecutive days at the end of the experiment, to obtain final weights. Body weights and measurements viz. withering height, width at the hind

quarters, body length and heart girth were recorded at weekly intervals. Feed intake of the weaners were recorded daily during each feeding time in the morning and evening at 0730 and 1630 h. Refusals were measured for both the concentrate and the roughages and recorded to calculate feed intake.

Table 3.6: **Content of vitamins and trace mineral elements in Super Vita™– Mino (per 100 g)**

Contents	Amounts/Units	
	i.u.[1]	mg[2]
Vitamin A	1,000,000	–
Vitamin D	560,000	–
Vitamin E	750	–
Vitamin K	–	400.00
Vitamin B1	–	550.00
Vitamin B2	–	100.00
Pantothenic acid	–	2,500.00
Nicotinic acid	–	2,000.00
Vitamin B6	–	1,000.00
Vitamin H	–	7.50
Vitamin B12	–	2.00
Vitamin C	–	1,500.00
Iron	–	80.00
Manganese	–	15.00
Magnesium	–	167.00
Copper	–	10.80
Zinc	–	10.80
Selenium	–	12.50
Cobalt	–	1.19
Iodine	–	15.00
Amino	–	10.00

[1]International Unit; [2] Milligram.

Source: Wellcome (1991)

3.2.1.10 Blood sampling and plasma collection

The aim of blood sampling was to measure the plasma glucose and FFA (free fatty acids) concentrations of the weaners to determine their nutritional status.

The blood samples were collected at the interval of 7 days for 5 weeks (see section 3.2.1.12) beginning on the second week of the experimental period. Blood samples were obtained through the jugular veins (Plate 12) and collected in EDTA coated vacutainer™. Collection was done early in the morning before feeding. The collected samples were analysed at the Department of Physiology in the Faculty of Veterinary Medicine, Sokoine University of Agriculture.

The plasma samples were obtained by centrifugation of the blood samples at 3000–3500 RPM for 15 minutes. They were preserved in a deep freezer at – 20^{0}C.

3.2.1.11 Blood assays.

Plasma glucose concentrations were determined using dehydrogenase method, a commercial available kit (MERCKOTEST™). The method and procedure were used as described by Payne, (1978) and Thilsted (1980).

Plate 12: Blood sample of a weaner goat obtained through the jugular vein

Plasma FFA concentrations were determined by using enzymatic spectrophotometry which is available using the kit from WAKO – NEFAC™) (Payne, 1978; Thilsted, 1980).

3.2.1.12 Chemical analysis

NDF and ADL for the urea treated maize stover with and without molasses were analysed according to the method by Goering and Van Soest (1970). The procedure used for chemical analysis in section 3.1.2.8 was employed in this experiment for all the dried feed samples and refusals.

3.2.1.13 Statistical analyses

a) The effects of feed regime and sex on growth performance were assessed by means of analysis of variance (Snedecor and Cochran, 1982), which was carried out using a computer program (SAS, 1990). Data was adjusted using preliminary period measurements (liveweight, height at withers, heart girth, body length and width at hind quarters) as covariates.

The following analysis of variance model was used:–

$$Yijk = \mu + Ai + Bj + (AB)ij + b(Xijk - M) + eijk$$

where,

Yijk = the value of response variable on the k^{th} animal of i^{th} sex in the j^{th} treatment.

μ = overall mean of the response variable.

Ai = effect of i^{th} sex (i = 1 or 2).

Bj = effect of the j^{th} treatment (j = 1, 2,...4).

(AB)ij = interaction between the i^{th} sex and j^{th} treatment.

b = regression coefficient of response variable on the initial weight or other body measurements.

Xijk = weight or other body measurements in the preliminary period of the k^{th} individual of the i^{th} sex category in the j^{th} treatment.

M = overall mean of the variables in the preliminary period.

eijk = residual component specific for the k^{th} individual of the i^{th} sex assigned to the j^{th} treatment.

Least Square Means were compared using GLM procedures to record the difference between means.

Interaction between sex and treatment were non-significant, thus data for males and females were pooled together. The pooled data were then analysed according to the model:-

$Yij = \mu + Ai + b(Xij + M) + eij$ where,

μ = overall mean of the response variable.

Yij = effect on the j^{th} animal of the i^{th} treatment

Ai = effect of i^{th} treatment

b = regression coefficient of response variable on the initial weight or other body measurements.

Xij = weight or other body measurements in the preliminary period of the j^{th} individual of in the i^{th} treatment.

M = overall mean of the variables in the preliminary period.

eij = residual component specific for the j^{th} individual of the assigned to the i^{th} treatment.

b) Statistical analysis for blood samples was done using similar model (GLM) to that employed for body weights, but no covariance analysis was applied.

3.3 Rumen metabolism studies

3.3.1 Introduction

Incubation of feed samples in nylon bags in the rumen of fistulated sheep or cows has been used to evaluate the rate and extent of dry matter, protein, cellulose and NDF degradation (Mehrez and Ørskov 1977; Weisbjerg *et al.* 1990). The degradation curves obtained from these incubations have been used to predict intake by cattle (Ørskov *et al.* 1980 and Weisbjerg *et al.* 1990). In this present work including all the other rumen metabolism experiments fistulated goats were used

instead of extrapolating data from sheep as it has been often the case with digestibility reviews (Jotee, 1984). Moreover, it has been suggested that materials incubated in sacco should first be incorporated in the diet, in order to adjust the rumen microbes to the diets (Ørskov, 1982). This was done in the current studies.

The rumen environment experiments were also used to calculate the AAT - PBV (Madsen, 1985). AAT–PBV give indicators on the true protein availability of dry LL substitution on CSC as protein supplement sources to lactating and weaner goats (See formula for AAT–PBV in section 3.3.2.5(iv). Therefore two experiments were conducted to study the degradability and rumen parameters.

3.3.2 Materials common to both rumen metabolism experiments

3.3.2.1 Research site

The experiments were conducted in the lower DASP farm, in metabolic cages.

3.3.2.2 Experimental animals and their management

Digestibility experiments were to be carried out for comparison with the degradability experiments. Shortage of experimental goats made impossible to conduct the digestiblity experiments. Four *in vitro* experiments were carried out to compare with the 2 *in sacco* experiments. *In vitro* digestibility was not done for

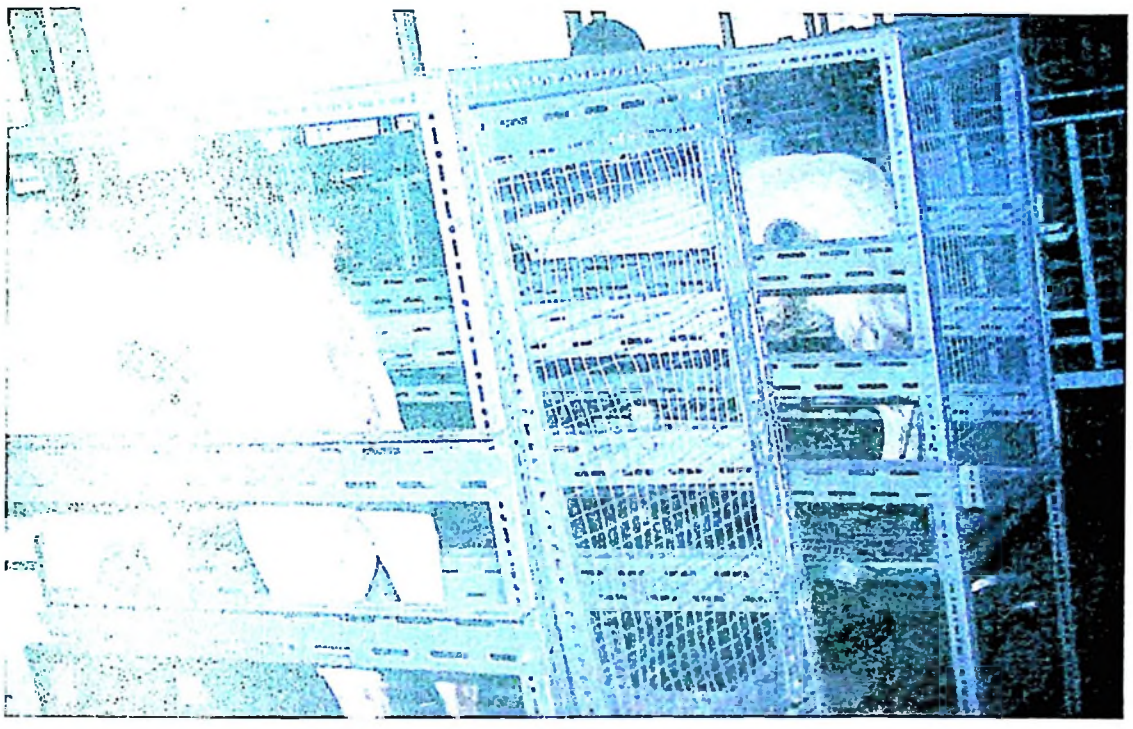

Plate 13: Fistulated bucks, each fitted with a rumen cannula 40 mm diameter

Experiment 3 due to lack of electricity, which was necessary for the water bath used in *in vitro* studies.

Four bucks of cross – bred Norwegian x Upgraded Tanzanian goats were fistulated, fitted with cannulae of size 40mm in diameter (Plate 13) as described by Ørskov *et al.*(1980). They were allowed four weeks to recover from surgical trauma before being used for the studies. The animals had an average initial weight of 32.1±1.50 kg and were obtained from MRU. They were selected based on their age and good health condition. One week before the commencement of the experiments the bucks were dewormed with seponver™. Ticks, lice and other external parasites were controlled by dipping the animals in an acaricide solution of Toxaphane™. The animals were thereafter introduced to metabolic cages.

3.3.2.3 Feeding

The fistulated bucks were fed a basal diet of elephant grass hay and the composition of the concentrate as shown in Table 3.7. The basal diet was given at 35g/kg $W^{0.75}$ with concentrate supplementation aiming to give a roughage to concentrate ratio of 70:30 recommended for optimum rumen environment (Sundstøl, F. personal communication, 1991). However, refusals of hay which were between 5 – 10% of total hay offered were also recorded. Minerals and salt were offered at the rate of 15g and 10g per animal per day respectively. Feeds were offered to the animals in two portions: in the morning at 0900h and afternoon at 1500h. Fresh drinking water

was given *ad-lib* and measured volumetrically. This was during both the preliminary and experimental period. Fourteen days preliminary period were allowed for the animals to get accustomed to the new diets and this period gave the bucks' rumen microbes ample time to get used to the new experimental feeds. Feeds offered to these animals will be described under each topic of the specific experiment. Feed intake and refusals were recorded daily as for the previous experiments and there were no refusals left from the concentrates.

Table 3.7: Feed composition of the standard diet offered

Standard diet	Concentrate
Elephant grass hay fed at 35g kg/$W^{0.75}$	1 part of maize bran + 2 parts CSC Total amount at 22 g/kg$W^{0.75}$

3.3.2.4 Sampling

Feeds offered and refused and urine output were collected at 0730h and weighed. Around 10% of each were subsampled and bulked for chemical analyses. Urine samples were however collected at the end of each collection period to assess the DHP, a by product of mimosine.

3.3.2.5 Preparing, inserting, washing and drying the bags and calculating degradability data for both Experiments 5 and 6

a) Preparation of samples for incubation

Rumen degradabilities were measured using the nylon bag technique as outlined by Ørskov *et al.* (1980).

Feed samples were air dried and ground using a hammer mill with 2.5 mm screen size. Two grammes of the air dried samples were weighed into labelled weighed nylon bags (80mm X 20mm; pore size of 44μm, Plate 14). At the same time 2 g samples were weighed into crucibles and dried in an oven for 48h at 60^0C to obtain the DM of the sample. These were ashed at 550^0C for 5h to determine the organic matter (OM).

Plate 14: Two grammes of the dried feed samples weighed into labelled nylon bags

b) Placing of samples in the rumen

Ten bags (duplicate of the five samples namely, LL, CSC, MB, MM and CG) were tied firmly using nylon strings and were anchored with about 25cm of nylon thread in the rumen of each of the four bucks. It was not possible to insert more than 10 samples of bags per given time.

c) Removing and washing of samples

The incubation time used in each buck for each sample were 0, 2, 6, 12, 24, 48, 72 and 96h. The bags containing the undigested residues, that is those removed from the rumen after each incubation time were thoroughly washed in running tap water for about five minutes. The bags were then dried at 60^0C for 48h to a constant weight, cooled in a desiccator and their weight taken. The dried residues were transferred from the bags into weighed labelled crucibles and weighed. They were ashed at 550^0C for 5h. Water solubility (0 or washing loss) of the samples were measured by incubating duplicate samples in water at room temperature for 2 hours. They were then processed in a similar manner as those from the rumen.

d) Derived parameters / calculation

The extent of Dry Matter loss (DML), Organic Matter loss (OML) and Protein loss (PL) in the rumen were calculated by the difference between sample weights before

and after incubation divided by sample weight before incubation.

Effective Ruminal Degradability (ERD) was calculated using the following equation according to Kristensen et al 1982:-

(1) $P = a + bc/c+k$,

where P is effective ruminal degradability, k is the passage rate.

The percentage of the material degraded (p) after a certain time (t) was described by the equation (Ørskov and McDonald, 1979):-

(2) $p = a+b\ (1-e^{-ct})$ where a, b, and c are constants

where;

p = the percentage degradation at time t

a = water soluble component (intercept of the degradation curve at time zero)

b = not water soluble, but potentially rumen

degradable part

a+b = potentially rumen digestible part (asymptote)

c = degradation rate of insoluble material

The asymptote a+b (the maximum digestibility of the feed ingredients) – cannot exceed 100. It follows that 100 – (a+b) represents the fraction which will appear to be undegradable in the rumen.

The values of both the equations (1) and (2) were calculated by a computer using NAWAY program developed by Ørskov et al (1980) and Ørskov (1982).

Digested carbohydrates in the rumen for all feedstuffs calculated according to Hvelplund and Madsen (1990):-

Digested carbohydrate = Digested OM - digested (CP+EE).

Data of digested OM and CP from rumen degraded feeds in this study were used to calculate digested carbohydrate. Data of digested EE was obtained according to Weisbjerg and Hvelplund (1993).

Microbial Protein Synthesis (MPS) was derived from the formula by NKJ Protein Group (1985):- MPS = DCHO*(0.179)

A direct measurement of the AAT and PBV value of all available feeds using fistulated animals is not realistic, and therefore formulas were developed by which the AAT and PBV were expressed by factors which are either constants, or variables which can be related to analysis on the feeds (Hvelpund and Madsen, 1990):-

AAT g/kg DM = g crude protein /kg DM

* (1-degradability in the rumen)

* proportion of amino acids in undegraded feed protein

(= 85% for concentrates and 65% for roughages)

* digestibility in the small intestine of undegraded

amino acids (82%)

+ g microbial protein produced (179g/kg DCHO)

* proportion of amino acids in microbial protein (70%)

* digestiblity in the small intestine of microbial

amino acids (0.85); therefore,

AAT g/kg DM = gCP*(1–degradability)*0.65*082 + gDCHO*0.125*0.85

PBV g/kg DM = g crude protein /kg DM

* degradability in the rumen

– microbial protein produced /kg DM (g DCHO * 179)

therefore,

PBV g/kg DM = gCP*(degradability) – gDCHO*0.179

3.3.3 Materials and methods specific to each experiment

3.3.3.1 Experiment 5: Degradability study using bucks fed a standard diet

This experiment was thus carried out to measure the degradability of the different feed components in the rumen of goats fed a standard diet (Table 3.7). The animals were placed in their respective cages ready for inserting nylon bags into their rumen.

3.3.3.2 Experiment 6: Degradability study using bucks fed treatment diets

The experiment was done to measure the effect of feeding the four diet combinations (fed to lactating and weaner goats) on the degradability of the roughages, Rhodes and *Hyparrhenia rufa* hay, urea treated maize stover (with and without molasses) and supplementary diets (LL, cotton seed cake, maize bran and maize meal).

During the preliminary period same diets and basal roughages offered to the same periods in Experiments 1, 2, 3 and 4 were offered to these bucks at different times. During the experimental periods the four different treatment diets which formed the basis for the difference among the four ration combinations fed to the goats in Experiments 1 to 4 were likewise assigned to the bucks. Roughage to concentrate ratio offered were 70:30, and in addition mineral supplements and clean water were given as for Experiment 5. Feed intake of the feedstuffs and roughage refusals were recorded daily.

3.3.3.3 Rumen environment evaluation

a) Introduction

The rumen system is said to be isothermal and is regulated by the homeothermic metabolism of the host animal (Van Soest, 1983). There is a relatively constant influx of water and feed, the fermentation of the latter giving rise to a considerable amount of acid. The pH (6–7), however, remains relatively constant, because fermentation acids are removed by absorption across the rumen wall and neutralized by salivary buffers (Van Soest, 1983).

Rumen ammonia concentration can be used as a tool to diagnose a deficiency of fermentable N in a diet (Preston, 1986). As a "rule of thumb", rumen ammonia nitrogen should be at least 5 mg/100 ml rumen liquor, although, values as high as 15–20 mg/100 ml rumen liquor may be necessary for optimum fermentation of fibrous feeds (Preston, 1986).

Measurements of the concentrations and amount of VFA are important because these acids make such a large contribution to the dietary energy of the animal (Van Soest, 1983). The level of total VFA is also indicative of total fermentation rate (Preston, 1986).

The aim for measuring the three rumen parameters in the present study was therefore, to evaluate the rumen environment affected by the standard and the different diet combinations.

b) Collection of rumen liquor

The rumen liquor from these animals were sucked using a sucking pump through the cannulae after which the fluid was collected for determination of pH, NH_3–N and VFAs concentration.

c) Rumen pH

150 – 200 ml samples of rumen liquor were withdrawn before feeding (0800h) and at 2h interval for 24 hours. At each collection time the liquor was strained through a double layered surgical gauze, thereafter 20–30 ml were immediately withdrawn to measure pH. The rest of the liquor was simultaneously placed into a cool box to suppress microbial activities. A total of 12 samples per buck were thus collected. The pH was determined using an electrical Digital – pH – meter (Knick, Struers model).

d) Rumen NH_3–N concentration

Some 130–170 ml of rumen fluid remaining after pH determination was taken to the laboratory where 10 ml were put into duplicate test tubes. The test tubes with rumen fluid were centrifuged at 3500 rpm for 15 minutes. The supernatant was decanted into another test tube with 2–3 drops of concentrated HCl to avoid N losses, and mixed up thoroughly ready for NH_3–N concentration determination by using Kjeldahl method (McDonald *et al.* 1991).

e) Volatile fatty acids (VFAs concentration)

From the same rumen liquor brought to the laboratory for pH and NH_3–N analysis 10 ml was put into other test tubes in duplicate. They were immediately frozen until analysed by gas liquid chromatograph at the Applied Microbiology Unit, Department of Botany of the University of Dar es Salaam.

f) VFAs analysis procedure

The amounts of VFAs in the rumen liquor were determined using a Hewlett Packard Gas Chromotograph (G.C.) model 5890. The G.C. was equipped with a flame ionization detector set at 130^{0}C oven temperature followed by injection and detection temperatures of 170^{0}C and 175^{0}C respectively. Flow rate of the carrier gas (N_2) was 33 ml/minute.

The G.C. was fitted with a coiled column 180cm by 2mm internal diameter, packed with 10% SP 1200 per 1% H_3PO_4 on 80/100 chromosorb material. Prior to use for the VFA determination, the packed column was conditioned by being heated in the G.C. from 50 – 190^{0}C at a rate of 2^{0}C/minute. After reaching 190^{0}C the temperature was maintained at this point overnight with the flow rate of carrier gas (N_2) at 33ml/minute.

Rumen liquor samples were prepared by first pipetting 900µl of a well homogenized sample into an Eppendorf tube. Into this, 100 µl isobutyric acid (internal standard) followed by 150µl of 20% orthophosphoric acid were added and the samples were thoroughly mixed on a vortex mixer. The mixture was centrifuged for 30 minutes in an Eppendorf Centrifuge machine. After centrifuging, the supernatant in each tube was decanted into another Eppendorf tube and was ready for injection into the G.C.

g) Calculation

In order to quantify VFA, 0.2µl of a standard composed of acetic acid, propionic acid and valeric acid in the ratio of 3:1:1:1 g/l was injected after being treated as done for the rumen liquor samples. During the analysis, the column was cleaned several times by injecting 0.2µl of 20% H_3PO_4. The concentration of acetic acid was calculated by relating its peak area in sample to the peak area of the internal

standard in both the sample and the standard as follows:-

$$\text{Concentration of Acetic acid g/l} = \frac{(As/IBs) * 3}{(Ast/IBst)}$$

where:

As = Peak area of acetic acid in the sample

IBs = Isobutyric acid peak area in the sample

Ast = Peak area of acid in the standard

IBst = Isobutyric acid peak area in the standard

The same formula was used to calculate the concentrations of propionic, butyric acid and valeric acid, but this time by multiplying by 1. To change g/l to mM/l the g/l of the VFA concentration sample is divided by molecular weight (MW)[1] then multiplied by 1000. e.g. 3.360 g/l acetic acid = (3.360)/60)*1000 = 56 mM/l.

MW: Acetate = 60; Propionate = 74; Butyrate = 88; Valeric acid = 103.

3.3.3.4 Statistical analyses

a) Experiment 5

The degradability (effective degradability, the constant values, a, b and c) and rumen parameters (pH, NH_3–N and VFAs) data were all analysed using GLM procedure (SAS, 1990), according to the following model:

$Y_{ijk} = \mu + F_i + G_j + e_{ijk}$

where μ is Overall mean

Y_{ijk} = response of the k^{th} record from the i^{th} feed degraded by the j^{th} goat

F_i = fixed effect of the i^{th} feed degraded (i=1,2,...5)

G_j = fixed effect of the j^{th} goat (j=1,2,...4)

e_{ijk} = Residual (error term)

b) Experiment 6

The data on effective degradability, the constants values a, b and c and rumen parameters (pH, NH_3–N and VFA) were all analysed using the SAS (1990) and following the Latin Square model as shown below:–

$Yijk = \mu + A_i + B_j + C_k + e_{ijk}$

where,

Yijk = response of the k^{th} animal of j^{th} period in the i^{th} treatment.

μ = overall mean

Ai = fixed treatment effect (i=1,2,...4)

Bj = period effect (j=1,2,...4)

Ck = fixed animal effect (k=1,2,...4)

eijk = residual (error term)

The data was analysed using the SAS General Linear Model (GLM) procedures (SAS, 1990).

3.4 *In vitro* DMD and OMD of leucaena and other experimental feed ingredients.

The *in vitro* digestibility experiment was carried out so as to have a clear picture of the digestibility coefficients of the individual roughages and the concentrate used. Their results were compared with those of the degradability values of similar feeds.

Rumen liquor for *in vitro* digestibility was collected from the four bucks. This was done on the 14th day from the time the animals started feeding on the experimental diets. Before being used, the liquor was sieved through a clean surgical gauze material – double folded to remove all the undigested particles. The liquor was placed in 4 rubber stoppered conical flasks representing each buck and were partially submerged in a water bath at 37^{0}C.

Duplicate samples (0.5g) of each of the experimental ingredient diets: maize bran, maize meal, cotton seed cake, LL, elephant grass, Rhodes and *Hyparrhenia rufa* grasses hay, urea treated maize stover (with and without molasses) and untreated maize stover were all analysed and calculated for *in vitro* Dry and Organic matter digestibilities according to Tilley and Terry (1963).

CHAPTER 4.0

RESULTS

4.1 Experiments 1 and 2: Effect of substituting dry leucaena leaves for cotton seed cake on performance of lactating goats

There was no significant interaction between year and treatments for experiments 1A and 1B (Experiment 1); 2A and 2B (Experiment 2). Therefore the 2 years were combined into their respective Experiments 1 and 2 according to the roughage used.

4.1.1 Health of the animals

All the animals were in good health throughout Experiments 1. For Experiment 2 cases of diarrhoea were observed in two does during the third week of the preliminary period. They were removed from the experiment. The rest of the animals were in good health throughout the rest of the experimental period.

4.1.2 Chemical composition of the feeds

The chemical composition of feeds used in Experiments 1 and 2 are presented in Tables 4.1 and 4.2.

Table 4.1 Chemical composition of feed ingredients in Experiment 1

	Maize bran	Cotton seed cake	Dry leucaena	Fresh elephant grass
Dry matter, %	91.7	93.1	92.6	28
In dry matter, g/kg:				
OM	971	930	898	883
Ash	25	65	94	117
EE	50	110	34	17
CP	92	332	263	142
CF	107	167	151	299
NFE	726	327	458	425
Mimosine			27	
Ca	9.6	2.7	18.8	4.4
P	7.8	8.1	2.5	3.5
Na	2.1	0.43	0.1	0.01
K	11.2	10.0	24.8	13.1
ME, MJ/kg DM[1]	13.35	12.81	11.38	9.66
IVDMD	75.8	53.2	47.2	38.8
IVOMD	75.0	50.2	45.0	34.9

[1] Refer to ME formula in section 3.1.2.8 (g)

Table 4.2 Chemical composition of feed ingredients in Experiment 2

	Maize bran	Maize meal	Cotton seed cake	Dry leucaena	Rhodes grass hay
Dry matter, %	94.3	90.3	94.4	93.9	93.6
In dry matter, g/kg:					
OM	976	961	935	894	904
Ash	27	40	61	100	96
EE	56	97	104	36	15
CP	94	102	350	227	48
CF	85	67	177	161	351
NFE	738	695	308	476	489
Mimosine				29	
Ca	10.2	9.0	4.1	22.6	3.2
P	9.8	7.9	7.3	3.3	0.9
Na	2.3	0.2	0.47	0.1	0.11
K	16.4	12.5	11.2	24.6	21.0
ME, MJ/kg DM[1]	13.62	14.3	12.62	11.31	9.6
IVDMD	75.8	82.7	53.2	47.2	35.9
IVOMD	75.0	79.3	50.2	45.0	34.7

[1] Refer to ME formula in section 3.1.2.8 (g)

Elephant grass used in Experiment 1 was *Pennisetum purpureum* (cultivar local–hairy type). Leucaena consisted of dried leaves with a substantial amount of pods and dried flowers (Plate 15), which were all (ungrounded) consumed without selection (Plate 16). DM contents of dry feeds were quite high (> 900 g/kg DM) as shown in Table 4.1. Leucaena had a higher CP content than the roughages, being two and five fold that of elephant grass and Rhodes grass hay respectively. CP and CF contents of cotton seed cake were 96 and 16 g/kg DM respectively higher than that of leucaena leaves. As expected the CF contents of the roughages were higher, with Rhodes grass ranking the first followed by elephant grass. Ash content was higher in elephant grass compared to the rest of the feeds. Leucaena leaves had higher Ca content than the rest of the feeds, being six and seven fold that of cotton seed cake and Rhodes grass respectively. Sodium content in cotton seed cake was 78% higher than that of leucaena, while K content in leucaena was 57% higher than that of cotton seed cake. The *in vitro* DM and OM digestibility coefficients for maize meal in all the treatment diets were higher than those of maize bran, cotton seed cake, leucaena and Rhodes grass hay. Rumen liquor for *in vitro* analysis was taken from bucks consuming a combination of the same feeds that their feed ingredients were analysed from. Detailed work on this is explained in Chapter 3 (section 3.4.1).

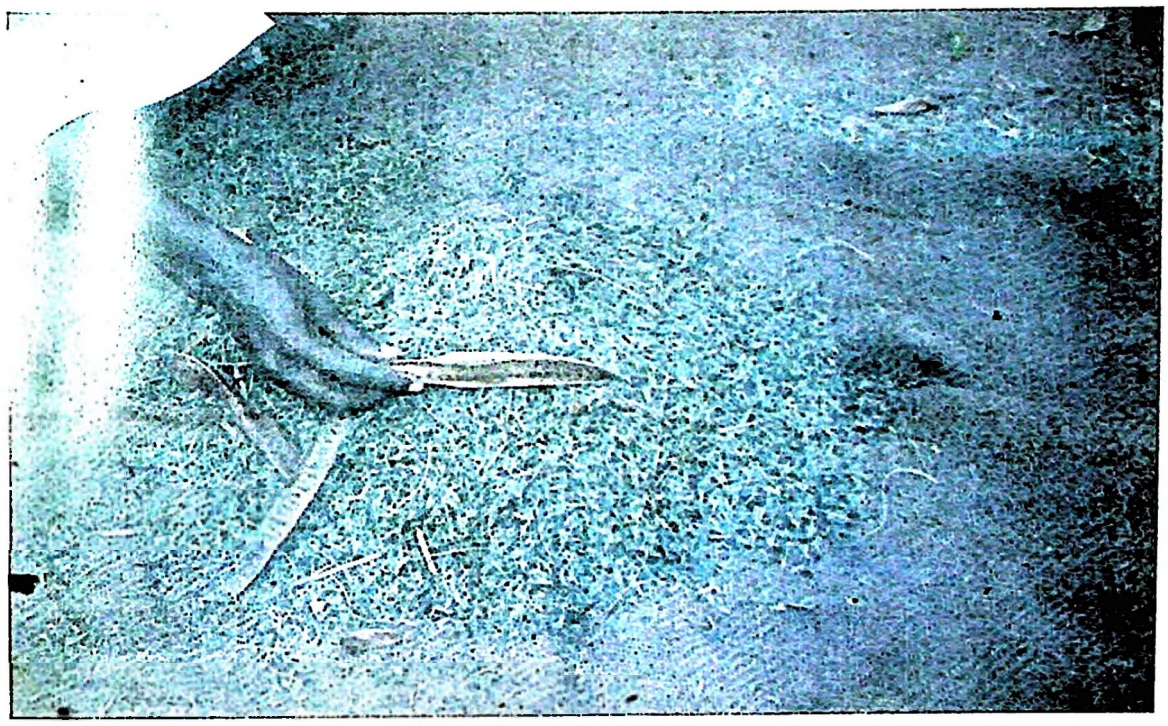

Plate 15: Dried leucaena leaves with some pods and flowers

Plate 16: Dairy goats consuming leucaena leaves, including pods and flowers without selecting

4.1.3 Feed intake for lactating does in Experiment 1

Daily feed intake for does in Experiment 1 is shown in Table 4.3. Leucaena leaves, cotton seed cake and maize bran were offered in amounts reported in Chapter 3 (section 3.1.3.1.3) and the animals consumed all of them. Mimosine intake increased with increasing level of leucaena intake. AAT intake was less variable than both protein and DCP intake. Roughage intake decreased as the level of leucaena increased. Only average values on feed intake were reported, as the animals were group fed on roughage.

4.1.4 Performance of lactating does in Experiment 1.

Actual milk and FCM yields per day are presented in litres in Table 4.4. There were no significant differences ($P>0.5$) between treatments for both the actual milk and FCM yields. ANOVA tables of total and weekly milk yields are given in Appendices 4.1 and 4.2. Butterfat percent, protein content and body weight change from the does were not significantly ($P>0.05$) affected by the substitution levels of leucaena. Energy efficiency of actual milk and FCM yields was slightly better, although not significant ($P>0.05$) for does in treatments 1 and 2 compared to those of other treatments.

Table 4.3. Mean daily feed intake in the lactating goats fed different substitution levels of cotton seed cake with dry leucaena leaves as protein supplements. Experiment 1

Parameters	TREATMENTS 1	2	3	4
No. of animals	7	7	7	7
Initial age of does in months	39.0	39.0	39.0	39.0
Mean daily Intake (gDM/d/animal):				
Dry leucaena	0.0	167.8	335.7	503.5
Cotton seed cake	281.2	181.5	93.7	0.0
Maize bran	463.5	463.5	463.5	463.5
Elephant grass	543.0	478.0	429.0	381.0
Total DM intake, g/d/animal	1287.7	1290.8	1321.9	1348.0
Feed intake, kg DM/100 kg BW,	4.3	4.3	4.5	4.6
AAT g/d/animal	96	95	98	102
PBV "	0	1	4	5
DCHO "	531	534	548	560
MPS "	95	96	98	100
Protein, g/d/animal	216.0	214.0	218.0	221.0
DCP "	148.0	146.6	149.3	151.4
ME: MJ/d/animal	15.0	15.1	15.4	15.6
Protein/Energy ratio	13.3	13.1	13.1	12.9
Mimosine, g/d /animal	0.0	4.7	9.4	14.1

Table 4.4. The effect of substituting dry leucaena leaves for cotton seed cake on daily milk yield, chemical composition of milk and bodyweight change. Experiment 1 (LSmeans±SEM)

Parameters	TREATMENTS 1	2	3	4	p[1]
From week 5 to 12					
Milk yield, l	0.84±0.08	0.97±0.08	0.88±0.08	0.83±0.09	0.441 NS
Fat corrected milk, (FCM)[2,1]	0.82±0.09	0.98±0.09	0.90±0.09	0.85±0.10	0.462 NS
ME, MJ/l milk[3]	7.6	6.9	8.0	8.3	
ME, MJ/l FCM[3]	6.9	6.9	7.2	7.5	
Butter fat,%	3.90±0.29	3.60±0.28	4.10±0.28	3.90±0.29	0.385 NS
Protein (N x 6.38),%	3.09±0.13	2.93±0.13	3.02±0.13	3.38±0.13	0.084 NS
Body weight (Initial), kg	31.00±0.88	32.30±0.93	29.40±0.88	29.80±0.10	0.444 NS
Body weight (week 12), "	30.60±1.06	32.20±1.12	35.50±1.06	33.90±1.20	0.186 NS
Body weight change, "	-0.40±0.52	-0.10±0.50	6.10±0.51	4.10±0.51	0.903 NS

[1]Probability level from the analysis of variance
[2]Four percent Fat Corrected Milk
[3]Production energy (Total energy - maintenance) per liter of milk or FCM

There were no significant (P>0.05) differences for the bodyweight changes of the does between treatments .

4.1.5 Feed intake for lactating does in Experiment 2

Daily feed intake for does in Experiment 2 is presented in Table 4.5. Amount of concentrate diets offered to these animals were reported in Chapter 3 (Table 3.4 section 3.1.3.2.3). Mimosine intake followed same trend to that of leucaena. Rhodes grass intake declined as the leucaena level increased, but total feed DM intake increased in correspondence with increase in leucaena level. AAT intake gave a similar picture to that of Experiment 1.

4.1.6 Performance of lactating does in Experiment 2

Actual milk and FCM yields in litres per day are shown in Table 4.6. ANOVA tables of total and weekly milk yields are given in Appendices 4.3 and 4.4. Substitution of leucaena leaves for cotton seed cake did not significantly (P>0.05) affect actual milk and FCM yield. Total solids, solids not fat and ash contents of milk were not significantly (P>0.05) affected by the treatments. Butterfat percent was significantly (P<0.01) higher from the milk of does in treatment 3 than of the does in the rest of the treatments. Protein content from the milk of does in treatment 1 was significantly (P<0.05) higher than that of does in treatments 2, 3 and 4.

Table 4.5. Mean daily feed intake in the lactating goats fed different substitution levels of cotton seed cake with dry leucaena leaves as protein supplements. Experiment 2

Parameters	TREATMENTS 1	2	3	4
No. of animals	14	14	13	13
Initial age of does in months	49.1	49.1	49.2	49.7
Mean daily intake (gDM/d/animal):				
Dry leucaena	0.0	167.8	335.7	503.5
Cotton seed cake	281.2	181.5	93.7	0.0
Maize bran + maize meal	549.0	549.0	549.0	549.0
Rhodes grass	714.3	675.3	642.6	623.7
Total DM Intake, g/d/animal	1544.5	1573.6	1621.0	1676.2
Feed intake, kg DM/100 kg BW	4.3	4.3	4.5	4.6
AAT g/d/animal	106	109	112	117
PBV "	-8	-8	-7	-7
DCHO "	435	459	488	516
MPS "	78	82	87	92
Protein, g/d/animal	177.6	183.0	192.8	201.1
DCP "	122.0	125.0	132.0	138.0
ME: MJ/d/animal	16.2	16.3	16.7	17.7
Protein/Energy ratio	11.0	11.2	11.5	11.4
Mimosine, g/d/animal	0.0	4.7	9.4	14.1

Table 4.6. The effect of feeding different substitution levels of cotton seed cake with dry leucaena leaves on daily milk yield, chemical composition of milk and bodyweight change. Experiment 2 (LSmeans±SEM)

Parameters		TREATMENTS 1	2	3	4	p
From week 5 to 12						
Milk yield, l		0.96±0.05	0.92±0.06	0.96±0.06	0.98±0.05	0.984 NS
Fat corrected milk (FCM),l		1.10±0.06	1.10±0.06	1.19±0.06	1.15±0.06	0.568 NS
ME, MJ/l milk		7.6	6.9	8.0	8.3	
ME, MJ/l FCM[4]		6.9	6.9	7.2	7.5	
Total solids	%	13.89±0.22	13.47±0.22	13.41±0.21	13.35±0.21	0.290 NS
Butter fat[5]	"	5.13±0.11[b]	5.07±0.11[b]	5.71±0.12[a]	5.22±0.11[b]	0.010*
Solid not fat	"	8.76±0.19	8.63±0.19	7.70±0.18	8.13±0.18	0.300 NS
Protein (N x 6.38)	"	3.69±0.06[b]	3.53±0.06[a]	3.47±0.06[b]	3.41±0.06[b]	0.011*
Ash	"	0.80±0.05	0.78±0.05	0.94±0.05	0.78±0.05	0.094 NS
Body weight (week 4),	kg	35.30±0.55	34.10±0.82	36.50±0.62	35.40±0.57	0.109 NS
Body weight (week 12),	"	36.80±0.77	37.90±0.82	37.10±0.84	37.30±0.77	0.754 NS
Body weight change,	"	1.50±0.51	3.80±0.49	0.60±0.48	1.90±0.49	0.085 NS

[ab]: Means in the same row with different superscripts are significantly different at 5% levels. The same results hold for the subsequent tables bearing the same superscript in the text

Energy efficiency performed poorest for actual milk yield in treatment 4, but the reverse was true for FCM yield. The does in this experiment did not loose weight either, neither was there a significant (P>0.05) difference in the initial bodyweight changes between treatments.

4.1.7 Milk minerals

Milk minerals were not analysed from Experiment 1 due to one week's power cut which made the milk curdle. Milk minerals (Ca, Na, P and K) which were measured in Experiment 2 were not significantly affected by the treatment diets (Table 4.7, Appendix 4.5).

4.1.8 Experiment 3: Effect of fresh leucaena leaves versus cotton seed cake on performance of lactating does

4.1.8.1 Health of the animals

All the does in this experiment were in good health throughout the preliminary and experimental periods.

Table 4.7. Chemical composition of feed ingredients in Experiment 3

	Maize bran	Cotton seed cake	Fresh leucaena	*Hyparrhenia rufa* grass
	93	96	30	94
Dry matter, %				
In dry matter, g/kg:				
OM	976	946	925	833
Ash	24	54	75	167
EE	43	64	42	8
CP	88	260	209	29
CF	71	140	149	364
NFE	775	483	525	532
Mimosine			33	
Ca	9.4	3.5	22.9	2.4
P	7.9	7.8	2.7	1.4
Na	1.6	0.5	0.12	0.13
K	16.1	11.5	20.5	17
ME, MJ/kg DM	13.57	12.57	11.91	9.86

4.1.8.2 Chemical composition of the feeds

The chemical composition of the feeds fed to the lactating goats in Experiment 3 are shown in Table 4.8. DM for all the feeds were high except for fresh leucaena which had the lowest content (300 g/kg). Ash content of leucaena ranked highest of all the feed ingredients of the mixture, although *Hyparrhenia rufa* was highest as a roughage. Ether extract and CP components of cotton seed cake were higher than those of leucaena. Energy content of maize bran was higher in comparison with the other feed ingredients.

Calcium content of leucaena was seven and ten fold those of cotton seed cake and *Hyparrhenia rufa* grass respectively. The Ca:P ratio was highest (8.5) in fresh leucaena and lowest (0.5) in cotton seed cake. Of all the feed supplements, leucaena had the lowest sodium content, while its K content was generally high.

4.1.8.3 Feed intake for lactating does

Amounts on offer for fresh leucaena, cotton seed cake and maize bran were fixed, except in treatment 4, where *ad-lib* amounts of fresh leucaena leaves were offered to the does as detailed in Chapter 3. The diet composition in Experiment 3 was not isonitrogenous in this experiment (Table 4.9). Protein levels were varied to compare fresh leucaena with cotton seed cake, in treatments 3 and 4 versus treatment 2 respectively. Treatment 1 was

Table 4.8. Chemical composition of feed ingredients in Experiment 3

	Maize bran	Cotton seed cake	Fresh leucaena	*Hyparrhenia rufa* grass
	93	96	30	94
Dry matter, %				
In Dry Matter, g/kg:				
OM	976	946	925	833
Ash	24	54	75	167
EE	43	64	42	8
CP	88	260	209	29
CF	71	140	149	364
NFE	775	483	525	532
Mimosine			33	
Ca	9.4	3.5	22.9	2.4
P	7.9	7.8	2.7	1.4
Na	1.6	0.5	0.12	0.13
K	16.1	11.5	20.5	17
ME, MJ/kg DM	13.57	12.57	11.91	9.86

Table 4.9. Mean daily feed intake in the lactating goats fed two levels of fresh leucaena leaves versus cotton seed cake. Experiment 3

Parameters	TREATMENTS 1	2	3	4
No. of animals	7	7	7	7
Initial age of does in months	38.3	37.8	37.8	38.0
Mean daily intake (g DM/d/animal):				
Fresh leucaena	0	0	108	225
Cotton seed cake	0	268	0	0
Maize bran	557	557	557	557
Hyparrhenia rufa grass hay	676	514	665	505
Total DM Intake, g/d/animal	1233	1339	1330	1287
Feed Intake, kg DM per 100 kg BW	3.7	4.3	4.0	4.0
AAT g/d/animal	41	58.5	47.3	52.4
PBV "	-67	-36	-62	-46
DCHO "	306	396	340	365
MPS "	54	70	60	65
Protein, g/d/animal/[1]	68.1	132.2	89.9	109.7
DCP "	47.0	91.0	62.0	75.0
ME: MJ/d/animal	14.1	15.9	15.2	15.1
Protein/Energy ratio	4.8	8.3	5.9	7.3
Mimosine, g/d/animal	0.0	0.0	3.7	7.7

[1]Treatment diets were not isonitrogenous

regarded as a control diet. Protein and DCP intake was higher in treatment 2 than in treatments 4, 3 and 1. Energy intake was higher in treatment 2 than in the other treatments. Generally, AAT and PBV intake indicated that there would be a need to supplement the feeds with balanced protein and carbohydrate for better production. Mimosine intake increased with the increasing amount of leucaena ingested.

4.1.8.4 Performance of lactating goats in Experiment 3

Performance of the lactating does in Experiment 3 is presented in Table 4.10. ANOVA tables of total and weekly milk yields (raw data) are given in Appendices 4.6 & 4.7. There was no significant (P>0.05) difference between treatments, neither for daily milk nor for FCM yields given in liters per day. Does on treatment 3, on a 108 g/kg DM fresh LL without cotton seed cake gave a higher FCM than those in treatments 4, 2 and 1, but were not significantly (P>0.05) different between treatments. Actual milk yield was higher for does in treatment 4 than in the other treatments, but the differences were not significant (P>0.05). Does in treatment 1 performed poorer compared to treatment 4 with differences of 0.19 liter of actual milk and 0.27 liter of FCM. Energy utilization efficiency for producing actual milk and FCM was higher (ME, MJ/l) in treatment 4 than in treatments 3, 2 and 1.

There was no significant (P>0.05) difference for both the initial and final weights and

Table 4.10. The effect of fresh leucaena leaves intake versus cotton seed cake and maize bran on daily milk yield, chemical composition of milk and body weight change. Experiment 3 (LSmeans±SEM)

Parameters		TREATMENTS 1	2	3	4	p
From week 3 to 8						
Daily milk yield, l		0.63±0.04	0.78±0.04	0.79±0.04	0.82±0.04	0.103 NS
Fat corrected milk (FCM)		0.81±0.08	1.01±0.08	1.07±0.08	1.08±0.08	0.152 NS
ME, MJ/l milk		9.0	8.3	7.7	7.6	
ME, MJ/l FCM		7.7	6.6	5.6	5.5	
Total solids	%	14.57±0.28	14.71±0.29	15.01±0.29	14.77±0.29	0.751 NS
Butter fat	"	5.99±0.17	5.96±0.16	6.38±0.16	6.13±0.17	0.127 NS
Solid not fat	"	8.58±0.23	8.75±23	8.63±0.23	8.64±0.23	0.996 NS
Protein (N x 6.38)	"	3.39±0.09	3.45±0.09	3.62±0.09	3.43±0.09	0.287 NS
Ash	"	0.85±0.01	0.85±0.02	0.84±0.01	0.82±0.01	0.403 NS
Body weight (week 2),	kg	33.60±1.00	31.30±1.89	34.20±2.37	32.40±2.05	0.796 NS
Body weight (week 8),	"	33.26±0.66	31.60±1.59	34.80±0.60	34.60±2.16	0.976 NS
Body weight change,	"	0.34±0.62	0.30±0.62	0.60±0.62	2.20±0.62	0.194 NS

also for bodyweight changes between treatments.

4.1.8.5 Milk minerals

Treatment diets had no significant (P>0.05) effect on Ca, Na, P and K results obtained from the milk of does in Experiment 3 (Table 4.11).

4.2 Experiment 4: Effect of substituting dry leucaena leaves for cotton seed cake on performance of weaner goats

4.2.1 Health of the animals

During the preliminary period, 2 male and 3 female weaner goats succumbed to some body weakness, diarrhoea and coccidiosis. These animals were isolated, treated and replaced by some reserved goats of a similar age. Consequently, on the fourth week of the preliminary period all the weaner goats were prophylactically treated against coccidiosis.

4.2.2 Chemical composition of the feeds

The chemical composition of the feeds fed to the growing weaner goats are

Table 4.11. Minerals in milk (g/l) as affected by the treatment diets in Experiment 3

Minerals	TREATMENTS				SEM	P
	1	2	3	4		
Calcium	1.33	1.23	1.23	1.31	0.06	0.492
Sodium	0.60	0.66	0.54	0.64	0.05	0.455
Phosphorus	0.96	0.86	0.91	1.09	0.08	0.201
Potassium	1.59	1.64	1.74	1.86	0.10	0.256

presented in Table 4.12. Chemical contents of NFE, CF, EE, Ash, CP and OM of leucaena used in this experiment were close to those of the leucaena used in Experiments 1 to 3. Cotton seed cake showed lower values of CF, CP, Ash and no differences in values of NFE and OM in this experiment compared to those for Experiments 1 to 3.

The quality of the maize stover, before treating it with urea, was poorer than the roughages used in Experiments 1 to 3. CP, EE, and NFE of the maize stover were lower and CF higher than those of *Hyparrhenia rufa* grass hay and Rhodes grass hay. After treating the maize stover with 5% urea, it exhibited a higher level of CP than those of *Hyparrhenia rufa* grass hay and Rhodes grass, but equalled that of the

Table 4.12. Chemical composition of feed ingredients in Experiment 4

	Maize bran	Cotton seed cake	Dry leucaena	UMSM[1]	UMS[2]	MS[3]	Molasses
Dry matter, %	91.5	95.9	94.6	44	64.8	94.2	71.7
In Dry Matter, g/kg:							
OM	962	947	890	887	900	917	880
Ash	38	53	110	113	100	83	120
EE	70	73	47	9	7	4	29
CP	103	294	222	87	71	28	43
CF	58	124	178	328	399	416	7
NFE	730	–	–	463	423	468	801
Mimosine	–	–	25	–	–	–	–
Ca	8.3	3.2	23.3	2.9	2.7	–	8.7
P	6.7	8.0	3.1	1.2	1.1	–	1
Na	1.5	0.41	0.14	0.11	0.17	–	0.21
K	13.0	11.2	20.6	23.6	19.9	–	37.9
ME, MJ/kg DM	13.92	12.8	11.21	9.45	8.99	9.09	12.66
IVDMD	74.1	57.8	51.5	58.4	50.1	48.3	–
IVOMD	73.0	55.2	48.2	57.9	49	47.8	–

[1] 5% urea treated maize stover sprinkled with 5% molasses
[2] 5% urea treated maize stover without molasses
[3] Untreated maize stover

elephant grass used in Experiment 1. Chemical composition of the 5% urea treated maize stover, sprinkled with 5% molasses did not however differ markedly from the same maize stover without molasses, and were both improved two fold in their CP content.

Calcium content of leucaena was three and eight fold that of cotton seed cake and 5% urea treated maize stover without molasses and was about nine fold to the same maize stover sprinkled with molasses, respectively. The ratio of Ca:P was highest (7.5) in leucaena and lowest (0.4) in cotton seed cake. Sodium content was lowest in leucaena compared to the other feed ingredients while its K content was rather high, but highest for molasses.

In vitro digestibility of feeds used in Experiment 4 are shown in Table 4.12. The *in vitro* DM and OM of dry leucaena was lower than that of cotton seed cake in this experiment. The coefficients of maize bran ranked the highest in all the feeds analysed in these experiments. The trend from the untreated to treated maize stover without and with molasses was an increase in *in vitro* DM and OM corresponding to urea treatment and further in addition to the sprinkled molasses. There was an increase in *in vitro* DM and OM of 1.8 and 1.2 percent units respectively from untreated to urea treated, while from untreated to urea treated with molasses the *in vitro* DM and OM increased by 10.1 and 10.1 percent units respectively.

4.2.3 Feed intake

Mean voluntary intake (Table 4.13) showed that supplementary feed offered (Table 3.5 in Chapter 3) was not all consumed. Nevertheless some individual animals, especially the male weaners were able to finish all their supplementary feeds in some of the days. Generally, total DM, intake as a percent of body weight, protein, and energy intake of the males were slightly higher than those of the females, but were not significantly ($P>0.05$) different. This is one of the factors that led to combining data for the two sexes and the others have been elaborated in Chapter 3. Protein supplement had varying effects on nutrient intake in the weaners. Intake levels of crude protein per day ranged from 79.9 – 90.4 g. Total energy intake ranged from 6.4 – 7.0 MJ ME/d following the same trend to that of protein intake.

The roughage intake did not decrease with increasing level of leucaena intake as was noticed for the lactating goats. Initially the weaner goats were reluctant to accept the 5% urea treated maize stover without molasses. After sprinkling it with the 5% molasses they started licking and eating the stover continuously. Males were noted to consume it more liberally than the females, although the amounts were not significantly ($P> 0.05$) different. After a period of about four weeks all the weaners were consuming it with relish.

Table 4.13. Mean daily feed intake in the weaner goats fed different substitution levels of cotton seed cake with dry leucaena leaves as protein supplements. Experiment 4

Parameters	TREATMENTS 1	2	3	4
No. of animals	10	10	10	10
Initial age in months	4	4	4	4
Mean daily intake (g DM/d/animal):				
Dry leucaena leaves	0.0	95.0	189.7	215.6
Cotton seed cake	144.0	96.0	48.0	0.0
Maize bran	229.2	214.9	199.6	179.9
UMSM[1]	159.3	151.0	155.0	150.0
Total DM intake, g/d/animal	532.3	556.9	592.3	543.5
Feed intake, kg DM/100 kg BW	4.0	4.0	4.3	4.1
AAT g/d/animal	32	34	38	34
PBV "	18	16	17	11
DCHO "	260	256	259	241
MPS "	46	46	46	43
ME: MJ/d/animal	6.6	6.7	7.0	6.4
Protein, g/d/animal	80.0	84.8	90.4	79.6
DCP "	55.0	58.0	62.0	55.0
Protein/Energy ratio	12.1	12.7	12.9	12.4
Mimosine, g/d/animal	0.0	2.7	5.3	6.0

4.2.4 Liveweight changes and blood parameters

In Experiment 4 interaction between sex and treatment were non-significant (P> 0.05), and data obtained for males and females were therefore pooled together in comparing treatment effect.

Mean weight gain and blood parameters of the weaner goats' are shown in Table 4.14. ANOVA tables of total and weekly body weights are given in Appendices 4.8 and 4.9. The largest mean difference in weight gain between the lowest and the highest weight gain was only 11.4 g/d. Daily feed intakes were also very similar. Thus, weaners in treatment 3 had a tendency of showing higher average daily gain than those on treatments 2, 1 and 4 respectively. Furthermore, weaners in treatment 4 had higher energy effiency than those on treatments 1, 2 and 3, but were not significantly (P>0.05) different. Treatments *per se* did not significantly (P> 0.05) affect growth rate of the weaner goats (Appendix Table 4.8). Blood FFA and glucose concentration levels were not significantly (P>0.05) affected by the treatment diets.

Table 4.14. The effect of substituting dry leucaena leaves for cotton seed cake on growth of weaner goats. Experiment 4 (LSmeans±SEM)

Parameters	TREATMENTS 1	2	3	4	p	
From week 5 to 14						
No. of animals (males/females)	5/5	5/5	5/5	5/5		
Bodyweight, kg:						
At the start of experiment (week 5)	12.4±0.15	12.1±0.16	12.2±0.16	12.1±0.06	0.468	NS
Final weight (week 14)	16.5±0.41	17.0±0.42	17.1±0.42	16.3±0.42	0.484	NS
Average daily gain, g	58.2±4.71	65.2±4.75	67.0±4.72	55.6±4.79	0.295	NS
ME, MJ/kg gain	41.0	42.0	45.0	39.0		
Feed conversion ratio, kg DM/kg gain	9.2	7.7	7.3	9.5		
Free fatty acids in blood, µmol/l	388.0±49.47	462.0±49.47	422.0±49.47	340.0±49.47	0.377	NS
Glucose in blood, mmol/l	3.89±0.35	3.84±0.35	3.92±0.35	3.76±0.35	0.988	NS

Table 4.15. The effect of substituting dry leucaena leaves for cotton seed cake on body measurements of weaner goats. Experiment 4 (LSmeans±SE)

Parameters	TREATMENTS 1	2	3	4	p
From week 5 to 14					
Body measurements (cms)					
Initial					
a. Height at the wither	50.3±0.64	51.1±0.66	50.1±0.65	49.6±0.68	
b. Heart girth	51.0±0.67	52.0±0.63	51.7±0.64	50.0±0.66	
c. Body length	44.4±0.63	45.5±0.65	43.4±0.66	45.1±0.68	
d. Width at hind quarter	11.0±0.40	11.8±0.40	11.3±0.42	11.7±0.38	
Final					
a. Height at the wither	57.0±0.65	57.8±0.65	56.9±0.55	56.4±0.56	0.853 NS
b. Heart girth	57.5±0.52	57.4±0.52	58.4±0.52	57.4±0.53	0.481 NS
c. Body length	52.2±0.53	53.3±0.57	53.3±0.52	52.1±0.52	0.107 NS
d. Width at hind quarter[2]	14.1±0.27^{ab}	14.8±0.29^{a}	14.6±0.26^{a}	13.7±0.27^{b}	0.107 NS

4.2.5 Body measurements

Body measurements of the weaner goats are shown in Table 4.15. The effect of substituting dry leucaena for cotton seed cake did not significantly ($P>0.05$) affect the final height at the wither, heart girth, body length, but weaner's width at hind quarters from treatments 2 and 3 were significantly ($P<0.05$) higher than the same measurements from weaners in treatments 1 and 4.

4.3 Rumen metabolism studies

4.3.1 Experiment 5: Degradability study using bucks fed a standard diet

4.3.1.1 AAT and PBV of bucks fed the standard diet

The AAT–PBV mean values for the feed ingredients calculated from bucks fed standard diet from Experiment 5 are presented in Table 4.16. Cotton seed cake showed higher AAT–PBV than the other feeds. Rhodes grass was lower in AAT–PBV values compared to the rest of the feeds. DCHO and MPS of maize meal

Table 4.16. **Protein, amino acid and carbohydrate utilization measured in the rumen of bucks fed diets from Experiment 5 (According to Hvelplund and Madsen, 1990)**

Feed	AAT	PBV	DCHO	MPS
Leucaena	76	86	407	73
Cotton seed cake	104	152	464	83
Maize bran	64	-31	437	78
Maize meal	65	-28	528	94
Rhodes grass hay	56	-52	203	36

Table 4.17. DM, OM and protein degradability characteristics of the feed ingredients (g/kg DM) in the rumen of bucks fed standard diet. Experiments 5.

Feed	FEED CONSTANTS			
	a	b	c	a+b
DMD				
Leucaena leaves	359	299	0.643	779
Cotton seed cake	405	385	0.633	802
Maize bran	309	606	0.475	915
Maize meal	332	592	0.840	924
Rhodes grass	179	491	0.420	668
OMD				
Leucaena leaves	299	463	0.740	787
Cotton seed cake	353	442	0.870	795
Maize bran	270	625	0.538	895
Maize meal	285	632	0.863	917
Rhodes grass	96	540	0.453	636
PD				
Leucaena leaves	455	477	0.855	932
Cotton seed cake	596	342	0.480	937
Maize bran	441	472	0.468	912
Maize meal	522	435	0.545	957
Rhodes grass	357	412	0.804	769

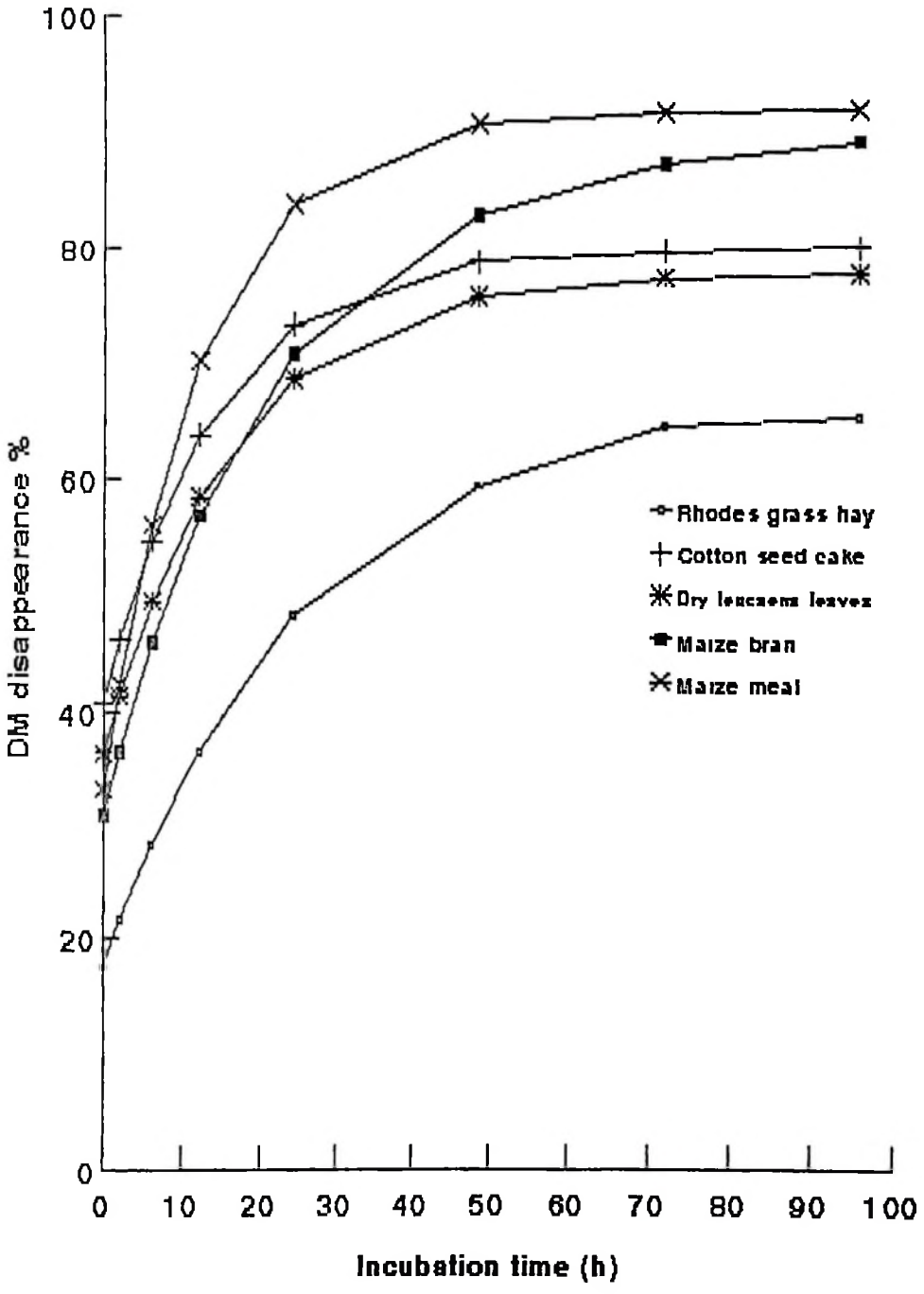

Figure 3: DM disappearance of different feeds from the rumen of bucks fed standard diet (Experiment 5)

ranked highest followed by those of maize bran, cotton seed cake, leucaena and Rhodes grass respectively.

4.3.1.2 Degradability characteristics of the individual feeds incubated in the rumen of bucks fed standard diet

Results of DM, OM and protein degradation kinetics of the feeds measured in Experiment 5 are given in Table 4.17 and the pattern of the degradability of the same feeds are illustrated in Fig. 3. The highest degradation rate of the feed ingredients occured between 0 and 48h, followed by a gradual decrease in degradation rate up to 96h. Maize meal was degraded the most followed by maize bran, cotton seed cake, leucaena and finally Rhodes grass. Results for effective degradabilities at 4 different outflow rates and 48h degradability of the feeds incubated in the rumen of the bucks fed standard diet are shown in Table 4.18. The table shows that there is a close relatioship between the degradation rate at 0.01/h outflow rate and the effective degradability at 48h. Effective degradability was decreasing with increasing outflow rate.

4.3.1.3 Rumen parameters

Results of rumen pH, NH_3N concentration and VFAs from the rumen of bucks fed standard diet are presented in Table 4.19. Illustrations of the rumen parameters, pH

Table 4.18. Effective DM, OM and protein degradability of feed ingredients (g/kg DM) in the rumen of four bucks fed standard diet. Experiment 5.

	Fractional passage rate				
	0.01	0.02	0.03	0.04	48h
DMD					
Leucaena	725	681	647	619	743
Cotton seed cake	753	717	690	664	763
Maize bran	800	724	670	629	817
Maize meal	859	807	765	729	904
Rhodes grass	570	506	438	425	622
OMD					
Leucaena	710	669	635	592	728
Cotton seed cake	746	708	710	651	739
Maize bran	789	716	662	621	815
Maize meal	850	795	751	713	898
Rhodes grass	536	467	417	379	581
PD					
Leucaena	875	831	795	766	918
Cotton seed cake	877	835	804	780	890
Maize bran	831	771	736	689	822
Maize meal	880	838	801	771	910
Rhodes grass	686	631	592	563	725

Table 4.19. Rumen, pH, NH_3-N (mg/l) and VFA concentration (mM/l) and relative proportions taken diurnally and nocturnally from fistulated bucks given a standard diet (LSmeans±SEM). Experiment 5

Time (h)	Rumen pH	Rumen NH_3-N (mg/l)	Rumen VFA Total mM/l	VFA concentration, mmol/mol C_2	C_3	C_4	C_5	C_2/C_3
0800[1] First feeding		6.83±0.05	113.68±13.87	67	729	192	73	6 3.81
1000[1/2]		6.62±0.04	166.15± 9.81	57	714	200	79	7 3.62
1400[1] Second feeding		6.54±0.05	154.75±13.87	50	725	192	76	6 3.62
1600		6.34±0.05	120.96±13.87	–	–	–	–	– –
1800		–	–	44± 6.4	686±12.49	223± 9.22	84±3.94	8±1.46 3.15
2000		6.53±0.05	85.54±13.87	45± 6.4	716±12.49	204± 9.22	74±3.94	7±1.46 3.54
2200		6.54±0.05	89.95±13.87	53± 6.4	720±12.49	204± 9.22	73±3.94	8±1.46 3.63
2400		6.55±0.05	80.84±13.87	40± 6.4	723±12.49	199± 9.22	74±3.94	8±1.46 3.72
0200		6.60±0.05	108.59±13.87	45± 6.4	716±12.49	194± 9.22	82±3.94	8±1.46 3.70
0400		6.59±0.05	127.13±13.87	45± 6.4	688±12.49	220± 9.22	83±3.94	9±1.46 3.26
0600		6.67±0.05	102.66±13.87	52± 6.4	741±12.49	179± 9.22	71±3.94	9±1.46 4.15

[1] Only means for VFAs were obtained for these particular hours

[2] Observations taken at this hour were twice the others, thus gave a smaller SE than the rest

and NH_3N are shown in comparison with the standard values in Figures 5, 6, 7 and 8 (sections 4.3.7 to 4.3.7.3). Rumen pH and NH_3N varied with feeding time in the different experiments and ranged between 6.0 to 7.0 and 30 to 327 mg/l respectively. Rumen VFAs reported from the rumen of the bucks fed standard diet (Table 4.19) was within or close to the ranges of total VFA, C2, C3, C4, C5 and ratios of C2/C3 reported in the other experiments (Tables 4.28 and 4.30).

4.3.1.4 *In vitro* digestibility

Means of the *in vitro* DM and OM digestibility coefficients obtained from the feeds measured in Experiment 5 are shown in Table 4.19. All the concentrate feeds had higher values of *in vitro* DM and OM digestibility coefficients than those of the roughages. DM and OM digestibilities of maize meal ranked the highest.

Table 4.20. **Mean *In vitro* DM and OM (%) digestibility co-efficients of the feed ingredients analysed in Experiment 5.**

FEEDSTUFFS	IVDMD	IVOMD
Dry leucaena	52.7	50.0
Cotton seed cake	61.4	59.4
Maize bran	71.0	69.5
Maize meal	75.1	79.7
Mixed concentrate used in the standard diet	67.2	63.6
Rhodes grass	44.9	43.5
Elephant grass	38.8	34.9

4.3.6 Experiment 6: Degradability study with bucks fed treatment diets used in Experiments 1 to 4

4.3.6.1 AAT and PBV of bucks fed diets used in Experiments 1 to 4

Average AAT–PBV values for the feed ingredients used in Experiments 1 to 4 are shown and individual values are shown in Table 4.21. The formula for calculating AAT–PBV values is refered to in Chapter 3, section 3.3.1. PBV values for leucaena and cotton seed cake were positive, but negative for the rest of the feeds. If PBV is negative, this means that the microbes need more nitrogen to ferment the feed, than is available from degraded protein from the feed in the rumen. If PBV is positive it means that the amount of protein degraded in the rumen is in excess compared to the amount necessary for microbial growth which can be obtained on the basis of the amount carbohyrate digested (Hvelplund and Madsen, 1990). Generally the DCHO and MPS of concentrates were higher than for roughages except for urea treated maize stover sprinkled with molasses. AAT–PBV, DCHO and MPS coefficients for elephant grass and *Hyparrhenia rufa* grass hay were calculated using effective degradability values according to Hvelplund and Madsen (1990).

Table 4.21 Protein, amino acid and carbohydrate utilization measured in the rumen of bucks fed treatment diets used in Experiments 1 to 4 (According to Hvelplund and Madsen, 1990)

Experiments 1 and 2		SE
Amino acids absorbable in the intestines (AAT)		
Leucaena	93.3	1.3
Cotton seed cake	119.3	2.3
Maize bran	79.3	0.7
Maize meal	69.3	2.3
Rhodes grass hay	16.3	0.4
Protein balance in the rumen (PBV)		
Leucaena	80.5	2.4
Cotton seed cake	155.3	3.0
Maize bran	-35.0	1.1
Maize meal	-21.8	1.0
Rhodes grass hay	-50.0	0.9
Digestible carbohydrates (DCHO)		
Leucaena	395.0	3.7
Cotton seed cake	388.0	3.9
Maize bran	466.3	8.2
Maize meal	471.8	3.3
Rhodes grass hay	96.8	4.8
Microbial protein synthesis (MPS)		
Leucaena	70.3	0.7
Cotton seed cake	69.3	0.7
Maize bran	83.0	1.5
Maize meal	84.0	0.6
Rhodes grass hay	17.3	1.0

Table 4.21 continued:

Experiment 3		
Amino acids absorbable in the intestines (AAT)		
Leucaena	84	
Cotton seed cake	107	
Maize bran	63	
Hyparrhenia rufa	46	
Protein balance in the rumen (PBV)		
Leucaena	40	
Cotton seed cake	74	
Maize bran	-37	
Hyparrhenia rufa	-68	
Digestible carbohydrates (DCHO)		
Leucaena	315	
Cotton seed cake	376	
Maize bran	465	
Hyparrhenia rufa	70	
Microbial protein synthesis (MPS)		
Leucaena	56	
Cotton seed cake	67	
Maize bran	83	
Hyparrhenia rufa	12	
Experiment 4		
Amino acids absorbable in the intestines (AAT)		
Leucaena	83.0	0.79
Cotton seed cake	89.3	1.1
Maize bran	53.5	0.2
UMSM	84.0	0.4
UMS	57.5	0.6
MS	43.3	0.7

Table 4.21 continued:

Protein balance in the rumen (PBV)		
Leucaena	80.5	2.4
Cotton seed cake	155.3	3.0
Maize bran	-35.0	1.1
UMSM	-0.8	0.2
UMS	-54.0	0.4
MS	-153.8	0.4
Digestible carbohydrates (DCHO)		
Leucaena	407.0	1.7
Cotton seed cake	524.0	2.8
Maize bran	408.3	0.7
UMSM	521.3	0.7
UMS	190.8	2.4
MS	112.0	0.4
Microbial protein synthesis (MPS)		
Leucaena	72.0	0.4
Cotton seed cake	92.8	0.7
Maize bran	72.8	0.7
UMSM	93.3	0.2
UMS	33.3	0.7
MS	20.5	0.6

[1]Values obtained in Experiment 3 were calculated using effective degradability from Experiment 5 and paper by Kimambo *et al.* (1994)

4.3.6.2 Degradability characteristics of feeds measured in the rumen of bucks fed treatment diets used in Experiments 1 to 4

Least mean square results of DM, OM and protein degradability kinetics of Experiments 1 and 2 were calculated from the fitted exponential equation by Ørskov and McDonald (1979) and are shown in Table 4.22. The DM losses from the nylon bags of different feeds, after incubation at different hours in the rumen are shown in Appendix Table 4.11. Leucaena was significantly ($P<0.05$) higher for protein zero intercept (a) in treatment 3 than in treatments 2, 4 and 1 respectively. It was slightly higher for potentially degradable (b) fraction in treatment 1 compared to the rest of the treatments. Rate constant and potential degradability (a+b) of leucaena's DM, OM and protein were similar in all the four treatments. The zero time intercept and the potential degradability were slightly higher for cotton seed cake than for leucaena. Cotton seed cake had significantly ($P<0.05$) higher b DM fraction in treatment 2 than in treatments 3, 4 and 1. DM, degradation rate constant c for cotton seed cake was slightly higher in treatment 1 than in treatments 3, 4 and 2. Cotton seed cake's a+b DM was significantly ($P<0.05$) higher in treatment 2 than in treatments 3, 4 and 1 respectively. The rate of degradation values were slightly higher for maize bran compared to maize meal and both these values were close to those of leucaena and cotton seed cake respectively. Potential degradabilities for maize bran and maize meal were higher than those of Rhodes grass and the values

Table 4.22. DM, OM and protein degradability characteristics of the feed ingredients (g/kg DM) used in Experiments 1 and 2 from equation P = a+b (1-e $^{-ct}$) (LSmeans±SEM).

Feed	TREATMENTS				SEM	P
	1	2	3	4		
Replications	4	4	4	4		
DMD						
Leucaena						
a	360	374	351	348	8.92	0.234NS
b	465	431	436	451	16.14	0.483NS
c	0.429	0.695	0.560	0.565	0.10	0.340NS
a+b	824	804	787	798	11.99	0.243NS
Cotton seed cake						
a	409	404	388	392	7.02	0.181NS
b	417^{c}	534^{a}	469^{ab}	454^{b}	22.06	0.027*
c	0.555	0.246	0.434	0.382	0.07	0.086NS
a+b	826^{c}	938^{a}	856^{b}	846^{bc}	21.53	0.023*
Maize bran						
a	354	352	350	344	9.84	0.890NS
b	585	595	593	591	19.67	0.982NS
c	0.589	0.558	0.745	0.552	0.15	0.788NS
a+b	939	947	943	935	20.50	0.978NS
Maize meal						
a	363	369	387	383	13.28	0.555NS
b	585	614	569	585	22.29	0.571NS
c	0.526	0.451	0.531	0.483	0.11	0.945NS
a+b	968	945	982	975	22.49	0.696NS
Rhodes grass						
a	151	157	142	153	7.45	0.564NS
b	465	439	568	445	51.29	0.311NS
c	0.212	0.224	0.202	0.233	0.06	0.985NS
a+b	616	596	710	598	51.25	0.392NS
OMD						
Leucaena						
a	301	271	284	274	15.66	0.565NS
b	494	521	519	502	18.97	0.703NS
c	0.507	0.694	0.585	0.679	0.12	0.662NS
a+b	795	793	803	777	14.96	0.669NS
Cotton seed cake						
a	340	352	326	333	10.58	0.392NS
b	486	531	543	560	27.25	0.319NS
c	0.334	0.323	0.443	0.324	0.08	0.660NS
a+b	826	883	869	893	32.36	0.504NS

Table 4.22 continued:

Maize bran						
a	265	270	244	248	18.78	0.728NS
b	685	699	706	703	28.41	0.952NS
c	0.508	0.465	0.594	0.477	0.08	0.641NS
a+b	950	968	950	952	21.88	0.918NS
OMD						
Maize meal						
a	314	311	300	294	8.43	0.320NS
b	645	670	666	663	14.31	0.641NS
c	0.481	0.402	0.458	0.472	0.07	0.829NS
a+b	959	981	963	957	12.37	0.200NS
Rhodes grass						
a	67	71	78	82	6.89	0.465NS
b	580	504	545	480	67.52	0.738NS
c	0.232	0.333	0.281	0.287	0.07	0.766NS
a+b	647	574	632	562	69.26	0.800NS
PD						
Leucaena						
a	404[c]	451[b]	459[a]	450[b]	9.98	0.014*
b	525	478	449	481	18.64	0.099NS
c	0.649	0.556	0.468	0.572	0.06	0.678NS
a+b	928	929	908	932	12.11	0.501NS
Cotton seed cake						
a	387	419	423	356	35.56	0.536NS
b	551	548	550	590	16.13	0.259NS
c	0.532	0.395	0.407	0.428	0.13	0.876NS
a+b	938	967	973	946	12.11	0.501NS
Maize bran						
a	475	449	455	428	15.98	0.286NS
b	501	516	507	543	22.76	0.586NS
c	0.408	0.386	0.387	0.398	0.07	0.994NS
a+b	976	964	962	972	19.77	0.955NS
Maize meal						
a	430	430	474	475	33.23	0.616NS
b	540	516	508	500	19.55	0.535NS
c	0.288	0.476	0.274	0.290	0.08	0.272NS
a+b	968	945	982	975	22.49	0.696NS
Rhodes grass						
a	297	313	248	330	41.25	0.563NS
b	493	471	523	501	33.35	0.757NS
c	0.307	0.355	0.466	0.278	0.09	0.616NS
a+b	790	785	771	831	24.24	0.394NS

of the latter were lower than those of the rest of the feeds. The potentially degradable (b) fraction followed a reverse trend to that of rate of degradation and potential degradability. Significant differences were not (P>0.05) observed between treatments.

The effective degradability (ED) at 0.04h fractional passage rate for calculating AAT–PBVs are shown in Table 4.23. The four different fractional passage rates (0.01 to 0.04/h) and 48h degradabilities of the same are shown in Appendix Table 4.12. The ED decreased as the fractional passage rate increased from 0.01 to 0.04/h. The values of 0.01/h were closely related to their corresponding 48h degradabilities for all the feed ingredients irrespective of their treatment diets. There were no significant differences (P>0.05) between treatments, though for DMD of leucaena at 0.01 and 48h the values were slightly higher in treatment 1 than the same values in other treatments.

Mean values of DM, OM and protein degradability characteristics of feeds measured in the rumen of bucks fed treatment diets from Experiment 3 are shown in Table 4.24 (Appendix 4.13). Degradability values for maize bran were higher than the rest of the feeds.

Table 4.23. Effective DM, OM and protein degradability of the feed ingredients (g/kg DM) used in Experiments 1 and 2 at 4 % fractional passage rate (LSmeans±SEM).

Feed	TREATMENTS 1	2	3	4	SEM	P
Replications	4	4	4	4		
Fractional passage rate						
DMD						
Leucaena	595	647	602	606	14.92	0.125NS
Cotton seed cake	638	600	613	613	16.69	0.466NS
Maize bran	691	699	706	686	12.72	0.507NS
Maize meal	670	685	703	696	23.39	0.765NS
Rhodes grass	305	296	309	317	11.21	0.646NS
OMD						
Leucaena	572	590	574	584	17.06	0.868NS
Cotton seed cake	568	586	578	567	21.46	0.910NS
Maize bran	673	645	655	628	16.51	0.343NS
Maize meal	658	667	650	652	24.20	0.924NS
Rhodes grass	257	283	276	275	13.51	0.608NS
PD						
Leucaena	757	731	729	715	26.21	0.724NS
Cotton seed cake	727	750	748	774	19.63	0.453NS
Maize bran	714	698	700	694	10.42	0.556NS
Maize meal	718	721	742	700	12.22	0.188NS
Rhodes grass	624	624	614	630	31.36	0.988NS

Table 4.24 Rumen DM, OM and protein degradability of the feed ingredients (g/kg DM) incubated in the rumen of bucks fed the treatment diets used in Experiment 3 (means)

	Feed	Time	DML	OML	PL
	Fresh I.I.	48	68.8	67.5	81.0
SE			1.8	2.0	0.6
	Cotton seed cake	48	81.0	79.8	87.0
SE			0.6	0.60	0.8
	Maize bran	48	86.0	85.3	88.3
SE			0.8	0.7	1.6
	Hyparrhenia rufa	48	45.5	42.3	51.3
SE			1.6	1.6	0.4
	Fresh I.I.	24	64.0	62.8	68.5
SE			1.3	1.1	0.4
	Cotton seed cake	24	71.5	69.5	75.5
SE			0.6	0.6	0.8
	Maize bran	24	77.3	77.3	80.3
SE			1.6	1.1	1.4
	Hyparrhenia rufa	24	31.8	26.5	39.5
SE			2.9	3.5	1.3
	Fresh I.I.	0	22.5	18.0	24.5
SE			4.6	3.3	5.6
	Cotton seed cake	0	20.5	14.5	27.5
SE			3.6	2.5	4.9
	Maize bran	0	28.5	27.5	31.5
SE			0.3	0.3	0.3
	Hyparrhenia rufa	0	13	12	14.5
SE			0.5	0.5	0.3

Degradability characteristics of untreated maize stover, treated maize stover without and the same treated stover sprinkled with molasses measured in the rumen of the bucks fed diets from Experiment 4 are illustrated in Fig. 4. DM, OM and protein losses from the nylon bags of the stovers after incubation from 0 to 120h are shown in Appendix Table 4.14. It is obvious from the graph that the treated maize stover sprinkled with molasses was more degraded than the same without molasses and finally the untreated maize stover. Means of DM, OM and protein degradability constants of the feeds measured from the rumen of the bucks fed diet from Experiment 4 are shown in Table 4.25. Substitution of dry leucaena leaves for cotton seed cake did not significantly ($P>0.05$) affect the zero time intercept, degradation rate constants and the potential degradability of DM, OM and protein shown for overall results.

The mean DM, OM and protein degradation rate constants for cotton seed cake were higher in all the four treatments compared to similar values for leucaena. Zero time intercept and the potential degradabilities followed a similar trend for both cotton seed cake and leucaena in the four treatments. Maize bran values were all slightly lower compared to those of cotton seed cake, but in contrast to leucaena, the DM, OM and protein degradation rate constants and their potential degradabilities were higher for the maize bran. The DM, OM and protein degradation rate constants were highest for urea treated maize stover sprinkled with molasses.

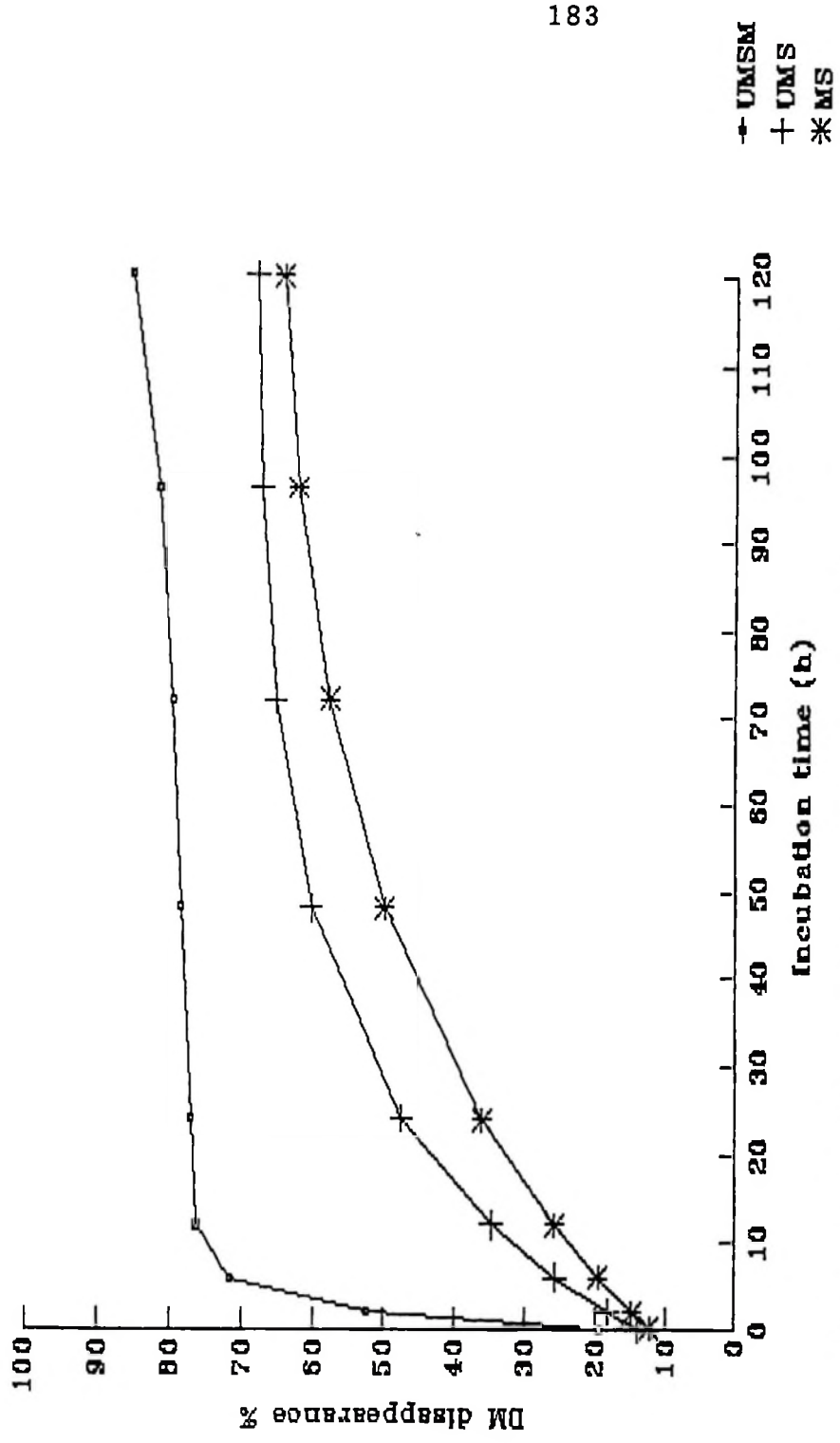

Figure 4. DM disappearance characteristic of urea-treated with, (UMSM) without molasses (UMS) and untreated (MS). Experiment 4

Table 4.25. DM, OM and protein degradability characteristics of the feed ingredients (g/kg DM) used in Experiment 4 from equation $P = a+b\ (1-e^{-ct})$ (means).

Feed	TREATMENT				Means
	1	2	3	4	
Replications	2	2	2	2	
DMD					
Leucaena					
a	331	327	322	322	326
b	462	497	499	533	498
c	0.590	0.577	0.547	0.604	0.580
a+b	793	824	821	855	823
Cotton seed cake					
a	397	404	418	404	406
b	472	465	418	476	458
c	0.937	0.875	0.982	0.751	0.886
a+b	869	869	836	880	864
Maize bran					
a	249	238	252	252	248
b	632	550	525	595	576
c	0.839	0.701	1.704	0.631	0.969
a+b	881	788	777	847	823
MS					
a	121	120	119	126	122
b	544	576	583	580	571
c	0.257	0.244	0.207	0.219	0.232
a+b	665	696	702	706	692
UMS					
a	130	161	146	118	139
b	526	520	582	602	558
c	0.379	0.390	0.293	0.530	0.398
a+b	656	681	728	720	696
UMSM					
a	215	117	181	207	195
b	577	582	577	576	578
c	2.861	6.115	5.434	3.212	4.416
a+b	792	759	758	783	773
OMD					
Leucaena					
a	233	564	233	245	244
b	545	551	567	568	558
c	0.684	0.675	0.658	0.765	0.696
a+b	778	815	800	814	802
Cotton seed cake					
a	332	338	352	341	341
b	512	521	476	537	512
c	1.140	1.024	1.088	0.820	1.018
a+b	844	859	828	878	953
OMD					
Maize bran					
a	163	182	197	207	187
b	522	580	555	595	576
c	1.219	0.775	0.780	0.740	1.130
a+b	685	762	752	814	753

Table 4.25 continued:

MS					
a	40	58	41	61	50
b	582	624	623	613	611
c	0.352	0.254	0.239	0.264	0.277
a+b	622	682	664	674	661
UMS					
a	96	84	99	89	92
b	544	580	640	588	588
c	0.316	0.362	0.255	0.575	0.377
a+b	640	664	739	677	680
UMSM					
a	269	216	269	200	239
b	530	582	577	578	544
c	1.078	2.389	1.367	2.389	1.806
a+b	799	764	787	778	782
PD					
Leucaena					
a	376	363	368	378	370
b	504	530	525	522	522
c	0.635	0.761	0.658	0.780	0.709
a+b	880	893	901	895	892
Cotton seed cake					
a	362	391	352	393	375
b	583	569	594	569	579
c	0.795	0.816	0.726	0.593	0.733
a+b	945	960	946	962	953
Maize bran					
a	441	443	447	440	443
b	537	537	547	528	537
c	0.755	0.725	0.636	0.784	0.725
a+b	978	980	994	968	980
MS					
a	372	336	349	383	360
b	356	342	380	322	350
c	0.185	0.079	0.191	0.221	0.169
a+b	728	678	729	705	710
UMS					
a	382	346	357	371	364
b	440	429	417	433	430
c	1.954	5.910	3.230	2.363	3.364
a+b	822	775	774	804	794
UMSM					
a	360	360	361	361	361
b	554	553	558	564	557
c	13.840	8.210	8.005	7.747	9.452
a+b	914	913	919	925	918

Mean effective degradability at 0.04/h fractional passage rate and 48h degradability values of the feeds measured in the rumen of bucks fed diets from Experiment 4 are presented in Table 4.26. Mean effective degradability at 0.01/h to 0.04/h fractional passage rates are shown in Appendix Table 4.15. Effective degradability decreased as the fractional passage rate increased from 0.01 to 0.04/h, similar to those presented in Appendix Table 4.13 for the bucks fed treatment diets from Experiments 1 and 2. From the overall results, effective degradabilities did not show significant ($P<0.05$) differences between treatments.

4.3.7 Rumen parameters and urinary 3-hydroxy-4(1H)-pyridone (DHP)

4.3.7.1 Rumen parameters from the bucks fed treatment diets used in Experiments 1 to 4

Least mean squares of rumen pH measured in bucks fed treatment diets used in Experiments 1 and 2 during 24 hours diurnally and nocturnally are illustrated in Fig. 5 and their individual figures are given in Appendix 4.16. The influence of the treatment diets on pH were highly significant ($P<0.05$) starting at 1000 and from 2000 to 0600h respectively (Appendix Table 4.16). The overall results indicated that rumen pH was significantly ($P<0.05$) higher in treatments 3 and 4 than in treatments 2 and 1 respectively. The rumen pH was highest before morning feed for treatment 3, and showed a continuous drop in pH for the next 5 to 10 hours. The rest of the treatments including the standard diet showed a sharp drop for each of their pH measurements, after first feeding,

Table 4.26. Effective DM, OM and PD of the feed ingredients (g/kg DM) in the rumen of bucks fed treatment diets used in Experiment 4 at 4% fractional passage rate

Feed	TREATMENTS 1	2	3	4	
Replications	2	2	2	2	MEAN
Fractional passage rate					
DMD					
Leucaena	606	620	610	643	620
Cotton seed cake	727	722	715	714	720
Maize bran	676	588	678	616	640
MS	333	338	318	331	330
UMS	386	418	392	461	414
UMSM	721	723	718	719	720
OMD					
Leucaena	577	609	586	618	598
Cotton seed cake	711	713	700	702	706
Maize bran	556	564	650	601	593
MS	312	300	274	305	298
UMS	336	359	348	436	370
UMSM	656	685	670	695	677
PD					
Leucaena	685	710	700	718	703
Cotton seed cake	824	831	821	803	820
Maize bran	792	788	782	790	788
MS	484	435	472	498	472
UMS	746	748	728	741	741
UMSM	899	888	892	897	894

then a slight rise in all of them were observed. A continuous drop in pH was more conspicuous for treatment 1 followed by in treatment 2. After second feeding (at 1500h) the pH drop persited for one hour for all the treatments and four hours for pH in treatment 3. Thereafter a gradual rise occured in all the treatments from the nocturnal to morning hours. The pH of the standard diet continuously rose above the rest of the treatments starting at 1200h to the morning hours.

The influence of the substitution of dry leucaena for cotton seed cake significantly ($P<0.05$) affected the diurnal and nocturnal rumen NH_3N concentration (Fig. 6 and Appendix Table 4.16). Rumen NH_3-N concentration level was significantly higher ($P<0.05$) for the bucks fed treaments 1 and 2 followed by the concentration in treatments 4 and 3 at both 1200 and 2000h respectively. At 0200h, rumen NH3-N concentration were significantly ($P<0.01$) lower in treatment 1 than the concentration in all the other treatments. At 0400h, NH_3-N concentration was significantly ($P<0.05$) higher in treatment 1 than the concentration of the same in treatments 3, 2 and 4 respectively. The overall rumen NH_3-N concentration were not significantly ($P>0.05$) affected by the treatment diets. There was no definite trend of the NH_3-N concentration in all the treatments illustrated in Fig. 6 although fluctuations as affected by feeding times were obvious. A general increase in NH_3-N concentration level was noted after morning and afternoon feeding, but was not conspicuous for the latter time. NH_3-N concentration in treatment 3 however, had a strange drop after morning feeding, flexed into a brief rise it

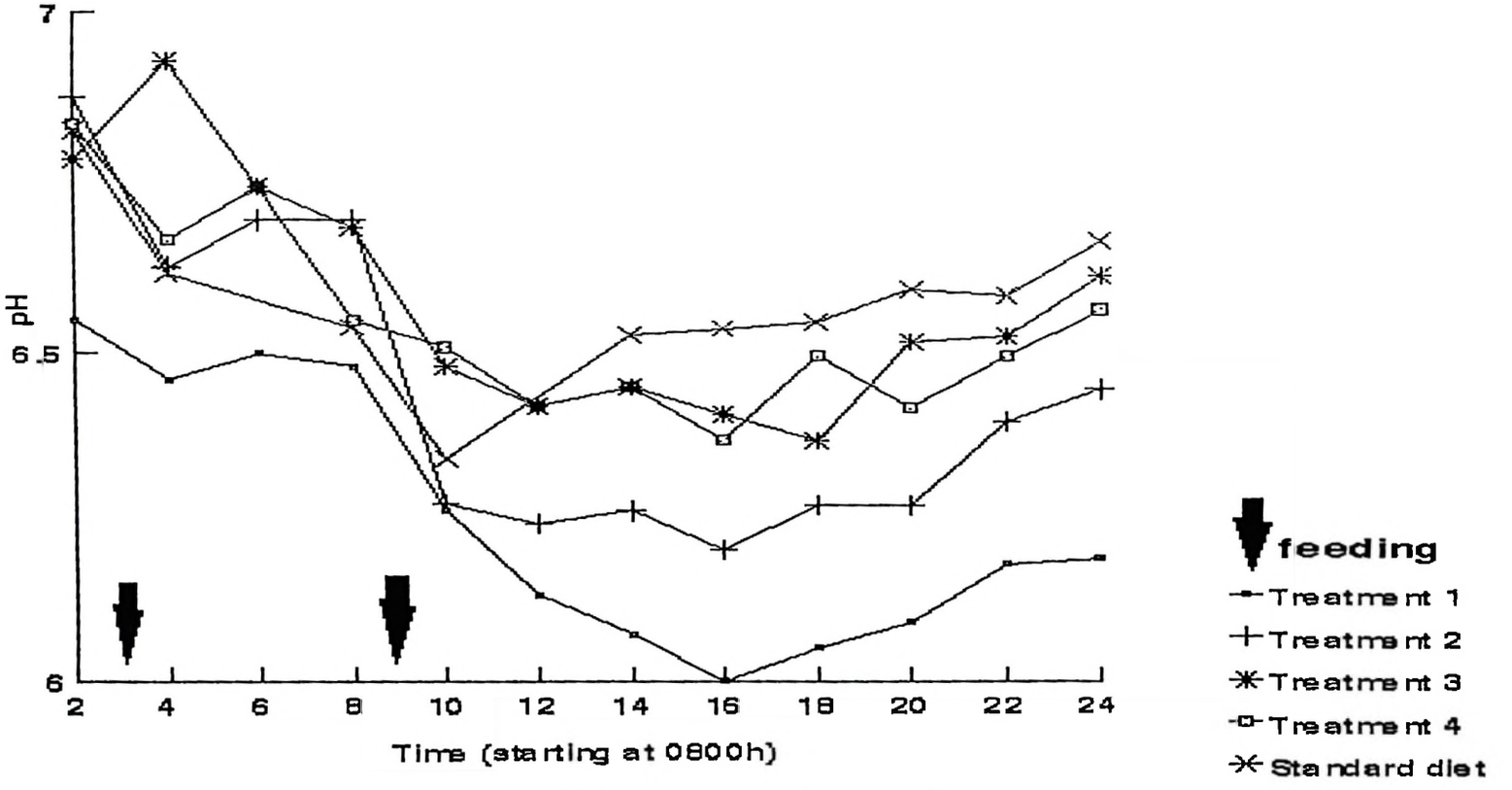

Figure 5. Rumen pH of bucks fed treatment diets used in Experiments 1 and 2

then followed the pattern of the other treatments. NH3-N concentration had a sharp drop towards morning hours of the following day, while in treatment 1 it stabilized in a parallel line to time and in treatment 3 had a sharp rise.

Means of rumen pH measured in the bucks fed treatment diets from Experiment 3, diurnally and nocturnally, during the 24 hours are illustrated in Fig. 7 (Appendix Table 4.17). The overall results indicated a significantly ($P<0.05$) higher pH for rumen liquor in treatment 3 than the pH in treatments 4, 1 and 2 respectively. Before morning feeding, there was a slightly lower rumen pH from treatment diets 2 and 4, while the reverse was true for those in treatment diets 1 and 3. After feeding, there was a flex of increase of pH in all the treatments, thereafter a slight decline, to a straight line for pH in treatment 2. The latter declined to pH 6 around 1800h, followed by a gradual increase to the following morning of the next day.

Rumen NH_3-N concentration levels were significantly ($P<0.01$) different in all the treatments diurnally and nocturnally for all the sampling hours (Fig. 8 and Appendix Table 4.17). The overall results showed rumen NH_3-N concentration level was significantly ($P<0.05$) higher in treatment 4 followed by the NH_3-N in treatments 3, 2 and 1 respectively. The pattern of rumen NH3-N concentration (Fig. 8) followed similar trend to that of individual time and of the overall results. NH_3-N concentration for rumen liquor in treatment 4 was significantly ($P<0.01$) above the rest of the treatments and the highest value of 327 mg/l was observed at 1200h where the highest level of leucaena (treatment 4) was offered Means of the rumen pH measured in bucks fed treatment diets

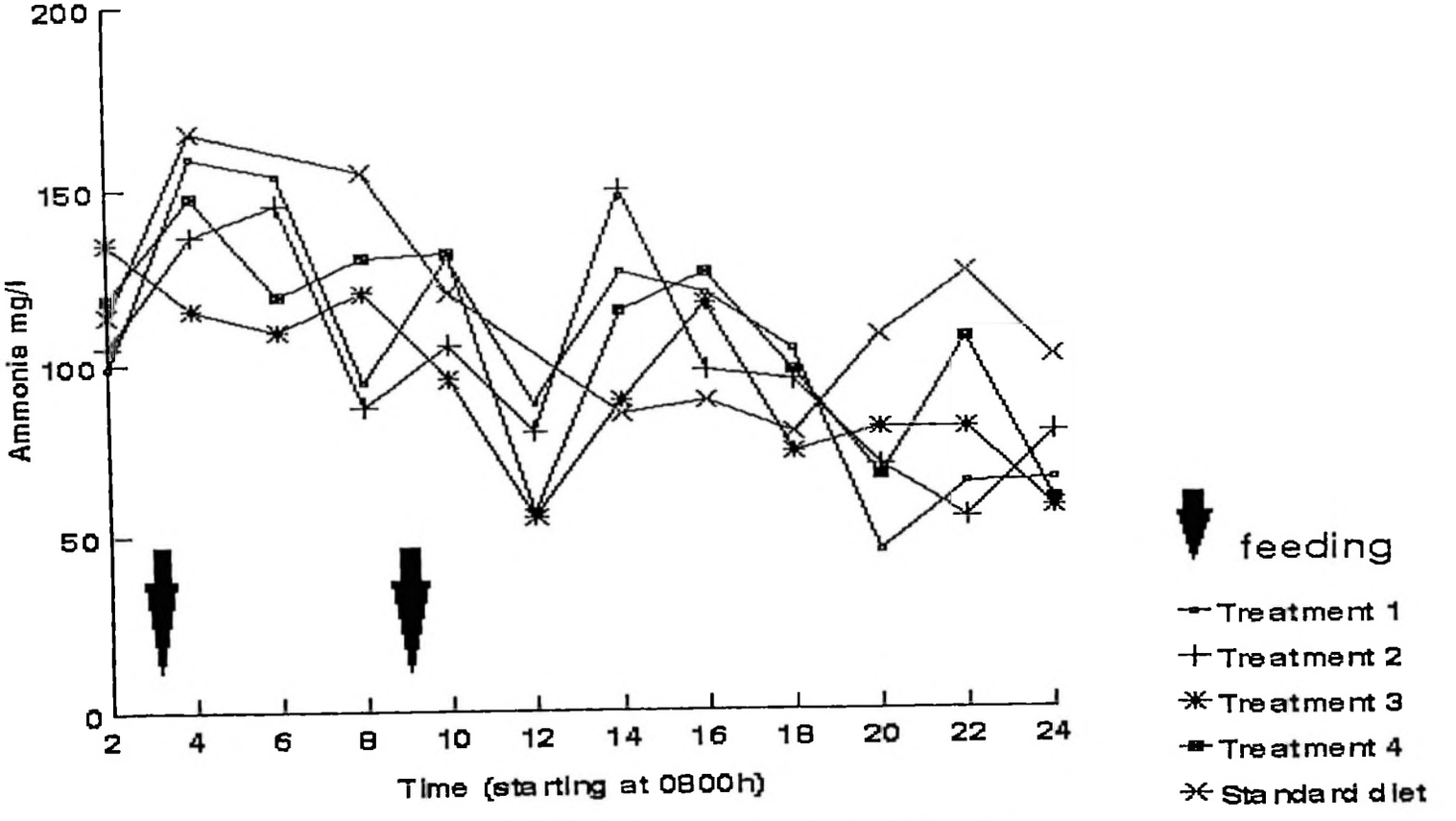

Figure 6. Rumen ammonia concentration of bucks fed treatment diets used in Experiments 1 and 2

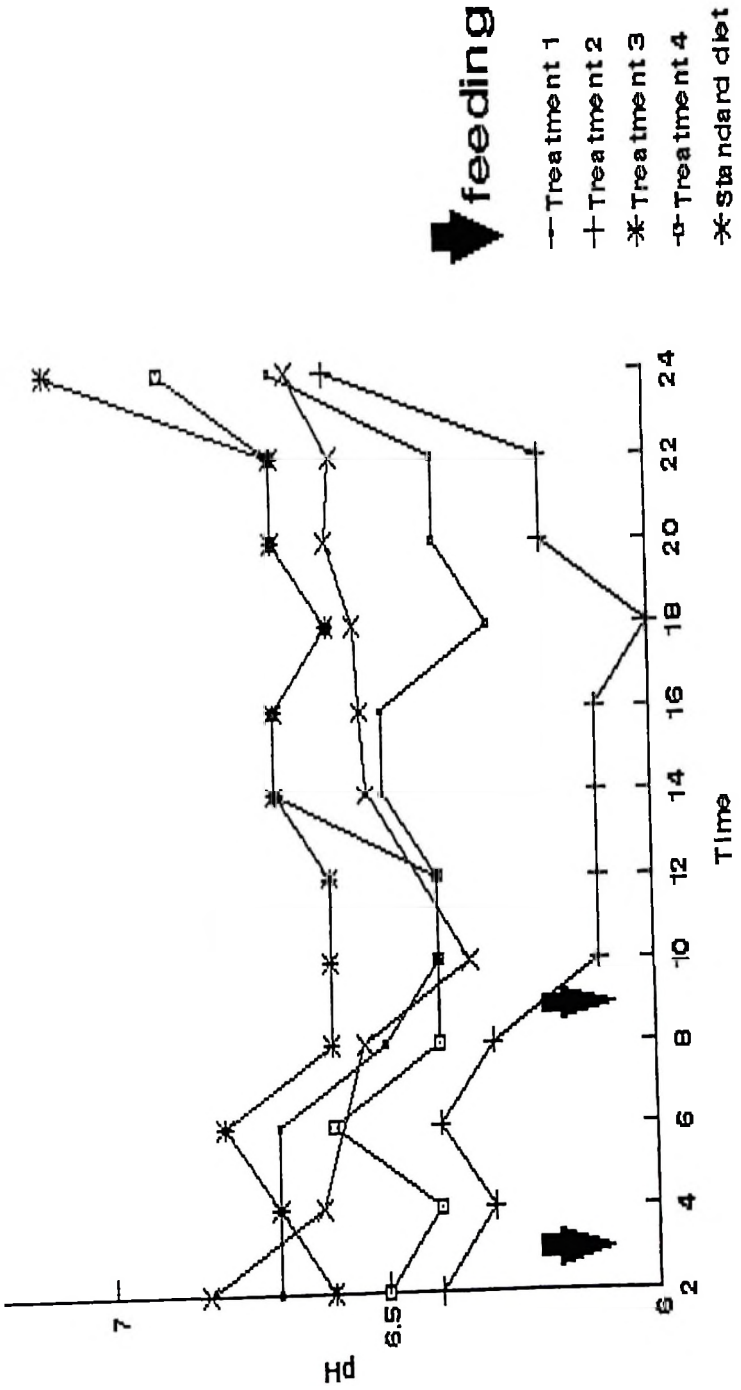

Fig 7. Rumen pH of bucks fed treatment diets used in Experiment 3

from Experiment 4 diurnally and nocturnally during 24 hours are shown in Fig. 9 and Appendix Table 4.18. Rumen pH were significantly ($P<0.05$) higher in treatments 4 and 2 than that from the other treatments (Appendix Table 4.18). The pH pattern of the rumen liquor for treatment 4 showed a stable decrease before and after morning feeding, stabilizing at a line parallel to time for 2 hours; rising gradually for another 2 hours, decreasing and flexing to increasing gradually and staying on a straight line for the rest of the night to the next day. The other treatments had a tendency of following a similar pattern, although rumen pH in treatment 1 declined gradually towards the next morning hours. Influence on rumen NH_3-N concentration of substitution of dry leucaena for cotton seed cake was significantly ($P<0.05$) different in all the treatments diurnally and nocturnally except at 1400h before afternoon feeding (Fig. 10 and Appendix 4.18). At first feeding, rumen NH_3-N concentration of rumen liquor in treatments 4 and 3 were significantly ($P<0.05$) higher than that in treatments 1 and 2. At 1000 and 1200h, NH_3-N concentration of rumen liquor in treatment 1 was significantly ($P<0.05$) higher than those in the rest of the treatments. Fig. 10 shows that NH_3-N concentration had a similar trend in all treatments, but values for treatment 4 was consistently higher.

The content of volatile fatty acids in rumen liquor from the bucks fed diets from Experiments 1 and 2 showed very little diurnal and nocturnal variation within the treatment diets (Table 4.27). Total VFA (mM) and molar proportion (mmol/mol) of

acetate (C_2), propionate (C_3), butyrate (C_4), valerate (C_5) and the ratio of acetate to propionate (C_2/C_3) were not significantly (P>0.05) affected by the four treatment diets. Overall molar proportion of C_2 was significantly higher (P<0.01) and of C_3 significantly (P<0.05) lower in treatment 1 than in the rest of the treatments (Table 4.27). Molar proportion of C_4 was significantly (P<0.01) higher in treatment 3 than in treatments 4, 2 and 1. Ratio of C_2/C_3 was significantly (P<0.01) higher in treatment 1 than in treatments 3, 4 and 2.

Means of rumen VFAs in bucks fed treatment diets used in Experiment 4 are presented in Table 4.28. Analysis from the overall results showed that total VFAs of rumen liquor in treatment 3 was significantly (P<0.05) higher than in treatments 4, 2 and 1 in that order. Molar proportions of C_2 in treatment 1 were also found to be significantly (P<0.01) higher than in treatments 4, 3 and 2. In treatment 2 the molar proportion of C_3 was significantly (P<0.1) higher than in treatments 3, 4 and 1. Molar proportion of C_4 was not significantly (P>0.05) affected by the treatments, but the molar proportion of C_5 was noted to be significantly (P<0.05) higher in treatment 1 compared to those in treatments 3, 2 and 4 in decreasing order. The C_2/C_3 ratio was also significantly (P<0.05) higher in treatment 1 compared to those in treatments 4, 3 and 2.

Average values of urinary DHP concentration increased with increasing level of leucaena consumed as seen in the bucks fed treatment diets used in Experiments 1 to 4 (Table 4.29).

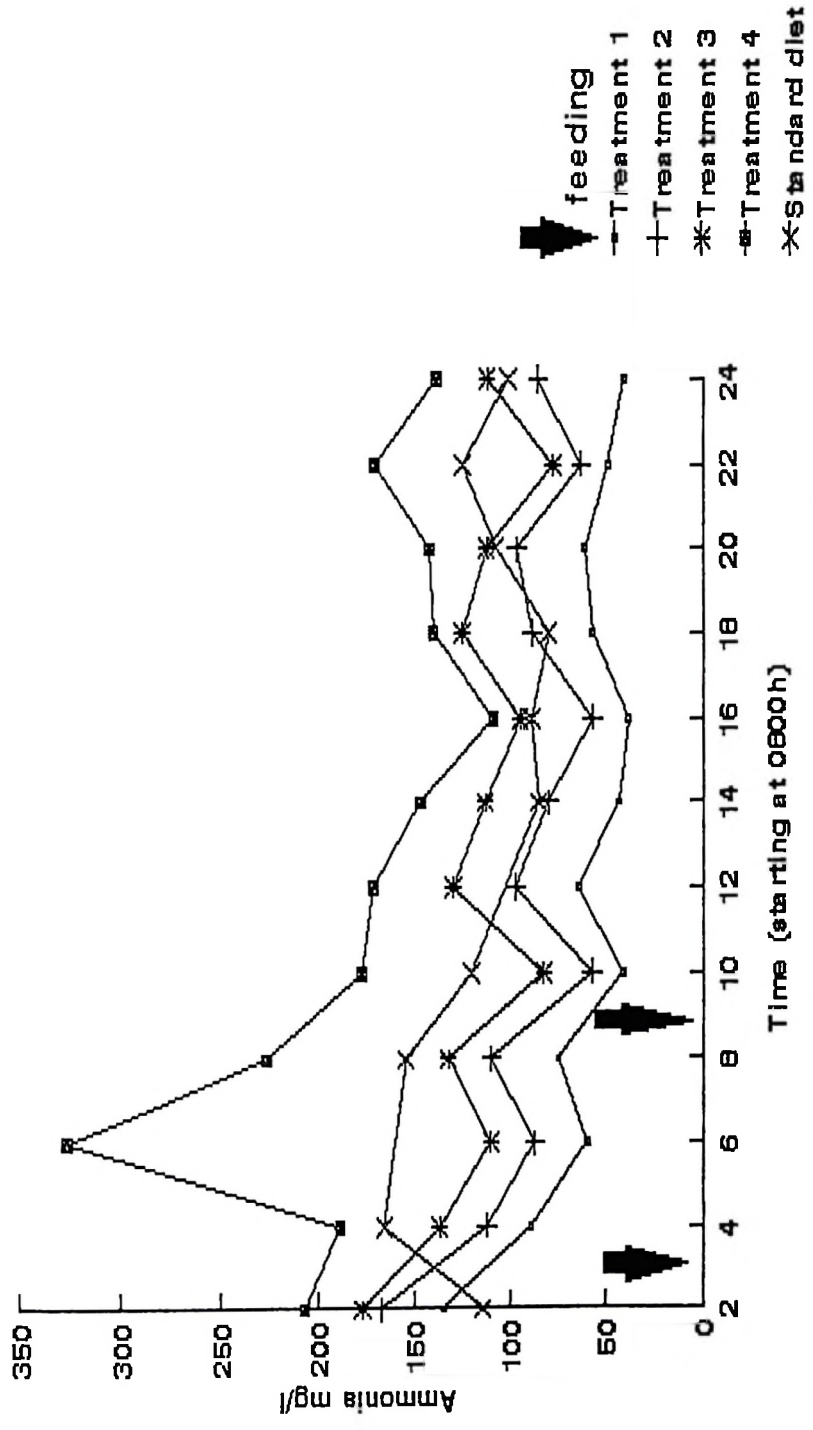

Figure 8. Rumen ammonia concentration of bucks fed treatment diets used in Experiment 3

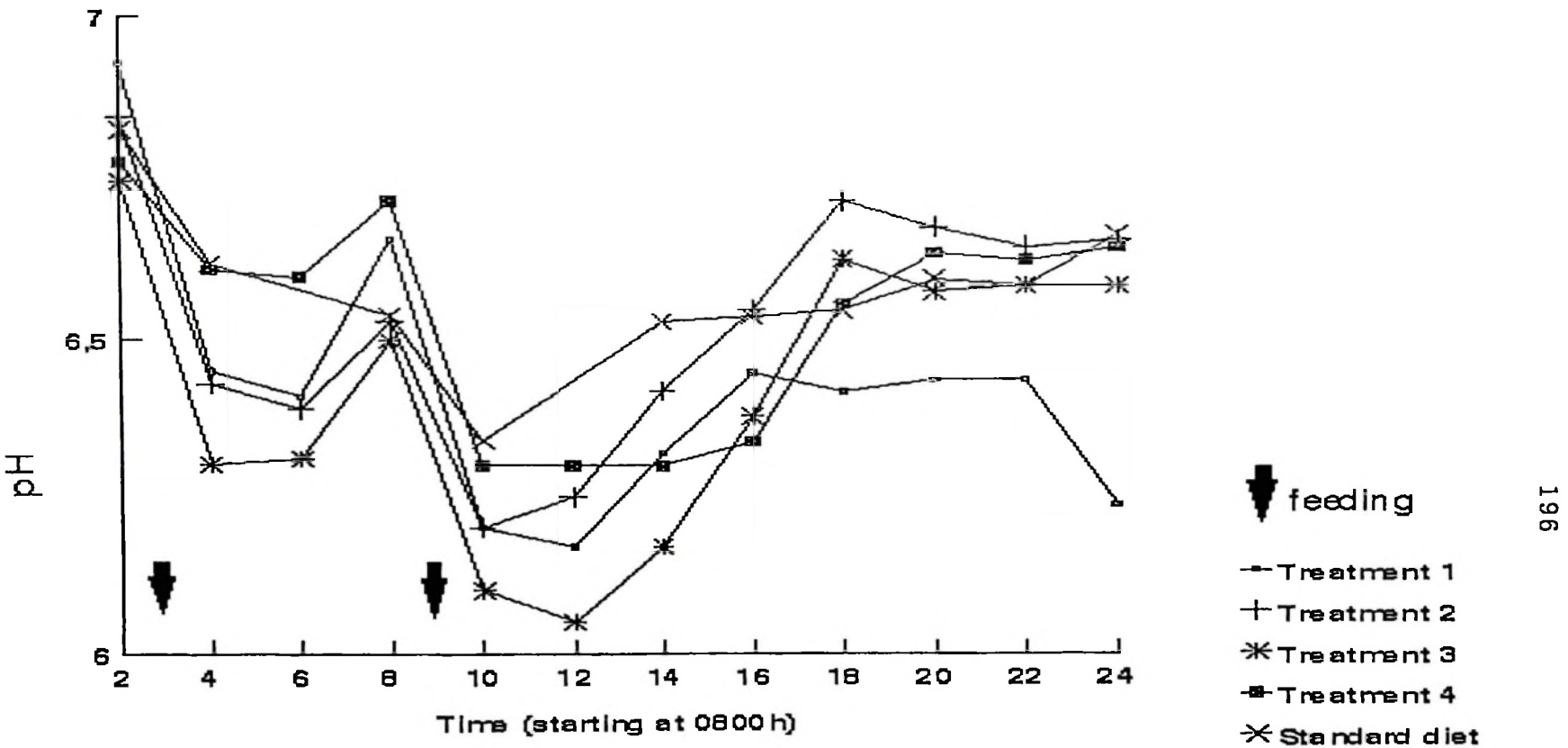

Figure 9. Rumen pH of bucks fed treatment diets used in Experiment 4

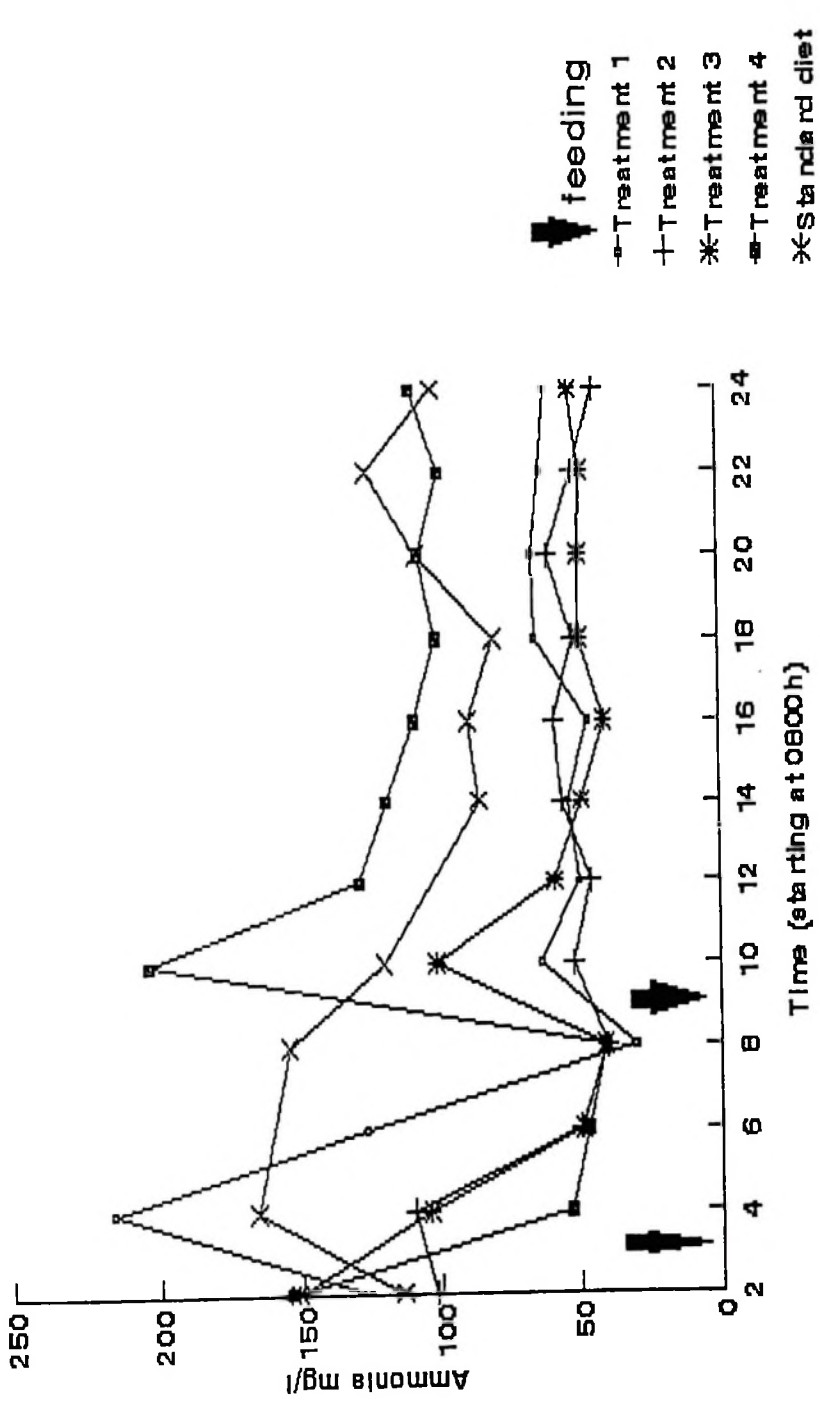

Figure 10: Rumen ammonia concentration of bucks fed treatment diets used in Experiment 4

Table 4.27. Diurnal and nocturnal rumen VFA concentration (mH/l and mmol/mol) for fistulated bucks fed four treatment diets used in Experiments 1 and 2 (LSmeans±SEM)

Time (h) Replications	VFAs	TREATMENTS 1 4	2 4	3 4	4 4	SEM	P
0800 First feeding	Total(mH/l)	75	151	42	50	8.63	0.105NS
	C_2(m/M)[1]	740	680	698	684	18.46	0.154NS
	C_3 "	175	206	188	207	14.44	0.388NS
	C_4 "	79	103	106	101	8.03	0.131NS
	C_5 "	6	11	9	8	2.32	0.600NS
	C_2/C_3	4.73	3.55	4.30	3.46	0.47	0.241NS
1000	Total	39	62	53	50	8.14	0.390NS
	C_2	773	716	711	730	20.13	0.300NS
	C_3	131	187	182	179	13.87	0.166NS
	C_4	81	86	94	84	13.16	0.895NS
	C_5	16	12	14	8	4.31	0.682NS
	C_2/C_3	5.90	3.83	3.94	4.15	0.47	0.135NS
1200	Total	47	46	42	59	5.33	0.222NS
	C_2	731	711	683	692	14.75	0.175NS
	C_3	181	191	206	208	12.41	0.430NS
	C_4	80	91	103	93	6.91	0.222NS
	C_5	8	7	8	8	0.41	0.152NS
	C_2/C_3	4.45	4.82	3.24	2.74	0.39	0.425NS
1400 Second feeding	Total	44	30	47	59	4.92	0.096NS
	C_2	775	706	717	717	16.49	0.162NS
	C_3	137	188	165	173	10.14	0.128NS
	C_4	79	97	111	103	8.48	0.231NS
	C_5	10	10	7	8	2.21	0.792NS
	C_2/C_3	5.67	3.78	4.42	4.19	0.40	0.134NS
1600	Total	50	47	61	74	6.38	0.085NS
	C_2	725	698	719	716	25.87	0.896NS
	C_3	177	212	182	187	17.66	0.555NS
	C_4	88	80	91	90	9.88	0.861NS
	C_5	10	10	8	7	1.92	0.643NS
	C_2/C_3	4.71	3.37	3.97	3.91	0.53	0.427NS
1800	Total	49	81	46	67	18.77	0.587NS
	C_2	759	729	668	690	30.67	0.330NS
	C_3	171	188	232	216	28.13	0.517NS
	C_4	57	76	94	88	13.69	0.419NS
	C_5	12	9	6	8	4.78	0.848NS
	C_2/C_3	4.82	3.91	3.04	3.31	0.77	0.486NS
2000	Total	49	49	42	72	-	-
	C_2	815	709	704	702	-	-
	C_3	127	206	181	179	-	-
	C_4	48	78	106	110	-	-
	C_5	9	7	9	8	-	-
	C_2/C_3	6.41	3.45	3.89	3.92	-	-

Table 4.27 continued

2400	Total	66	70	76	77	10.39	0.844NS
	C_2	776	715	696	725	27.69	0.368NS
	C_3	154	203	194	195	15.98	0.302NS
	C_4	66	76	99	70	13.68	0.447NS
	C_5	5	7	11	11	3.68	0.610NS
	C_2/C_3	5.24	3.55	3.59	3.72	0.62	0.335NS
0200	Total	51	46	42	61	14.72	0.829NS
	C_2	800	723	694	715	27.48	0.207NS
	C_3	135	175	163	168	21.73	0.631NS
	C_4	61	91	13	11	26.15	0.405NS
	C_5	5	12	11	8	3.43	0.528NS
	C_2/C_3	6.05	4.29	4.28	4.27	0.76	0.401NS
0400	Total	63	51	38	56	–	–
Second feeding	C_2	821	709	711	719	–	–
	C_3	123	205	152	148	–	–
	C_4	51	80	127	124	–	–
	C_5	5	5	10	9	–	–
	C_2/C_3	6.69	3.45	5.58	4.86	–	–
0600	Total	51	50	33	44	–	–
	C_2	320	717	691	711	–	–
	C_3	125	197	187	179	–	–
	C_4	50	80	109	96	–	–
	C_5	5	7	13	14	–	–
	C_2/C_3	6.57	3.64	6.36	7.39	–	–
Overall	Total	54	52	48	60	3.47	0.083NS
	C_2	767 [a]	712 [b]	704 [b]	711 [b]	8.32	<0.001**
	C_3	151 [b]	189 [a]	177 [a]	181 [a]	8.14	0.006**
	C_4	74 [c]	89 [b]	110 [a]	100 [ab]	4.51	<0.001**
	C_5	8	9	9	8	0.86	0.863NS
	C_2/C_3	5.43[a]	3.90[b]	4.27[b]	4.16[b]	0.22	<0.001**

[1]mmol/mol

Table 4.28. Diurnal and nocturnal rumen VFA concentration (mM/l and mmol/mol) for fistulated bucks fed treatment diets used in Experiment 4 (means) and (LSmeans±SEM)

Time (h) Replications	VFA	TREATMENTS 1 2	2 2	3 2	4 2	SEM	P
0800 First feeding	Total	32	59	67	69		
	C_2	740	680	698	684		
	C_3	175	206	188	207		
	C_4	79	103	106	101		
	C_5	6	11	9	8		
	C_2/C_3	4.73	3.55	4.30	3.46		
1200	Total	33	45	63	50		
	C_2	697	634	653	675		
	C_3	191	257	249	229		
	C_4	101	100	87	89		
	C_5	10	8	11	7		
	C_2/C_3	3.65	2.46	2.62	2.94		
1600 After second feeding	Total	39	33	33	46		
	C_2	670	631	632	645		
	C_3	196	281	253	257		
	C_4	118	80	105	90		
	C_5	7	8	9	7		
	C_2/C_3	3.42	2.24	2.50	2.51		
2000	Total	46	52	60	37		
	C_2	693	650	656	673		
	C_3	203	254	249	232		
	C_4	95	90	85	89		
	C_5	8	7	9	6		
	C_2/C_3	3.41	2.56	2.64	2.90		
2400	Total	40	38	69	42		
	C_2	688	656	695	667		
	C_3	208	242	207	244		
	C_4	94	95	93	79		
	C_5	10	7	5	10		
	C_2/C_3	3.30	2.71	3.37	2.73		
0400	Total	51	42	64	69		
	C_2	689	650	653	694		
	C_3	207	245	252	208		
	C_4	92	98	87	92		
	C_5	11	7	9	5		
	C_2/C_3	3.33	2.65	2.59	3.33		
Overall	Total	40^{c}	45^{c}	59^{a}	52^{ab}	4.14	0.024*
	C_2	693^{a}	647^{d}	662^{c}	667^{b}	4.80	<0.001**
	C_3	198^{c}	251^{a}	241^{ab}	227^{b}	6.21	<0.001**
	C_4	98	95	89	89	3.92	0.255NS
	C_5	11^{a}	7^{c}	8^{ab}	7^{c}	0.83	0.016*
	C_2/C_3	3.51^{a}	2.59^{c}	2.76^{c}	3.01^{b}	0.10	<0.001**

Table 4.30. **Urinary 3-hydroxy – 4(1H) – pyridone (g/l) output from four bucks fed treatment diets used in Experiments 1 to 4**

Treatment no.	Experiments 1 and 2	Experiment 3	Experiment 4
1	0.0	0.0	0.0
2	0.1	0.0	0.08
3	0.13	0.11	0.11
4	0.17	0.20	0.16

[2]Treatment;

4.4 Water intake

Water intake expressed in absolute value (kg/d), as % of liveweight, as kg water intake per kg DMI and as g per g ash in Experiments 1 and 2, and 5 are shown in Table 4.30. In Experiments 1 and 2, treatment 1 had significantly ($P<0.01$) higher absolute water intake than in treatments 2, 3 and 4. Water intake as % of liveweight was higher ($P<0.05$) in treatments 1 and 2 followed by treatments 4 and 3. Generally the same values in Experiment 5 were higher than those in Experiments 1 and 2 except for DMI, ash and water intake expressed as kg per kg DMI.

Table 4.30. Water intake by cross-bred bucks fed diets used in Experiments 1 and 2, and 5

T[1]	Number of replications	Liveweight (kg)	Dry matter intake (kg/d)	Ash intake g/d	Water intake (kg/d)	Water intake as % of L/wt	g water intake/g ash	kg water intake/ kg DM intake
Experiments 1 and 2								
1	4	39.5	1.16	86.1	2.26^{a}	5.7^{a}	26.2^{a}	1.95^{a}
2	4	39.5	1.13	77.2	2.17^{ab}	5.5^{a}	28.1^{a}	1.92^{a}
3	4	39.5	1.34	76.4	2.07^{bc}	5.2^{b}	27.1^{a}	1.54^{a}
4	4	39.5	1.39	84.7	1.97^{c}	5.0^{c}	23.3^{b}	1.42^{b}
SEM[3]		2.1	0.06	2.2	0.056	0.41	0.76	0.050
P[4]					0.001**	0.014*	<0.001***	0.001**
Experiment 5[2]								
	4	37.6	1.0	68.5	2.7	7.2	39.4	2.7
SE[5]		2.1	0.05	3.5	0.20	0.26	2.38	0.15

[1]Treatment; [2]Bucks were fed same feeds (standard diet); [3]Standard Error of Mean; [4]Probability level from the analysis of variance: [5]Standard error

Water intake expressed as a proportion of DMI followed a similar trend to that of water intake as a proportion of ash in both Experiments 1 and 2.

Water intake from Experiments 3 and 4 were not reported.

CHAPTER 5

DISCUSSION

5.1 PRODUCTION EXPERIMENTS

5.1.1 Chemical composition and *in vitro* digestibility of the feeds in Experiments 1 to 4

The chemical constituents of the feeds used in this study are in agreement with those reported elsewhere (Göhl, 1981; Jones and Megarrity, 1983; Ngaiza, 1985; Shoo, 1986; Devendra, 1986; Swai, 1987). For Experiments 1 and 2, CP level of leucaena of 244.8 g/kgDM was within the range reported by other scientists, ranging from 210 to 340 g/kgDM (Upadhyay *et al.* 1974; NAS, 1979: Meulen *et al.* 1984). Dried leucaena was used in most of the experiments in this study, as it was easier to measure the amount eaten by the animal due to its uniformity than for fresh leucaena. Mimosine content was similar to those reported by other researchers (Jones, 1979; Wong and Devendra, 1982) although others have reported higher levels (Wahyuni *et al.* 1983; Adeneye, 1991) than obtained in this study. The CP content of cotton seed cake usually varies amongst undecorticated, decorticated and partly decorticated forms. The value reported from this study of 340 g/kgDM was from the decorticated type purchased from a Morogoro factory as described in Chapter 3). The CP content of cotton seed cake analysed at the Department of Animal Science and Production, SUA have been observed to vary from

267 to 428 g/kgDM over the years (Personal observation). Biwi (1984) and Luziga (1993) reported values of 411.2 and 386 g/kg DM which were 17% and 12% above values obtained from the present experiments. Possible reason for such high variations could be due to contamination and quality of the cotton seed cake purchased from the factory which produces two types, solvent extracted and unextracted. Solvent extracted has higher CP and could have been the type purchased by Biwi (1984) and Luziga (1993) despite the fact that they did not report the type they used.

The mineral content pattern is comparable to those reported by other workers (see Chapter 2). Calcium and phosphorus contents of leucaena, has been reported to vary with soil conditions, climate and stage of harvesting (Norton, 1994). The contents in the present study were rather high with ratio of Ca:P of 7. The ratio is higher than recommended value of Ca:P ratio of 2:1 for ruminants (Norton, 1994). The higher ratios found in leucaena leaves might be off balanced by mixing with other low ratio supplements like cotton seed cake or other leguminous plants. Good mixture of leucaena to cotton seed cake would be at a ratio of 1:1 (Tables 4.1 and 4.2).

For Experiment 3, variations in chemical composition of the feeds as compared to those reported in the literature could be due to different soil conditions, processing and storage methods. For instance, leucaena cut from the Mafiga plots could vary from that cut from the Magadu research unit. The DM content of leucaena was similar to that reported by Devendra (1986), while its CP content was consistent with those reported by

other workers (Upadhyay *et al.* 1974; Brewbaker, 1986). Both CP and ash contents of the fresh leucaena were lower than those of dry leucaena used in the previous experiment (Table 4.1). The ash content from fresh leucaena was lower than that from dry leucaena. Part of the higher ash content of the dried leucaena could have come from the sand on the floor where it was kept for drying. Organic matter, EE, CF and mimosine contents were similar in both fresh and dry leucaena, while those of NFE were higher in the fresh leucaena. Cotton seed cake used in this experiment had higher values of DM, OM, NFE and lower ash, EE, CP and CF contents than the cotton seed cake used in Experiments 1 and 2. This could have been due to differences in factory processing or type of cotton seed cake as pointed out in Experiments 1 and 2. Maize bran used in all the milk production Experiments showed the same chemical values (Tables 4.1 and 4.12), except for the CP, CF and EE contents which were slightly lower for Experiment 3 than for Experiments 1 and 2. However, the differences between CP contents are within the ranges reported by other workers (Luziga, 1993). Contents of CP, as high as 137g/kg DM have been reported (Biwi, 1984).

Leucaena used in Experiment 4 did not differ significantly in values of NFE, CF, EE, ash, CP and OM from the LL used in Experiments 1 to 3. Cotton seed cake showed lower values of CF, CP, ash and no differences in values of NFE and OM in this experiment as compared to those for Experiments 1 and 3. The N of urea treated maize stover without and with molasses were 2 and 3 fold respectively that of untreated maize stover (Table 4.12). Urea treatment has succeeded over the years to improve nitrogen

content, digestibility and intake by ruminants fed the stovers compared to ruminants offered untreated stovers or grazing on the standing hay of the stovers (Urio, 1981; Biwi, 1984; Kilongozi, 1992; Arellano *et al.*, 1993). Total energy supplied from the ration including that obtained from molasses was shown to adequately cater for energy requirement of these animals.

The *in vitro* digestibility coefficients of DM of dry leucaena leaves in Experiments 1 and 2 are lower than *in vivo* reported by Upadhyay *et al.* 1974; Jones, 1979; Meulen *et al.* 1979; Richards *et al.* 1994a) and were lower than the *in sacco* dry matter loss values at 48h. Norton's (1994) observations contradicted previous reports by Ørskov *et al.* (1990), in that the *in sacco* values had a tendency of over estimating the *in vivo* while those of *in vitro* as in this study had a tendency of underestimating the digestibility compared with *in vivo* data of digestibility. One interesting feature was the similar trend of *in vitro* digestibility coefficients and degradability values (Table 4.9). This means that the *in vitro* DM and OM digestibility coefficients of the roughages, protein and energy supplements were reflected in the *in sacco* DM and OM degradability kinetics of the same feeds. It is likely that *in vivo* DM and OM coefficients would have followed a similar trend (Richards *et al.* 1994ab). Madsen and Hvelplund (1985) showed that single *in vitro* measurements predicted the *in vivo* degradation very poorly. This was probably attributed to the microbial attachment of the partly degraded feeds. They noted further that when feeds with a low protein content (barley and beetpulp–molasses) were excluded, then the relation between *in vivo* and *in vitro* degradation at 24 hours becomes

better. In Experiments 1 and 2, *in vitro* DM for the maize bran and maize meal agreed with the degradablity results at 24 hours, as supported by the findings of Madsen and Hvelplund (1985). The rest of the feeds seem to fit at *in sacco* degradability hours of between 6 and 12 hours.

The results of the *in vitro* DM and OM digestibility coefficients for Experiment 4 (Table 4.12) are lower than those of the degradabilities and are supported by those in Experiments 1 and 2. Kibon and Ørskov (1993) reported better results from nylon bag technique than *in vitro* gas technique in terms of precision and prediction of DM intake and apparent digestibility, although other workers (Neathery, 1972; Cottrill, 1993; Weisbjerg and Hvelplund, 1993) found the nylon bag technique to be quite variable. The *in vitro* techique of Tilley and Terry (1963) used in this study, can be used efficiently as a guide for comparison with *in sacco* techniques (as cited in the literature review section 2.12). The limitations found with the *in vitro* are obvious in terms of time, speed of analysis and difficulties in maintaining the appropriate temperatures. The *in vitro* DM and OM digestibility coefficients trend from the untreated to treated maize stover with molasses in the present study was increasing consistently with their DM and OM losses (Appendix 4.14)

In vitro digestibility results obtained from Experiment 5 were used for comparison with the degradability results of the same feeds. Maize bran and maize meal DM and OM digestibility coefficients were closer to their DM and OM losses at 48h (Table 4.20)

corresponding with a passage rate of 0.02 and 0.03/h respectively. Rhodes grass DM and OM coefficients were closer to their DM and OM losses at 24h corresponding with 0.03/h.

Despite the fact that both *in vitro* and *in sacco* methods have major limitations (Cottrill, 1993), the former can be used as a means of providing base–line data on which to evaluate other systems as was used in the present study. The latter technique offers a relatively quick, simple and cost–effective means of estimating N degradability of concentrate feeds, at a fixed outflow rate, with a reasonable degree of accuracy (Cottrill, 1993).

5.1.2 Feed and nutrient intake

Lack of adequate numbers of lactating does for replication so as to have analysed the data statistically in these experiments have resulted into high variability of the data. Thus feed intake data was calculated by difference between offer and refusal and their mean values reported in their respective tables. Feed intake in goats depends on production capacity, physiological stage, age and breed of the animals (Morand–Fehr, 1981). The DMI of the does in this experiment (Table 4.4) was consistent with those reported by Kearl (1982); Devendra and McLeroy, (1987) that DMI of lactating does from tropical areas (meat or dual purpose) is 2.8–5.0% of body weight and from the temperate areas, greater than 5% (Devendra and McLeroy, 1987; NRC, 1989). Actual

intake of total protein and energy were higher than recommended intakes NRC (1989). There could have been two possibilities to these results, either there were some spillage of feed, (though would be more on the roughage side) which was calculated as consumed by the goats. Secondly, some of the animals could be changing the extra protein and energy into body fat, thus gained weight (Gall, 1981). The P/E ratio was within a good range 11 to 13.3 recommended by Oltner and Wiktorson (1983) and NRC (1989). The protein to energy (P/E) ratio is an important factor in animal production (Preston and Leng, 1987). The amino acid supply affects a large number of biological functions within the animal. Therefore, the amount of protein absorbed relative to energy will be highly related to the level of production achieved. For example, milk production and growth in young animals as in the present research, is expected to respond to increases in P/E ratio. The AAT intake from these experiments were consistent with the CP and DCP values (Table 4.3) contradicting the views given by Thuen and Vik–Mo (1985) that CP and DCP gave higher variation than either AAT or PDI intakes.

Although it is generally accepted that basal feed intake tend to increase with protein supplementation (Van Soest, 1983; Kempton and Leng, 1979; Leng, 1987; Norton, 1994; Muinga, 1993), there was a tendency towards an inverse relationship between protein and roughage intake in this study. The main advantage of the leucaena substitution for cotton seed cake was the improvement of the total DMI as content of leucaena in the diet increased, which agree with other reports (Mtenga and Shoo, 1990;

Kimambo et al. 1992; Shayo, 1992; Richards *et al.* 1994ab). The increased DMI could have been brought about by the different type of carbohydrate (maize meal) ingested by the does. The carbohydrate could have increased rate of digestion, higher flow rate and thus encourage higher feed intake.

Limitations of animals in Experiment 3 were similar to that reported for previous experiments. Therefore, feed intake could not be analysed statistically. The protein intake in this experiment was lower than recommended values by NRC (1989) but energy intake was adequate. The calculated P/E ratio was lowest and highest in treatments 1 and 2 respectively. The calculated (NRC, 1989) P/E is 12 which agrees with that recommended by Oltner and Wiktorsson (1983).

Dairy cows showed a reduced feed intake when PBV was low, at −50 gN per day equal to −3 to −4 gN per Scandinavian Feed Unit (Madsen and Hvelplund, 1988). AAT–PBV reported in Experiment 1 and 2 appeared sufficient to support lactating goats. They were from 96 and 0 g/kg DM to 102 and 5 g/kg DM in treatments 1 to 4 equivalent to 15.4 gN and 0 gN to 16.3gN and 0.8gN per day respectively. The data shows that does producing less than 2 kg milk would require 42 AAT, per/kg energy corrected milk (ECM) and PBV between −20 and −30. The values shown from this experiment) are probably too high and either may be due to the fact that most of the feed (Table 4.3 consumed by the does was metabolized and deposited as fat, thus resulting in the does gaining or because the feeds in the nylon bags were hand washed, or both. The French

system has developed the protein digested in the small intestine (PDI) nutrient allowances for dairy goats which could be compared to the Nordic system of AAT–PBV system (Madsen, 1985). However, in the present experiment, it would be more difficult to apply or compare with the PDI system (Morand and Sauvant, 1989) since the weights postulated in the latter's tables are higher (starting from 50 to 70 kg) than the ones reported in the present experiment (30 to 36 kg).

The AAT–PBV contents reported for Experiment 3 is much less than for the previous Experiments 1 and 2. This was consistent with the requirement reported by Heje (1994). However, these does were shown to perform poorer when compared to the ones from Experiments 1 and 2 and would require improvement of the diet as will be shown in the following section.

The mimosine intake in Experiment 1 was higher for diets in treatments 3 and 4 than in treatment 2. Perera (1990) recommended maximum mimosine intake of 0.18 g/kgLW/d, which is equivalent to 10–20% dietary leucaena supplement for goats. The amount of mimosine consumed in treatment 4 exceeded that of Perera (1990) by 0.24 g/kgLW/d, and that in treatment 3 by 0.08 g/kgLW/d. The amount in treatment 2 was less by 0.03 g/kgLW/d to the recommended level. Adejumo and Ademosun (1991) recommended maximum intake of 1.0g mimosine/$kg^{0.75}$ which is equivalent to 30% leucaena for West African Dwarf sheep and goats and in this experiment the does consuming the highest level of leucaena had 1.1 mimosine/$kg^{0.75}$ might not have been a

safe intake of mimosine. Thus the performance in milk yield could have been affected for does in treatment 4 (Experiment 1), although the condition of the does were not affected.

For Experiment 3 mimosine intake of 0.11g/kgLW/d in treatment 3 was 0.07g less than the safe maximum recommendation of 0.18g/kgLW/d by Perera (1990); while the intake of 0.22g/kgLW/d in treatment 4 was 0.04g above the safe recommendation. The excess amount could have been lowered by combining leucaena with cotton seed cake, but treatment 4 did not receive this combination (according to the plan of the experiment). Adejumo and Ademosun (1991) had a contrasting view to Perera's (1990) that up to 1.0g mimosine/$kg^{0.75}$ could be safely consumed by goats. It implies then that in this experiment the does consuming the highest level of leucaena had only 0.57g mimosine/$kg^{0.75}$ which is a safe intake of mimosine according to Adejumo and Ademosun (1991).

5.1.3 Performance of the lactating does

Stage of lactation (lactation number – see Appendix Tables 4.2 and 4.4) varied extensively, probably due to low conception rate reported on the average value of 53% (Kiango, unpublished) which made the does differ in their milk production. For instance, majority of does observed to yield more milk were those in advanced lactation number (from 2 to 5). Secondly the potential for higher milk, above one liter, from these does was rather poor. However, low or high milk yield from the does were due to treatment effect because a covariance analysis of the data was carried out (see section 3.1.2.9).

The Least square means for daily actual milk yield ranged from 0.83 to 0.97, and that for daily FCM yield ranged from 0.82 to 0.98. Though not significantly different, the higher milk yield in treatment 2 may indicate a complimentary effect of leucaena's (13% of DM) substitution and cotton seed cake (14% of DM). This could have been due to the mineral ratio of Ca:P (see section 5.1) balanced by both protein supplements. Some farmers in Tanzania have already been supplementing 1:1 ratio of dry leucaena:cotton seed cake to their lactating cows. At this level, they probably get more milk yield from their cows than when either leucaena or cotton seed cake is given separately. Kishore *et al.* (1989) and recently Richards *et al.* (1994ab) have similarly recommended 50% replacement of concentrate mixture with leucaena hay or other tropical tree legumes such as gliricidia. Getachew *et al.* (1994) reported that when cotton seed cake was fed

together with legumes as a supplement to maize stover there was an improvement in the weight gains of sheep compared to when legumes alone were offered to the sheep. In Experiment 2 performance in milk yield by does was not significantly (P>0.05) affected by treatments. Although in treatments 3 and 4 supplemented with 21 and 30% leucaena level (DM) respectively; the increasing amount of actual milk yield might have been improved by addition of maize meal in the diets on top of the high levels of leucaena DM. This is supported by findings of Suarez *et al.* (1987 cited by Jones, 1994) and Muinga (1993). Suarez *et al.* (1987, cited by Jones, 1994) recorded a 33% increase in milk production from supplementary grazing of leucaena, and a 57% increase from supplementary feeding of 6 kg of concentrate in addition to leucaena per cow per day. The increase in energy feed supplement on top of protein supplements appear to have ameliorated the performances of does. The gap between protein and energy supply was probably narrowed and resulted into better efficiency of nutrient utilization than if the gap between the former two had been wider (Whittmore *et al.* 1988). There were no significant differences (P>0.05) reported for actual FCM yields, total solids, solid not fat and ash contents of the does in the four treatments. This may explain why in the same Experiment 2, where highest level of leucaena was offered in treatment 4, negative effect was not observed as in treatment 4, Experiment 1. This could have been due to contribution from maize meal, that relatively good doe performance was seen in Experiment 2. These results may be comparable to those of Kishore *et al.* (1989) and Richards *et al.* (1994ab).

In Experiment 1, lack of significant differences in butterfat and protein content percent of the milk and other related factors, like milk yield reflected a clear similarity in the nutritive values of the treatment diets. In Experiment 2, the significant effect of treatment diet on butterfat percent cannot be explained (Table 4.6). Other workers have reported increased values of butterfat with increase in the protein levels of total diet offered to lactating animals (Gall, 1981; Van Soest, 1983).

Energy efficiency in producing one liter of actual milk or FCM (MJ ME/l) in all the four treatments in the two experiments ranged from 6.9 to 8.3 (Tables 4.4 and 4.6). This corresponds with values reported and documented by Devendra and McLeroy (1987) and Kearl (1982). Liveweights were not significantly affected by the changes in diets, though does in treatments 3 and 2 in Experiments 1 were heavier than their counterparts in the other treatments respectively. In Experiment 2 the body weight changes were all positive. It is common to find lactating animals losing weight, especially during their initial stage of lactation (Gall, 1981). This is due to higher physiological demand for more energy (Pereka and Riis, 1992). When leucaena is combined with high energy concentrates, as was the case in Experiment 2, the results have been remarkable in both milk yields and body weight gains (Saudeco *et al.* 1980).

Total potential milk yield from the does in Experiment 3 seemed lower than the potential milk yield from the previous experiments. It was not known whether the lower values were genetical or environmental. However, better animal performance on concentrate–

supplemented diets has been attributed to a greater energy intake due to greater energy concentration compared with the legume (Richards *et al.* 1994ab). It was not quite clear as to why does in treatment 2 supplemented with 20% cotton seed cake did not perform as good or better than the rest of the animals in the other treatments. Problem here could have been sampling technique of the feed offered rather than energy intake *per–se*. However, it has been stated that, the maximal yield of microbial protein will not meet the net requirements of high producing animals, such as young, fast growing lambs and ewes during early lactation (Ørskov and Robinson, 1981). It was evident in this experiment that the does required protein supplements which escaped degradation in the rumen and a balanced P/E ratio (Preston and Leng, 1987); as the rumen microbes need an increasing supply of degradable protein or long polypeptide with increasing percentage of cell walls in the total ration for ruminants (Thomsen, 1985).

Energy for producing milk and FCM was most efficient in treatment 4, compared to treatments 3, 2 and 1. This could have been due to maize bran supplemented, on top of the *ad–lib* leucaena, which provided easily digestible carbohydrate by the rumen microbes and the animals were making up for the extra energy from the *ad–lib* leucaena offered, although it was not easy to quantify it. Although same amount of maize bran was offered in the rest of the treatments, a complimentary protein supply could have been limiting. Other observations elsewhere have shown that less concentrate was fed with leucaena supplementation (Milera *et al.* 1989). Future experiments should re–investigate on the report by Milera *et al.* (1989), for it may require a good quality

roughage material. Total solids, butterfat percent, solid–not fat, protein and ash, were all not ($P>0.05$) affected by treatments. There was no weight loses as is usual with lactating animals. These results are comparable to the weight results the Experiment 2.

5.1.4 Milk minerals

Milk mineral composition from Experiments 2 and 3 is in agreement with the values reported by other workers (Haenlein, 1980; Jaouen, 1981; Devendra and Burns, 1983; Haenlein and Cassese, 1984; Kurwijila *et al.* 1988). The macro–mineral elements, calcium, phosphorus, potassium, chloride, sodium and magnesium are the principal minerals in milk (Bath *et al.* 1980). Milk minerals reported from this study were a reflection of a balanced nutrition of the lactating goats. Unless feeds offered to lactating ruminants are deficient in some critically needed minerals like Ca and P (at 2:1 ratio); balanced diet as offered in this experiment showed adequate supply of minerals in all the four treatments. Thompson and Fowler (1990) have recommended that it was safer to over feed mineral supplements to animals by an appreciable amounts of up 20% of the requirement by the animal.

5.1.5 Conclusion on lactating experiments

It can be concluded from these experiments that cotton seed cake can be effectively substituted by the relatively cheap source of protein, *Leucaena leucocephala*. It is apparent that leucaena substituting cotton seed cake at the 13% on DM basis

(Experiment 1, treatment 2) resulted into better performance compared to the other treatments, although the differences were not statistically significant (P>0.05). At this level the mimosine content consumed in the dry leucaena leaves was within the safe limits and is supported by Perera (1990) and Adejumo and Ademosun (1991).

After addition of higher energy (maize meal) along with maize bran and the protein sources, a higher level of leucaena, 21 to 30% resulted into better performance from the does in milk yield. With higher energy supplement, probably the toxic effect of mimosine and other phenolic compounds in the leucaena were depressed. It seems that maize bran alone could not supply enough energy to depress the toxic effect as seen in Experiment 1. Sources of easily digestible carbohydrate are therefore needed for the rumen microbes to readily attack the carbohyrate. In greater multiplication, the microbes could work on the by-pass protein sources simultaneouly and finally on the less readily available cellulose from the roughages. If the prices of goat milk are attractive, a goat keeper could spend more money to supplement a balanced protein : energy ration for better efficiency on nutrient utilization. A higher level of leucaena to substitute cotton seed cake as reported in Experiment 2 compared to Experiment 1 could be offered to the lactating does.

The analysed data thus indicate the importance of supplementing poor quality hay with leucaena, but an energy source such as maize bran with or without maize meal in attaining an acceptable level of performance from crossbred dairy goats is needed.

However, it is the economics involved in the energy supplements that should be determined by the livestock keeper and the prices for the supplements should be compared to the conventional dairy meals.

Results from Experiment 3 have shown that feeding of fresh leucaena or cotton seed cake separately, will not lead into as good performance as when the two protein supplements are fed together in a mixture. These results could be compared to those in Experiment 1 where treatments 1 and 4 had lower milk yield than in treatments 2 and 3. There is a need to provide the does with fresh leucaena leaves in combination with oil seed meals such as cotton seed cake. Probably due to the low level of dry matter content in the fresh leucaena, consumed in treatment 4 by the does, there could have been a shortage of energy accruing from the higher intake of leucaena. Future research should look into the possibility of manipulating diet combination between that of Experiments 1 and 2 using fresh leucaena instead of the dry leucaena.

5.2 Growth study of weaner goats (Experiment 4).

5.2.1 Feed intake

DMI of 4.0 to 4.3 as percent of body weight observed in this experiment is consistent with those reported by others for growing goats in the tropics (Kearl, 1982; Devendra and McLeroy, 1987).

The level of feed intake depends on several factors such as age and growth rate of the kids, nature of the feeds and mode of feeding (Gall, 1981). The weaner goats in this study (4 months old) were in their fast growing period according to Gall (1981) and Devendra and McLeroy, (1987). Both the protein and energy intake were higher than the recommended levels by NRC (1989). The P/E ratio was higher than the calculated ratio (8.3) from the NRC (1989) table.

Some of the animals consumed slightly above (79.9 – 90.4 g CP/d) their requirement levels which range from 52 – 83 g CP/d (NRC, 1981; Devendra and McLeroy, 1987; Kearl, 1982). Total energy intake found in this study (Table 4.13) agree with those reported by these scientists, ranging from 5.75 – 6.7 ME, MJ/day. Vitamins and trace elements were given to the growing animals because of the urea treated maize stover offered to them, which needed vitamin A supplement (Schiere and Ibrahim, 1989). AAT intake in this experiment is consistent with the recommedations given by Heje (1994). The new proposed system (AAT–PBV) has been claimed to be better than the

traditional, DCP (Madsen, 1985); Thuen and Vik-Mo, 1985) in that:-

1) it predicts the amount of amino acids absorbed from the small intestine (AAT), 2) it predicts the nitrogen supply of the rumen microrganisms (PBV) and 3) it looks more stable than the traditional, but was not easy to prove it in the present experiment, probably due to fewer observations. A more salient advantage of the new system over the traditional system is that the former differentiates between what has been absorbed as amino acids (AA) and expresses the N requirements of the rumen microorganisms (Madsen, 1985).

Variation in the stover intake was observed between individual animals. However, there was an increase in total DMI from treatments 1 to 3 then declined in treatment 4 (Table 4.13). The findings of total DMI are consistent with those of Kimambo *et al.* (1992) and Getachew *et al.* (1994) in that high levels of legumes such as leucaena supplements have a tendency of reducing roughage intake and increasing total DMI.

Mimosine intake were 0.16, 0.31 and 0.37g/kgLW/d for weaners in treatments 2, 3 and 4 respectively. These values were -0.02, +0.13 and +0.19 over the recommended level of +0.18/kgLW/d (equivalent to 10 to 20% leucaena) intake by goats (Perera, 1990). It appears that the weaners in treatment 4 had reached the toxic level of leucaena intake though there were no visual signs to indicate this, but lower bodyweights could have been an initial indicator of mimosine toxicity. The mimosine intake of 0.36, 0.71 and

0.82g mimosine/kg$^{0.75}$ BW by the weaners in treatment diets 2, 3 and 4 respectively is within the safe range recommended by Adejemo and Ademosun (1991).

5.2.2 Liveweight changes and blood parameters.

The observed growth rate of 55.6g/d to 67.0g/d (Table 4.14) for the weaners in this experiment were lower than those reported by Susuma and Madsen (1992). They reported an average daily gain of from 63 to 94 g for same breed of goats born at different time of the year. Reports by Mtenga and Shoo (1990) showed lower growth rates, ranging from 20 to 30 g/d in cross-bred goats offered 100, 200 and *ad-libitum* dry leucaena. Devendra and McLeroy (1987) attributed rate of growth in goats to breed differences and nutritional management. Daily liveweight gains reported in this experiment concur with those of Devendra and McLeroy (1987) and Hadjipanayiotou *et al.* (1991).

Based on this experiment, it can be deduced that there was a positive correlation between energy supply and growth rate and the weaner goats were not in negative energy balance. It is thus clear that the weaners were supplied with adequate energy, as represented by the energy values reflected by the plasma concentrations of FFA and glucose (Table 4.14). Young growing ruminants have relatively higher mean total plasma FFA and glucose concentration than adult ruminants (Riis, 1983). Some studies have also shown that there is a close reciprocal relationship between plasma FFA and

glucose concentration (r= – 0.97), (Giesecke, 1983; Bas *et al.* 1991). On the other hand plasma glucose concentration may not prove to be a good indicator of the nutritional status of the growing goats. The reason being that as the rumen of the animals develop with age, propionate reserved for gluconeogenesis becomes a better energy indicator (Van Soest, 1983). The lowest performance of the weaner goats supplemented with the highest level of leucaena could be due to slower release of energy compared to the greater levels of ammonia concentration in animals fed treatment diet 4 as observed in the bucks fed this diet (Table 4.13 versus Appendix 4.18).

5.2.3 Body measurements

Body measurements for the weaners were similar in all the four treatments in this study except the weaners's width at hind quarters, observed in treatments 2 and 3. This could have signified a better substitution effect of dry leucaena leaves for cotton seed cake in the respective treatments. These values corresponded with their final weights, average daily gain, energy, protein and feed intake (Table 4.14). Cochran *et al.*(1984) observed significant growth in body measurements in goats supplemented with 10, 20, 30 and 40% dry leucaena leaves on a maize stover basal diet.

5.2.4 Conclusion growth study

It is concluded in this experiment that *Leucaena leucocephala* leaves can safely substitute 23 to 43 percent of the crude protein (equivalent to 17–32% of total diet)

supplied by cotton seed cake in a 5% urea-treated maize stover diet for weaner goats without any adverse effect on nutrient utilization. Levels beyond 32% percent of the protein revealed trends of reduced performance of the weaners. This could have been due to toxic effects accruing from the mimosine in the highest level of leucaena offered.

5.3 Rumen metabolism studies

5.3.1 AAT and PBV of bucks fed a standard diet (Experiment 5)

AAT-PBV values reported in this experiment was done so as to quantify the supply of amino acids to the animals fed diets used in Experiments 1 to 4. The mean values of DCHO and MPS of the feeds measured in this study are consistent with those reported by Luziga (1993), except that those in the present study are a little lower than the calculated values from the former worker. Results for leucaena and Rhodes grass were compared with legumes and grass hays respectively reported by these workers (Hvelplund and Madsen, 1990). The higher AAT-PBV shown for cotton seed cake implies that it can supply substantial amount of N for rumen microbes and bypass nutrients (Preston, 1981), and when fed together with forage legumes as protein supplements, may increase total feed intake and the digestibility of cell-wall constituents (Getachew *et al.* 1994). This observation is in line with results observed in this study that it was better to feed the animals a combined supplement of leucaena and cotton seed cake than either of these separately.

5.3.2 Degradability characteristics of the feeds incubated in the rumen of bucks fed standard diet (Experiment 5)

Results reported in this experiment were used as a measure against which the degradability characteristics of the same feeds determined in Experiment 6 (See Chapter 3, section 3.3.3.2.f) could be compared. When the degradation kinetics of the treatment diets (LL, CSC, maize bran, maize meal and Rhodes grass) used in Experiments 1, 2 and 4 were compared to those of Experiment 5, the values were consistently a little lower or higher than those from the latter experiment.

The effective degradability of protein or concentrates in the Nordic countries is usually calculated using a fractional passage rate of 0.08/h (Madsen and Hvelplund, 1985; NKJ, 1985). In this study a fractional passage rate of 0.04/h was assumed to be more reasonable because of more roughage type feed and the close relationship that was found between the degradation at the 0.01/h fractional passage rate and the DM losses of the feeds at 48h (Table 4.18). Similar to the previous experiments, effective degradabilty decreased with increasing fractional passage rate. The longer the retention time the greater is the microbial fermentation of cellulose and hemicellulose which cannot be digested by the animal's own enzymes (Adejumo and Ademosun, 1991). Roughages, such as Rhodes grass, if offered to the animals with a small amount of green feed, such as leucaena, will increase the number of cellulolytic microbes ready to digest the roughage, but will impose a longer retention time for the roughage compared to the

supplements. The high degradability values, especially noted for cotton seed cake and leucaena feeds, were a reflection of higher digestibilities compared to Rhodes grass. Generally legumes have exhibited faster rate and greater extent of *in sacco* N degradability than grasses (Mgheni *et al.* 1993; Richards *et al.* 1994ab)

It can be suggested that reduction of particle size by a grinder or milling machine for instance, leucaena leaf meal reported by other workers for ruminants (Richards *et al.* 1994a) or grinding of oil meal cakes as done in this experiment could be avoided as this process renders the feed material relatively little chance to be degraded in the rumen, increasing the fractional passage rate and ultimately reducing the effective degradability.

5.3.3 Rumen parameters (Experiment 5)

The rumen environment is to a great extent influenced by roughage: concentrate ratio. An ideal condition of creating an optimally conducive environment (roughage: concentrate of 70:30) for dairy goats, was appropriately made possible over the degradability studies where the bucks were individually fed. This was reflected in the pH values (Table 4.19) that ranged from 6.34 to 6.83 diurnally and nocturnally throughout the collection period. Such an environment has been proposed by Ørskov and Ryle (1990) to be typically an ideal environment for growth of cellulytic bacteria. Maintanance of rumen pH is attained through the high buffering capacity of saliva and the removal of VFA through absorption (Van Soest, 1983). Based on the optimum

environment created for the rumen microbes, it can be deduced from this experiment that the microbial growth and digestion of the roughage, were at their maximal level of utilization. Results of pH values were consistent with those reported in Experiments 1 through 4 in the present study.

The rumen ammonia ranging from 81 to 166 mg/l in the present experiment is above the critical level (50mg/l) suggested by Preston (1981) and Satter (1986), although as high as 150 to 200 mg N/l has been proposed depending on the diet (Preston and Leng, 1987). These values (Table 4.19) are comparable to those reported in the other experiments although those in Experiment 5 maintained a better level of NH_3N, probably due to better balanced diet for optimum rumen environment throughout the experiment compared to the others.

The ammonia in rumen liquor is the key intermediate in the microbial degradation and synthesis of protein (McDonald *et al.* 1991). If the rumen liquor is below 50mg/l, this may suggest a diet deficient in protein or that protein has resisted degradation (McDonald *et al.* 1991) and the growth of rumen organisms will be slow leading to retardation of carbohydrate breakdown. The optimum environment in the present experiment was thus conducive for proper microbial protein synthesis. On the other hand a faster protein degradation than synthesis may mean an excess ammonia. Such a situation leads to ammonia being absorbed into the blood, carried to the liver and converted to urea. Some of the urea may be returned to the rumen via the saliva, and

also directly through the rumen wall, but the greater part is excreted in the urine and thus wasted. To avoid this spillage the highest level should not exceed 300mg/l NH_3N and in this experiment the highest level was 166mg/l.

Rumen VFAs reported in Experiment 5 (Table 4.18) was within or close to the ranges of total VFA, C2, C3, C4, C5 and ratios of C2/C3 reported in Experiments 1, 2, and 4. Generally production rates of the rumen parameters vary diurnally as a consequence of eating patterns. The pattern following a meal shows a rise of VFA and a drop in pH, followed by a slow recovery to original condition. These results show the importance of having some standard measurements to compare treatment results.

5.4 Degradability study with bucks fed diets used in the production experiments (Experiment 6)

5.4.1 AAT and PBV of diets used in Experiments 1 to 4

The AAT–PBV values of maize bran, maize meal and cotton seed cake reported in this study are consistent with those reported in Experiment 5, but slightly higher than those reported by Madsen and Hvelplund (1982). This can be partly explained by the fact that the fractional passage rate values used in the Nordic countries at that time was 0.08/h while that used in this study for tropical feeds was 0.04/h. Although leucaena and Rhodes grass were not reported in their observations, their values seem to fall within those given for other leguminous plants and other grasses respectively. For instance,

lucerne hay at flowering stage had AAT of 68 g/kg DM and PBV of 37 g/kg DM and grass hays in general had AAT of 77 and PBV of 26 g/kg DM respectively (Madsen and Hvelplund, 1982). The PBV value of −74 g/kgDM reported for grasses (hay) by Madsen and Hvelplund (1982) was lower than that obtained in this study which ranged from −47 to −50 g/kg DM (Appendix Table 4.10). Weisbjerg and Hvelplund (1993) assessed the reproducibility of the nylon bag method, and the standard deviation showed the reproducibility between laboratories to be quite poor. Similar views have been reported by Van Straalen and Tamminga (1990) and Cottrill (1993). There is therefore a need for further standardization of this procedure between laboratories.

AAT–PBV as measures for protein value of the feeds is also applicable to growing animals, such as the weaner goats in the present experiment. It is commonly used for dairy animals in the Nordic countries (Madsen, 1985; Vik–Mo and Lindberg, 1985). It has been reported (Vik–Mo and Lindberg, 1985) that moderate negative PBV can be tolerated with dairy cows. Such values are probably similarly handled for growing animals, as their requirement for protein–energy balance is inevitable. Morand and Sauvant (1989) have also developed nutrient requirements for young dairy goats in France based on the PDI system. The requirements have been established for young female goats reaching about 31 and 32.5 kg at the age of 7 and 8 months respectively. The weaners in this experiment did not attain these weights and so it would be oversestimating their requirements based on the French system. AAT–PBV intake reported for the weaners were quite sufficent when compared to the lactating does

intakes in Experiments 1 and 2.

5.4.2 Degradability characteristics of the feeds measured in the rumen of bucks fed diets used in Experiments 1 to 4

The degradability kinetics of some of the feeds used in these experiments are consistent with those reported by Mgheni *et al.* (1993) and Richard *et al.* (1994ab). The zero time intercept for leucaena reported by Mgheni *et al.* (1993) were a little lower, though their potential degradable fraction were slightly higher than the values in the present experiments. It has been stipulated elsewhere that diet and animal variation can influence degradability (Khorasani *et al.* 1993). Such findings were noticed in the present study, although most of the values were not statistically significant (P>0.05).

The low degradability values of leucaena and cotton seed cake reported elsewhere have culminated into making the two feed supplements good by-pass proteins (Norton, 1994). By-pass protein is defined as any portion of a protein meal that escapes the rumen intact and is available for digestion in the intestines (Preston and Leng, 1987). Generally, the protein degradation kinetics reported for all the feeds in this study are in consistent with those reported by Hvelplund and Madsen (1990), although a little higher at times. This could have been caused by higher particle losses through overused nylon bags in our laboratory.

The findings of close relationship between the ED values of 0.01/h and the degradabilities at 48h in the present study agree with findings of Kimambo *et al.* (1994). This is in contrast to the findings by Madsen and Hvelplund (1985), who reported a close relatioship between *in vivo* degradation and nylon bag degradability at 0.08/h fractional passage rate. However, these discrepancies depend immensely on the diet used. *In sacco* DM and OM losses at 48h are regarded as being closer to the mean retention time of the feed in the rumen (Ørskov *et al.* 1990). In other words the 48h DM and OM losses obtained from this study can be used as an estimate of *in vivo* DM and OM digestibility and is supported by Wanapat *et al.* (1986).

The DM and OM losses of fresh leucaena reported in Experiment 3 (Appendix Table 4.11) are comparable to those of Norton (1994), although for fresh leucaena the DM loss was 600g/kg which was 12.7% less compared to the average DM loss (688g/kg) for fresh leucaena in the present experiment. The DM, OM and protein degradabilities of leucaena may vary depending on the basal diet offered to the animal or whether it was sun dried versus oven dried and this may probably explain the wide range of 400–840g/kg of DM reported for dry and fresh leucaena (Kabatange and Shayo, 1991; Norton, 1994).

The protein degradability reported for *Hyparrhenia rufa* grass in Experiment 3 was about 19% less than the CP *in vivo* digestibility coefficient given by Göhl (1981) and equal to effective degradability reported by Kimambo *et al.* (1994). Some of the

roughages, such as *Hyparrhenia rufa* in this experiment can have lower DM, OM and protein losses at 48h compared to *in vivo* DM, OM and protein, thus contrasting the views made by (Norton, 1994) that generally *in sacco* degradability have a tendency of overestimating *in vivo* digestibilities of the same feeds under study.

For the bucks fed on treatment diets used in Experiment 4 however, the DM, OM and protein degradability kinetics of the protein sources were similar in all the treatments. It has been stated that between 20 and 100% of the protein in many diets based on high protein forages, protein meals may be soluble (Preston and Leng, 1987) which is consistent with the protein supplements and even the energy feeds used in this study. It is the water soluble fraction (zero time intercept) that greatly influences the potential degradability of the feeds and their fractional passage rates (Ørskov *et al.* 1980).

The DMD zero time intercept and the asymptote (a+b) ranged from 322 to 331 and 793 to 855 g/kg respectively for dry leucaena and agree with the ranges reported by Kibon and Ørskov (1993) for various browses. The oilcakes, cotton seed cake, in Experiment 4 and in the other experiments have been noted to show similar degradability kinetics to leucaena, though in most cases slightly above and agree with the previous statement by Preston and Leng (1987). The degradation rate c of DM of the leucaena in the present experiment ranged from 0.547 to 0.604g/kg/h which are comparable to those reported by Kibon and Ørskov (1993). Lower degradation rate c of DM for untreated maize stover (mean 0.232 g/kg/h) was observed to correspond with its low potential degradability

(mean 692g/kg) compared to urea treated maize stover plus molasses showing greater mean degradation c DM of 4.416g/kg/h corresponding with their mean potential degradability of 773g/kg.

It was interesting to note the linear increase in the degradabilities from untreated to urea treated maize stover plus molasses. Other workers have also observed increased degradability related to *in vivo* digestiblity from untreated to urea treated maize stover, which in turn corresponded with increase in total DMI (Biwi, 1982; Kilongozi 1992; Shem *et al.* 1993). Fig. 4 gives a typical pattern in relation to these observations as supported by these workers. It proves that degradation of a feed can be limited by the strong structural material (CWC) which must be penetrated by the microbes. Thus it is not a deficiency of N *per se*, for urea treatment increases degradability by a gradual hydrolysis of urea during ensiling which easily breaks down the cell wall of the stover (Wanapat *et al.* 1985). This process enhances digestibility of the stover as was the case in this study. Digestibility of the basal diet is important in utilization of N in the rumen as the rumen microbes require digestible energy to utilize ammonia for microbial protein synthesis (MPS). The OM and protein degradation kinetics followed similar trend to the DM degradability kinetics.

The high correlation (R^2=0.93 and 0.90) of DMI with 24 and 48h degradation values reported by Kibon and Ørskov (1993) could be related to the DM losses at 48h of the feeds reported in this experiment. Thus results of these workers confirm that DMI and

growth of goats given browse could be predicted from their degradability characteristics. The higher degradation kinetics and their effective degradabilities observed for the urea treated maize stover plus molasses in the present study suggest that the potentially degradable materials will pass across the rumen faster and hence create a space for more feed intake by the bucks. Even though a greater percentage of the N of the urea treated stover plus molasses was released in the rumen, absolute quantities of N assumed to reach small intestine were probably more than twice greater for the highest level of leucaena supplement (treatment 4, in rumen of the bucks fed diet used in Experiment 4) than for urea treated maize stover sprinkled with molasses. Greater estimated absolute quantities of ruminally degradable N and escape N for tropical legumes than for grasses have been reported by other workers (Brown and Pitman, 1991; Mgheni *et al.* 1994). Ammonia production from the degradation of leucaena incubation may have been related to the quantity of soluble N present in these feeds.

Mean DM losses at 48h of the roughages used in this study compare favourably to each other, irrespective of treatment diets. DM losses at 48h for Rhodes grass incubated in the rumen of the bucks fed treatment diets used in Experiments 1 and 2 ranged from 567 to 631 g/kg DM compared to that degraded in the rumen of the bucks fed standard diet, which was an avarage of 620 g/kg DM. Although the rest of the roughages were not incubated in the rumen of the bucks fed a standard diet, some of them such as *Hyparrhenia rufa* was found to be 455 g/kg DM, DM loss at 48h incubated in the rumen of the bucks fed treatment diets used in Experiment 3 (Table 4.24). DM losses at 48h

for UMSM (urea treated maize stover sprinkled with molasses), UMS (urea treated maize without molasses) and MS (untreated stover) incubated in the rumen of bucks fed treatment diets used in Experiment 4 were 790, 600 and 500 g/kg DM respectively. These values are consistent with other roughages reported by Luziga (1993), Mgheni (1993) and Kimambo *et al.* (1994). The latter author reported digestibility of full bloom *Hyparrhenia rufa* to be 445 g/kg DM and its maximum rumen degradability at 192h to be 564 g/kg DM. It was obvious therefore, that the *in vivo* digestibility of the *Hyparrhenia rufa* grass hay was closer to its DM loss at 48h used in this study.

5.4.3 Rumen parameters and urinary DHP of bucks fed treatment diets used in Experiments 1 to 4

Overall results of the rumen parameters of the bucks fed treatment diets used in Experiments 1 to 4 and compared to Experiment 5 had no particular trend which was common throughout the study. There were a few exceptions, such as rumen pH and total VFAs decreasing and increasing respectively with feeding, but would not be consistent at the same hours reported in the different treatments and experiments.

It was thus necessary to discuss some of the results per given experiment. Rumen fermentation in the present study was generally influenced by the treatment diets and sometimes probably by the individual animal. It has been documented that when rumen pH is reduced below 6, feed intake will decrease rapidly due to cellulose fermentation being abolished (Ørskov and Ryle, 1990). Consequently such a rumen environment may lead to acidosis in the host (Van Soest, 1983). Cellulolytic bacteria need a rumen

pH between about 6.2 and 7.0 in order to multiply rapidly.

The pH reported in the present study (Appendix Tables 4.16 to 4.18) was within the recommended range, although at times lower than those reported in Experiment 5 (Table 4.19, section 4.3.1.3). Rumen pH levels have been noted to decrease with feed intake, especially concentrate feeds (Madsen and Hvelplund, 1988). In the present study the depression was observed after morning and afternoon feeding (Fig 5). During the latter time, the effect was more persistent with treatment 3, for Experiments 1 and 2 (Appendix Table 4.16) meaning that complimentarity of leucaena and cotton seed cake could have been more magnified and achieve a longer retention time in the rumen than in the other treatments.

With the fact that feeds offered to these animals were isonitrogenous, it was evident through the reflection of high variation of rumen pH that there could have been some slight changes, though not atypical (Fig 5). Probably the phenolic and tannin compounds in leucaena could have contributed to variation in pH levels. This is consistent with the report by Rodriquez *et al.* (1975) that tannin present in dry leucaena forms complexes with proteins thus preventing protein degradation by inhibiting microbial enzymes (proteases and cellulases) and growth by adsorption to cell membrane. Thus different levels of leucaena in the present experiments could have effected slightly different rumen environments, shown by the varying rumen parameters (Figures 5 to 10; Tables 4.27 and 4.28).

Rumen ammonia from the rumen of the bucks fed diets used in Experiments 1 and 2 and exposed to treatments 1 to 4 were significantly ($P<0.05$) higher in most of the hours sampled than in some of the hours due to the proper fermentation effected by supplemented N. This triggered microbial growth and were efficiently utilizing the available carbohydrate incorporated in the supplemented diets. Only rumen ammonia from the buck fed treatment 1 diet (at 0200h) showed a level (46 mg/l) below critical (50 mg/l) recommended by Satter, (1986); Preston and Leng (1987). At this hour pH was lowest in the same treatment diet (Appendix Table 4.16). The low levels were probably due to the low turnover rate of the rumen contents nocturnally (Barry and Manley, 1985; Madsen and Hvelplund, 1988) and may also depend on the sampling technique, sometimes disturbed by the animal movement. Overall fluctuations of NH_3N noted in Fig 6 may not be fully explained, but they are related to the kinetics digestibilities of the different feeds in the rumen. In support of these observations, fluctuations of rumen ammonia with sampling time has also been recorded by Richards *et al.* (1994b), even though ruminal ammonia release from gliricidia in the latter study increased in a linear manner with advancing incubation time.

Madsen and Hvelplund (1988) reported on a highly significant relationship between PBV supply and mean rumen NH_3–N concentration. In the present experiment, it was observed that there was an indication of slight increase of PBV (Table 4.3 versus Appendix Table 4.16) with increasing level of leucaena.

For the bucks fed treatment diets from Experiment 3, changes in the rumen pH and NH_3–N (Fig 7 and 8) had a tendency of acquiring a similar pattern at other times, although not immediately after feeding because pH had a tendency of getting depressed while NH_3N displayed a rising effect. This concept concur with that of Valentine and Bartsch (1987) who reported that the trend of diurnal post feeding on pH and NH_3–N were similar, but their magnitudes differed depending on the nutrient composition of the diet. As the level of pH started rising (in the rumen of bucks fed diets used in Experiment 3) inversely to NH_3–N concentration, at about 5–6 hours after feeding, this pattern was associated with absorption of VFA and increase in saliva secretion as animals continued chewing the *Hyparrhenia rufa* grass hay. This finding is supported by the findings of Valentine and Bartsch (1987).

The pattern of the rumen ammonia concentration (Fig 8) was consistent with protein solubility and degradation characteristics of the feeds in this experiment. The linear increase in rumen ammonia concentration from the rumen of the animals fed treatment diets 3 and 4 was consistent with relatively larger ruminally degradable protein in fresh leucaena compared with the treatment diets 2 and 1 of cotton seed cake and maize bran supplements. These findings are comparable to those of Muinga (1993) and Richards *et al.* (1994ab). Muinga (1993) also reported an increase in rumen NH_3N concentration with increased level of leucaena supplementation. Plant proteins, in this case leucaena, are less readily fermentable (retarded by phenolics) than diets treated with chemicals

such as urea (Shayo, 1992). This is a phenomenon which could have contributed to the NH_3N released in the rumen to have persisted longer in treatments 3 and 4 respectively compared to the other treaments in this experiment.

The pattern in Fig 9, for bucks fed treatment diets used in Experiment 4 showed that pH was highest before morning feed and had a continuous drop for the next 4 to 6 hours after feeding, followed by a small increase before next feeding (at 1500h). These results are comparable to findings reported in the previous experiments and by Madsen and Hvelplund (1988). The highest and lowest levels were 6.7 and 6.2 just before morning and after afternoon feeding respectively in the present experiment. The afternoon feed caused a further drop in pH, between 1500 and 2000 hours and thereafter a gradual increase in pH throughout the night. The means were significantly higher ($P<0.01$) in the rumen of the bucks fed treatment 2 and 4 diets. These results are also comparable to those reported for Experiments 1 and 2 (Appendix Table 4.16) in which similar diet combination differing in basal roughage were supplied to the goats.

It is depicted in Fig 10 that three hours after morning feeding, the ammonia nitrogen concentrations rose to mean values of 216 mg/l in the rumen of the buck fed treatment 4 diet. The diurnal variation in NH_3–N and pH concentration in combination with the source of N supplementation indicate, that not only the mean NH_3–N and pH concentration, but also the hours with NH_3–N and pH concentration below a certain level, like 50 mg/l and 6.0 respectively (Madsen and Hvelplund, 1988; Preston, 1986),

may be attributed to the low N supply to the rumen microorganisms. The lowest levels in this experiment were 30.1 mg/l NH_3–N (at 1400 h) and 6.05 pH (at 1800h) which gave a sudden drop that cannot be explained in relation to the N supplement. If this had occured during the night it could have been due to relatively many hours without animals being fed. It has been observed that the lowest NH_3–N concentration in the rumen liquor were obtained during the night, with an increasing pH after 2400h to next feeding time (Madsen and Hvelplund, 1988).

Although there was a pattern of lower NH_3–N starting at 1600h throughout diurnally from treaments 1 to 3, the rumen of the buck fed treatment diet 4 had persistently higher concentration and could have been due to the explanation given by other workers (Muinga, 1993); Richards *et al.* 1994ab) and was evidently similar to that of highest level of leucaena (treatment 4) in Experiment 3. Richards *et al.* (1994b) reported a greater ammonia release from the legumes than from elephant grass. This was attributed to the legumes containing a greater quantity of ruminally degradable N. It was not clear as to why the treatment diet with the highest level of cotton seed cake (treatment 2) did not keep up with as high NH_3–N as for the dry leucaena leaves. These variations could have been attributed to differences in total protein and the degradability values. Although the urea incorporated in treating maize stover could have alleviated the situation of the low N, explanation to this is that most of the N had evaporated due to hydrolysis during aeration and sampling of the treated stover. Another view given by Preston and Leng (1987) is that urea given in a single dose is unlikely to maintain rumen

levels above the minimum requirement for efficient fermentation for more than a few hours per day. The findings in this experiment agree with those of Leng (1982) and Ørskov (1987) that when rumen degradable protein (RDP) are given together with UDP, both these supplements are correcting for a fermentable-N and amino acid deficiency being compatible in increasing ruminant production.

Total and individual VFAs reported for the treatment diets in rumen of bucks fed diets used in Experiments 1 and 2 (Table 4.27) compare favourably with those reported in the literature (Chapter 2, section 2.8.3). From the overall results, C_2 being significantly higher in the rumen of the bucks on treatment 1 diet could reveal an important information on the higher intake of the Rhodes grass. This could be in line with a remark by Tyrell *et al.* (1982) that if the proportion of glucogenic energy in the total VFA energy is high, C_2 is used with high efficiency. This may apply to Experiment 2 where Rhodes grass was used as a basal roughage.

Overall molar proportion of C_3 increased almost progressively with molar proportion of C_4, but were almost in opposite direction to C_2. The drop in molar proportions of C_2 is usually caused by the dilutory effect of a large increase in amount of C_3 (Van Soest, 1983). The C_2/C_3 ratio followed a similar pattern to that of C_2. These observations are consistent with those of Muinga (1993). Muinga (1993) found that when maize bran was included in the diet together with 8 kg leucaena, the molar proportions of C_4 was significantly increased and there was a tendency for C_3 to increase inversely to C_2.

Table 4.26 and Appendix Table 4.16 showed that total rumen VFA and NH_3N were not significantly affected by treatment diets. Rumen pH was significantly ($P<0.05$) higher in treatments 3 and 4 than in treatments 2 and 1. Although rumen pH was not consistent with the other parameters, overall rumen parameters were in line with the recommended levels (Khorasani *et al.* 1993) for proper fermentation in all the four treatments.

VFAs of the bucks fed treatment diets used in Experiment 4 showed diurnal and nocturnal variations and that there were some changes related to feeding, as reflected in the overall results (Table 4.28). The significant ($P<0.05$) increase in total VFA in treatments 3 and 4 followed by treatments 2 and 1 was positively correlated to the feed intake. The highest molar proportion of C_2 in the rumen of the buck fed treatment 1 diet could have been attributed to slightly higher intake of urea treated stover though the pattern was not consistent with the rest of the treatments (Table 4.12). High C_2 is always associated with high fibre content of the diet (Molina *et al.* 1993; Ørskov and Oltjen, 1993; Park *et al.* 1994) and was seen in bucks fed treatment diets used in Experiments 1 and 2. The highest amount of molar proportion of C_3 was consistent with the high energy (42 ME, MJ/kg gain) in the treatment diet 2 (Table 4.14) although treatment 3 had the highest energy (45 ME, MJ/kg gain).

Higher molar proportions of isovalerate and isobutyrate have been found to increase with increasing level of UDP (Khorasani *et al.* 1993) which could have suggested that the synthesis of bacterial protein was increased. It applies to this experiment that the

rumen microbes are efficiently degrading the protein supplements supplied in all the four treatments due to a good amount of energy supplied from the maize bran and probably molasses which was sprinkled for palatability. The molar proportions of the C_2 tended to decrease with increasing molar concentrations of C_3 and vice versa. Thus from the overall results (Table 4.28 and Appendix Table 4.18), treatment 3 which showed significantly ($P<0.05$) higher rumen VFA had significantly ($P<0.01$) lower rumen pH as was expected and moderately high value of rumen NH_3N concentration.

Least Mean Square values of the rumen parameters obtained in the present experiment agree with those reported by Luziga (1993) for sun-dried leucaena and cotton seed cake supplemented treatment diets. However total VFAs reported by Luziga (1993) were twice higher than those reported in the present study. The molar proportions of the individual acids were similar in both studies. The ratios of $C_2/C_3/C_4/C_5$ were in agreement with those reported by Ørskov and Oltjen (1993) 74:18:5:0.8 respectively which were more pronounced in steers fed the cellulose diets than when they were fed glucose, sucrose, starch plus glucose or starch diets. It is evidenced further that the molar proportions of VFAs produced from these treatments are somewhat midway of 70:21:8 and 50:40:10 ($C_2/C_3/C_4$) given for typical forage and solely grain diets (Flachowsky and Tiroke, 1993). The ratios in the present study, for all the experiments are consistent with the ratio of hay:concentrate of 60:40, recommended ideal for dairy ruminant animals (McDonald *et al.* 1991).

Urinary DHP concentration (0.08–0.2g/l) from the urine samples of the bucks fed treatment diets from Experiments 1 to 4 are within the safe limits and is supported by Quirk *et al.* (1988). The authors found that 2.8g/l DHP and above induced depressions in growth rate of the steers. Furthermore, Pound and Martinez (1983) reported 0.2g/l urinary concentration to be normal for goats compared to 5.0g/l in Australian goats that succumbed to all known side effects of mimosine toxicity.

5.5 Water intake

When the bucks consumed diet formulated for Experiments 1 and 2, their absolute water intake did not increase with increasing level of dry leucaena as reported by other workers (Banda and Ayoade, 1986; Mtenga and Shoo, 1990). In fact the reverse was true, in that absolute water intake decreased with increasing level of leucaena intake, even though the bucks in treatments 1 and 4 had higher ($P<0.001$) DMI than in treatments 2 and 3. It would have been more logic if the more N the animal consumed the more the water intake. This was not so in the present experiment, primarily due to the feeds in the different treatments being isonitrogenous. Secondly, there could have been animal variation. The trend would have been that the more the DMI the higher the water intake, but it was not so with the bucks in treatment 4. There is therefore no proper explanation for this strange trend. Water intake as % of liveweight, as a proportion of ash intake and kg water intake per kg DMI followed similar trend to the absolute water intake.

Generally when the bucks were offered treatment diets from Experiments 1 and 2, they consumed less absolute water in all the treatments than when they were offered standard diet. Probable explanation to this could be due to the amount of water calculated from the elephant grass hay (44% DM) offered to these animals as basal diet (Chapter 3, section 3.3.2.3) and also due to higher temperatures at the time Experiment 5 was carried out than at the time Experiments 1 and 2 were conducted which did not affect all the bucks in the same manner. Secondly the nature of the diets offered determined by its DM content could have affected the consistency in water intake. Drier feeds may have higher DM content and when consumed cause animals to embibe more water (NRC, 1989)

Normal body water content of the goat varies with age, amount of fat in the body, diet and environmental temperatures (Shoo, 1986; NRC, 1989). It is also apparent that exotic or cross bred goats consume more water, especially when placed in tropical environments than the indigenous goats (Devendra and McLeroy, 1987). French recommendations for water intake in goats are 145.6g water per $kg^{0.75}$ BW for maintanance and 1.43 kg water per kilogram of milk as a production requirement (NRC, 1989). In Experiment 5, 178 g water BW $kg^{0.75}$ BW were consumed by the bucks which was a little higher than the French recommendation. Probably, because the former reported for temperate countries, climate was not as hot as in the environment for the present study. Moreover, being cross-bred goats in a tropical climate, they were

bound to consume more water. It would not be appropriate to transform this information to the lactating does in the present experiment, thus further work on this subject pertinent to lactating does warrants further study.

CHAPTER 6.0

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The present study involved feeding experiments on substitution of dry leucaena leaves (DLL) for cotton seed cake (CSC), except in Experiment 3 where fresh leucaena leaves was compared to cotton seed cake (Table 6.1).

Table 6.1: **Summary of the feeding plan for comparing dry leucaena leaves (DLL) and fresh leucaena leaves (FLL) with cotton seed cake to dairy goats.**

TREATMENTS[1]	Feeding plan for Experiments 1, 2 (lactation) and 4 (growth)
1	Level 0 DLL + Level 3 CSC
2	Level 1 DLL + Level 2 CSC
3	Level 2 DLL + Level 1 CSC
4	Level 3 DLL + Level 0 CSC
	Feeding plan for Experiment 3 (lactation)
1	Level 0 FLL + Level 0 CSC
2	Level 0 FLL + Level 1 CSC
3	Level 1 FLL + Level 0 CSC
4	Level 2 FLL + Level 0 CSC

[1] DLL and FLL: Dry and Fresh Leucaena leucocephala respectively.

In Table 6.1 only the roughages were different, where elephant grass, Rhodes grass hay and urea treated maize stover were used for Experiments 1, 2 and 4 respectively. In Experiment 3 fresh leucaena was fed along with *Hyparrhenia rufa* grass hay as a basal roughage.

In Experiments 1 and 2 the lactating does produced actual daily milk that ranged from 0.83 to 0.97 l/d, between treatments. Actual milk yield from does in Experiment 3 ranged from 0.63 to 0.82 l/d. Growth rate of the weaner goats ranged from 55.6 to 67.0 g/d. Treatment diets in these experiments had no significant effect on milk yield and growth rate. Total DMI of the does were increasing with the level of leucaena in all the treatment diets except for Experiments 3 and 4 where a slight decline in total DMI was observed in their last treatment (4). Although energy and protein intake seemed adequate as recommended by NRC (1989), it was not reflected in the growth rate of the weaners. Higher liveweight gains of the same breeds have been reported by Susuma and Madsen (1992). They obtained up to 94g/d growth rate of growing goat kids.

Major weaknesses in this study was due to fewer animals than initially projected and scarcity of roughage material. This led to limited data which did not have adequate reproduceability due to lack of replication. Type of roughage material which was initially intended was Rhodes grass hay but was not available in sufficient quantities at the time required. An alternative measure was taken to feed elephant grass, but was

consumed by the animals with difficulty due to its roughness and hairness. This constraint led to looking for other alternatives of purchasing Rhodes grass hay and later *Hyparrhenia rufa* grass hay far away from the University farm.

Observations made from Experiment 3 have revealed shortage in both protein and energy supplement in relation to requirement, affecting the performace of the does. The mimosine contents consumed by the does in this experiment were rather low and highest intake was found in treatment 4 (0.57g/kg $^{0.75}$DM) compared to the maximum safe intake of mimosine of 1g/kg$^{0.75}$DM. Apart from the non-side effects of mimosine, leucaena supplement in this experiment confirmed the need to combine the fodder legume with cotton seed cakes up to 1:1 ratio.

AAT-PBV system used in the Nordic countries has proved its advantages over the traditional system in predicting the amount of amino acids absorbed from the small intestine (AAT) and the nitrogen supply of the rumen microorganisms (PBV) (Hvelplund and Madsen, 1990). This system may act as a guide in calculating the exact amount of protein required by a ruminant animal, and thus apply the low input cost-high production economical feeding method.

Labour for grinding 1 ton of CSC was costed at 17000 Tshs and the factory price of 1 ton of CSC was 55000 Tshs. Therefore, total cost of cotton seed cake was 72000 Tshs/ton. Labour for drying and threshing 1 sack of DLL (weighing 10 kg) by hand

costed 200 Tshs. It costed 150 Tshs for a 10 kg fresh leucaena leaves plucked out of its stems ready for feeding. Prices of Rhodes and *Hyparrhenia rufa* grass hays were 150 Tshs per bale. Table 6.2 shows the calculated fuel and other feed costs. The latter costs were derived from Tables 4.2, 4.4, 4.8 and 4.12.

Table 6.2 shows that feeding of LL was economically viable in Experiment 1, but this was not the case for Experiments 2 and 3. Benefit – cost ratio was at break–even for all the treatments in Experiment 4. The major setback in Experiments 2 and 3 was the purchasing of hay far away from the sight of the experiments. This excercise culminated into high costs of fuel, although bales of hay were relatively not expensive.

Table 6.2: Economics[1] of feeding the treatment diets in Experiments 1 to 4

	Treatments			
Experiments	1	2	3	4
Experiment 1 (lactating goats) for 56 days				
Input				
Total DMI (kg)	72.1	72.3	74.0	75.5
Feed costs (Tshs)	1326.6	1356.7	1316.2	1299.2
Fuel costs (Tshs)	98.2	111.2	111.2	109.9
Total costs (Tshs)	1423.1	1467.9	1427.4	1409.1
Output				
Total milk yield (l)[2]	47.0	54.3	49.3	46.5
Price per liter (Tshs)	100	100	100	100
Total revenue (Tshs)	4704	5432	4928	4648
Profit	3280.9	3964.1	3500.6	3243.9
Benefit:cost ratio	3.3	3.7	3.5	3.3

Table 6.2 continued:

Experiment 2 (lactating goats) for 56 days

Input

Total DMI (kg)	86.5	88.1	90.8	93.9
Feed costs (Tshs)	1691.7	1641.6	1592.7	1543.0
Fuel costs (Tshs)	6000.0	6000.0	6000.0	6000.0
Total costs (Tshs)	7691.7	7641.6	7592.7	7543.0

Output

Total milk yield (l)	53.8	51.5	53.8	54.9
Price per liter (Tshs)	100	100	100	100
Total revenue (Tshs)	5376	5152	5375	5488
Profit	-2315.7	-2489.6	-2217.7	-2055.0
Benefit:cost ratio	0.7	0.7	0.7	0.7

Table 6.2 continued:

Experiment 3 (lactating goats) for 42 days

Input				
Total DMI (kg)	51.8	56.2	55.9	54.1
Feed costs (Tshs)	667.0	1154.5	1347.4	2212.6
Fuel costs (Tshs)	6000.0	6000.0	6000.0	6000.0
Total costs (Tshs)	6667.0	7154.5	7374.7	8239.9
Output				
Total milk yield (l)	26.5	32.8	33.2	34.4
Price per liter (Tshs)	100	100	100	100
Total revenue (Tshs)	2646	3276	3318	3444
Profit	−4021	−3878.5	−4056.7	−4795.9
Benefit:cost ratio	0.4	0.5	0.4	0.4

Table 6.2 continued:

Experiment 4 (weaner goats[3]) for 70 days				
Input				
Total DMI (kg)	37.3	39.0	41.5	38.0
Feed costs (Tshs)	697.1	687.0	678.8	671.5
Fuel costs (Tshs)	156.4	157.7	157.7	156.0
Total costs (Tshs)	953.5	844.5	836.5	827.5
Output				
Total weight gain (kg)	4.1	4.9	4.9	4.2
Price per liveweight	200	200	200	200
Total revenue (Tshs)	820	980	980	840
Profit	-33.5	118.5	126.5	-2.5
Benefit:cost ratio	1.0	1.2	1.2	1.0

[1] Costs were based on purchasing, processing and labour (Prices prevailing in 1991/92 during the final stages of the experiments, 1US$= 350 Tshs).
[2] 1 liter of milk was selling at 100 Tshs.
[3] Weaner goat was selling at 200 Tshs / kg liveweight (raising costs were disregarded)

6.2 RECOMMENDATIONS

Experiments in the present study had certain limitations and these included small sample size per treatment and lack of uniformity of animals in terms of weight, age and state of lactation. Furthermore, for treatment effects to be accurately assessed, it would have been better to use animals with higher milk potential (1.5 l/d and above) than animals used in the present study which was less than 1.0 l/d. In addition roughages used in the present study varied from experiment to experiment. It is therefore recommended that new methods be sought to evaluate feeds and develop alternative approaches to research, where facilities do not demand access to sufficient feeds and animal numbers to conduct such experiments. Secondly, on-farm survey work of current usage of leucaena on dairy goats in different parts of Tanzania should be carried out.

The biochemistry of LL utilization by dairy lactating goats needs further investigation. It must be stated that values obtained for degradability, rumen parameters, AAT-PBV and water intake were derived using bucks and it would have been of interest to work directly with the lactating animals.

It would be of interest to compare the relative advantages of *Leucaena leucocephala* in relation to other multipurpose trees in terms of dry matter yield, replacement value of nitrogen in oil cakes and performance of animals at different physiological stages.

There is also a need for further data on the economics of leucaena use as feed for animals. There is a need to quantify the economics of the "cut and carry" systems and its implications on the family labour use and time gender accounting. Furthermore, the economic implications of drying leucaena versus using it fresh need to be established. Research programmes should focus on quantification of plant biomass which can be harvested and marketed for animal feeding with emphasis on appropriate management practices and tree improvement. Previous assessment of multipurpose tree production have almost always focused exclusively on biological yields, without regard to economics. This can lead to mistaken recommendations, since farmers are often interested in both reducing risk and enhancing their incomes.

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APPENDICES

Appendix Table 2.1. Some of the more important native fodder trees and shrubs found in Tanzania and generally / occasionally browsed or "cut and carried" and offered to ruminants

Scientific name	Common / native name
Acacia mellifera[2]	Murugara(Sukuma), Mkambele (Gogo)
Acacia nilotica[2]	Ol - Kiloriti (Masai, Arusha)
Acacia tortolis[2]	Mkungungu (Gogo) Sanzavi, Oldepesi (Arusha)
Albizia harveyi and A. lebbek[2]	Msanje (Chagga)
Albizia schimperiana[2]	Mfuruanje (Chagga)
Blepharispermum zanguebaricum[2]	Lutugutu (Pogoro), Mlenga, Mlanga, Mlonga (Sambaa)
Boscia mossambicensis[2]	Mtumba (Gogo), Msingisa (Rangi)
Bridelia micrantha[1]	Mwarie (Chagga)
Cadaba kirkii[2]	Mlanga (Sangu, Hehe)
Commiphora zimmermanni[1]	Mfifina (Chagga)
Cordia gharaf[2]	Mudawa (Gogo), Ol durgo (Masai)
Cordia holstii[1]	Mringaringa (Chagga)
Crotalaria species[2]	Mshesha (Chagga), Mposhokwe (Pare)
Croton macrostachyus[1]	Mfurufuru (Chagga)
Croton polytrichus[2]	Lweja (Sukuma)
Cussonia holstii[1]	Mengere (Chagga)
Dalbergia melanoxylon[2]	Mpingo (Swahili)
Delonix elata[2]	Msele (Gogo), Ol-donoroinoroi (Masai)
Dichrostachys cinerea[2]	Mtunduru (Swahili), Lantern (English)

Appendix 2.1 continued:

Dracaena afromontana[1]	Masale (Chagga)
Eriobotrya japonica[1]	Helimu (")
Gliricidia sepium[2]	-
Grewia bicolor[2]	Mkole (Gogo)
Grewia similis[2]	Mtafuta (Gogo), Mnangu (Rangi)
Grevillea robusta[1]	Mweresi (Chagga)
Ilex mitis[1]	Ndiri (")
Macaranga kilimandscharica[1]	Mhaa (")
Markhamia zanzibarica[2]	Mtalawanda (Swahili)
Maragaritaria discoides[2]	Mshamana (Chagga)
Persea americana[1]	Mparachichi (Swahili)
Tamarindus indica[2]	Mkwaju (Swahili)
Tephrosia villosa[2]	Mlandu (Gogo)

Source: [1]Jumbe, (Unpublished); [2]Backlund and Bellskog(1991); Temu,R.P.C. (Personal communication, 1993)

Appendix Table 4.1. Experiment 1. Anova tables for actual milk yield (MILKTOT), fat corrected milk (FCMTOT), butterfat (AVBF), liveweights from week 5 to 12.

Dependent Variable: MILKTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	10262282906	932934810	10.82	0.0001
Error	16	1380197762	86262360		
Corrected Total	27	11642480668			
YEAR	1	98725	98725	0.00	0.9734
TREAT	3	245148475	81716158	0.95	0.4412
LACTNO	3	239854859	79951620	0.93	0.4504
YEAR*TREAT	3	141898438	47299479	0.55	0.6564
PRELMLK	1	2382928005	2382928005	27.62	0.0001

Dependent Variable: FCMTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	8161927357	741993396	7.24	0.0002
Error	16	1640255108	102515944		
Corrected Total	27	9802182465			
YEAR	1	77940649	77940649	0.76	0.3961
TREAT	3	277602913	92534304	0.90	0.4616
LACTNO	3	1264327291	421442430	4.11	0.0243
YEAR*TREAT	3	166901866	55633955	0.54	0.6600

Appendix 4.1 continued:

PRELFCM	1	773779835	773779835	7.55	0.0143

Dependent Variable: AVBF(%)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	12.92776199	1.17525109	3.72	0.0087
Error	16	5.04881725	0.31555108		
Corrected Total	27	17.97657924			
YEAR	1	0.34334121	0.34334121	1.09	0.3124
TREAT	3	1.02518737	0.34172912	1.08	0.3845
LACTNO	3	2.26901628	0.75633876	2.40	0.1062
YEAR*TREAT	3	0.59109470	0.19703157	0.62	0.6095
PRELBF	1	5.89493275	5.89493275	18.68	0.0005

Dependent Variable: WT6 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	527.2658999	47.9332636	15.05	0.0001
Error	16	50.9751715	3.1859482		
Corrected Total	27	578.2410714			
YEAR	1	2.9652553	2.9652553	0.93	0.3490
TREAT	3	8.9980304	2.9993435	0.94	0.4438
LACTNO	3	2.5041062	0.8347021	0.26	0.8517
YEAR*TREAT	3	0.0502057	0.0167352	0.01	0.9995
PRELWT	1	174.1498285	174.1498285	54.66	0.0001

Appendix 4.1 continued:

Dependent Variable: WT8 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	542.6269911	49.3297265	19.66	0.0001
Error	16	40.1401518	2.5087595		
Corrected Total	27	582.7671429			
YEAR	1	0.3311772	0.3311772	0.13	0.7211
TREAT	3	18.6025026	6.2008342	2.47	0.0991
LACTNO	3	13.9136256	4.6378752	1.85	0.1790
YEAR*TREAT	3	1.1194635	0.3731545	0.15	0.9290
PRELWT	1	174.9165149	174.9165149	69.72	0.0001

Dependent Variable: WT10 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	534.6403747	48.6036704	14.53	0.0001
Error	16	53.5292682	3.3455793		
Corrected Total	27	588.1696429			
YEAR	1	0.0019308	0.0019308	0.00	0.9811
TREAT	3	26.3885487	8.7961829	2.63	0.0858
LACTNO	3	11.8198596	3.9399532	1.18	0.3493
YEAR*TREAT	3	4.4332305	1.4777435	0.44	0.7264
PRELWT	1	163.3179541	163.3179541	48.82	0.0001

Appendix 4.1 continued:

Dependent Variable: WT12 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	11	533.6709552	48.5155414	10.52	0.0001
Error	16	73.7961877	4.6122617		
Corrected Total	27	607.4671429			
YEAR	1	1.9796367	1.9796367	0.43	0.5217
TREAT	3	25.0086839	8.3362280	1.81	0.1864
LACTNO	3	14.3793021	4.7931007	1.04	0.4019
YEAR*TREAT	3	1.2782733	0.4260911	0.09	0.9632
PRELWT	1	124.6199234	124.6199234	27.02	0.0001

Appendix Table 4.2. Experiment 1. Total weekly milk yield (mls), butterfat (%) and fourtnight liveweight (kg). First four weeks data were covariates (PREMILK, PREBF AND PREWT).

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK5MK[5]	WK5BF[6]	WK6MK	WK6BF	WK6WT[8]
450	1	2	1	6212	3.33	32.00	7700	4.00	6300	2.90	32
400	1	2	1	3500	3.00	30.00	3500	3.00	4700	3.10	28
21330	1	2	1	5530	5.28	35.70	6650	4.90	5110	5.10	36
24593	1	3	1	10097	4.08	34.85	12600	3.20	12600	3.30	35
27502	1	3	2	12775	2.63	46.75	16800	4.00	16800	2.60	44
1001	1	2	2	5915	3.83	33.10	7700	2.60	7000	3.00	35
27610	1	2	2	5425	4.50	24.10	6720	3.90	6300	4.00	25
398	1	2	2	8475	4.63	32.50	9100	4.70	9100	4.90	35
24600	1	2	3	8855	3.13	31.60	12950	2.90	11900	3.70	33
27630	1	2	3	3885	5.68	26.35	3920	4.60	4480	5.00	29
24598	1	3	3	6195	4.03	34.85	5110	6.50	8400	6.00	37
27640	1	2	3	6510	4.30	35.00	5140	5.60	6510	3.60	34
21200	1	6	4	6282	4.00	31.85	5530	3.40	5530	3.00	32
27482	1	1	4	6562	3.95	23.00	5320	4.00	5320	5.00	27
1012	1	2	4	5305	3.50	29.60	5330	3.40	5350	3.00	33
27691	1	1	4	6277	4.75	31.60	5320	3.90	5320	5.00	30
27689	2	1	1	4452	3.95	23.00	4410	4.90	3990	4.70	25
1020	2	2	1	3867	4.00	30.75	3600	4.00	3720	3.60	27
27694	2	1	1	3690	4.70	27.00	4060	4.80	4060	4.90	27
199	2	2	2	3042	3.45	31.75	2170	3.10	2520	3.20	33
27467	2	1	2	4045	5.05	28.75	4690	4.50	5180	4.00	28
27700	2	1	2	4707	3.40	28.00	4340	3.00	5740	3.00	28
27688	2	1	3	4095	3.38	24.00	4830	3.90	5320	3.40	25
27451	2	1	3	4210	4.63	26.00	4690	4.60	4690	4.60	27
27695	2	1	3	4397	5.08	28.25	4270	4.60	5530	4.70	29
27686	2	1	4	7970	4.35	32.75	4900	4.20	5060	4.80	34
27482	2	1	4	5082	3.73	30.50	4340	3.50	5040	4.00	31
27485	2	1	4	3957	5.95	25.75	4060	5.50	4200	4.60	25

Appendix 4.2 continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK7MK	WK7BF	WK8MK	WK8BF	WK8WT
450	1	2	1	6212	3.33	32.00	6650	3.20	6860	4.30	33
400	1	2	1	3500	3.00	30.00	3200	3.00	3500	3.20	28
21330	1	2	1	5530	5.28	35.70	5110	5.20	3640	5.00	36
24593	1	3	1	10097	4.08	34.85	9100	3.30	7700	5.90	35
27502	1	3	2	12775	2.63	46.75	16100	2.10	16100	3.20	45
1001	1	2	2	5915	3.83	33.10	7700	2.50	6230	4.80	35
27610	1	2	2	5425	4.50	24.10	5810	4.00	5810	2.80	26
398	1	2	2	8475	4.63	32.50	9100	5.00	7840	2.50	34
24600	1	2	3	8855	3.13	31.60	9450	2.80	8120	4.50	33
27630	1	2	3	3885	5.68	26.35	3150	5.00	2660	4.80	29
24598	1	3	3	6195	4.03	34.85	8400	7.00	8000	6.00	38
27640	1	2	3	6510	4.30	35.00	4900	5.00	5320	4.10	34
21200	1	6	4	6282	4.00	31.85	5600	3.40	5530	4.10	32
27482	1	1	4	6562	3.95	23.00	5670	5.40	5670	5.00	28
1012	1	2	4	5305	3.50	29.60	5530	3.40	5530	3.20	34
27691	1	1	4	6277	4.75	31.60	5670	5.40	5680	5.00	30
27689	2	1	1	4452	3.95	23.00	4000	4.10	4400	3.70	24
1020	2	2	1	3867	4.00	30.75	3980	3.60	3990	4.40	31
27694	2	1	1	3690	4.70	27.00	4100	4.50	4050	4.20	27
199	2	2	2	3042	3.45	31.75	2500	3.50	2600	4.00	33
27467	2	1	2	4045	5.05	28.75	5160	4.30	5200	4.20	28
27700	2	1	2	4707	3.40	28.00	5780	3.50	5600	4.00	28
27688	2	1	3	4095	3.38	24.00	3780	3.00	3920	3.20	25
27451	2	1	3	4210	4.63	26.00	4700	5.00	4500	4.50	27
27695	2	1	3	4397	5.08	28.25	5500	4.60	5600	4.50	29
27686	2	1	4	7970	4.35	32.75	5000	4.90	5050	5.00	35
27482	2	1	4	5082	3.73	30.50	5050	4.40	5060	4.20	33
27485	2	1	4	3957	5.95	25.75	4560	4.70	4600	4.80	25

Appendix 4.2 continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK9MK	WK9BF	WK10MK	WK10BF	WK10WT
450	1	2	1	6212	3.33	32.00	5390	3.00	6160	2.60	33
400	1	2	1	3500	3.00	30.00	3500	3.00	5810	3.20	27
21330	1	2	1	5530	5.28	35.70	3640	6.00	3600	6.00	35
24593	1	3	1	10097	4.08	34.85	7700	3.10	7000	3.20	35
27502	1	3	2	12775	2.63	46.75	15400	5.00	16100	2.20	45
1001	1	2	2	5915	3.83	33.10	5330	2.30	5530	2.30	36
27610	1	2	2	5425	4.50	24.10	4900	3.40	4900	3.90	27
398	1	2	2	8475	4.63	32.50	7840	5.00	7700	4.40	34
24600	1	2	3	8855	3.13	31.60	8400	2.70	8400	2.50	33
27630	1	2	3	3885	5.68	26.35	3500	4.60	2800	4.60	30
24598	1	3	3	6195	4.03	34.85	7200	5.50	7000	6.50	38
27640	1	2	3	6510	4.30	35.00	5320	4.00	5200	5.20	34
21200	1	6	4	6282	4.00	31.85	6370	3.20	7700	3.00	33
27482	1	1	4	6562	3.95	23.00	5320	4.00	5320	4.60	29
1012	1	2	4	5305	3.50	29.60	6370	3.00	7700	3.10	35
27691	1	1	4	6277	4.75	31.60	5600	4.50	5500	4.60	31
27689	2	1	1	4452	3.95	23.00	4200	4.50	5180	4.60	24
1020	2	2	1	3867	4.00	30.75	3710	3.50	3570	3.00	31
27694	2	1	1	3690	4.70	27.00	3080	4.10	3080	4.30	27
199	2	2	2	3042	3.45	31.75	2930	3.60	2940	2.90	33
27467	2	1	2	4045	5.05	28.75	5300	4.40	5320	4.40	28
27700	2	1	2	4707	3.40	28.00	5060	4.20	5040	3.00	28
27688	2	1	3	4095	3.38	24.00	4200	3.30	4130	3.10	24
27451	2	1	3	4210	4.63	26.00	4600	4.60	4480	5.00	28
27695	2	1	3	4397	5.08	28.25	5520	4.70	3570	5.00	29
27686	2	1	4	7970	4.35	32.75	5060	5.00	5060	4.80	36
27482	2	1	4	5082	3.73	30.50	4900	4.30	4900	3.50	32
27485	2	1	4	3957	5.95	25.75	4580	5.00	4410	4.50	25

Appendix 4.2 Continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK11MK	WK11BF	WK12MK	WK12BF	WK12WT
450	1	2	1	6212	3.33	32.00	6580	2.80	5810	3.10	35
400	1	2	1	3500	3.00	30.00	6160	5.00	6170	3.10	28
21330	1	2	1	5530	5.28	35.70	3600	5.00	3500	5.00	35
24593	1	3	1	10097	4.08	34.85	7700	3.30	7000	3.40	36
27502	1	3	2	12775	2.63	46.75	16100	2.00	16100	2.30	44
1001	1	2	2	5915	3.83	33.10	6020	2.20	5950	2.40	38
27610	1	2	2	5425	4.50	24.10	5950	3.40	5460	4.00	28
398	1	2	2	8475	4.63	32.50	8400	4.00	8400	4.40	34
24600	1	2	3	8855	3.13	31.60	9100	3.00	9100	2.70	36
27630	1	2	3	3885	5.68	26.35	2800	4.60	2660	4.70	30
24598	1	3	3	6195	4.03	34.85	7200	5.00	6350	5.90	40
27640	1	2	3	6510	4.30	35.00	5010	5.00	5100	4.60	35
21200	1	6	4	6282	4.00	31.85	7700	3.10	7700	3.30	33
27482	1	1	4	6562	3.95	23.00	4900	5.00	4950	4.50	30
1012	1	2	4	5305	3.50	29.60	7700	3.30	7700	3.30	36
27691	1	1	4	6277	4.75	31.60	6000	5.00	5900	4.50	31
27689	2	1	1	4452	3.95	23.00	4620	3.90	4620	3.90	25
1020	2	2	1	3867	4.00	30.75	3990	3.10	4620	3.00	30
27694	2	1	1	3690	4.70	27.00	3990	4.50	4200	4.00	27
199	2	2	2	3042	3.45	31.75	2520	2.50	3500	2.50	33
27467	2	1	2	4045	5.05	28.75	5110	4.70	4270	4.10	29
27700	2	1	2	4707	3.40	28.00	5180	3.30	5460	3.00	28
27688	2	1	3	4095	3.38	24.00	4620	3.70	3500	3.50	24
27451	2	1	3	4210	4.63	26.00	4550	4.80	4500	4.20	28
27695	2	1	3	4397	5.08	28.25	3640	4.50	4200	4.40	30
27686	2	1	4	7970	4.35	32.75	5040	5.00	5000	5.00	35
27482	2	1	4	5082	3.73	30.50	5040	3.30	5040	3.50	33
27485	2	1	4	3957	5.95	25.75	4270	4.00	4410	4.90	26

[1]Doe number; [2]Year; [3]Treatment; [4]Lactation number; [5]Week 5 milk yield; [6]Week 5 butterfat %; [7]Week 6 body weight (etc. to week 12)

Appendix Table 4.3. Experiment 2. Anova tables for actual milk yield (MILKTOT), fat corrected milk (FCMTOT), butterfat (AVBF), liveweights from week 5 to 12.

Dependent Variable: MILKTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	13353674252	953833875	13.77	0.0001
Error	38	2632542695	69277439		
Corrected Total	52	15986216947			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
YEAR	1	1984232	1984232	0.03	0.8665
TREAT	3	10732185	3577395	0.05	0.9843
LACTNO	6	202332023	33722004	0.49	0.8140
YEAR*TREAT	3	261537760	87179253	1.26	0.3023
PRELMLK	1	8278707175	8278707175	119.50	0.0001

Dependent Variable: FCMTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	14684673221	1048905230	11.45	0.0001
Error	38	3481462172	91617426		
Corrected Total	52	18166135394			
YEAR	1	158457335	158457335	1.73	0.1963
TREAT	3	187817749	62605916	0.68	0.5677
LACTNO	6	278195644	46365941	0.51	0.7998
YEAR*TREAT	3	213136802	71045601	0.78	0.5150
PRELFCM	1	8787940162	8787940162	95.92	0.0001

Appendix Table 4.3 continued:

Dependent Variable: AVBF (%)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	14.72556323	1.05182594	10.68	0.0001
Error	38	3.74227875	0.09848102		
Corrected Total	52	18.46784198			
YEAR	1	0.90250142	0.90250142	9.16	0.0044
TREAT	3	3.01394396	1.00464799	10.20	0.0001
LACTNO	6	0.51186097	0.08531016	0.87	0.5284
YEAR*TREAT	3	0.54664690	0.18221563	1.85	0.1545
PRELBF	1	7.27778600	7.27778600	73.90	0.0001

Dependent Variable: WT6 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	1061.972437	75.855174	27.99	0.0001
Error	39	105.675711	2.709634		
Corrected Total	53	1167.648148			
YEAR	1	2.2232561	2.2232561	0.82	0.3706
TREAT	3	17.4825039	5.8275013	2.15	0.1094
LACTNO	6	80.7899915	13.4649986	4.97	0.0007
YEAR*TREAT	3	7.4735092	2.4911697	0.92	0.4405
PRELWT	1	858.5810978	858.5810978	316.86	0.0001

Appendix Table 4.3 continued:

Dependent Variable: WT8 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	997.4810791	71.2486485	23.46	0.0001
Error	39	118.4309579	3.0366912		
Corrected Total	53	1115.9120370			
YEAR	1	4.0202609	4.0202609	1.32	0.2569
TREAT	3	8.2976803	2.7658934	0.91	0.4446
LACTNO	6	81.6077335	13.6012889	4.48	0.0015
YEAR*TREAT	3	4.7501741	1.5833914	0.52	0.6701
PRELWT	1	816.4170388	816.4170388	268.85	0.0001

Dependent Variable: WT10 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	940.9780093	67.2127149	23.05	0.0001
Error	39	113.7251389	2.9160292		
Corrected Total	53	1054.7031481			
YEAR	1	3.7458827	3.7458827	1.28	0.2640
TREAT	3	12.0595608	4.0198536	1.38	0.2636
LACTNO	6	48.1531631	8.0255272	2.75	0.0251
YEAR*TREAT	3	2.6418158	0.8806053	0.30	0.8238
PRELWT	1	779.7721778	779.7721778	267.41	0.0001

Appendix Table 4.3 continued:

Dependent Variable: WT12 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	14	822.6678242	58.7619874	11.79	0.0001
Error	38	189.3793456	4.9836670		
Corrected Total	52	1012.0471698			
YEAR	1	0.9634912	0.9634912	0.19	0.6627
TREAT	3	5.9688093	1.9896031	0.40	0.7543
LACTNO	6	50.6887617	8.4481269	1.70	0.1488
YEAR*TREAT	3	2.6636659	0.8878886	0.18	0.9105
PRELWT	1	669.2439554	669.2439554	134.29	0.0001

Appendix Table 4.4. Experiment 2. Total weekly milk yield (mls), butterfat (%) and fourtnight liveweight (kg), from week 5 to 12. First four weeks data were covariates (PREMILK, PREBF AND PREWT).

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK5MK[5]	WK5BF[6]	WK6MK	WK6BF	WK6WT[7]
302	4	6	1	5500	4.65	33.33	6160	4.60	6360	5.00	34
307	4	2	1	6080	4.20	36.67	6600	4.60	6160	4.70	36
323	4	2	1	4510	6.30	27.17	4460	6.20	6040	6.40	31
348	4	1	1	8132	4.18	32.33	9340	3.50	9360	4.00	32
360	4	2	1	6375	4.75	34.00	6940	5.90	8140	3.30	34
414	4	1	1	4505	5.25	37.83	5540	6.10	5060	5.00	37
309	4	3	2	6615	4.08	25.17	7260	4.00	7300	5.30	27
315	4	3	2	8490	4.18	36.50	10200	4.00	10240	3.70	38
339	4	1	2	5480	5.15	35.67	6920	5.30	5960	5.10	35
346	4	3	2	5125	4.15	27.50	7500	5.60	7000	4.40	30
354	4	2	2	6710	5.48	33.67	7380	5.90	6780	6.00	35
422	4	2	2	5270	4.35	31.33	7280	4.20	6120	4.70	33
312	4	4	3	6845	4.20	38.83	7760	5.20	6260	4.60	40
316	4	2	3	3855	5.40	37.33	3980	6.30	4340	6.00	40
325	4	4	3	10730	4.23	37.83	9220	4.60	10840	4.30	39
334	4	2	3	4395	3.75	34.50	6020	4.00	5120	4.50	38
351	4	1	3	6355	4.50	30.00	6840	5.50	6140	4.60	30
352	4	3	3	9710	4.10	36.83	10700	4.60	9820	5.10	36
353	4	2	3	7020	4.83	29.83	7200	5.20	6800	5.60	32
310	4	4	4	7445	4.73	29.50	8440	5.00	7220	5.00	29
311	4	2	4	6695	4.83	33.50	7000	5.10	6280	5.20	34
355	4	2	4	8695	4.93	37.50	8300	5.00	8720	4.50	40
359	4	1	4	6705	4.85	36.17	6020	5.00	7000	5.10	36
419	4	3	4	10880	4.50	38.67	10620	4.50	11620	4.60	42
420	4	4	4	8695	4.13	35.00	9980	4.30	10640	4.00	37
424	4	1	4	10535	5.10	39.17	9380	4.80	9760	5.00	40
310	5	5	1	8295	5.08	31.83	9340	4.30	9180	5.00	34

Appendix Table 4.4 continued:

333	5	4	1	3432	5.68	32.33	3380	5.70	2740	5.70	35
349	5	3	1	5030	5.88	34.17	6000	5.60	5540	5.50	35
351	5	2	1	7510	5.40	32.83	7680	5.00	7340	5.10	34
414	5	2	1	9905	5.80	41.33	11180	5.40	12560	5.20	44
422	5	3	1	5745	5.45	37.50	6940	5.20	6580	5.20	38
454	5	1	1	5550	5.33	29.10	6980	4.80	6740	4.70	27
302	5	7	2	3050	5.63	39.00	2140	4.60	2380	4.90	39
307	5	3	2	5597	4.90	37.17	6680	5.00	6280	4.10	39
309	5	4	2	5165	5.40	28.50	6760	4.60	7220	4.60	29
354	5	3	2	7035	6.25	36.50	6780	5.30	6480	6.20	38
379	5	2	2	3905	6.30	26.17	4460	6.20	4360	6.00	28
424	5	2	2	9265	5.70	44.17	7840	5.90	8100	5.40	44
504	5	1	2	5300	5.55	27.50	6010	6.00	6440	5.20	27
355	5	3	3	7260	5.28	43.33	7780	4.70	8260	4.90	45
359	5	2	3	9440	4.85	38.17	10580	4.50	9940	4.50	40
360	5	3	3	4115	5.60	38.17	3780	5.40	3060	5.50	38
362	5	3	3	8330	5.18	31.83	9540	6.00	9780	5.30	33
377	5	2	3	5210	6.00	30.50	6660	5.80	6600	5.80	33
419	5	4	3	10505	4.78	42.33	9520	5.00	10540	4.50	42
451	5	1	3	4440	4.73	38.90	6800	5.00	7580	5.30	31
320	5	3	4	4715	6.50	29.67	4700	5.30	4340	6.50	32
325	5	5	4	10000	4.95	40.17	12700	5.00	12400	5.30	43
339	5	2	4	7275	5.38	35.50	7300	4.30	8320	5.80	41
352	5	4	4	10790	4.75	41.00	11360	4.20	10060	4.60	43
353	5	3	4	9405	5.10	32.33	10300	4.90	10080	5.10	35
374	5	2	4	4130	6.25	26.00	4200	5.50	4980	5.90	30
485	5	1	4	5935	6.08	30.67	7010	4.90	6480	6.00	33

Appendix Table 4.4 continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK7MK	WK7BF	WK8MK	WK8BF	WK8WT
302	4	6	1	5500	4.65	33.33	5180	4.40	5460	4.40	36
307	4	2	1	6080	4.20	36.66	6520	3.80	5680	3.80	39
323	4	2	1	4510	6.30	27.16	4940	7.00	4960	7.00	32
348	4	1	1	8132	4.18	32.33	9040	3.90	8820	4.10	32
360	4	2	1	6375	4.75	34.00	6320	4.70	6080	5.50	35
414	4	1	1	4505	5.25	37.83	4480	7.00	5040	6.00	39
309	4	3	2	6615	4.08	25.16	5920	4.30	7480	3.80	27
315	4	3	2	8490	4.18	36.50	11380	4.00	11080	3.90	40
339	4	1	2	5480	5.15	35.66	5100	4.80	4000	4.80	37
346	4	3	2	5125	4.15	27.50	6760	5.30	6880	4.60	33
354	4	2	2	6710	5.48	33.66	6120	5.40	6280	5.50	37
422	4	2	2	5270	4.35	31.33	6340	4.90	5460	5.10	35
312	4	4	3	6845	4.20	38.83	6820	4.10	7300	4.50	41
316	4	2	3	3855	5.40	37.33	3740	7.00	3600	7.00	40
325	4	4	3	10730	4.23	37.83	9960	5.00	9240	5.00	41
334	4	2	3	4395	3.75	34.50	5060	6.30	4520	7.00	39
351	4	1	3	6355	4.50	30.00	7800	5.30	5800	5.40	30
352	4	3	3	9710	4.10	36.83	10000	5.00	10240	4.90	36
353	4	2	3	7020	4.83	29.83	7280	5.40	6500	5.30	31
310	4	4	4	7445	4.73	29.50	7180	4.90	7800	5.00	30
311	4	2	4	6695	4.83	33.50	8020	5.40	6960	5.50	35
355	4	2	4	8695	4.93	37.50	9050	5.00	8520	5.40	41
359	4	1	4	6705	4.85	36.16	6280	5.20	8030	5.10	38
419	4	3	4	10880	4.50	38.66	10980	4.50	11720	4.90	43
420	4	4	4	8695	4.13	35.00	11380	4.50	9600	4.60	37
424	4	1	4	10535	5.10	39.16	9320	4.70	9420	5.00	41
310	5	5	1	8295	5.08	31.83	8260	4.70	8900	4.60	33
333	5	4	1	3432	5.68	32.33	2040	6.20	2240	5.90	37
349	5	3	1	5030	5.88	34.16	4520	6.00	3960	5.90	36
351	5	2	1	7510	5.40	32.83	7040	5.90	6520	5.30	35

Appendix Table 4.4 continued:

414	5	2	1	9905	5.80	41.33	11180	5.40	12940	5.70	45
422	5	3	1	5745	5.45	37.50	6820	5.70	6400	5.60	38
454	5	1	1	5550	5.33	29.10	5720	4.80	5600	5.00	28
302	5	7	2	3050	5.63	39.00	2040	6.50	1120	6.10	40
307	5	3	2	5597	4.90	37.16	6100	4.80	6020	4.90	40
309	5	4	2	5165	5.40	28.50	7560	4.80	6380	4.20	30
354	5	3	2	7035	6.25	36.50	5980	7.30	6040	7.40	39
379	5	2	2	3905	6.30	26.16	4240	7.00	4720	7.00	30
424	5	2	2	9265	5.70	44.16	7660	5.00	8320	5.60	43
504	5	1	2	5300	5.55	27.50	6620	5.10	6300	5.90	28
355	5	3	3	7260	5.28	43.33	7360	5.40	7660	5.50	46
359	5	2	3	9440	4.85	38.16	10220	4.90	10260	5.00	41
360	5	3	3	4115	5.60	38.16	3320	5.80	2580	5.80	39
362	5	3	3	8330	5.18	31.83	8980	5.60	8440	5.40	35
377	5	2	3	5210	6.00	30.50	6940	6.50	6580	6.10	34
419	5	4	3	10505	4.78	42.33	10640	4.60	9840	4.90	43
451	5	1	3	4440	4.73	38.90	6560	5.50	6480	5.30	33
320	5	3	4	4715	6.50	29.66	4800	7.00	4620	7.00	33
325	5	5	4	10000	4.95	40.16	11120	4.70	9740	4.90	41
339	5	2	4	7275	5.38	35.50	8680	4.90	8960	5.10	40
352	5	4	4	10790	4.75	41.00	11920	4.10	11720	4.80	43
353	5	3	4	9405	5.10	32.33	10300	4.90	10080	5.10	35
374	5	2	4	4130	6.25	26.00	4200	5.50	4980	5.90	30
485	5	1	4	5935	6.08	30.67	7010	4.90	6480	6.00	33

Appendix 4.4 continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK9MK	WK9BF	WK10MK	WK10BF	WK10WT
302	4	6	1	5500	4.65	33.33	5180	4.40	5460	4.40	36
307	4	2	1	6080	4.20	36.66	6520	3.80	5680	3.80	39
323	4	2	1	4510	6.30	27.16	4940	7.00	4960	7.00	32

Appendix Table 4.4 continued:

348	4	1	1	8132	4.18	32.33	9040	3.90	8820	4.10	32
360	4	2	1	6375	4.75	34.00	6320	4.70	6080	5.50	35
414	4	1	1	4505	5.25	37.83	4480	7.00	5040	6.00	39
309	4	3	2	6615	4.08	25.16	5920	4.30	7480	3.80	27
315	4	3	2	8490	4.18	36.50	11380	4.00	11080	3.90	40
339	4	1	2	5480	5.15	35.66	5100	4.80	4000	4.80	37
346	4	3	2	5125	4.15	27.50	6760	5.30	6880	4.60	33
354	4	2	2	6710	5.48	33.66	6120	5.40	6280	5.50	37
422	4	2	2	5270	4.35	31.33	6340	4.90	5460	5.10	35
312	4	4	3	6845	4.20	38.83	6820	4.10	7300	4.50	41
316	4	2	3	3855	5.40	37.33	3740	7.00	3600	7.00	40
325	4	4	3	10730	4.23	37.83	9960	5.00	9240	5.00	41
334	4	2	3	4395	3.75	34.50	5060	6.30	4520	7.00	39
351	4	1	3	6355	4.50	30.00	7800	5.30	5800	5.40	30
352	4	3	3	9710	4.10	36.83	10000	5.00	10240	4.90	36
353	4	2	3	7020	4.83	29.83	7280	5.40	6500	5.30	31
310	4	4	4	7445	4.73	29.50	7180	4.90	7800	5.00	30
311	4	2	4	6695	4.83	33.50	8020	5.40	6960	5.50	35
355	4	2	4	8695	4.93	37.50	9050	5.00	8520	5.40	41
359	4	1	4	6705	4.85	36.16	6280	5.20	8030	5.10	38
419	4	3	4	10880	4.50	38.66	10980	4.50	11720	4.90	43
420	4	4	4	8695	4.13	35.00	11380	4.50	9600	4.60	37
424	4	1	4	10535	5.10	39.16	9320	4.70	9420	5.00	41
310	5	5	1	8295	5.08	31.83	8260	4.70	8900	4.60	33
333	5	4	1	3432	5.68	32.33	2040	6.20	2240	5.90	37
349	5	3	1	5030	5.88	34.16	4520	6.00	3960	5.90	36
351	5	2	1	7510	5.40	32.83	7040	5.90	6520	5.30	35
414	5	2	1	9905	5.80	41.33	13840	5.40	12940	5.70	45
422	5	3	1	5745	5.45	37.50	6820	5.70	6400	5.60	38
454	5	1	1	5550	5.33	29.10	5720	4.80	5600	5.00	28
302	5	7	2	3050	5.63	39.00	2040	6.50	1120	6.10	40
307	5	3	2	5597	4.90	37.16	6100	4.80	6080	5.50	35

Appendix Table 4.4 continued:

309	5	4	2	5165	5.40	28.50	7560	4.80	6380	4.20	30
354	5	3	2	7035	6.25	36.50	5980	7.30	6040	7.40	39
379	5	2	2	3905	6.30	26.16	4240	7.00	4720	7.00	30
424	5	2	2	9265	5.70	44.16	7660	5.00	8320	5.60	43
504	5	1	2	5300	5.55	27.50	6620	5.10	6300	5.90	28
355	5	3	3	7260	5.28	43.33	7360	5.40	7660	5.50	46
359	5	2	3	9440	4.85	38.16	10220	4.90	10260	5.00	41
360	5	3	3	4115	5.60	38.16	3320	5.80	2580	5.80	39
362	5	3	3	8330	5.18	31.83	8980	5.60	8440	5.40	35
377	5	2	3	5210	6.00	30.50	6940	6.50	6580	6.10	34
419	5	4	3	10505	4.78	42.33	10640	4.60	9840	4.90	43
451	5	1	3	4440	4.73	38.90	6560	5.50	6480	5.30	33
320	5	3	4	4715	6.50	29.66	4800	7.00	4620	7.00	33
325	5	5	4	10000	4.95	40.16	11120	4.70	9740	4.90	41
339	5	2	4	7275	5.38	35.50	8680	4.90	8960	5.10	40
352	5	4	4	10790	4.75	41.00	11920	4.10	11720	4.80	43
353	5	3	4	9405	5.10	32.33	9700	5.20	9520	5.30	35
374	5	2	4	4130	6.25	26.00	4240	6.10	4200	5.80	32
485	5	1	4	5935	6.08	30.66	6880	6.10	6940	5.90	33

Appendix Table 4.4 continued:

GOATN[1]	Y[2]	T[3]	L[4]	PREMILK	PREBF	PREWT	WK11MK	WK11BF	WK12MK	WK12BF	WK12WT
302	4	6	1	5500	4.65	33.33	5080	5.40	3460	6.30	37
307	4	2	1	6080	4.20	36.66	6760	4.20	6120	4.60	42
323	4	2	1	4510	6.30	27.16	.	.	.	.	.
348	4	1	1	8132	4.18	32.33	9680	4.10	10300	4.10	33
360	4	2	1	6375	4.75	34.00	6140	5.10	5820	4.50	36
414	4	1	1	4505	5.25	37.83	3640	6.20	1120	5.80	36
309	4	3	2	6615	4.08	25.16	8500	4.00	7880	3.20	28
315	4	3	2	8490	4.18	36.50	12360	4.00	13580	4.00	39

Appendix Table 4.4 continued:

339	4	1	2	5480	5.15	35.66	6440	5.40	5700	7.10	39
346	4	3	2	5125	4.15	27.50	6460	3.60	6400	4.30	33
354	4	2	2	6710	5.48	33.66	5140	6.30	5180	7.00	38
422	4	2	2	5270	4.35	31.33	7440	5.00	5820	5.00	35
312	4	4	3	6845	4.20	38.83	6580	5.00	7140	4.90	40
316	4	2	3	3855	5.40	37.33	2780	6.60	2740	6.00	43
325	4	4	3	10730	4.23	37.83	9900	5.00	10240	5.10	42
334	4	2	3	4395	3.75	34.50	4830	6.30	3840	6.30	40
351	4	1	3	6355	4.50	30.00	6560	5.60	6720	5.10	32
352	4	3	3	9710	4.10	36.83	9020	6.00	9020	6.00	36
353	4	2	3	7020	4.83	29.83	6260	6.00	6280	5.80	30
310	4	4	4	7445	4.73	29.50	6600	5.10	5540	5.50	29
311	4	2	4	6695	4.83	33.50	6660	6.30	6020	6.00	34
355	4	2	4	8695	4.93	37.50	7340	5.00	7400	5.10	42
359	4	1	4	6705	4.85	36.16	7200	5.10	6660	5.30	38
419	4	3	4	10880	4.50	38.66	10700	4.50	9820	4.20	44
420	4	4	4	8695	4.13	35.00	10400	5.30	10200	5.00	36
424	4	1	4	10535	5.10	39.16	8920	4.90	8060	5.00	40
310	5	5	1	8295	5.08	31.83	8760	4.50	7420	4.70	33
333	5	4	1	3432	5.68	32.33	1840	6.50	880	7.40	37
349	5	3	1	5030	5.88	34.16	3760	5.90	4720	6.50	34
351	5	2	1	7510	5.40	32.83	7220	5.30	6660	5.50	35
414	5	2	1	9905	5.80	41.33	12100	5.80	11200	5.30	44
422	5	3	1	5745	5.45	37.50	5920	5.40	6180	6.00	36
454	5	1	1	5550	5.33	29.10	4900	5.60	4540	4.50	33
302	5	7	2	3050	5.63	39.00	980	6.00	1140	6.10	42
307	5	3	2	5597	4.90	37.16	6500	4.70	6280	4.40	42
309	5	4	2	5165	5.40	28.50	8180	4.00	7400	4.00	32
354	5	3	2	7035	6.25	36.50	4400	6.50	4860	5.60	38
379	5	2	2	3905	6.30	26.16	4120	6.40	4040	6.20	32
424	5	2	2	9265	5.70	44.16	4640	5.60	3400	5.30	43
504	5	1	2	5300	5.55	27.50	6480	4.60	5940	5.50	28
355	5	3	3	7260	5.28	43.33	6820	5.40	6580	5.60	45

Appendix Table 4.4 continued:

359	5	2	3	9440	4.85	38.16	9080	5.00	8840	5.90	41
360	5	3	3	4115	5.60	38.16	2400	5.20	2380	6.30	41
362	5	3	3	8330	5.18	31.83	8400	5.50	7940	5.80	34
377	5	2	3	5210	6.00	30.50	6180	6.40	5560	6.40	36
419	5	4	3	10505	4.78	42.33	9440	5.00	9480	5.00	43
451	5	1	3	4440	4.73	38.90	6740	4.60	6540	5.30	33
320	5	3	4	4715	6.50	29.66	5100	6.60	4940	5.00	33
325	5	5	4	10000	4.95	40.16	9620	4.20	8940	5.10	41
339	5	2	4	7275	5.38	35.50	9180	5.30	9240	5.80	40
352	5	4	4	10790	4.75	41.00	10020	4.70	9040	4.70	42
353	5	3	4	9405	5.10	32.33	8740	5.00	8680	5.90	34
374	5	2	4	4130	6.25	26.00	4220	6.40	3820	6.00	32
485	5	1	4	5935	6.08	30.66	6560	6.80	6160	6.40	31
485	5	1	4	5935	6.08	30.66	6400	5.50	6460	6.10	32

[1] Doe number
[2] Year
[3] Treatment
[4] Lactation number
[5,6,7]:See footnote of Appendix Table 4.2

Appendix Table 4.5. Weekly records of minerals in milk (g/l) as affected by the treatment diets in Experiment 2

Minerals	T R E A T M E N T S				SEM	P
Week 5	1	2	3	4		
Calcium	1.30	1.18	1.28	1.28	0.10	0.908
Sodium	0.47	0.51	0.55	0.51	0.06	0.835
Phosphorus	0.94	1.01	1.01	1.03	0.06	0.729
Potassium	1.50	1.43	1.67	1.70	0.11	0.231
Week 6						
Calcium	1.21	1.24	1.24	1.33	0.07	0.062
Sodium	0.45	0.62	0.44	0.51	0.05	0.817
Phosphorus	0.96	1.02	1.00	1.05	0.07	0.828
Potassium	1.55	1.70	1.63	1.46	0.09	0.271
Week 7						
Calcium	1.09^{b}	1.42^{a}	1.32^{a}	1.37^{a}	0.63	0.013*
Sodium	0.48	0.53	0.55	0.57	0.04	0.545
Phosphorus	1.05	0.93	1.03	1.07	0.06	0.343
Potassium	1.63	1.54	1.64	1.69	0.11	0.780
Week 8						
Calcium	1.34^{a}	0.91^{b}	1.28^{a}	1.28^{a}	0.08	0.016*
Sodium	0.67^{a}	0.48^{b}	0.57^{ab}	0.47^{b}	0.04	0.005**
Phosphorus	1.01	1.03	0.99	1.04	0.05	0.966
Potassium	1.59	1.82	1.67	1.52	0.08	0.092

Appendix Table 4.5 continued.

Week 9						
Calcium	1.25	1.27	1.17	1.18	0.10	0.851
Sodium	0.42	0.58	0.50	0.54	0.06	0.315
Phosphorus	0.91	1.01	1.03	1.05	0.06	0.391
Potassium	1.86	1.71	1.68	1.75	0.08	0.473
Week 10						
Calcium	1.28	1.33	1.30	1.16	0.07	0.262
Sodium	0.45	0.51	0.58	0.60	0.07	0.420
Phosphorus	1.04	0.99	1.06	0.96	0.06	0.646
Potassium	2.93	1.53	1.53	1.66	0.06	0.344
Week 11						
Calcium	1.32	1.52	1.28	1.42	0.10	0.402
Sodium	0.53	0.50	0.57	0.50	0.04	0.694
Phosphorus	1.00	0.98	0.87	1.02	0.06	0.330
Potassium	1.83	1.68	1.57	1.87	0.10	0.113
Week 12						
Calcium	1.25	1.48	1.27	1.19	0.09	0.204
Sodium	0.48	0.54	0.52	0.56	0.05	0.736
Phosphorus	0.98	1.05	0.87	0.93	0.07	0.273
Potassium	1.68	1.82	1.61	1.74	0.07	0.222

Appendix Table 4.6. Experiment 3. Anova tables for actual milk yield (MILKTOT), fat corrected milk (FCMTOT), butterfat (AVBF) and liveweights from week 3 to 8.

Dependent Variable: MILKTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	2359781323	294972665	14.58	0.0001
Error	19	384470213	20235274		
Corrected Total	27	2744251536			
TREAT	3	143597225	47865742	2.37	0.1031
LACTNO	1	3525250	3525250	0.17	0.6811
LACTNO*TREAT	3	62606669	20868890	1.03	0.4011
PRELMILK	1	1238193719	1238193719	61.19	0.0001

Dependent Variable: FCMTOT (mls/week)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	3575065698	446883212	5.73	0.0009
Error	19	1480888798	77941516		
Corrected Total	27	5055954496			
TREAT	3	460940680	153646893	1.97	0.1525
LACTNO	1	144348643	144348643	1.85	0.1895
LACTNO*TREAT	3	450865432	150288477	1.93	0.1593
PRELFCM	1	1664607820	1664607820	21.36	0.0002

Appendix Table 4.6 continued:

Dependent Variable: AVBF (%)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1.84519337	0.23064917	1.28	0.3097
Error	19	3.41853679	0.17992299		
Corrected Total	27	5.26373016			
TREAT	3	1.16117427	0.38705809	2.15	0.1274
LACTNO	1	0.00966000	0.00966000	0.05	0.8192
LACTNO*TREAT	3	0.93622155	0.31207385	1.73	0.1939
PRELBF	1	0.00320496	0.00320496	0.02	0.8952

Dependent Variable: WT3 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1011.214650	126.401831	189.97	0.0001
Error	19	12.642493	0.665394		
Corrected Total	27	1023.857143			
TREAT	3	0.6808279	0.2269426	0.34	0.7959
LACTNO	1	0.0039286	0.0039286	0.01	0.9396
LACTNO*TREAT	3	0.6208644	0.2069548	0.31	0.8172
PRELWT	1	479.2895302	479.2895302	720.31	0.0001

Appendix Table 4.6 continued:

Dependent Variable: WT4 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	957.2483712	119.6560464	105.91	0.0001
Error	19	21.4659145	1.1297850		
Corrected Total	27	978.7142857			
TREAT	3	0.2542710	0.0847570	0.08	0.9727
LACTNO	1	0.2630560	0.2630560	0.23	0.6349
LACTNO*TREAT	3	0.6544607	0.2181536	0.19	0.8998
PRELWT	1	442.9217022	442.9217022	392.04	0.0001

Dependent Variable: WT5 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	1004.433648	125.554206	110.07	0.0001
Error	19	21.673495	1.140710		
Corrected Total	27	1026.107143			
TREAT	3	1.4240255	0.4746752	0.42	0.7434
LACTNO	1	0.5050641	0.5050641	0.44	0.5138
LACTNO*TREAT	3	0.9596516	0.3198839	0.28	0.8388
PRELWT	1	450.9128743	450.9128743	395.29	0.0001

Appendix Table 4.6 continued:

Dependent Variable: WT6 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	911.2982870	113.9122859	74.30	0.0001
Error	19	29.1302844	1.5331729		
Corrected Total	27	940.4285714			
TREAT	3	1.0700572	0.3566857	0.23	0.8725
LACTNO	1	0.0242913	0.0242913	0.02	0.9012
LACTNO*TREAT	3	2.0724263	0.6908088	0.45	0.7198
PRELWT	1	445.6539774	445.6539774	290.67	0.0001

Dependent Variable: WT7 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	880.1606791	110.0200849	49.16	0.0001
Error	19	42.5178923	2.2377838		
Corrected Total	27	922.6785714			
TREAT	3	1.1440323	0.3813441	0.17	0.9150
LACTNO	1	1.2256630	1.2256630	0.55	0.4683
LACTNO*TREAT	3	1.6116731	0.5372244	0.24	0.8673

Appendix Table 4.6 continued:

Dependent Variable: WT8 (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	969.0633571	121.1329196	40.83	0.0001
Error	19	56.3652143	2.9665902		
Corrected Total	27	1025.4285714			
TREAT	3	0.6059859	0.2019953	0.07	0.9762
LACTNO	1	1.2674468	1.2674468	0.43	0.5212
LACTNO*TREAT	3	4.7154529	1.5718176	0.53	0.6672
PRELWT	1	422.4616540	422.4616540	142.41	0.0001

Appendix Table 4.7. Experiment 3. Weekly milk yield (mls), butterfat (%), and weekly liveweight. First two weeks' data were covariates (PREMILK, PREBF AND PREWT).

GOATN[1]	T[2]	L[3]	PREMILK	PREBF	PREWT	WK3MK[4]	WK3BF[5]	WK3WT[6]	WK4MK	WK4BF	WK4WT
414	1	3	7600	6.50	41	9487	6.00	42	8220	6.00	42
355	1	4	8050	6.05	44	7640	5.90	45	7760	6.00	45
351	1	5	5750	6.10	34	5160	5.90	35	4560	4.50	35
329	1	6	5990	7.40	32	4680	6.20	32	3740	7.10	33
372	1	4	4540	6.35	32	3860	6.70	35	3140	6.00	34
519	1	1	4610	5.70	23	3220	5.90	24	2740	5.50	24
587	1	1	4990	5.90	22	3600	5.30	23	2600	6.30	23
307	2	6	3900	3.00	34	3930	6.00	34	4480	5.90	35
335	2	4	5100	7.00	35	4860	6.90	34	4500	6.50	34
400	2	3	3190	5.70	33	3600	6.20	34	3600	4.60	35
353	2	4	4140	5.70	34	4160	5.30	34	4260	5.20	33
496	2	2	6070	5.40	24	6580	5.10	25	6460	4.20	25
362	2	4	7320	5.30	34	6840	6.20	34	6920	6.00	34
561	2	1	5100	6.00	23	3860	6.20	23	4880	7.50	24
575	3	1	5010	6.20	26	4920	6.20	28	4180	7.30	28
515	3	1	4580	6.45	31	4680	6.60	31	4700	6.40	31
424	3	4	12280	2.40	46	10800	7.00	47	10380	5.80	47
320	3	4	5820	6.40	32	6560	6.10	32	6620	6.80	32
422	3	4	7020	3.40	36	6560	6.20	37	6620	6.70	37
385	3	3	5760	6.25	30	6100	5.00	32	6660	5.20	34
360	3	4	6200	6.15	36	5640	5.70	38	6360	7.10	37
325	4	6	8260	3.50	39	7740	5.10	40	8180	6.00	40
354	4	4	6640	5.00	36	7080	6.00	37	5060	3.70	38
359	4	4	9140	6.20	33	9040	5.30	34	8260	5.90	35
379	4	3	4970	5.70	28	4420	5.60	29	5440	5.00	30
409	4	2	5560	3.25	27	4380	7.10	28	4680	6.70	29
530	4	1	5260	6.60	25	5640	7.10	26	6900	7.50	27
505	4	1	5400	5.70	29	6380	5.80	29	6300	5.90	29

Appendix Table 4.7 continued

GOATN[1]	T[2]	L[3]	PREMILK	PREBF	PREWT	WK5MK	WK5BF	WK5WT	WK6MK	WK6BF	WK6WT
414	1	3	7600	6.50	41	7540	5.90	43	7500	5.60	43
355	1	4	8050	6.05	44	6500	5.30	45	6260	7.20	45
351	1	5	5750	6.10	34	4560	5.50	36	3780	6.20	35
329	1	6	5990	7.40	32	4480	6.30	33	4000	7.70	33
372	1	4	4540	6.35	32	2340	6.60	35	2980	6.00	34
519	1	1	4610	5.70	23	2480	5.40	24	4080	6.20	25
587	1	1	4990	5.90	22	2560	5.80	24	2620	4.60	24
307	2	6	3900	3.00	34	5100	6.00	35	4380	5.30	34
335	2	4	5100	7.00	35	4740	6.30	35	5280	6.40	34
400	2	3	3190	5.70	33	3620	4.70	35	3100	6.30	35
353	2	4	4140	5.70	34	4820	5.70	34	4820	6.80	34
496	2	2	6070	5.40	24	5940	6.60	25	5620	4.20	26
362	2	4	7320	5.30	34	7320	6.00	35	6360	5.70	34
561	2	1	5100	6.00	23	4780	5.90	24	4080	6.40	24
575	3	1	5010	6.20	26	4080	6.60	29	3860	7.10	27
515	3	1	4580	6.45	31	4240	6.90	32	4780	6.90	31
424	3	4	12280	2.40	46	9780	5.70	48	9640	6.90	47
320	3	4	5820	6.40	32	6740	6.60	33	6520	6.00	32
422	3	4	7020	3.40	36	6740	7.00	38	6520	7.30	36
385	3	3	5760	6.25	30	5280	7.70	35	4360	7.50	34
360	3	4	6200	6.15	36	6580	6.90	38	5840	6.10	37
325	4	6	8260	3.50	39	6066	6.20	41	7180	6.60	39
354	4	4	6640	5.00	36	6060	6.00	38	6280	6.40	38
359	4	4	9140	6.20	33	9140	5.70	36	7620	5.90	37
379	4	3	4970	5.70	28	5020	6.20	30	4500	5.00	31
409	4	2	5560	3.25	27	5240	6.00	30	4760	6.10	29
530	4	1	5260	6.60	25	6400	5.60	27	6840	6.70	27
505	4	1	5400	5.70	29	6880	6.20	29	6020	6.10	29

Appendix Table 4.7 continued

GN[1]	T[2]	L[3]	PMK	PBF	PWT	MK7	BF7	WT7	MK8	BF8	WT8
414	1	3	7600	6.50	41	7240	6.00	42	7060	6.00	44
355	1	4	8050	6.05	44	4500	5.80	43	4660	5.60	42
351	1	5	5750	6.10	34	3900	4.00	34	4020	7.20	34
329	1	6	5990	7.40	32	2820	6.60	33	2660	8.10	34
372	1	4	4540	6.35	32	2560	7.10	34	2780	6.30	34
519	1	1	4610	5.70	23	2160	5.80	24	2620	6.00	25
587	1	1	4990	5.90	22	2160	5.00	23	2400	5.80	24
307	2	6	3900	3.00	34	4120	5.00	34	4260	6.60	35
335	2	4	5100	7.00	35	4220	6.30	35	4200	7.00	35
400	2	3	3190	5.70	33	2700	4.90	35	3000	6.20	36
353	2	4	4140	5.70	34	4420	6.00	33	4220	6.30	34
496	2	2	6070	5.40	24	4180	6.00	25	4400	6.00	24
362	2	4	7320	5.30	34	5840	5.80	34	5140	5.20	34
561	2	1	5100	6.00	23	3760	7.30	24	3520	7.20	25
575	3	1	5010	6.20	26	3740	6.60	27	3600	7.00	28
515	3	1	4580	6.45	31	4000	4.00	30	3940	5.90	32
424	3	4	12280	2.40	46	8620	5.40	46	8360	6.60	49
320	3	4	5820	6.40	32	6120	5.60	32	5640	7.50	30
422	3	4	7020	3.40	36	6120	5.40	36	5940	6.90	37
385	3	3	5760	6.25	30	5320	5.90	35	5220	7.70	36
360	3	4	6200	6.15	36	5160	5.40	37	5000	7.10	38
325	4	6	8260	3.50	39	7360	6.60	39	7300	5.80	40
354	4	4	6640	5.00	36	5660	7.20	38	5100	6.00	39
359	4	4	9140	6.20	33	7620	6.20	38	7050	5.60	39
379	4	3	4970	5.70	28	4560	7.40	31	4240	6.90	31
409	4	2	5560	3.25	27	4440	7.10	28	4380	7.70	29
530	4	1	5260	6.60	25	6040	5.30	27	5740	5.50	26
505	4	1	5400	5.70	29	6010	6.60	30	5640	7.50	30

[1]Doe; [2]Treatment; [3]Lactation number; [4]Week 3 milk yield;
[5]Week 3 butterfat; [6]Week 3 body weight (etc: to week 8)

Appendix Table 4.8. Experiment 4. Anova tables for weaner's total liveweights

Dependent Variable: WTTOT (kg)

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	8	5574.276707	696.784588	9.80	0.0001
Error	31	2203.182293	71.070397		
Corrected Total	39	7777.459000			
SEX	1	1561.988486	1561.988486	21.98	0.0001
TREAT	3	219.764864	73.254955	1.03	0.3925
SEX*TREAT	3	172.831704	57.610568	0.81	0.4977
PRELWT	1	2417.597707	2417.597707	34.02	0.0001

Appendix Table 4.9. Experiment 4. Weekly body weights of the weaner goats (1=males, 2=females).

GOATN[1]	SEX	T[2]	PRELWT[3]	WT5[4]	WT6	WT7	WT8	WT9	WT10	WT11	WT12	WT13	WT14
621	1	2	9.65	10.50	11.30	13.00	12.20	12.50	13.50	13.20	13.60	14.00	14.00
649	2	2	12.03	13.00	14.00	14.50	15.00	15.60	16.50	16.80	17.50	18.00	18.10
652	1	4	10.00	11.00	11.60	12.20	13.00	13.70	14.50	15.00	15.50	16.00	16.00
653	1	4	11.43	12.40	13.30	13.50	13.80	14.70	15.50	16.20	16.50	17.20	17.20
654	2	3	9.95	11.50	11.60	12.20	12.20	13.70	14.50	14.00	15.50	15.80	16.00
656	1	2	11.20	13.50	14.60	15.50	16.00	17.60	18.50	19.50	20.40	21.40	21.50
659	1	4	11.98	13.50	14.30	14.70	15.60	16.20	17.50	18.00	18.50	19.50	19.50
660	2	4	10.15	11.00	14.40	11.60	11.70	12.30	13.00	13.00	13.50	14.00	14.00
661	2	3	10.63	11.50	12.10	12.50	13.20	14.00	14.80	15.00	15.50	15.00	15.00
662	1	1	10.10	12.00	12.80	13.00	13.20	14.50	16.00	16.00	16.40	17.00	17.00
663	1	1	11.20	12.20	13.00	13.40	14.00	14.50	15.00	15.50	15.20	15.80	16.00
664	2	3	11.40	12.50	12.90	13.00	13.50	14.50	15.00	14.00	15.00	15.50	15.10
665	2	2	10.28	10.70	11.10	11.50	11.60	12.50	13.50	14.00	14.50	14.50	14.60
667	1	3	12.00	13.20	13.60	14.40	14.90	16.00	18.00	18.50	19.50	20.50	20.50
670	2	1	10.75	12.00	12.00	13.00	13.20	13.50	14.20	14.20	14.50	15.00	15.00
673	2	1	9.75	10.50	10.50	11.50	11.60	13.00	13.30	13.00	13.50	13.50	13.50
676	1	1	11.25	13.00	14.00	14.00	14.70	15.30	16.00	16.70	16.50	16.50	16.60
677	2	3	11.30	13.80	14.00	14.00	13.70	14.00	13.00	13.50	13.50	14.00	14.10
679	1	3	12.30	14.20	14.30	15.00	16.00	16.70	18.00	19.00	20.00	20.50	20.60
680	1	4	10.88	11.40	12.00	12.50	13.00	13.50	14.50	14.50	15.40	16.50	16.50
682	1	3	11.53	11.90	13.90	14.80	14.00	16.20	18.00	18.20	19.50	20.00	20.10
687	1	2	11.45	13.00	13.50	14.40	14.70	15.60	17.00	17.50	17.40	18.20	18.50
688	1	4	9.90	11.00	11.70	12.20	12.50	13.00	14.00	14.50	14.50	15.20	15.30
689	2	1	9.43	11.00	11.70	12.40	13.00	14.00	15.00	15.00	15.50	16.00	16.20
690	1	3	11.63	12.40	13.50	14.00	14.30	15.60	16.50	17.50	18.20	19.00	19.10

Appendix Table 4.9 continued:

691	2	2	11.00	11.50	14.00	14.10	15.20	16.00	16.50	16.50	17.40	17.50	17.50
692	1	2	12.25	13.40	14.30	15.00	15.20	15.50	17.00	17.50	18.50	19.50	20.00
693	2	1	12.10	13.00	13.60	14.20	14.60	15.40	15.50	16.00	16.30	17.00	17.00
695	1	2	10.50	11.90	13.00	13.00	14.00	15.00	16.00	15.50	16.50	17.00	17.00
696	2	4	11.55	12.80	13.30	13.50	14.30	14.00	15.50	15.80	16.50	17.00	17.00
697	2	3	11.68	12.00	12.10	12.90	13.40	14.50	15.50	15.50	16.00	16.50	16.50
698	1	1	10.60	12.50	14.00	14.40	14.50	15.50	17.00	16.80	17.40	18.00	18.10
699	2	2	11.35	11.70	12.00	12.50	13.00	14.00	14.40	15.00	15.00	15.40	15.50
701	2	1	11.93	13.00	13.90	14.50	15.00	15.50	16.00	16.00	16.50	17.00	17.20
703	2	4	10.50	11.50	11.90	12.00	12.30	12.90	13.50	13.50	14.00	14.50	14.60
706	2	4	10.10	11.00	11.60	11.60	11.90	12.50	13.00	13.00	13.50	14.00	14.00
708	1	3	10.13	11.50	11.40	12.80	12.90	15.50	14.50	15.00	15.50	16.20	16.20
709	2	4	10.15	11.10	11.50	11.50	12.00	12.50	13.00	13.50	14.00	14.50	14.60
711	1	1	12.35	13.50	14.10	13.90	14.50	15.00	16.00	16.50	16.50	17.00	17.00
713	2	2	13.00	14.00	12.20	13.10	14.00	14.50	14.70	15.00	15.80	16.00	16.20

[1]Weaner's number
[2]Treatment
[3]Weights of the first four weeks were covariates
[4]Experimental liveweights from weeks 5 to 14.

Appendix Table 4.10. Amount of amino acids absorbed in the small intestine (AAT) and protein balance in the rumen (PBV), digested carbohydrate (DCHO) and microbial protein synthesis (MPS), g/kg DM of feed of the rumen of bucks fed treatment diet from Experiments 1 and 2

Feed	Treatment	AAT	PBV	DCHO	MPS
Leucaena	1	89	88	387	69
Leucaena	2	95	78	405	72
Leucaena	3	93	81	389	69
Leucaena	4	96	75	399	71
MEAN		93	80	395	71
SE		1.55	2.30	3.67	0.66
Cotton seed cake	1	123	149	381	68
Cotton seed cake	2	120	153	399	71
Cotton seed cake	3	119	154	391	70
Cotton seed cake	4	112	165	380	68
MEAN		119	155	388	69
SE		2.04	2.96	3.90	0.70
Maize bran	1	81	-38	489	87
Maize bran	2	79	-34	461	82
Maize bran	3	80	-36	471	84
Maize bran	4	77	-32	444	79
MEAN		79	-35	466	83
SE		0.64	1.13	8.15	1.46
Maize meal	1	77	-24	473	84
Maize meal	2	67	-25	482	86
Maize meal	3	66	-20	465	83
Maize meal	4	67	-24	467	83
MEAN		69	-23	472	84
SE		2.29	1.01	3.30	0.59
Rhodes grass hay	1	45	-47	81	14
Rhodes grass hay	2	47	-52	107	19
Rhodes grass hay	3	47	-51	100	18
Rhodes grass hay	4	46	-50	99	18
MEAN		46	-50	96	17
SE		0.40	0.88	4.80	0.86

Appendix Table 4.11 Means of DM, OM and protein losses (DML, OML and PL) of the feeds leucaena, cotton seed cake, maize bran, maize meal and Rhodes grass (LEUC, CSC, MB, MM and RG) from 0 to 96 hours in treatments 1 to 4), used in Experiments 1 and 2.

FEED/h	0	2	6	12	24	48	72	96
DML(T[1])								
LEUC1	36.90	41.80	49.80	58.50	68.00	74.00	75.20	75.50
LEUC2	37.80	41.50	48.00	55.80	66.20	75.60	78.80	79.80
LEUC3	35.20	40.30	48.90	58.50	69.60	77.60	79.40	79.80
LEUC4	35.50	41.80	51.80	61.70	71.50	76.60	77.30	77.40
MEAN	36.35	41.35	49.63	58.63	68.83	75.95	77.68	78.13
SE	0.53	0.31	0.71	1.05	0.98	0.67	0.81	0.90
OML								
LEUC1	29.50	36.50	47.30	57.90	67.90	72.80	72.40	73.50
LEUC2	31.40	36.40	44.80	54.30	65.90	74.70	76.90	77.50
LEUC3	26.70	34.10	46.00	58.10	70.40	77.10	78.10	78.30
LEUC4	31.40	36.40	44.80	54.30	65.90	74.70	76.90	77.50
MEAN	29.75	35.85	45.73	56.15	67.53	74.83	76.08	76.70
SE	0.96	0.51	0.52	0.93	0.93	0.77	1.09	0.94
PL								
LEUC1	45.80	54.30	66.80	78.10	87.50	90.90	91.20	91.30
LEUC2	47.30	52.10	60.40	69.80	81.50	90.80	93.20	93.90
LEUC3	43.50	50.90	62.50	74.30	86.20	92.50	93.50	93.60
LEUC4	45.50	52.00	62.50	73.50	85.20	92.20	93.40	93.70
MEAN	45.53	52.33	63.05	73.93	85.10	91.60	92.83	93.13
SE	0.68	0.62	1.17	1.48	1.11	0.38	0.47	0.53
DML								
CSC1	40.20	47.00	57.10	66.50	74.70	78.00	78.30	78.40
CSC2	41.50	46.80	55.40	64.40	74.10	79.90	80.90	81.10
CSC3	39.80	44.20	51.70	60.20	70.50	78.40	80.30	80.80
CSC4	41.50	46.80	55.40	64.40	74.10	79.90	80.90	81.10

Appendix Table 4.11 continued:

MEAN	40.75	46.20	54.90	63.88	73.35	79.05	80.10	80.35
SE	0.38	0.58	0.99	1.15	0.83	0.43	0.54	0.57
OML								
CSC1	34.30	43.00	55.60	66.40	74.70	77.40	77.50	77.50
CSC2	36.30	44.00	55.50	66.00	75.10	78.70	79.00	79.00
CSC3	37.40	42.30	50.50	59.80	70.90	79.20	81.30	81.80
CSC4	33.10	39.60	50.10	60.10	71.90	78.00	79.00	79.10
MEAN	35.28	42.23	52.93	63.08	73.15	78.33	79.20	79.35
SE	0.84	0.82	1.32	1.57	0.90	0.34	0.68	0.78
PL								
CSC1	59.60	63.30	69.50	76.40	84.80	91.00	92.50	92.90
CSC2	59.50	62.60	67.90	74.20	82.20	89.00	91.00	91.60
CSC3	60.30	63.10	68.00	74.00	82.30	90.20	93.00	94.10
CSC4	58.80	61.50	66.50	72.60	81.20	89.80	93.20	94.50
MEAN	59.55	62.63	67.98	74.30	82.63	90.00	92.43	93.28
SE	0.27	0.35	0.53	0.68	0.67	0.36	0.43	0.57
DML								
MB1	34.30	37.70	43.90	51.80	63.60	76.60	82.50	85.10
MB2	26.60	34.90	48.50	63.30	80.20	91.40	93.70	94.20
MB3	28.60	36.60	49.70	64.00	79.90	90.30	92.50	92.90
MB4	33.90	36.70	41.90	48.70	59.80	74.00	81.80	86.00
MEAN	30.85	36.48	46.00	56.95	70.88	83.08	87.63	89.55
SE	1.67	0.51	1.61	3.40	4.64	3.92	2.75	2.02
OML								
MB1	29.60	34.50	42.90	52.90	65.90	77.30	80.80	81.90
MB2	23.80	32.10	45.80	60.80	78.30	90.30	93.00	93.60
MB3	24.40	33.80	48.90	64.50	80.80	90.10	91.60	91.90
MB4	30.30	33.50	39.40	47.10	59.20	74.10	81.70	85.70
MEAN	27.03	33.48	44.25	56.33	71.05	82.95	86.78	88.28
SE	1.47	0.44	1.76	3.39	4.44	3.67	2.78	2.36

Appendix Table 4.11 continued:

PL								
MB1	45.90	49.40	55.70	63.50	74.70	86.50	91.30	93.20
MB2	41.30	44.90	51.30	59.30	71.20	84.30	90.10	92.60
MB3	43.10	49.00	58.50	68.60	79.50	86.20	87.50	87.70
MB4	41.30	44.90	51.30	59.30	71.20	84.30	90.10	92.60
MEAN	42.90	47.05	54.20	62.68	74.15	85.33	89.75	91.53
SE	0.94	1.08	1.53	1.92	1.70	0.52	0.70	1.11
DML								
MM1	34.10	42.70	56.30	69.90	83.40	90.30	91.30	91.40
MM2	33.20	41.80	55.50	69.50	83.80	91.60	92.80	93.00
MM3	33.20	44.50	61.00	75.50	87.00	90.90	91.20	91.20
MM4	32.40	40.00	52.50	66.10	81.30	91.40	93.40	93.90
MEAN	33.23	42.25	56.33	70.25	83.88	91.05	92.18	92.38
SE	0.30	0.81	1.53	1.69	1.02	0.25	0.48	0.56
OML								
MM1	28.60	38.10	52.90	67.80	82.30	89.60	90.60	90.80
MM2	27.30	36.90	52.10	67.50	82.90	91.10	92.30	92.50
MM3	27.00	39.80	58.20	74.00	86.00	89.90	90.20	90.20
MM4	31.10	39.00	52.00	65.80	81.20	91.00	92.90	93.30
MEAN	28.50	38.45	53.80	68.78	83.10	90.40	91.50	91.70
SE	0.81	0.54	1.28	1.56	0.89	0.33	0.57	0.63
PL								
MM1	51.10	56.00	64.40	73.70	84.80	92.90	94.90	95.30
MM2	55.10	59.30	66.50	74.80	85.20	93.60	96.00	96.60
MM3	51.80	56.60	64.60	73.50	83.90	91.30	93.00	93.40
MM4	50.80	54.70	61.40	69.60	80.70	91.10	94.71	96.00
MEAN	52.20	56.65	64.23	72.90	83.65	92.23	94.65	95.33
SE	0.86	0.84	0.92	0.99	0.89	0.53	0.54	0.60
DML								
RG1	18.30	21.80	28.00	35.90	47.60	60.50	66.20	68.70

Appendix Table 4.11 continued:

RG2	17.80	21.20	27.30	34.90	45.70	56.70	.	62.80
RG3	17.20	21.40	28.70	.	50.40	63.10	67.90	69.70
RG4	17.20	21.80	29.70	38.70	49.70	58.30	60.60	61.20
MEAN	17.63	21.55	28.43	36.50	48.35	59.65	64.90	65.60
SE	0.23	0.13	0.45	0.81	0.92	1.21	1.56	1.83
OMD								
RG1	10.00	14.10	21.40	30.60	43.90	58.20	64.20	66.70
RG2	9.76	13.90	21.20	30.10	42.50	54.70	.	60.80
RG3	8.80	13.70	22.20	.	45.90	58.40	62.50	63.90
RG4	9.70	15.20	24.40	34.70	47.10	56.30	58.60	59.20
MEAN	9.57	14.23	22.30	31.80	44.85	56.90	61.77	62.65
SE	0.23	0.29	0.64	1.03	0.89	0.76	1.17	1.44
PL								
RG1	39.90	42.70	47.80	54.00	62.80	71.60	75.00	76.30
RG2	37.50	39.90	44.30	50.00	58.70	69.00	74.10	76.50
RG3	30.70	34.70	41.80	50.50	62.30	73.50	77.60	79.00
RG4	34.60	38.20	44.30	51.40	60.70	68.50	70.80	71.50
MEAN	35.68	38.88	44.55	51.48	61.13	70.65	74.38	75.83
SE	1.72	1.45	1.07	0.77	0.80	1.01	1.22	1.36

Appendix Table 4.12. Effective DM, OM and protein degradability of the feed ingredients (g/kg DM) measured in the rumen of bucks fed treatment diets used in Experiments 1 and 2 (According to Ørskov and McDonald, 1979).

Feed	TREATMENTS				SEM	P
	1	2	3	4		
Replications	4	4	4	4		
Fractional passage rate[1]						
Cotton seed cake						
DMD						
0.01	752	774	750	752	12.50	0.524NS
0.02	702	689	687	690	14.52	0.877NS
0.03	666	636	644	646	16.00	0.606NS
0.04	638	600	613	613	16.69	0.466NS
48h	775	758	761	773	16.30	0.862NS
OMD						
0.01	734	754	732	740	12.30	0.603NS
0.02	656	676	660	658	18.23	0.850NS
0.03	604	623	613	605	20.86	0.905NS
0.04	568	586	578	567	21.46	0.910NS
48h	738	763	732	688	21.63	0.453NS
PD						
0.01	864	876	875	875	9.97	0.830NS
0.02	795	817	816	828	16.13	0.569NS
0.03	758	778	770	794	18.45	0.605NS
0.04	727	750	748	774	19.63	0.453NS
48h	835	891	892	896	26.83	0.371NS
Leucaena						
DMD						
0.01	731	758	718	727	10.31	0.098NS
0.02	671	712	668	676	12.35	0.101NS
0.03	627	676	630	637	13.99	0.110NS
0.04	595	647	602	606	14.92	0.125NS
48h	754	797	750	742	14.60	0.096NS
OMD						
0.01	709	710	709	708	11.62	0.999NS
0.02	649	660	650	656	15.45	0.949NS
0.03	600	621	607	616	16.52	0.820NS
0.04	572	590	574	584	17.06	0.868NS
48h	741	748	735	748	20.97	0.961NS
PD						
0.01	845	857	844	849	13.84	0.900NS
0.02	787	804	796	791	14.87	0.872NS
0.03	743	763	760	748	15.42	0.767NS
0.04	757	731	729	715	26.21	0.724NS
48h	887	896	904	873	21.16	0.770NS
Maize bran						
DMD						
0.01	845	857	855	844	8.11	0.557NS
0.02	779	790	792	777	6.95	0.355NS
0.03	728	741	744	727	9.68	0.512NS
0.04	691	699	706	686	12.72	0.507NS
48h	885	906	897	898	9.72	0.507NS

Appendix Table 4.12 continued:

OMD						
0.01	833	844	842	827	10.50	0.666NS
0.02	765	758	762	741	10.12	0.389NS
0.03	713	694	703	677	13.48	0.347NS
0.04	673	645	655	628	16.51	0.343NS
48h	876	892	896	875	17.34	0.829NS
PD						
0.01	864	849	853	857	11.92	0.832NS
0.02	796	780	784	783	11.14	0.781NS
0.03	749	733	736	732	10.77	0.659NS
0.04	714	698	700	694	10.42	0.556NS
48h	886	863	874	878	17.34	0.829NS
Maize meal						
DMD						
0.01	834	863	862	861	8.87	0.115NS
0.02	761	784	762	789	19.65	0.658NS
0.03	709	728	730	736	21.72	0.823NS
0.04	670	685	703	696	23.39	0.765NS
48h	861	909	898	898	20.91	0.450NS
OMD						
0.01	841	850	824	840	11.08	0.456NS
0.02	760	768	746	759	17.37	0.850NS
0.03	702	710	692	698	21.54	0.938NS
0.04	658	667	650	652	24.20	0.924NS
48h	879	880	869	886	18.16	0.924NS
PD						
0.01	856	878	862	853	9.87	0.329NS
0.02	791	794	811	781	11.97	0.411NS
0.03	748	752	772	733	11.89	0.214NS
0.04	718	721	742	700	12.22	0.188NS
48h	857	890	904	856	14.72	0.114NS
Rhodes grass						
DMD						
0.01	457	452	490	464	21.39	0.621NS
0.02	380	373	396	392	14.43	0.652NS
0.03	335	327	344	347	12.37	0.660NS
0.04	305	296	309	317	11.21	0.646NS
48h	434	425	459	452	21.84	0.673NS
OMD						
0.01	441	426	448	430	21.08	0.878NS
0.02	348	357	363	356	12.98	0.882NS
0.03	294	314	312	309	12.98	0.708NS
0.04	257	283	276	275	13.51	0.608NS
48h	415	416	426	427	16.91	0.936NS
PD						
0.01	717	722	707	735	19.58	0.814NS
0.02	674	677	660	685	23.88	0.922NS
0.03	643	646	633	653	28.88	0.974NS
0.04	624	624	614	630	31.36	0.988NS
48h	720	732	696	732	24.24	0.756NS

[1]0.01-0.04: 1-4% fractional passage rates per hour; 48h:Effective degradability at 48 hours

Appendix Table 4.13 Raw data of DM, OM and protein losses (DML, OML and PL) of the feeds, FLL, CSC, MB, and HR (fresh LL, cotton seed cake, maize bran and *Hyparrhenia rufa* grass hay), used in Experiment 3

TREATMENT	FEED	TIME	DML	OML	PL
1	FLL	48	66	64	79
2	FLL	48	68	67	82
3	FLL	48	66	65	81
4	FLL	48	75	74	82
MEAN			68.8	67.5	81.0
SE			1.85	1.95	0.61
1	CSC	48	79	78	89
2	CSC	48	82	81	85
3	CSC	48	81	79	88
4	CSC	48	82	81	86
MEAN			81.0	79.8	87.0
SE			0.61	0.65	0.79
1	MB	48	84	83	88
2	MB	48	88	87	91
3	MB	48	87	86	83
4	MB	48	85	85	91
MEAN			86.0	85.3	88.3
SE			0.79	0.74	1.63
1	HR	48	40	37	51
2	HR	48	47	43	52
3	HR	48	47	44	50
4	HR	48	48	45	52
MEAN			45.5	42.3	51.3
SE			1.60	1.56	0.41
1	FLL	24	60	59	67
2	FLL	24	64	63	69

Appendix Table 4.13 continued:

	3	FLL	24	65	64	69
	4	FLL	24	67	65	69
MEAN				64.0	62.8	68.5
SE				1.27	1.14	0.43
	1	CSC	24	70	69	74
	2	CSC	24	71	68	78
	3	CSC	24	72	70	74
	4	CSC	24	73	71	76
MEAN				71.5	69.5	75.5
SE				0.56	0.56	0.83
	1	MB	24	79	78	78
	2	MB	24	72	74	77
	3	MB	24	78	77	82
	4	MB	24	80	80	84
MEAN				77.3	77.3	80.3
SE				1.56	1.08	1.43
	1	HR	24	33	30	37
	2	HR	24	30	25	43
	3	HR	24	40	35	37
	4	HR	24	24	16	41
MEAN				31.8	26.5	39.5
SE				2.88	3.51	1.30
W		FLL	0	22	17	24
W		FLL	0	23	19	25
MEAN				22.5	18.0	24.5
SE				4.58	3.26	5.65
W		CSC	0	23	14	27
W		CSC	0	18	15	28
MEAN				20.5	14.5	27.5
SE				3.61	2.48	4.86

Appendix Table 4.13 continued:

W	MB	0	28	27	32
W	MB	0	29	28	31
MEAN			28.5	27.5	31.5
SE			0.25	0.25	0.25
W	HR	0	14	13	15
W	HR	0	12	11	14
MEAN			13	12	14.5
SE			0.50	0.50	0.25

Appendix Table 4.14 DM, OM and protein losses (DML, OML and PL) of untreated maize stover (MS), urea treated maize stover without (UMS) or with molasses (UMSM) from 0 to 120 hours, used in Experiment 4.

TREAT	FEEDNAME	0	2	6	12	24	48	72	96	120
T1	UMSM/DML	21.50	46.60	68.80	77.30	78.80	79.20	81.00	81.60	94.00
T2	UMSM/DML	17.10	58.80	74.40	75.90	75.90	80.10	80.70	82.90	83.40
T3	UMSM/DML	18.10	56.30	73.60	75.70	75.80	75.80	75.80	80.20	81.90
T4	UMSM/DML	20.70	48.00	69.90	77.00	78.20	79.90	82.30	83.50	84.40
MEAN		19.35	52.43	71.68	76.48	77.18	78.75	79.95	82.05	85.93
SE		0.90	2.61	1.19	0.34	0.67	0.87	1.24	0.63	2.37
T1	UMSM/OML	21.60	42.40	63.30	64.60	71.40	73.60	76.20	79.30	80.90
T2	UMSM/OML	26.90	39.30	55.30	60.90	68.70	76.80	78.70	79.70	82.60
T3	UMSM/OML	26.90	37.20	52.20	57.50	65.40	70.70	75.90	80.70	94.00
T4	UMSM/OML	20.00	42.00	64.00	74.50	77.70	77.80	79.00	82.80	83.80
MEAN		23.85	40.23	58.70	64.38	70.80	74.73	77.45	80.63	85.33
SE		1.55	1.06	2.54	3.18	2.26	1.40	0.70	0.68	2.56
T1	UMSM/PL	36.00	88.00	91.40	91.40	91.40	91.40	91.40	91.40	91.40
T2	UMSM/PL	36.00	80.00	81.00	88.00	91.40	94.00	94.00	94.00	94.00
T3	UMSM/PL	36.00	80.00	88.00	91.40	91.40	94.00	94.00	94.00	94.00
T4	UMSM/PL	36.00	80.00	88.00	91.90	92.40	92.00	94.00	94.00	94.00
MEAN		36.00	82.00	87.10	90.68	91.65	92.85	93.35	93.35	93.35
SE		0.00	1.73	1.89	0.78	0.22	0.58	0.56	0.56	0.56
T1	UMS/DML	13.00	16.80	23.70	32.20	44.40	57.00	62.10	64.20	65.00
T2	UMS/DML	16.10	20.00	27.00	35.50	47.70	60.10	64.90	66.80	67.60
T3	UMS/DML	14.60	17.90	24.00	31.90	44.00	58.50	65.70	69.30	71.10
T4	UMS/DML	12.00	17.80	28.20	40.10	55.10	67.20	70.60	71.60	71.80
MEAN		13.93	18.13	25.73	34.93	47.80	60.70	65.83	67.98	68.88
SE		0.78	0.58	0.96	1.65	2.23	1.95	1.53	1.38	1.37
T1	UMS/OML	9.60	12.90	19.00	26.80	38.50	52.10	58.40	61.40	62.80

Appendix Table 4.14 continued:

T2	UMS/OML	8.40	12.10	19.70	28.80	42.10	56.20	62.10	64.60	65.60
T3	UMS/OML	9.90	13.10	19.00	26.80	39.20	55.10	63.70	68.30	70.90
T4	UMS/OML	8.90	15.30	26.10	38.20	52.90	64.00	66.80	67.50	67.60
MEAN		9.20	13.35	20.95	30.15	43.18	56.85	62.75	65.45	66.73
SE		0.29	0.59	1.49	2.36	2.89	2.20	1.51	1.36	1.48
T1	UMS/PL	38.20	52.40	67.00	68.50	73.00	77.90	80.00	82.10	87.00
T2	UMS/PL	34.60	64.30	67.00	73.00	77.50	77.90	80.00	86.00	87.00
T3	UMS/PL	35.70	55.50	60.00	67.00	71.00	73.00	76.50	80.00	93.00
T4	UMS/PL	37.10	53.40	60.00	67.00	69.00	73.00	77.80	80.40	93.00
MEAN		36.40	56.40	63.50	68.88	72.63	75.45	78.58	82.13	90.00
SE		0.68	2.35	1.75	1.23	1.57	1.23	0.75	1.19	1.50
T1	MS/DML	12.00	14.70	19.80	26.60	37.50	51.80	59.70	64.00	65.00
T2	MS/DML	12.00	14.30	18.70	24.70	34.70	48.60	57.10	62.20	65.30
T3	MS/DML	12.60	15.10	20.00	26.00	36.30	50.40	58.60	63.50	66.40
T4	MS/DML	12.10	14.80	19.80	26.50	37.10	50.60	57.90	61.80	63.90
MEAN		12.18	14.73	19.58	25.95	36.40	50.35	58.33	62.88	65.15
SE		0.12	0.14	0.26	0.38	0.54	0.57	0.48	0.45	0.45
T1	MS/OML	4.00	7.90	15.10	24.00	37.20	51.40	57.60	60.20	61.30
T2	MS/OML	5.80	8.90	14.60	22.20	34.30	49.70	58.10	62.70	63.00
T3	MS/OML	4.10	7.00	12.40	19.60	31.30	46.60	55.20	60.10	62.80
T4	MS/OML	6.10	9.20	15.10	22.70	34.90	50.10	58.20	62.50	64.80
MEAN		5.00	8.25	14.30	22.13	34.43	49.45	57.28	61.38	62.98
SE		0.48	0.43	0.56	0.80	1.05	0.88	0.61	0.61	0.62
T1	MS/PL	37.20	38.50	40.90	44.30	50.00	58.10	63.40	66.70	68.90
T2	MS/PL	33.60	34.50	36.40	39.00	44.00	52.60	59.60	65.60	70.50
T3	MS/PL	34.90	36.40	39.10	42.70	48.90	57.80	63.30	66.90	69.10
T4	MS/PL	38.30	39.70	42.30	45.80	51.60	59.40	64.00	66.70	68.20
MEAN		36.00	37.28	39.68	42.95	48.63	56.98	62.58	66.48	69.18
SE		0.93	1.00	1.10	1.27	1.42	1.30	0.87	0.26	0.42

Appendix Table 4.15. Effective DM, OM and protein degradability of the feed ingredients (g/kg DM) in the rumen of bucks fed treatments diets used in Experiment 4

Feed	TREATMENTS				
	1	2	3	4	
Replications	2	2	2	2	
Fractional passage rate[1]					
Leucaena					
DMD					MEAN
0.01	726	751	744	779	750
0.02	676	696	687	723	696
0.03	637	654	644	678	653
0.04	606	620	610	643	620
48h	765	793	785	826	792
OMD					
0.01	708	743	726	747	731
0.02	655	688	668	695	677
0.03	612	645	623	653	633
0.04	577	609	586	618	598
48h	758	793	777	798	782
PD					
0.01	811	831	831	836	827
0.02	759	783	777	788	777
0.03	718	743	734	750	736
0.04	685	710	700	718	703
48h	856	879	878	883	874
Cotton seed cake					
DMD					
0.01	823	821	797	824	816
0.02	785	782	765	780	778
0.03	754	750	738	744	746
0.04	727	722	715	714	720
48h	863	861	832	867	856
OMD					
0.01	803	813	788	820	806
0.02	767	774	754	773	767
0.03	737	741	725	734	734
0.04	711	713	700	702	706
48h	842	856	826	675	800
PD					
0.01	905	917	904	905	908
0.02	873	882	870	863	872
0.03	846	854	843	830	843
0.04	824	831	821	803	820
48h	938	951	935	939	941
Maize bran					
DMD					
0.01	813	719	749	766	762
0.02	759	665	722	704	713
0.03	714	623	699	655	673
0.04	676	588	678	616	640
48h	827	720	775	818	785

Appendix Table 4.15 continued:

OMD					
0.01	646	695	722	742	701
0.02	612	692	696	685	671
0.03	582	599	672	639	623
0.04	556	564	650	601	593
48h	672	705	748	748	718
PD					
0.01	915	914	919	908	914
0.02	866	863	863	861	863
0.03	826	822	818	822	822
0.04	792	788	782	790	788
48h	964	963	968	956	963
Untreated maize stover					
DMD					
0.01	512	528	512	524	519
0.02	426	436	416	429	427
0.03	372	378	357	371	370
0.04	333	338	318	331	330
48h	506	518	486	504	504
OMD					
0.01	493	505	480	505	496
0.02	411	407	380	410	402
0.03	354	344	317	348	341
0.04	312	300	274	305	298
48h	514	497	466	501	495
PD					
0.01	603	602	599	605	602
0.02	543	507	535	552	534
0.03	508	462	497	520	497
0.04	484	435	472	498	472
48h	581	526	578	594	570
Urea treated maize stover without molasses					
DMD					
0.01	546	575	580	624	581
0.02	474	505	492	555	507
0.03	423	455	434	502	454
0.04	386	418	392	461	414
48h	570	601	585	672	607
OMD					
0.01	509	538	558	590	549
0.02	429	458	457	525	467
0.03	375	401	393	475	411
0.04	336	359	348	436	370
48h	521	562	551	640	569
PD					
0.01	800	768	761	786	779
0.02	780	761	750	770	765
0.03	763	754	738	755	753
0.04	746	748	728	741	741
48h	821	775	774	804	794
Urea treated maize stover sprinkled with molasses					
DMD					
0.01	773	750	747	765	759
0.02	754	741	737	749	745
0.03	737	732	727	733	732
0.04	721	723	718	719	720
48h	792	759	758	782	772

Appendix Table 4.15 Continued:

OMD					
0.01	754	742	752	755	751
0.02	716	721	722	734	723
0.03	684	703	694	714	699
0.04	656	685	670	695	677
48h	796	764	787	778	781
PD					
0.01	910	907	911	917	911
0.02	906	901	905	910	906
0.03	903	894	898	903	890
0.04	899	888	892	897	894
48h	914	914	918	924	918

Appendix Table 4.16. Diurnal and nocturnal rumen NH_3-N (mg/l) and pH, for fistulated bucks fed treatment diets used in Experiments 1 and 2 (LSmeans±SEM)

Time (h) Replications		TREATMENTS 1 4	2 4	3 4	4 4	SEM	P
0800 First feeding	NH_3-N	99.00	105.00	135.00	119.00	10.16	0.085NS
	pH	6.55	6.88	6.79	6.84	0.09	0.068NS
1000	NH_3-N	159.00	137.00	116.00	148.00	10.38	0.044NS
	pH	6.46^{a}	6.63^{b}	6.93^{b}	6.67^{b}	0.09	0.008**
1200	NH_3-N	154.00^{a}	146.00^{a}	110.00^{b}	120.00^{b}	6.96	<0.01***
	pH	6.50	6.70	6.75	6.75	0.09	0.109NS
1400 Second feeding	NH_3-N	95.00	88.00	121.00	131.00	14.24	0.134NS
	pH	6.48	6.70	6.69	6.55	0.10	0.309NS
1600	NH_3-N	131.00	106.00	96.00	132.00	10.82	0.079NS
	pH	6.26	6.27	6.48	6.51	0.08	0.079NS
1800	NH_3-N	89.00	81.00	56.00	57.00	9.86	0.055NS
	pH	6.13	6.24	6.42	6.42	0.09	0.075NS
2000	NH_3-N	127.00^{ab}	150.00^{a}	90.00^{b}	116.00^{ab}	13.43	0.032*
	pH	6.07^{b}	6.26^{a}	6.45^{a}	6.45^{a}	0.09	0.008**
2200	NH_3-N	121.00	99.00	118.00	127.00	10.18	0.264NS
	pH	6.00^{b}	6.20^{a}	6.41^{a}	6.37^{a}	0.07	0.003**
2400	NH_3-N	105.00	96.00	75.00	99.00	7.65	0.058NS
	pH	6.05^{c}	6.27^{bc}	6.37^{ab}	6.50^{a}	0.08	0.004**
0200	NH_3-N	46.00^{b}	71.00^{a}	82.00^{a}	68.00^{a}	8.47	0.037*
	pH	6.09^{b}	6.27^{b}	6.52^{a}	6.42^{ab}	0.08	0.004**
0400	NH_3-N	66.00^{bc}	56.00^{c}	82.00^{b}	108.00^{a}	8.81	0.002**
	pH	6.18^{c}	6.40^{b}	6.53^{a}	6.50^{b}	0.08	0.011*
0600	NH_3-N	67.00	81.00	59.00	61.00	10.09	0.452NS
	pH	6.19^{b}	6.45^{a}	6.62^{a}	6.57^{a}	0.08	0.007**
Overall	NH_3-N	105.00	101.00	95.00	107.00	3.80	0.121NS
	pH	6.23^{c}	6.44^{b}	6.58^{a}	6.55^{a}	0.03	<0.01***

^{a,b,c}: Means in the same row with different superscript are significantly different at the 5% level. The same results holds for the subsequent tables bearing the same superscript.

Appendix Table 4.17. Diurnal and nocturnal rumen NH_3-N (mg/l) and mean pH, for fistulated bucks fed treatment diets used in Experiment 3(LSmeans±SEM)

Time (h)		TREATMENTS 1	2	3	4	SEM	P
Replications		2	2	2	2		
0800	NH_3-N	135.00^{c}	167.00^{b}	177.00^{b}	207.00^{a}	7.02	0.008**
First feeding	pH	6.70	6.42	6.60	6.55		
1000	NH_3-N	89.00^{d}	112.00^{c}	137.00^{b}	189.00^{a}	0.96	<0.01***
	pH	6.70	6.32	6.70	6.44		
1200	NH_3-N	60.00^{d}	87.00^{c}	110.00^{b}	327.00^{a}	2.55	<0.01***
	pH	6.73	6.41	6.80	6.66		
1400	NH_3-N	75.00^{d}	110.00^{c}	133.00^{b}	227.00^{a}	1.67	<0.01***
Second feeding	pH	6.50	6.30	6.66	6.41		
1600	NH_3-N	42.00^{d}	58.00^{c}	83.00^{b}	179.00^{a}	1.36	<0.01***
	pH	6.48	6.14	6.63	6.42		
1800	NH_3-N	65.00^{d}	98.00^{c}	131.00^{b}	173.00^{a}	4.41	<0.003**
	pH	6.45	6.15	6.63	6.43		
2000	NH_3-N	44.00^{d}	81.00^{c}	114.00^{b}	148.00^{a}	1.67	<0.01***
	pH	6.47	6.12	6.73	6.73		
2200	NH_3-N	39.00^{d}	58.00^{c}	96.00^{b}	110.00^{a}	2.15	<0.01***
	pH	6.45	6.14	6.73	6.75		
2400	NH_3-N	58.00^{d}	90.00^{c}	127.00^{b}	142.00^{a}	2.15	<0.01***
	pH	6.37	6.06	6.66	6.60		
0200	NH_3-N	62.00^{d}	98.00^{c}	114.00^{b}	144.00^{a}	1.67	<0.01***
	pH	6.47	6.20	6.78	6.70		
0400	NH_3-N	50.00^{d}	64.00^{c}	79.00^{b}	173.00^{a}	2.36	<0.01***
	pH	6.47	6.25	6.78	6.70		
0600	NH_3-N	42.00^{d}	87.00^{c}	114.00^{b}	141.00^{a}	1.66	<0.01***
	pH	6.76	6.60	7.06	6.91		
Overall	NH_3-N	63.00^{d}	92.00^{c}	118.00^{b}	180.00^{a}	5.26	<0.01***
	pH	6.55^{c}	6.27^{d}	6.73^{a}	6.61^{b}	0.02	<0.01***

Appendix Table 4.18. Diurnal and nocturnal rumen NH_3-N (mg/l) and mean pH, for fistulated bucks fed treatment diets used in Experiment 4 (LSmeans±SEM)

Time (h) Replications		TREATMENTS 1 2	2 2	3 2	4 2	SEM	P
0800 First feeding	NH_3-N	126.00^{b}	102.00^{c}	152.00^{a}	154.00^{a}	1.340	<0.01***
	pH	6.93	6.85	6.75	6.78		
1000	NH_3-N	216.00^{a}	110.00^{b}	104.00^{b}	53.00^{c}	7.500	<0.005**
	pH	6.45	6.43	6.30	6.61		
1200	NH_3-N	127.00^{a}	50.00^{b}	49.00^{b}	47.00^{b}	2.010	<0.01***
	pH	6.41	6.39	6.31	6.60		
1400 Second feeding	NH_3-N	30.00	40.00	41.00	41.00	2.410	0.089NS
	pH	6.66	6.53	6.50	6.72		
1600	NH_3-N	64.00^{c}	52.00^{d}	102.00^{b}	204.00^{a}	1.700	<0.01***
	pH	6.20	6.20	6.10	6.30		
1800	NH_3-N	50.00^{b}	46.00^{b}	59.00^{b}	130.00^{a}	5.440	<0.01***
	pH	6.17	6.25	6.05	6.30		
2000	NH_3-N	54.00^{bc}	56.00^{b}	49.00^{c}	120.00^{a}	1.870	<0.01***
	pH	6.32	6.42	6.17	6.30		
2200	NH_3-N	47.00^{c}	59.00^{b}	41.00^{c}	110.00^{a}	2.020	<0.01***
	pH	6.45	6.55	6.38	6.34		
2400	NH_3-N	66.00^{b}	52.00^{c}	50.00^{c}	102.00^{a}	1.320	<0.01***
	pH	6.42	6.72	6.63	6.56		
0200	NH_3-N	67100^{b}	61.00^{c}	50.00^{d}	108.00^{a}	1.320	<0.01***
	pH	6.44	6.68	6.58	6.64		
0400	NH_3-N	64.00^{b}	52.00^{c}	49.00^{c}	101.00^{a}	1.520	<0.01***
	pH	6.44	6.65	6.59	6.63		
0600	NH_3-N	62.00^{b}	44.00^{d}	53.00^{c}	111.00^{a}	1.500	<0.01***
	pH	6.24	6.66	6.59	6.65		
Overall	NH_3-N	81.00^{b}	60.00^{c}	71.00^{bc}	103.00^{a}	6.640	<0.01***
	pH	6.43	6.53	6.41	6.54	0.018	<0.01***