THE EFFECT OF LEGUMINOUS BROWSE SUPPLEMENTATION ON MAIZE HUSK UTILIZATION BY GOATS INDIGENOUS TO THE EASTERN PROVINCE OF ZAMBIA

by

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suggested short title: Supplementation of maize husk with leguminous browse species

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Dedicated to my late sister and friend

SARAH MANYAMBA

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THE EFFECT OF BROWSE SUPPLEMENTATION ON MAIZE HUSK UTILIZATION BY GOATS

Phiri Donald Mwelwa Abstract MSc Plant Science

Small maize livestock farmers in the Eastern Province of Zambia badly need forage high in protein to supplement the protein deficient pasture grass. Nutrient intake, especially for the small ruminants with small gastro-intestinal capacity compared to metabolizable energy requirement, will be near or below maintenance if these poor quality feeds are not supplemented. High quality supplements however, are beyond the reach of the small scale farmers. The effect of feeding maize husk and leucaena as a mixture or separately on voluntary intake of maize husk was studied over a 40 day period. Ten male goats with an average weight of 15 kg were used. The method of feeding did not have any significant ($P>0.05$) effect on maize husk intake. In a separate experiment the effect of browse supplementation on maize husk utilization by goats was studied in a 12 week feeding and 2 week digestibility trial. Twenty-four goats were stratified according to their weight, and then randomly allocated to four treatments. The treatments were; maize husk plus urea; maize husk plus *Leucaena leucocephala* (3:2); maize husk plus *Calliandra calothyrsus* (3:2); and maize husk plus leucaena plus calliandra (3:1:1). Browse supplementation significantly replaced ($P<0.05$) the daily maize husk intake

expressed g/kg $W^{0.75}$. However, browse supplementation significantly increased ($P<0.05$) the total dry matter intake. The mean husk dry matter intake was 41.3, 24.8, 24.6, and 24.9g/kg$W^{0.75}$ for maize husk plus urea, maize husk plus leucaena, maize husk plus calliandra and maize husk plus leucaena plus calliandra respectively. The total dry matter intake was 41.3, 55.2, 52.5 g and 52.9g/kg$W^{0.75}$ for maize husk plus urea, maize husk plus leucaena, maize husk plus calliandra and maize husk plus leucaena plus calliandra respectively. Supplementation with leucaena and / or calliandra had a significant positive effect on diet dry matter digestibility and diet organic matter digestibility ($P<0.05$) but did not have any significant effect on acid detergent fibre digestibility ($P>0.05$). The average daily weight gain was significantly different ($P<0.05$) between the urea-supplemented goats and those supplemented with leucaena and / or calliandra as the browse-supplemented goats gained more weight as compared to the non browse supplemented goats. The results of the study indicates that leucaena and calliandra are both potentially valuable feed components.

Résumé

L'effet de la supplémentation du pâturage sur l'utilisation des glumes de maïs par les chèvres.

Phiri Donald Mwelwa Résumé M.Sc. Phytotechnie

Les petits éleveurs de la province de l'Est de Zambie, ont grand besoin d'une source de fourrages riches en protéine afin de supplémenter les pâturages déficients en cette matière. Sans supplémentation, l'apport alimentaire est proche ou en dessous des besoins d'entretien, en particulier chez les petits ruminants pour lesquels la capacité du système digestif est faible comparée aux besoins en énergie métabolisable. Les suppléments concentrés de haute qualité sont toutefois hors de la portée de ces fermiers. Dix boucs d'un poids moyen de 15kg ont été utilisés au cours d'une étude menée afin de comparer l'effet d'offrir des glumes et un supplément de leucaena, ensembles ou séparément. L'ingestion volontaire de glumes de maïs, mesurée sur une période de 40 jours, n'a pas été affectée ($p>0.05$) par la méthode d'alimentation. Au cours d'une autre étude, vingt quatre chèvres ont été regroupées selon leur poids et assignées aléatoirement à l'un des quatre traitements alimentaires afin d'étudier l'effet de la supplémentation du pâturage sur l'utilisation des glumes de maïs. Les traitements étaient les suivants: Glumes de maïs + Urée (U), Glumes de maïs + Leucaena (L,3:2), Glumes de maïs + Calliandra (LC,

3:1:1) sur une période de 12 semaines. Une étude de digestibilité de deux semaines a également été menée. La supplémentation du pâturage a entraîné une substitution significative ($P<0.05$) de l'ingestion quotidienne de glumes de maïs, exprimée en grammes par kilogramme de poids métabolique. Toutefois, la consommation de matière sèche totale était supérieure ($P<0.05$) chez les chèvres recevant un supplément. La consommation de matière sèche de Glumes de maïs était de 41.3, 24.8, 24.6, et 24.9g/$Kgw^{0.75}$ et celle de matière sèche totale de 41.3, 55.2, 52.5 et 52.9g/$Kgw^{0.75}$ pour les groupes U, L, et LC respectivement. La supplémentation de leucaena et de calliandra a également augmenté ($P<0.05$) la digestibilité de la matière sèche et de la matière organique mais non de la fibre ADF. Le gain moyen quotidien des chèvres recevant un supplément était supérieur ($P<0.05$) à celui de celles recevant de l'urée. Les résultats de cette étude indiquent que la supplémentation de leucaena ou de calliandra peut améliorer l'utilisation du pâturage de glumes de maïs.

Chapter 1.0

GENERAL INTRODUCTION

The main agricultural production system in the Eastern Province of Zambia is low input and extensive and is based on livestock grazing natural pastures. Goats (genus *Capra*) grow very rapidly during the rainy season (December to April) but lose weight during the dry season when they are forced to graze dead pasture residues which are generally of low nutritive value. As a result goats depend very much on crop residues such as maize (*Zea mays* L.) husk (Smith, 1966). Under these conditions protein content in the diet has been shown to be the major limiting factor affecting live weight gain (Pratchett et al., 1977).

The Eastern Province of Zambia produces large quantities of maize (Ministry of Agriculture Report, 1989). Maize production is associated with the generation of large quantities of maize husk (Owen, 1976). Maize husk consists largely of cellulose and related complex carbohydrates, which are potentially digestible by goats, cattle and sheep (Balch, 1977). Unfortunately maize husk has a low level of crude protein. Thus if eaten as the only feed, digestion is limited because the husk does not provide the micro-organisms of the rumen with sufficient nitrogen (Agriculture Research Council, 1980; Fernadez-Rivera et al., 1989b). This means that the animal can only process a small amount of feed in a given time and hence intake is low. Low intake coupled with low digestibility will limit the feeding value and animal performance supported by the husk. Therefore, there is a need to increase the availability of

crude protein the diet by physical, chemical, physio-chemical treatments or by other means. Current methods of improving the quality of maize husk by post-harvest treatment are not economical or technically feasible for small ruminant production in the Eastern Province of Zambia. Chemicals and facilities are expensive or not available. As a result chemical processing has had very little impact on increasing the quantity and quality of animal productivity in this region due to lack of practical application of the innovation by the small scale farmers. The successful use of maize husk under village conditions will therefore depend on direct use of a variety of supplements.

Under the present farming system (small scale maize livestock system) the agroforestry approach of incorporating woody perennial (shrubs or trees) into the existing farming system may constitute a sound practice. A perennial deep rooted legume capable of sustained heavy production of palatable high protein forage even during the dry season would seem most desirable. Such forage would improve the rumen environment for maximum utilization of pasture and / or crop residue while allowing improvement in animal performance. Tropical browse species such as *Gliricidia sepium, Leucaena leucocephala, Sesbania sesban,* etc. which are known to have high growth performance, and are rich in protein and other nutrients, offer an inexpensive means of supplementing the available feeds in the dry season.

The objective of this study was to determine the effect of supplementing maize husk with Leucaena leucocephala on intake,

digestibility and weight gain by growing goats.

Figure 1. Indigenous cattle in the Eastern Province of Zambia grazing on poor pasture in the early months of the dry season

Figure 2. Goats feeding on crop residues (maize husk)

Chapter 2.0

LITERATURE REVIEW

2.1 INTRODUCTION

Maize husk is by far the most abundant crop residue in the Eastern Province of Zambia. It has always played a major role as ruminant feed in this country. It is either grazed in situ or stall fed without treatment. The major constraint of maize husk is its low nutritive value. It has a low nitrogen and high fibre content and is poorly digested. Low intake and low digestibility are the primary factors limiting it's utilization by the ruminants.

2.2 UTILIZATION AND PERFORMANCE

Efficient utilization of roughage is dependent upon voluntary intake, digestion and the supported microbial growth (Van Soest, 1982). Available data in the literature has shown that intake and digestibility may be increased by physical processing or treating them with chemicals or by supplementing them with energy, protein, non-protein nitrogen and mineral to correct nutrient imbalances. In the existing farming system in the Eastern Province of Zambia, supplementation strategies are the most appropriate way to improve the utilization of the crop residues. High quality supplements, however are limited in availability and their use is difficult to justify economically.

2.3.0 METHODS TO IMPROVE INTAKE OF POOR QUALITY ROUGHAGE

2.3.1 SUPPLEMENTATION OF LOW QUALITY ROUGHAGE

2.3.1.2 ENERGY SUPPLEMENTATION

Energy supplementation to maize-husk based rations is essential but may not be as essential as nitrogen supplementation when considering the utilization of available nutrients by animals.

2.3.1.3 MINERAL SUPPLEMENTATION

According to Little (1985) crop residue based diets are likely to be deficient in sodium, phosphorus and copper. These are the same minerals found to be marginal or deficient in tropical grasses. Preston et al., (1986) reported that most straws are deficient in the same three minerals as well as sulphur, calcium and cobalt. The high levels of oxalates and silicates may further reduce the availability of calcium and magnesium, which are lost as silicates and oxalates in the urine and faeces.

At the level of production under unimproved systems in the small scale settings, goats do not often show symptoms of mineral deficiencies or respond to mineral supplementation (Smith, 1987).

2.3.1.4 Nitrogen supplementation

There is a lot of information on the intake and digestibility of roughage (Brandt et al., 1986a; Klopfenstein et al., 1981; Mosely, 1974; Cruickshank et al., 1985 and Paterson, 1982). These studies have had a common objective of increasing the efficiency of roughage utilization. Minson (1967) attained higher intake and increased efficiency of forage utilization by increasing dietary nitrogen through crop fertilization. Campling et al., (1962) reported an increase in the digestibility of wheat (*Triticum aestivum* L.) straw by 3% when supplemented with urea. Ammerman et al., (1972) reported an increase in voluntary intake of digit grass hays (2.6 and 4.6% CP) when they were supplemented with nitrogen in the form of natural proteins or non protein nitrogen (NPN). Saenger et al., (1982) observed an increase in dry matter intake when corn stover was ammoniated.

Supplementation with high protein foliage has been shown to increase the efficiency of utilization of crop residues by ruminants (Mosely, 1974; Klopfenstein et al., 1981; Paterson et al., 1982; Mosi et al., 1983; Cruickshank et al., 1985 and Brandt et al., 1986a).

2.4.0 THE USE OF LEGUMINOUS BROWSE SPECIES AS PROTEIN SUPPLEMENTS

Many legume trees or shrubs are presently or potentially available to the maize/livestock farmer in the Eastern Province of Zambia. The materials contain intermediate concentrations of crude protein (15-25%) and, if used as supplements may improve the rumen environment for maximum utilization of basal roughages while allowing improvement in animal performance.

In view of the high yield per unit area of leucaena (*Leucaena leucocephala*) and calliandra (*Calliandra calothrysus*) it was proposed in this study to determine the effect of these supplements on maize husk utilization. *Leuacaena leucocephala* and *Calliandra calothrysus* are tropical legumes which are rich in protein (Jones, 1979; Devendra, 1984 and Brewbaker, 1987).

2.4.1 LEUCAENA (LEUCAENA LEUCOCEPHALA)

2.4.1.1. AGRONOMIC CHARACTERISTICS

Leucaena is a shrub or a tree. It grows well in wide range of soils with the marked exception of those that are very acidic and water-logged (Jones, 1979).

The genus Leucaena is represented by many plant forms. The most common is the "Hawaiian leucaena". It is shrubby, free seeding and low yielding. The others are Peru, Cunningham, K8, and K28. Peru and K28 are tall and erect, and sparsely branched. All are palatable to livestock and grow rapidly after cutting (Jones,

1979). Though leucaena will grow anywhere in the tropics and subtropics within an annual rainfall range of 500 to 3 000 mm it is very specific in its Rhizobium requirements. Its yields in the wet tropics have been reported to be as high as 20 tonnes dry matter ha^{-1} $year^{-1}$ with crude protein yield in excess of 3 tonnes ha^{-1} $year^{-1}$ (NAS, 1977). In the dry tropics good forage varieties will yield 8 tones of edible dry matter ha^{-1} (Hill, 1977).

2.4.1.2 NUTRITIVE VALUE FOR RUMINANTS

According to NAS (1977) the leaf material of leucaena compares favourably with alfalfa. The leucaena leaf is also an excellent source of beta-carotene, which could be a valuable characteristic, particularly during the dry season when leucaena is able to retain its green leaf better than any pasture species.

Digestibility values of 50 to 71% have been reported in literature (Sing et al., 1967; Joshi et al., 1976; Upadhyaya et al., 1974).

The voluntary feed intake of leucaena ranges from 1.7 to 2.7 percent of body weight (Upadhyaya et al., 1974 and Jones et al., 1978). Compared to the excellent chemical composition and high digestibility values reported the voluntary feed intake values appear to be very low. Pen feeding experiments done by Singh et al., (1967); Upadhyaya et al.; (1974) and Jones et al., (1978) confirm that leucaena as a sole source of feed does not compare favourably with alfalfa even though chemical composition and digestibility values are similar. The reason for this difference

is probably associated with a toxic amino acid which is found in leucaena. Previous work indicates that the toxicity of leucaena is related to the presence of mimosine, a non-protein amino acid, in the plant material (Jones et al., 1976; Blunt et al, 1977; Megarrity et al., 1983; Jones et al., 1984). Ingested mimosine is metabolized in the rumen to 3-hydroxy-4(1H)-pyridone (DHP), which is a potent goitrogen (Hegarity et al., 1979). Circulating DHP prevents iodization of tyrosine, the first step in the synthesis of thyroxine, resulting in goiter development and reduced levels of thyroxine (T4) in the serum. The other problems include poor live weight gain, alopecia, ulceration of oesophagus and death of newborn offspring (Jones et al., 1976; Blunt et al., 1977).

Where leucaena have been fed as a protein supplement with other feeds there has been no toxic effects on the animal and performance has been comparable to supplementation with concentrated protein sources such as groundnut cake and meat meal. Leng et al., (1976) showed that supplementing a diet so that the overall protein content was 9 percent, gave daily live weight gains of 0.6 kg/head in cattle. In Malawi, sun dried leucaena has been used to supplement grazing. Supplemented steers gained more than the controls and were not significantly different from those obtained with a supplement of groundnut cake fed to provide the same crude protein as the leucaena (Thomas et al., 1977). Work by Alvarez et al., (1978) indicate that leucaena can effectively substitute a large portion of rice polishing or other feed byproducts from grains. Increased animal production was also found

in grazing dairy cows supplemented with leucaena (Flores et al., 1979). Cochran et al., (1984) carried out an experiment in which they studied the growth response of Peruvian Criollo goats consuming varying levels of *Acacia macrantha*, *Leucaena leucocephala* and corn stalks. They concluded that *A. macrantha* and *L. leucocephala* can be used successfully at levels of 40 to 100 percent and 30 to 40 percent of diet respectively, to supplement goats consuming poor quality roughage.

2.4.2 CALLIANDRA (CALLIANDRA CALOTHRYSUS)

2.4.2.1 AGRONOMIC CHARACTERISTICS

Calliandra is a tall shrub. Under favourable conditions it may grow up to a height of 12m however the average height is 4-6m. In Indonesia annual yields of 7-10 tons of dry fodder per hectare have been recorded (NAS, 1983)

2.4.2.2 NUTRITIVE VALUE FOR RUMINANTS

Calliandra is browsed by sheep, goats and cows. It has been used as supplement feed for sheep, goats and cows (NAS, 1983). Best results were obtained with 40-60 percent of the diet made up of calliandra. The leaves like those of leucaena are rich in protein (up to 22 percent crude protein, dry weight basis) and contain 30-75 percent fibre, 4-5 percent ash and 2-3 percent fat. Calliandra foliage unlike leucaena has only one simple polyphenol, (Quercetin-3-rhammoside), at a concentration of 1 percent.

No anti-nutritional substances have been found so far. Mimosine, which is of major concern in leucaena, is not found in calliandra. This means that the animal can consume more of calliandra than leucaena without any ill effects.

2.5.0 FORAGE QUALITY ANALYSIS

2.5.1 ANIMAL DIGESTION TRIAL

Ulyatt (1973) states that " the nutritive of a herbage is often divided into two components: The proportion that is digested, or apparent digestibility, and efficiency with which digested nutrients are utilized for maintenance and production." One of the ways to evaluate a feed is to carry out a digestion trial to determine the apparent digestibility coefficiency.

Animal digestion trials are normally expensive, laborious and time consuming, however they represent the yardstick by which chemical and artificial rumen techniques are assessed. The accuracy with which a chemical method or an in vitro technique measures the utilization of a forage is usually assessed by the correlation with animal digestion data.

The animal species most used in these trials are sheep (genus *Ovis*), goats (genus *Capra*) and cattle (genus *Bovine*). Several workers have compared the utilization of forage by the species, and the general opinion is that data obtained with sheep and goats can be used for cattle. Buchman et al., (1964) compared digestibility

and intake of alfalfa hay by calves, yearlings, heifers, cows and sheep. There was no significant difference between sheep and cows in the daily intake of hay per 45.5 kg body weight. Average digestion coefficient of dry matter, energy and protein were not significantly different among sheep, cows and yearlings however, the calves digested significantly less of the components. This lower digestibility was probably due to the age of the calves (9-10 weeks) and the higher intake of forages.

The length of the time given for the previous feed to get out of the alimentary canal and also for establishing a uniform rate of passage of feed products and excretion of faeces (preliminary period) and the time during which the excreta is collected (collection period) has been fairly well established. LeFevre et al., (1960), in a cellulose digestion involving four sheep, used a preliminary and collection period of 15 and 5 days, respectively. Buchman et al., (1964) used a preliminary period of 3 weeks with cattle and sheep. Vander Noot et al., (1965) used a 10 day preliminary period and 7 day collection period. Fonnesheck et al., (1981) in digestion trial involving sheep used a preliminary and collection period of 14 days and 7 days, respectively. In a standard trial it appears that a preliminary period of about 14 days and a collection period of 7 days are adequate. However, under certain circumstances, such as when the amount of feed material is limited, it may be necessary to decrease the preliminary period to 10 days.

Both ad libitum and restricted feeding methods are widely

practised. When animals are fed ad libitum, they tend to select the more digestible parts of the forage, such as leaves, and reject the stems. On the other hand, feed restriction, done to prevent selection by the animals, usually results in increased digestibility. Buchman et al., (1964) fed experimental animals at such a level as to have only 10% of the feed as refusals (orts) daily. Lance et al., (1963) in their corn and silage digestion trial fed only 85% of the established voluntary intake during the collection period. Baumgardt et al., (1964) fed an amount equal to 80–90% of the voluntary intake established during the preliminary period. Coelho (1982) fed 90% of the amount established during days 3-8 of the trial. In order to ensure complete consumption of the feed offered and also guard against increase in digestibility of the feed as a result of restricted feed intake, an intake of 90% of the established voluntary intake seems optimum during the collection period.

Another problem in digestion trials where ad libitum feeding is practised is the disposition of the refusals or orts. The orts can be assumed be of the same composition as the feed or its actual composition can be determined. If ort compositions are different from that of the feed offered, actual intake of the feed must be calculated.

Satter et al., (1962) reported that there were no significant differences among three cows in the digestibility of dry matter, energy and nitrogen whether they were fed two, four or eight times daily. However, increased frequency of feeding significantly

increased nitrogen retention. Experimental animals are usually fed twice daily at approximately the same times morning and evening.

2.5.3 PROXIMATE ANALYSIS

Workers at Weende Experimental Station in Germany in 1865 developed methods of appraising feeds which were correlated with their feeding value (Van Soest 1967) and divided total components of forage into six main categories (Van Soest 1982): moisture, ether extract, crude fibre, crude protein, ash and nitrogen free extract. The crude fibre fraction was considered to represent the indigestible part of the carbohydrates and nitrogen free extract was considered to represent the easily digestible starch and sugars; however it has been shown that digestion of crude fibre of forages by ruminants could be as extensive as that of the nitrogen free extract fraction (Van Soest, 1977). Determination of crude protein by measurement of total nitrogen considers nucleic acid-N and water soluble non-protein nitrogen (NPN) (Van Soest 1982). Multiplying N content by the factor 6.25 assumes that all the forage protein contain 16 % nitrogen. The composition of the fibre is also not distinct. The nitrogen free extract may contain as much or more of the lignin than the crude fibre fraction (Moxon et al., 1953). Another problem is that because nitrogen free extract is obtained by subtraction its accuracy is affected by all analytical errors associated with the crude fibre, crude protein,

ash, dry matter and ether extract determinations.

2.5.4 DETERGENT SYSTEM

The detergent system was proposed by Van Soest (1962). It divides components of forage into two major fractions: The cell contents and the cell wall constituents (Van Soest, 1982). It consists of boiling a sample of forage with a neutral detergent solution in which cell constituents are soluble. This neutral detergent indigestible portion of the forage can be subdivided into acid detergent fibre (ADF) containing cellulose, lignin, lignified-N and silica and fibre soluble in acid detergent solution. The separation can be done by boiling a portion of forage with an acid detergent solution for one hour. The weight of the residue after washing and drying represents the ADF. Further treatment of fibre with 72% sulphuric acid for 3 hours dissolves cellulose and leaves the detergent lignin. The hemicellulose content can be evaluated by subtracting ADF from NDF.

Chapter 3.0

EXPERIMENT 1

TITLE: THE EFFECT OF FEEDING MAIZE HUSK AND LEUCAENA AS MIXTURE OR SEPARATELY ON THE VOLUNTARY INTAKE OF THE HUSK

3.1 INTRODUCTION

The nutrients that an animal can extract from a feed are a function of the dry matter intake (DMI). Low voluntary feed intake is consistently observed with cereal straws and this has been attributed to the slow rate of removal of organic matter from the reticulo rumen. This occurs as a consequence of high concentration of slowly fermentable cell wall. An increase in intake of roughage after chemical treatment has been attributed to an increase in the rate of organic matter digestion as well as a increase in overall digestibility (Coombe et., al 1979).

3.2 OBJECTIVE

The objective of this experiment was to compare the intake of maize husk when it: (a) fed in a mixture with leaves of *Leucaena leucocephala*, and (b) fed in separate feed troughs of either husk or leucaena.

3.3 MATERIALS AND METHODS

3.3.1 BACKGROUND ON THE STUDY AREA

3.3.1.1 LOCATION

The Experiment was conducted at Mskera Regional Research Station in the Eastern Province of Zambia. The Eastern Province of Zambia occupies a land area of 70,000 square kilometres. It is situated between latitude 10 and 15 degrees south and longitude 30 to 35 degrees East. Msekera Regional Research Station is located on latitude 14 S and 32 E longitude (Figure 3).

3.3.1.2 TOPOGRAPHY

This region is characterized by gentle to moderate slopes that are interspersed with hills and minor escarpments (AFRENA Report, 1988). Seasonal waterlogged low lying area (dambos)are a common feature. The dambos are important grazing area during the dry season.

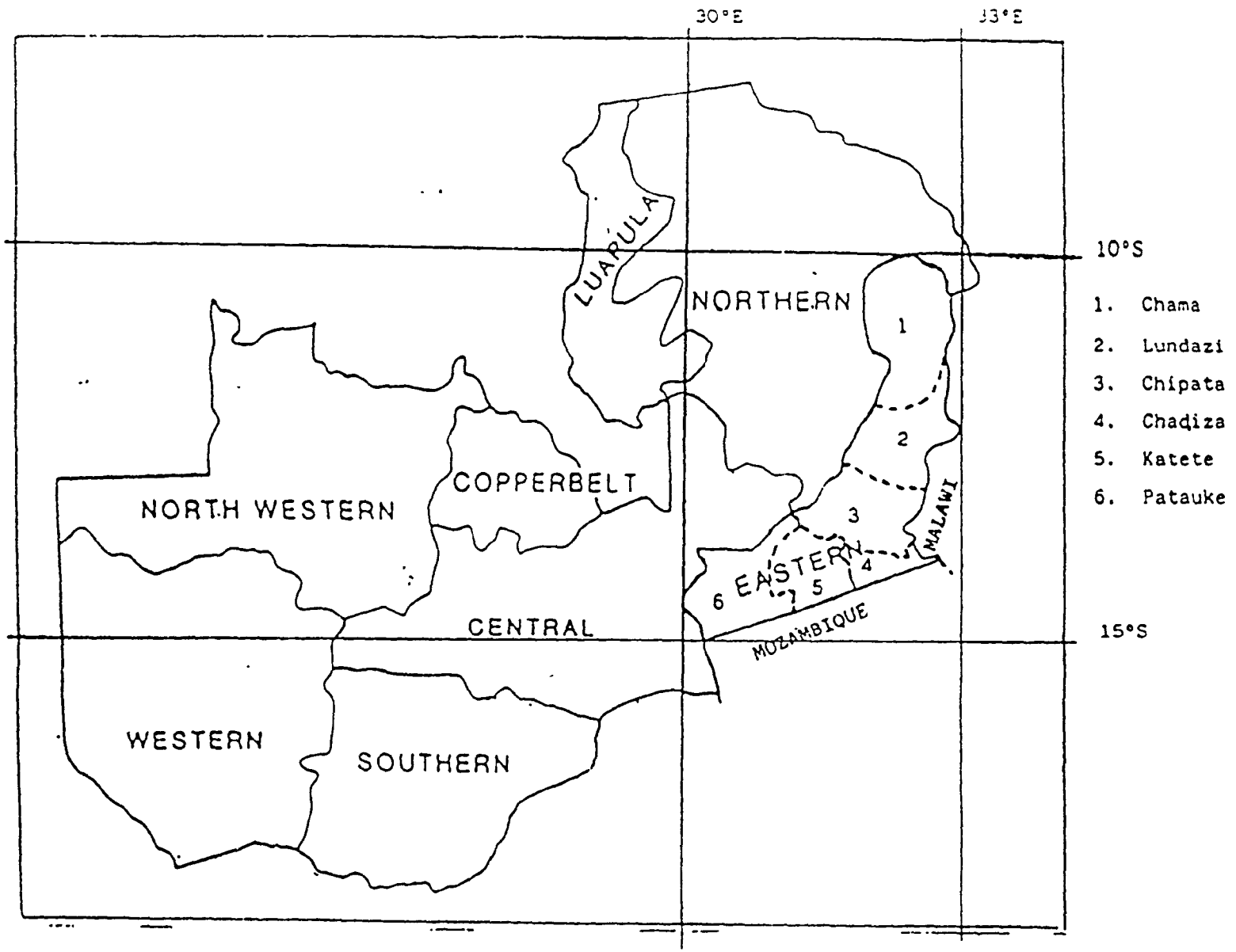

Figure 3. THE PROVINCES OF ZAMBIA AND THE SIX DISTRICTS OF EASTERN PROVINCE.

3.3.1.3 SOILS

Sandvelt is the most predominant soil group. The most common soil types are the yellowish and red to light yellowish brown loam sand soils on well drained sites. In some places, the loamy sands are interspersed with red clays and red brown loams while hydromorphic soils are found in seasonally waterlogged dambos (FAO/UNESCO classification). The soils at Msekera Agroforestry Research plots are predominantly medium (4.5 - 5.0) to strong acid (AFRENA Report, 1988)

3.3.1.4 CLIMATE

The seasons are (1) warm wet (December to April), (2) Cool dry (May to August) and (3) Hot dry (September to November). The rainfall averages about 960 mm per year (range 887 to 1041 mm per year) with about 85% of the rain falling in December, January, February and March (Unimodal). Figure 4 show the climatic data for Chipata (true for Msekera as well).

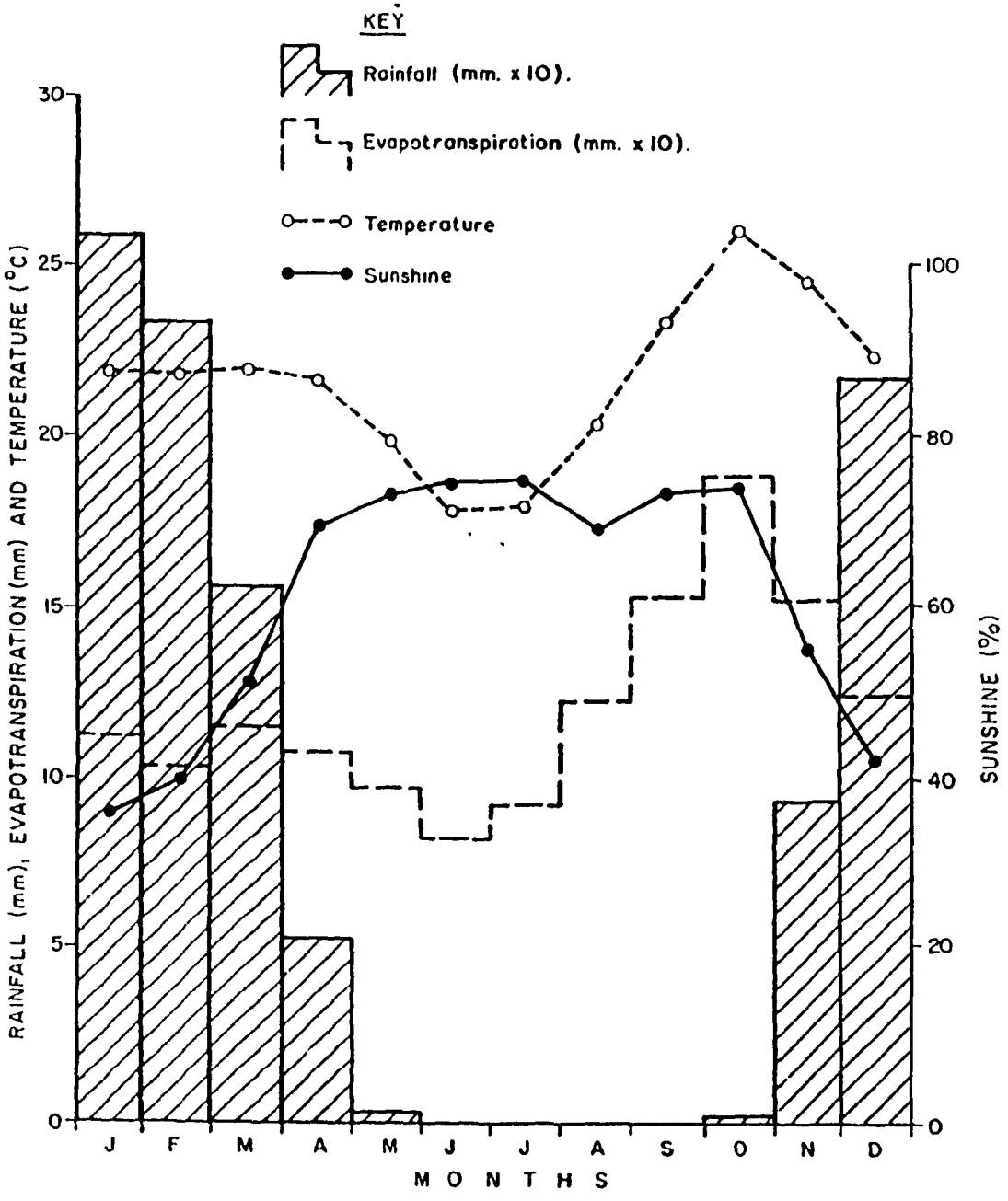

Figure 4. CLIMATIC DATA FOR CHIPATA

3.4 ANIMALS AND HOUSING

Ten male goats indigenous to the Eastern Province of Zambia were used. The indigenous goat, as found in the Eastern Province of Zambia, is fairly small, weighing about 36 kg at maturity if well grown. It has a distinct chunk meat conformation and carries muscle along the back and on the hind quarters. Colours are variable being, black, brown or roan , with or without white markings.

To insure the health of the animals, all were treated for internal parasites (worms) with an anthelmintic (Thiobendazole) and also they were sprayed with an acaricide (Toxaphene at 0.5%) to get rid of the external parasites (ticks). This was done two weeks before the beginning of the experiment. The animals were managed as a single group prior to assignment to treatments.

As there were no facilities available for animal feeding experiments at the Mskera Regional Research Station, the author constructed a goat house with individual feeding troughs using local materials (Figures 5,6 and 7). The entire floor was concrete with the exception of a central 1.5m passage which was covered with bricks. The length of the entire structure was 17m and the width was 4.8m. The side walls were made of bricks up to the height of 1.0m and bamboo sticks from the bricks up to the roof level. The bamboo sticks were placed 10cm apart. The area constructed with bamboo sticks was also reinforced with cotton sacks which were drawn during the day to provide maximum aeration and light penetration. The sides were covered at night to protect

the goats from cool winds.

The roof was made of corrugated iron sheets. The centre of the building was 2.8m from the ground and the sides 1.8m. This provided a gentle slope to the roof.

The individual pens were 1.0m x 1.5m. The sides of each pen were constructed with bamboo sticks placed 10.0cm apart up to the height of 1.8m. The doors had a eucalyptus pole frame with bamboo sticks across. The feeding troughs were of bricks, and were 60cm x 45cm x 15cm (Research Branch Agriculture Canada; 1988). Fresh water was provided daily in individual basins which were placed in front of each pen.

The entire structure had no light at night and no artificial heat was provided.

Figure 5. The goat house used in Experiment 1 and 2

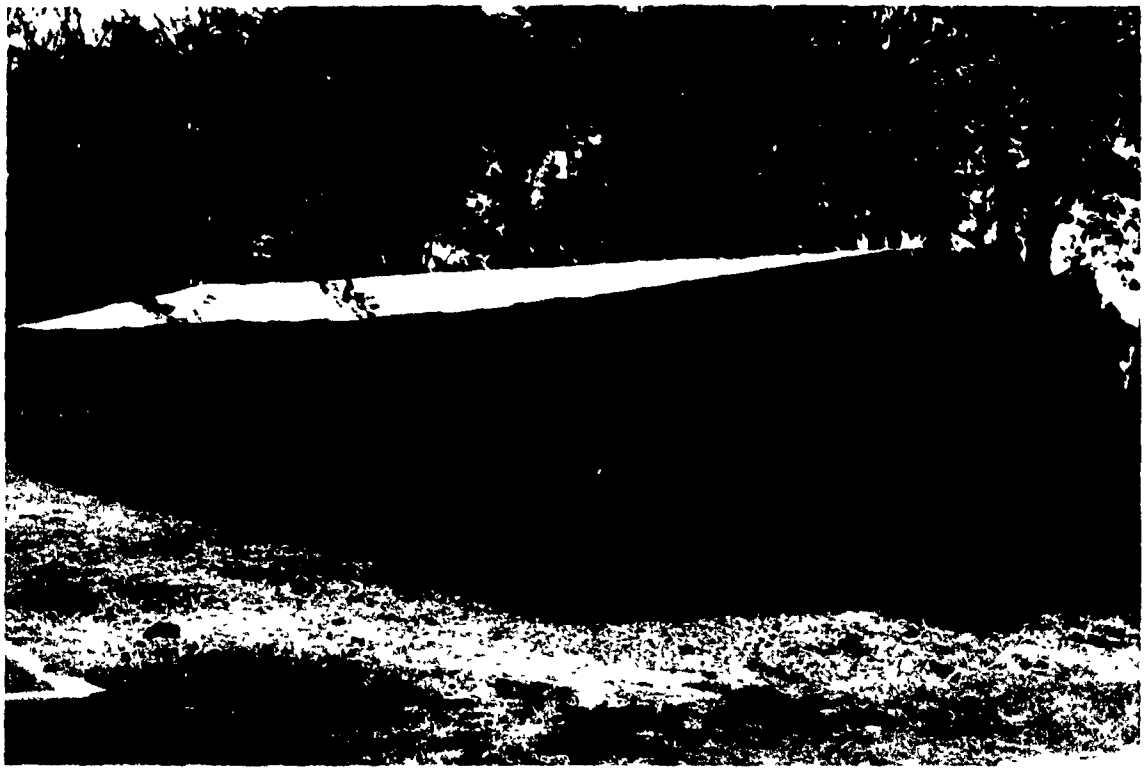

Figure 6. The interior of the goat house showing the passage and the water basins

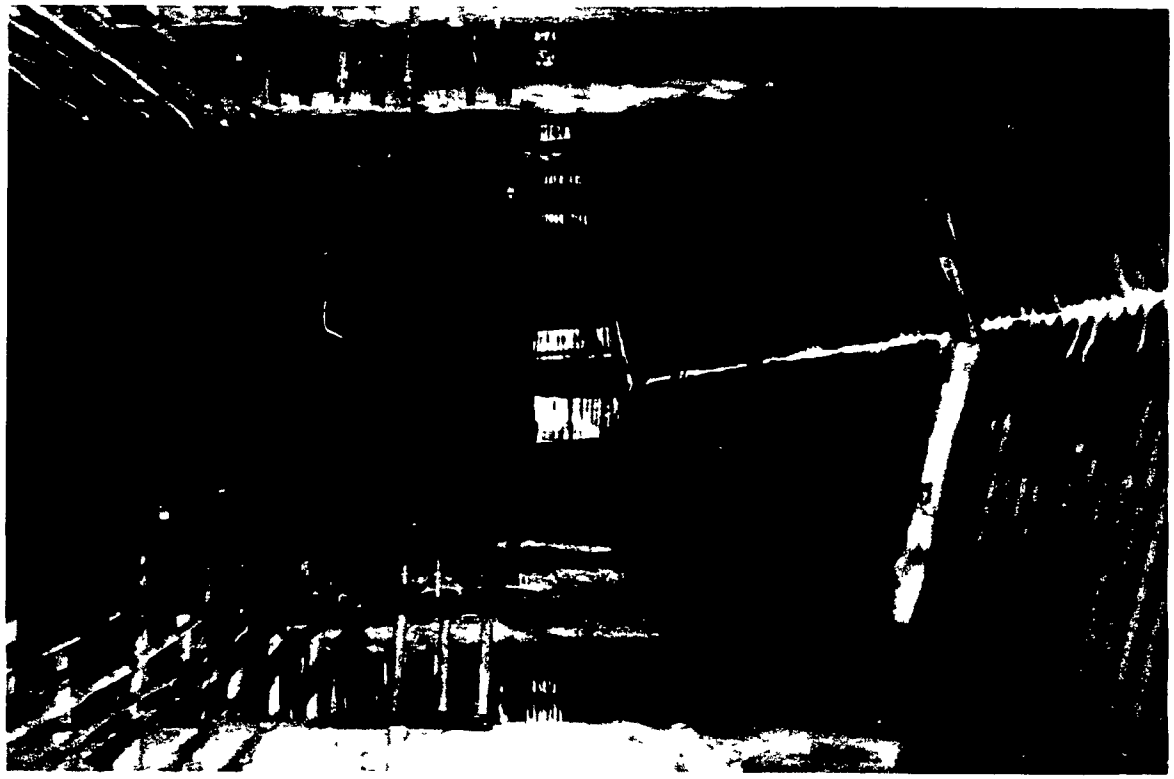

Figure 7. A close up of an individual pen.

3.5 DESIGN AND TREATMENT

A completely randomised design was used. There were two periods in this experiment. Each period was divided into a 13 day preliminary period and a 7 day collection period during which feed intake and digestibility were measured.

In period 1, five goats were offered 60% chopped maize husk mixed with 40 % *Leucaena leucocephala* foliage on dry matter basis. The two forages were mixed prior to feeding. The maize husk was chopped in smaller pieces of about 4 -10cm. This was done to reduce feed wastage and to facilitate feeding. The leucaena was harvested daily in the morning and afternoon. Harvesting was done by hands and only leaves and very small stems were fed without chopping it into smaller pieces. This was done reduce the amount of time spent on feed preparation. The leucaena plantation had been established for two years having been planted in December of 1987. In February 1990 the shrubs were cut at a height of 0.5m from the ground. It was the regrowth from this plants which was used in the experiment starting in April 1990.

The other five goats were also offered 60% maize husk and 40% *Leucaena laucocephala* foliage but in two separate troughs at the same time. In both cases the feed was offered in two equal meals, at 9:00 hrs. and at 15:00 hrs.

Figure 8. The regrowth from a two year stand of *Leucaena leucocephala*

In period 2 the treatments remained the same as in period 1; however, the animals were switched. Those that had maize husk plus leucaena as a mixture were offered maize husk and leucaena in separate troughs, and those that had maize husk in separate troughs were now offered maize husk plus leucaena as a mixture.

The animals were weighed at the beginning and at the end of each period. Weighing was conducted before morning meals to reduce variation in weight due to fluctuation in gut fill.

Additionally each goat had access to mineral lick and fresh water daily.

3.6 VOLUNTARY FEED INTAKE AND DIGESTIBILITY

Each period lasted 20 days; 13 day preliminary and 7 day collection period respectively. Each animal was offered 110 % of the intake of the previous day. However, if the intake by a goat dropped significantly below the average consumed in the preceding 3 to 4 days, the amount of feed offered was not reduced for several days. This ensured that any reduction in the voluntary feed consumption by the animal were long term changes and not short term (1 or 2 day) effects. Voluntary intake was determined on days 6 - 10 of the preliminary period. On day 12 an amount equivalent to 90% of the average daily voluntary intake was offered in two equal portions. Feed and refusals were sampled daily for DM determination. Fecal collection was done from day 14. Samples for chemical composition for each treatment group, were taken from feed daily and stored and sub sampled at the end of the digestion trial.

Total faecal collection for the individual goats was performed on daily basis. The faeces were collected from the floor and were dried at 70°c for 12 hours. At the end of the experiment the faeces for each animal were bulked with a representative sub sample of 10% being taken. Chemical composition was determined on samples from individual goats.

3.7 ANALYTICAL PROCEDURES

All samples of feeds and refusals were ground through a 1 mm screen in a hammer mill . Acid detergent fibre was determined by the method of Goering et al (1975). Dry matter and ash contents were determined by drying 1g of sample in a vacuum oven at 100°C over night and then igniting for 8 hours at 600°C. Crude protein in the sample was determined by the Kjeldhal method. Digestion coefficient (defined as the amount of a nutrient consumed which did not appear in the faeces) was obtained by subtracting the nutrient voided from the nutrient consumed, to obtain the digested nutrient. The digested nutrients were then divided by the nutrients that were consumed and the result multiplied by 100 to obtain the digestion coefficient as a percentage as indicated in the formula below.

$$\text{Digestion coefficient} = \frac{\text{digested nutrients}^a}{\text{nutrients consumed}^b} \times 100$$

[a]Digested nutrients = nutrients consumed - nutrients voided in the faeces

[b]Nutrients consumed = nutrients in the feed offered - nutrients in the feed refused

Voluntary feed intake was obtained by subtracting the refusals from the feed offered.

3.8 STATISTICAL ANALYSIS

Analysis of variance was carried out for feed intake and coefficient of digestion and Duncan's Multiple range test was used to determine the difference among treatment means when the F value was significant.

3.9 RESULTS AND DISCUSSION

3.9.1 CHEMICAL COMPOSITION OF MAIZE HUSK AND LEUCAENA

Chemical composition figures of the maize husk and leucaena are presented in Table 1.

The crude protein of leucaena was higher than 21.45 % reported by Upadhyay et al., (1974) but lower than 26.9 % obtained by van Eys et al., (1986).

The ADF value for leucaena was lower than that reported by Cochran et al., (1984) and van Eys et al., (1986). Cochran et al. (1984) reported a value of 29.1 and van Eys et al. (1986) reported the ADF value as 22.6 percent. A higher value of 40.35 percent was reported by Vearasilp (1981). This differences could be due to the

amounts of stems or twigs that was included in the sample material.

The ash content for the leucaena reported in this study was higher than 8.23 % reported by Upadhyay et al., (1977). A difference of this magnitude could have resulted from the sample material in terms of leaves, stems and twigs.

The maize husk crude protein, ash and dry matter obtained in the study were lower than those obtained by Banda et al. (1986). They had values of 4.38, 5.29 and 93.13 percent for crude protein, ash and dry matter respectively. However, these differences were expected because Banda et al. (1986) used maize stover in their study whereas in the present study only the husk was used.

The ADF value for maize husk reported in this study was lower than the 39 percent reported by National Research Council (1989). The reason for this difference could not be established from this study. There may a need to collect several samples of maize husk in the region (Eastern province of Zambia) to see whether values are generally lower in this area.

Table 1 (Expt 1). Chemical composition (% dry matter) of maize husk and *Leucaena leucocephala*

	maize husk	leucaena
Dry matter	87.0	28.0
Crude protein	4.0	25.2
Ash	3.9	10.6
ADF	30.0	22.6

ADF = Acid detergent fibre

3.9.2 DRY MATTER INTAKE

Daily dry matter intake was obtained by averaging the intakes for each goat and expressing it as daily dry matter intake as grams per day. Table 2 show the mean intake value for the goats in period 1 and period 2.

The intake of maize husk by the goats which were being fed maize husk and leucaena as a mixture was 201 g/day in period 1. The intake for those being fed separately was 204 g/day. In period 2 the intake of husk by the goats which were being fed maize husk and leucaena as mixture was 273 g/day and the goats being fed maize husk and leucaena separately had an intake of 271 g/day. Thus the feeding of maize husk and leucaena as a mixture did not increase ($P<0.05$) the intake of maize husk (Tables 2 and 3). There was however a significant ($P<0.05$) increase in the intake of maize husk

from period 1 to period 2. This was not surprising because the goats at this stage were bigger and had gotten more accustomed to the husk than in period 1. The reduction in the dry matter intake of leucaena in period 2 could have also been attributed to an increase in the twigs as the regrowth from the leucaena plants matured. The reasons for the decline in the total dry matter intake could not be established from this trial.

The total dry matter intake of the goats which were being fed the admixture was 368.8 g/day in period 1 and 353.3 g/day in period 2. For those fed separately it was 368.8 g/day for period 1 and 353.3 g/day in period 2. The total dry matter intake was about the same for period 1 and 2. Thus total diet dry matter intake was not affected ($P<0.05$) by the method of feeding.

Table 2. Voluntary intake of maize husk and total (maize husk plus leucaena) dry matter (g/day) for period 1 and 2.

		Period 1		Period 2	
Treatment	No. of animals	maize husk intake	Total DM intake	maize husk intake	Total DM intake
Mixture	5	201.7	368.0	273.6	353.0
Separate	5	204.2	368.0	271.6	353.0
S. E	2.8	2.0	3.1	8.0	

3.9.3 THE DIGESTIBILITY VALUES

Table 3 shows the diet dry matter, organic matter and acid detergent fibre digestibility obtained from the two methods of feeding. There was no significant difference ($P<0.05$) between the methods of feeding in any of the digestibility values.

Table 3. Digestibility values for maize husk plus leucaena fed as a mixture and separately (Period 1 and Period 2).

		Period 1			Period 2		
Trt[a]	No. of animals	DM	OM	ADF	DM	OM	ADF
Mixture	5	63.1	64.7	52.4	61.8	63.7	55.9
Separate	5	62.2	64.0	51.4	61.9	63.8	55.9
S.E		0.6	0.6	3.4	0.4	0.6	2.5

a = Treatment

S.E = Standard error

3.9.4 GENERAL DISCUSSION AND CONCLUSIONS

The results of this study clearly demonstrated that there was no significant difference in voluntary intake and digestibility between the two feeding methods. The data were considered to indicate that the intake of maize husk and diet digestibility was not better when fed as a mixture with *Leucaena leucocephala* than when offered separately but at the same time. This can be explained by an observation of the feeding behaviour of goats. The goats ate all the leucaena first in each case before the started eating the maize husk. In the case of the mixture the goats were able to separate the leucaena from the maize husk. As a result it made no difference whether the feed was offered separately or as an admixture provided they were offered at the same time. These results may appear to conflict with those obtained by Baker (1969) or from choice of animals under grazing situations (Milne et al., 1982). However, in the present experiment it must be recognised that maize husk plus leucaena was offered ad libitum in the ratio of 3:2 (dry matter basis), not the leucaena alone. Thus for the goat to be offered more of the leucaena it had also to consume a certain proportion of maize husk.

Chapter 4.0

EXPERIMENT #2

Title: The effect of supplementation of leguminous browse species *Leucaena leucocephala* and *Calliandra calothrysus* on the voluntary intake and digestibility of maize husk and weight gain by growing goats

4.1 INTRODUCTION

Maize husk is the most abundant crop residue in Zambia. however, the low protein and poor digestibility are the major factors limiting its utilization. Supplementation with high protein forage has been shown to increase the efficiency of utilization of crop residues by ruminants (Mosi et al., 1983; Kang et al., 1982). In this study supplementation is defined as the addition on a daily basis of a proportion of, in this case forage, to a basal diet. *Leucaena leucocephala* (leucaena) and *Calliandra calothyrsus* (calliandra) are tropical browse species which are rich in protein. A number of studies have demonstrated that they are useful protein supplements for ruminants fed poor quality roughage such as maize husk (Jones, 1979; Devendra, 1983, 1984). The objective of this study was to determine the effect of leucaena and/or calliandra supplement on the voluntary intake and digestibility of maize husk and weight gain by goats indigenous to the Eastern Province of Zambia.

4.2 MATERIALS AND METHODS

A randomised complete block design was used in this study. Twenty-four male goats indigenous to the Eastern Province of Zambia were used in this experiment. The goats were stratified on the basis of their live weights, and the divided into blocks of four goats with similar live weight. Within each weight group, treatment assignment was done at random. The goats were placed in individual pens and fed separately. The treatments were (a) maize husk plus 1% urea (b) maize husk + *Leucaena leucocephala* (3:2) (c) maize husk plus *Calliandra calothyrsus* (3:2) (d) maize husk plus leucaena plus calliandra (3:1:1). The ratios were on dry matter basis. Browse supplementation was being compared to maize husk plus urea because the crude protein in maize husk was very low (4.00 %) and its use as a sole feed would have resulted in lose of weight and eventually death of the animal (Pratchett et al., 1977; Agriculture Research Council 1980). In each treatment the feeds were offered to the goats as a mixture.

A two week preliminary period preceded the feeding trial. During the feeding trial which lasted 12 weeks the quantity of feed offered and refusals were measured daily. Once a week samples were taken from the feed and refusals and analyzed for dry matter (DM), organic matter (OM), crude protein (CP) and acid detergent fibre (ADF). Animals were weighed (using magma-weigh by Howe Richardson Co.) weekly before morning feeding. Feeding was done daily at approximately 8.00 am and 3.00 pm. Water was offered in individual basins, commercial mineral licks were available free of choice.

At the end of the feeding trial a digestibility trial was conducted. Since the animals had been on the same treatment as those in the digestibility trial, there was no preliminary period. Feed offered and refusals were sampled daily for dry matter determination. The collection period lasted for 7 days. Samples for chemical composition for each treatment group, were stored and sub sampled at the end of the digestion trial. During the digestibility trial the goats were given feed equivalent to 90% of the average daily voluntary intake (VI). Fecal collection was done two days after the reduction in feed offered. This was done to insure the removal of excess feed residue from the digestive tract. They were fed twice daily.

Variables and animal management were identical to those outlined for experiment 1.

Figure 9. Two year stand of *Calliandra calothrysus*.

4.3 STATISTICAL ANALYSIS

Statistical analysis was performed with a PC version of Statistical Analysis System (SAS Institute Inc., Box 8000, Cary, North Carolina). Differences due to diet were evaluated by analysis of variance for a randomized complete block design (Steel and Torrie, 1980). The linear model used was as follows:

$$Yij = U+Pi+Tj+Eij \quad i = 1, 2, 3 \text{ and } 4, \; j = 1, 2, 3 \text{ and } 4$$

where: Yij is the observation associated with jth experimental unit.

U is the overall mean.

Pi is the effect due to the ith block.

Tj is the effect due to jth treatment.

Eij is the random error associated with the ijth experimental unit.

A least-squares analysis was also used to obtain least squares estimate of differences between treatments for comparison purpose. Duncan multiple range test was used to determine differences among the treatment means when F Test was significant.

4.4 RESULTS AND DISCUSSION

4.4.1 Chemical composition of the feeds used in experiment 2

Chemical composition of the feedstuffs used in the experiment are presented in table 4. The crude protein of the husk was much lower than that of leucaena and calliandra. The fresh leucaena leaves contained 25.2% CP and calliandra contained 24.5% CP on dry matter basis. The value for crude protein reported in this study was higher than that (22 %) reported by NAS; 1983. These results also indicate that calliandra has a much higher ADF value than that of leucaena. This is probably due to the high leaf to stem ratio in calliandra as compared to that of leucaena.

Table 4. Chemical composition (% DM) of the feed used in experiment 2. (average of the 12 week period)

	maize husk	leucaena	calliandra
Dry matter	87.0	28.0	33.0
Crude protein	4.0	25.2	24.4
Ash	3.9	10.6	7.7
ADF	30.0	22.6	46.2

4.4.2 VOLUNTARY INTAKE

The dry matter intake of each treatment is indicated in Figure 10. The means for each animal are presented in appendix 3.

Browse supplementation significantly decreased the daily maize husk intake ($P<0.05$) expressed as g/day. According to Kempton et al. (1979) supplementation increased DM intake of rice straw and the total dry matter intake. Supplementation decreased the maize husk intake. This could have been due to substitution effects. However, browse supplementation significantly ($P\leq0.05$) raised the total daily dry matter intake. The increase in total feed intake was attributed to the intake of supplement in addition to maize husk. This is similar to the findings of Hulman et al (1981) and also Banda (1986) who reported significant increase in daily total dry matter intake when sugar cane tops and maize husk respectively were supplemented with leucaena. The dry matter intake of husk averaged 168.9 g/day. Average total dry matter of browse supplemented diets was 296.6 g/day. The results from this study are similar to those from a nutritional study at the International Livestock Centre for Africa (ILCA, 1983) in which leguminous browses were fed to sheep on ad libitum basal diet of *Panicum*. Similar results were also found by Adenosun et al. (1985) in which they used leucaena and gliricidia in separate trials as a supplement to Panicum hay.

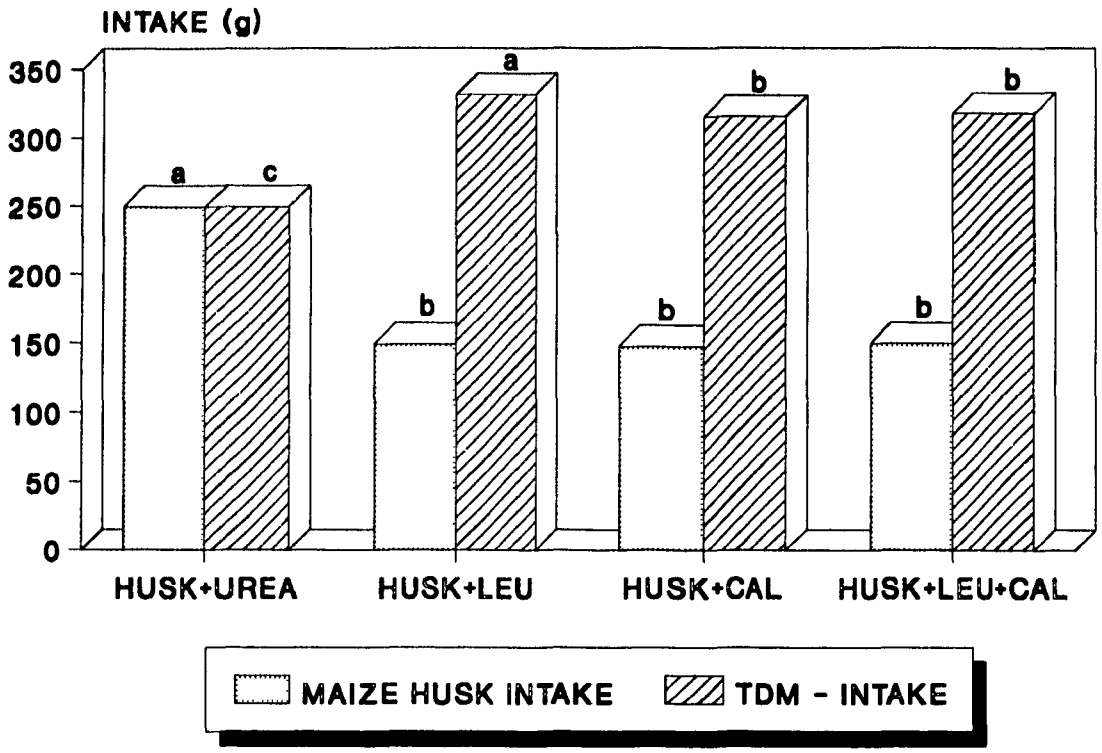

Figure 10. Mean daily husk and total dry matter intake for the rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal).

Table 5. Mean daily dry matter intakes of the components of rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal) (Experiment 2).

	Treatment				
	husk/urea	husk/leu	husk/cal	husk/cal/leu	S.E
Number	6	6	6	6	
Intake (g/d)					
maize husk	249.5a	149.2b	147.2b	149.4b	1.9
leucaena	----	182.4	------	------	
calliandra	----	-----	168. 1	-----	
leu plus cal	---	-----	------	168.0	
Total DMI	249.5c	331.6a	315.2b	317.4b	2.9

S.E = Standard error

Means followed by the same letter within the same row are not significantly different ($P<0.05$).

4.4.3 DIGESTIBILITY

The values for the apparent digestibility of dry matter (DM) organic matter (OM) and acid detergent fibre (ADF) are summarised in table 6 and Figure 12 - 14. The means for each animal are presented in appendix 4.

Browse supplementation had a significant effect on dry matter, organic matter and acid detergent fibre digestibility ($P>0.05$). However, there were no significant differences among the browse supplemented treatments for acid detergent fibre digestibility. The increased dry matter and organic matter digestibility due to browse supplementation obtained in the present study agrees with the findings of Devendra (1984) who reported significant increases in organic matter and crude protein digestibilities by replacing rice straw with 30% leucaena leaf hay in goat ration. The mean diet dry matter digestibility values in the present study are similar to those reported by, van Eys et al., (1986). Dry matter digestibility of mixed browse was studied by Adenosum et al. (1985) and found to have a value around 60% for the combinations tested.

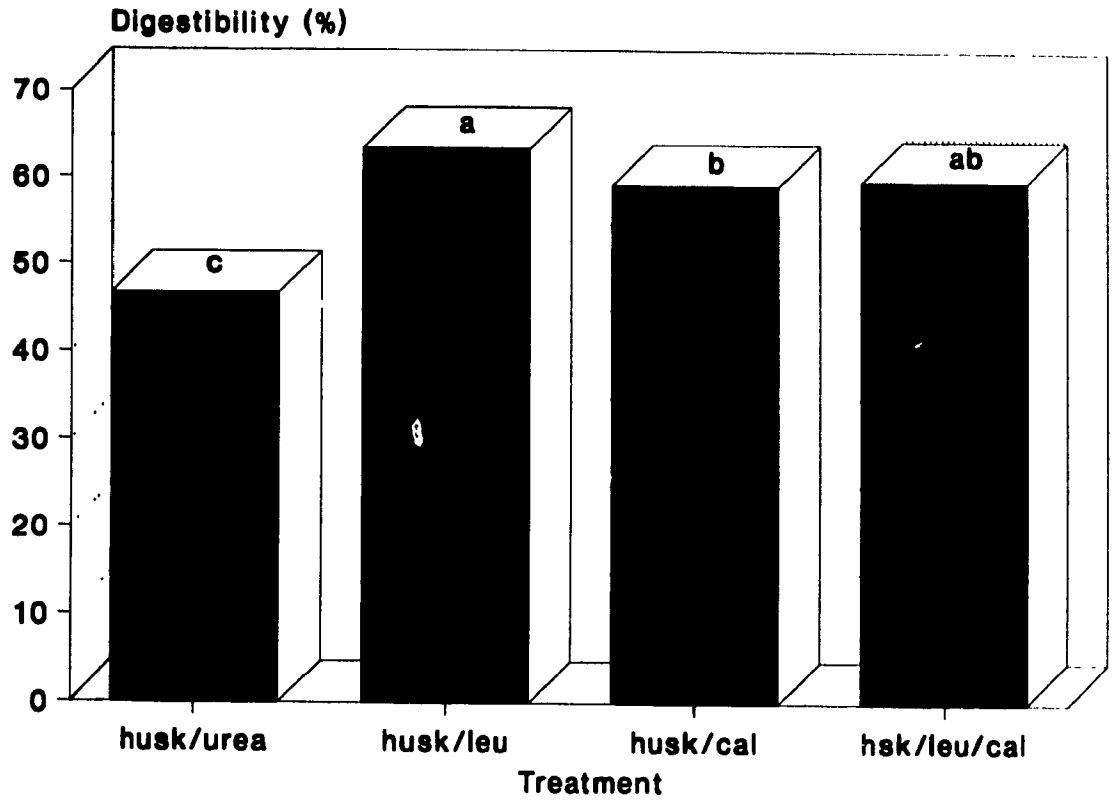

Figure 11. Mean dry matter digestibility (%) of rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal).

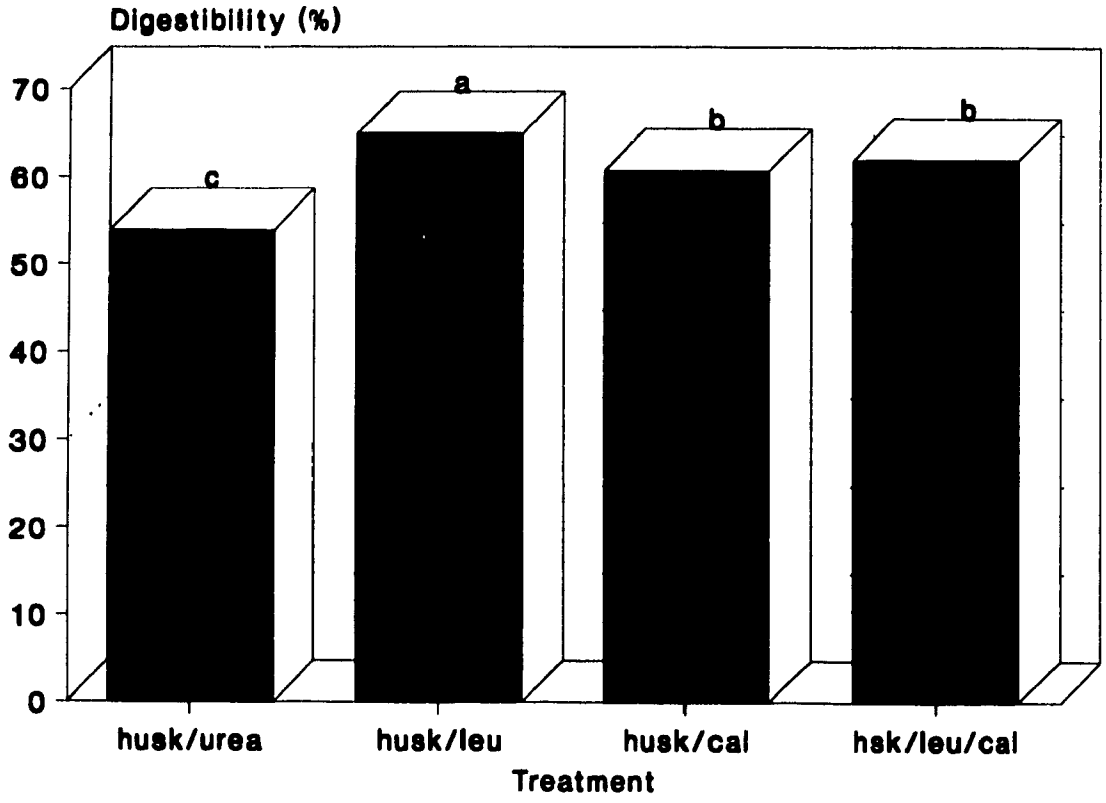

Figure 12. Mean organic matter digestibility (%) of rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal)

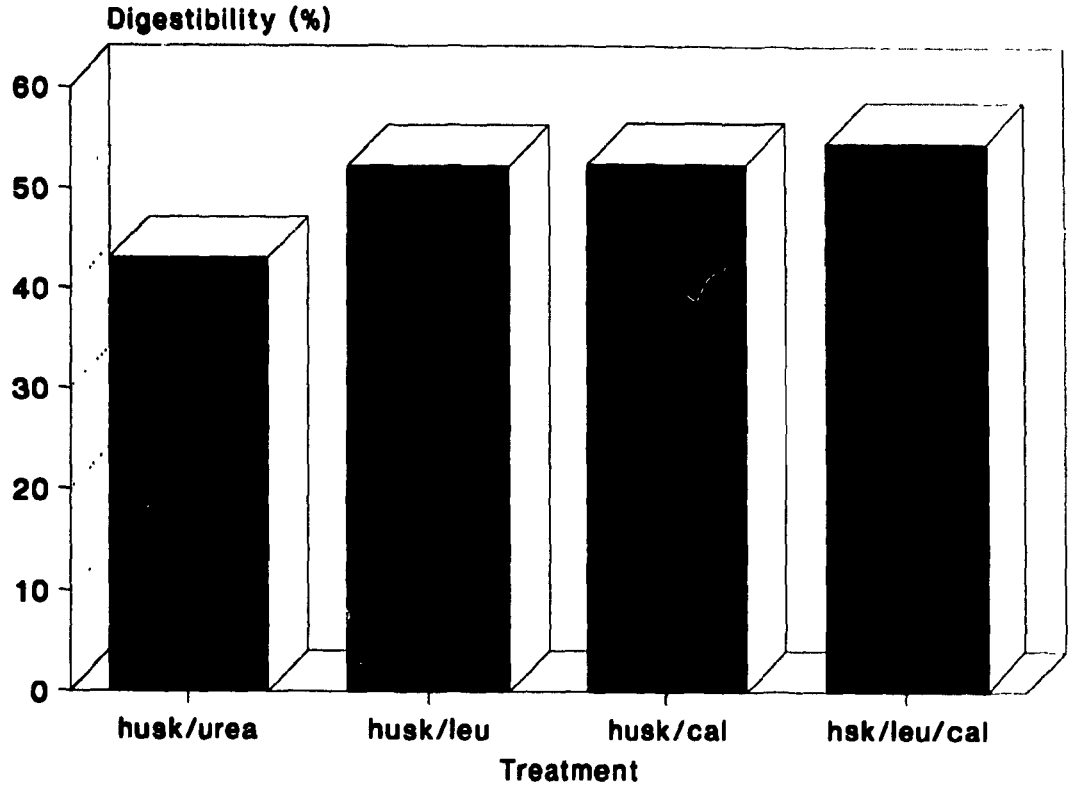

Figure 13. Mean acid detergent fibre digestibility (%) of rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal)

Table 6. Summary of the digestibility values (Experiment 2).

	Treatment				
	husk/urea	husk/leu	husk/cal	husk/cal/leu	S.E
Number	4	4	4	4	
Digestibility (%)					
DMD	46.7c	63.4 a	59.3b	59.8ab	2.5
OMD	53.9c	64.9 a	60.7b	61.9b	1.5
ADFD	43.1	52.2	52.4	54.5	7.6

S.E = Standard error

means in the same line with same letters are not significantly different (P>0.05).

DMD = Dry matter digestibility

OMD = Organic matter digestibility

ADFD = Acid detergent fibre digestibility

4.4.4 WEIGHT GAIN

The summary for the animal performance as a response to browse supplementation is shown in table 7 and Figure 14. Individual growth data is represented in Appendix 1.

The maize husk/urea treatment consumed by the goats in this experiment had a crude protein content of 7 %. This level of crude protein is considered adequate to meet requirements for maintenance only (National Research Council, 1989). There was in general, a considerable fluctuation in weight gain in this group as reflected by individual animal performance (appendix 1,table 1). Table 14 shows a decline in weight from week 1 to week 8 followed by a general improvement from week 8 to week 12. Overall there was an increase of 400 g from week 1 to week 12. This resulted in an average daily weight gain of 4.8 g/day.

The goats which were on maize husk plus leucaena showed a steady increase in weight from week 1 to week 12. At the end of the feeding experiment (week 12) they had gained 2400 g, average daily gain was 28.5 g. The animals in this group gained weight significantly ($P<0.05$) better than all the other groups.

The animals which were being fed maize husk plus calliandra had an average increase in weight from week 1 to week 4 of 660 g followed by a decline from week 4 to week 8 of 80 g. The reason for this decline could not be established from the experiment. However, there was an increase of 1000 g from week 8 to week 12. The average daily gain for this treatment was 19 g/day. The animals in this group did not perform as well as those that were

being fed maize husk plus leucaena and those that were being fed maize husk plus leucaena plus calliandra. However, they performed significantly ($P<0.05$) better than the animals that had no browse supplementation. The superior performance of leucaena may be due to the much lower acid detergent fibre (ADF) compared to calliandra.

The final group had maize husk plus leuacena plus calliandra. These animals showed a steady increase in weight gain, with an average weight gain of 22.6 g/day.

The findings of the present study are in agreement with the results from a study by Foster et al., 1983 in which they found that yearling and 2-year old cattle grazing *Heteropogon contortus* supplemented with leucaena (on a ratio of 1 ha of leucaena to 3 ha of native pasture) gained more weight than the unsupplemented cattle.

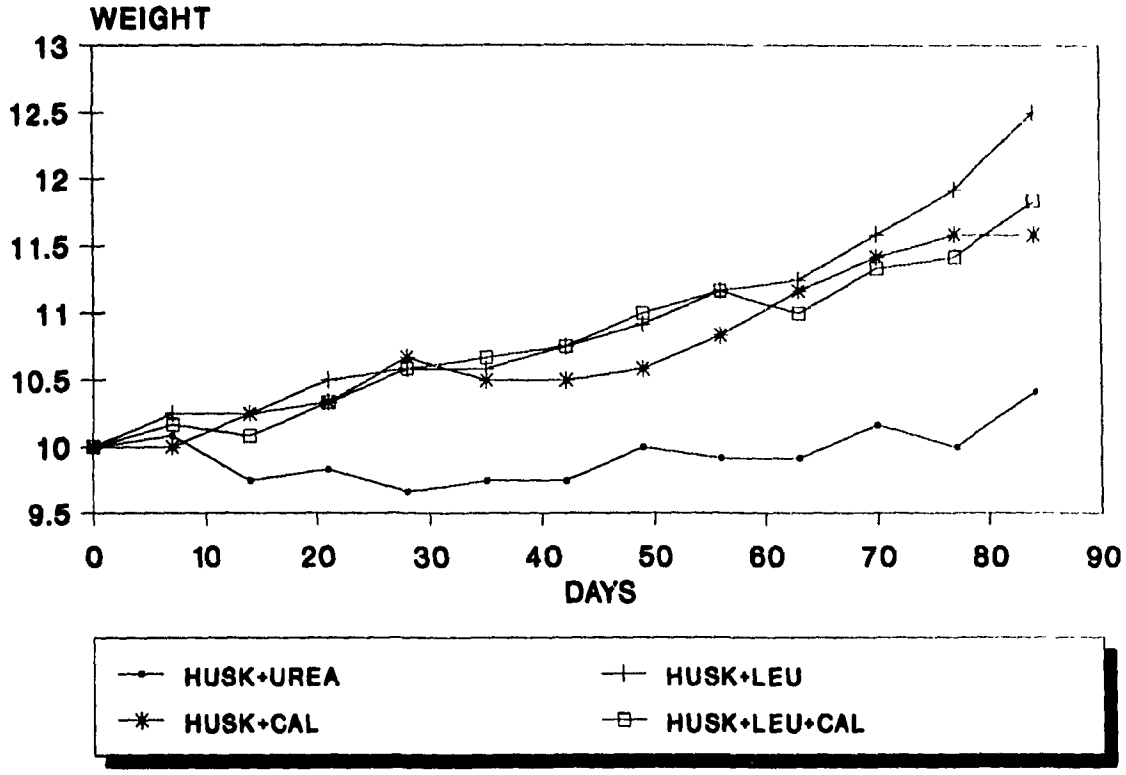

Figure 14. Cumulative weight gain (kg) of goats fed maize husk supplementd with urea, leucaena (leu) and / or calliandra (cal)

Table 7. Mean growth response of the goats fed rations of maize husk supplemented with urea, leucaena (leu) and / or calliandra (cal) during the twelve week period (Experiment 2).

	Treatment				
Item	Husk/urea	husk/leu	husk/cal	husk/leu/cal	S.E
animal weights during the feeding trial					
Number of animals	6	6	6	6	
Initial	10.0	10.0	10.0	10.0	
week 4	9.7	10.6	10.7	10.5	
week 8	9.5	11.2	10.6	11.2	
week 12	10.4	12.5	11.6	11.9	
Total gain(kg)	0.4	2.4	1.6	1.9	
Average daily gain(g)	4.8d	28.5a	19.0c	22.6b	0.2
Daily DM intake (kg)	0.25	0.33	0.32	0.32	
FE[a] (kg DM kg^{-1} gain)	52.1d	11.6a	16.8c	14.2b	

FE = Feed efficiency

means in the same line followed by the same letters are not significantly different (P>0.05).

4.5 CONCLUSION

The results of the study reported here indicate that leucaena and calliandra can increase diet dry matter intake and live weight gain. The results also indicate that though both are potentially valuable feed components *Leucaena leucocephala* is superior to *Calliandra calothrysus*.

Chapter 5.0

SUMMARY AND GENERAL CONCLUSION

The research herein reported involved the: (a) comparison of the voluntary intake of maize husk when it was (i) fed in mixture with *Leucaena leucocephala* and (ii) fed in separate feed troughs of either maize husk or leucaena. (b) use of leguminous browse species (*Leucaena leucocephala* and *Calliandra calothrysus*) as a protein supplement to maize husk used as ruminant feed.

The effects of the two methods of feeding and the use of the browse species as supplements were evaluated by measuring weight gains and simultaneously the digestibility and voluntary intake of maize husk and total dry matter intake. In both experiments the browse were hand harvested on daily basis. Maize husk and the browse specie were fed in 3:2 ratio (DM basis).

The average daily maize husk dry matter intake from the first experiment in period 1 was 201.7g and 204.2g for maize husk fed in mixture with leucaena (mixture) and in separate feeding troughs of either maize husk or leucaena (separate). In period 2 the values the values were 273.6g and 271.6g for the mixture and separate treatment. The values for total dry matter intake were 368.3g and 368.8g in period 1 and 353.3g and 353.3g in period 2 for the mixture and the separate treatments respectively. These results indicates no significant ($P>0.05$) difference in the two methods of feeding. The choice of which method to use should depend on the individual farmers' situation.

The digestibility values for diet dry matter were 46.7, 63.4,

59.3 and 59.7 for maize husk plus urea, maize husk plus leucaena, maize husk plus calliandra and maize husk plus leucaena plus calliandra respectively. Those for organic matter digestibility were 53.95, 64.99, 60.75 and 61.91 for maize husk plus urea (C), maize husk plus leucaena (T1), maize husk plus calliandra (T2) and maize husk plus leucaena plus calliandra (T3) respectively. Acid detergent fibre values were 43.11, 52.20, 52.45 and 54.55 for C, T1, T2 and T3 respectively. The browse supplemented diets varied significantly in dry matter and organic matter digestibility, but not in acid detergent fibre digestibility.

The average weight gains from the feeding trial were 4.9g, 28.7g, 18.5g and 18.5g for maize husk plus urea, maize husk plus leucaena maize husk plus calliandra maize husk plus calliandra plus leucaena respectively. There were significant difference in weight gain ($P<0.05$) between the browse and the non browse supplemented diets. During the dry season animals lose or simply do not gain weight due to low crude protein (Practchett et al. 1977) in the feeds. The present results indicates the feasibility of using the browse species as supplements for low protein feeds.

Ongoing agroforestry work at Mskera Research Station indicates that these browse species have also a great potential in soil improvement and fuel wood production (ICRAF Annual Report, 1989).

For the purpose of fodder production leucaena and calliandra could be planted in different configurations ie. i) pure stands ii) mixed with grasses and or herbaceous legumes in mixed or zonal arrangement (Agroforestry Research Project, 1987).

In conclusion the present study indicates the feasibility of using leucaena and or calliandra as protein supplements to improve the feed quality in dry season in the Eastern province of Zambia.

Chapter 6.0

6.1 FUTURE WORK

The results of the study reported here indicate that *Leucaena leucocephala* and *Calliandra calothyrsus* can successfully be used as protein supplement for goats indigenous to the Eastern Province of Zambia, commonly fed low quality roughage such as maize husk. Under these circumstances the agroforestry approach of incorporating woody perennial (trees and shrubs) into the existing farming systems may constitute a sound practise.

There is need now to determine the best management for the shrubs in order to maximise the production of edible dry matter during the dry season. There is also need to determine the optimum rate of supplementation and also how these supplements will be fed to a group of animals.

Literature cited

Adenosun, A.A., Jansen, H.J and Van Hontert, 1985. Goat management research at the University of Ife. In: Sheep and goats in humid West Africa, ILCA, Addis Ababa, Ethiopia pp 34-37.

Agricultural Research Council, 1980. The nutrient requirement of ruminant livestock. Commonwealth Agricultural Bureau, Farnham Royal

AFRENA, (1988) Agroforestry Research Project for the maize/livestock system in the unimodal upland plateau (Chipata/Katete) in the Eastern Province of Zambia.

Alvarez F.J, Apauche O and Preston T.R., 1978. *Leucaena leucocephala* as a protein supplement for sugar cane based diet: effects on fermentation and turnover rates. Tropical Animal Production. 3: 40-44.

Ammerman, C.B., Verde, G.J., Moore, J.E., Burns W.C and Chicco, C.F., 1972. Biuret, Urea and natural proteins as nitrogen supplements for low quality roughage for sheep. J. Animal Science 35: 121.

A.O.A.C., 1970. Official methods of analysis, 6th Ed. Association of Official Analytical Chemists. Washington D.C.

Balch ,C.C., 1977. The potential of poor-quality agricultural roughage for animal feeding. In: F.A.O Animal Production and Health Paper. Food and Agriculture organisation of the United Nations, Rome. pp 1-15.

Baumgardt, B. R., M. W. Taylor and J. L. Cason., 1962. Evaluation of forages in the laboratory. II. Simplified rumen procedures for estimating the digestible energy content of hays. J. Anim. Sci. 18: 1538.

Baker, H.A., 1969. Nutritive value of fresh and dried alfalfa and timothy at the early and late stages of maturity as measured by in vivo, invitro and chemical criteria. MSc Thesis, Macdonald College of Mc Gill University. 146p

Banda J.L.L and Ayaode J.A., 1986. Leucaena leaf hay (Leucaena leucocephala cv. Peru) as protein supplement for Malawian goats fed chopped maize stover. In: Better utilization of crop residues and by products in animal feeding. Research guidelines ed. Preston, T.R. Rome, Food and Agricultural Organisation of the U.N. 1986

Blunt, C.G. and Jones R.J., 1977. Steer live weight gains in relation to the time on the *Leucaena leucocephala* pasture. Tropical Grasslands 11: 159-64.

Braidt R.T., Klopfenstein T.J., 1986a. Evaluation of alfalfa corn

cob associative action. 1. Interaction between alfalfa hay and ruminal escape protein on growth of lambs and steers. J. Anim. Sci. 63: 902-910

Brewbaker, J.L., 1987. Leucaena: a multipurpose tree for tropical agroforestry. In: Agroforestry - a decade of development ed. H.A Steppler and P.K.R Nair, 1987.

Buchman, D. T. and R. W. Hemken., 1964. Ad libitum intake and digestibility of several alfalfa hays by cattle and sheep. J. Dairy Sci. 47: 861.

Brockington, N.R., 1960. Studies of growth of *Hyparrhenia* dominant grassland in Northern Rhodesia. J. Br. Grassland Soc. 15: 323-38.

Campling R.C., Freer M. and Bulch., 1962. Factors affecting the voluntary intake of food by cows. 111. The effect of urea on the voluntary intake of straw. Brit, J. Nutr. 16: 115.

Cochran R C, Delcarpio A J, Parker C F, Hallford B M, Vankeuren R W, Dehority B a, Vidal H and Cordero., 1984. Growth response of peruvian goats consuming varying levels of *Acacia mancracantha, Leucaena leucocephala* and corn stalks. Nutritional abstracts and review series B 54 (8): 495.

Coelho, M.B., 1982. Comparative foliage evaluation using infrared reflectance spectroscopy, microbial, enzymatic and chemical analyses. Ph D. Dissertation. Louisian State University, Baton Rouge.

Coombe J.B., Dinius D.A. Goering H.R. and Oltjen R.R., 1979. Wheat straw urea diets for beef steers: alkali treatment and supplementation with protein moneinsin and a feed intake stimulant. Journal of Animal Science 48: 1223-1233.

Cruickshank, G.J., Popi, D.P., Sykes A.R., 1985. Intake and duodenal protein flow in early weaned lambs grazing white clover, lucerne, rye grass and Prairie grass. Proc. of the Nz Society of Animal Production. 45: 113-116.

Devendra C., 1983. The nutritive value of *Leucaena leucocephala* (cv Peru) in balance and growth studies with goats and sheep. Nutrition abstracts and review series B 53 (12): 800.

Devendra C., 1984. Physical treatment of rice straw for goats and sheep and the response to substitution with variable levels of cassava (*Manihot esculente*), leucaena (*Leucaena leucocephala*) and gliricidia (*Gliricidia maculata*) forages. Nutrition abstracts and review series B 54 (9): 487.

Fernandez-Rivera, S, T.J Klopfenstein and T.L Thompson 1989b. A simulation model of forage yield, quality, intake and growth of growing cattle grazing cornstalks. J. Anim. Sci. 67: 581.

Ferraris, R., 1979. Productivity of *leucaena leucocephala* in the wet Tropics of North Queens land. Tropical Grassland 13: 20-27.

Fonnesheck, P. V., J. L. Christiansen and L. E. Harris., 1981. Factors affecting digestibility of nutrients by sheep. J. Anim. Sci. 52: 363.

Foster, A.H., Blight, G.W., 1983. Use of Leucaena leucocephala to supplement yearing and 2 year old cattle grazing spear grass in South East Queensland. Tropical Grassland, 17: 178.

Goering, H.K and P.J. Van Soest., 1975. Forage fibre analysis. Agr. Handbook

Hegarity, M.P., Lee, C.P., Chritie, G.S., Court, R.D. and Haydock, K.P (1979). The goitrogen 3-hydroxy-4 (H)-Pyridone, a ruminal metabolite from *Leucaena leucocephala*: effect in mice and rats. Aust. J. Biol Sci. 32, 27-40.

Hill G. D.,1971. *Leucaena leucocephala* for pastures in the tropics. Herb. Abst. 41: 111.

Hulman B, Owen E, Preston T.R., 1978. Comparison of *leucaena leucocephala* and groundnut cake as a protein source for beef cattle fed ad libitum molasse/urea in Mauritius. Tropical Animal Production 3: 1-8.

Hulman B and Preston T. R., 1981. Leucaena as a source of protein for animals fed whole sugar cane and urea. Tropical Animal Production 6: 318-321.

Hutton E.M and Beatlie W.M., 1976. Yield characteristics in three breed lines of the legume *Leucaena leucocephala*. Tropical Grasslands 10: 187.

ILCA (1983). Annual Report for 1982. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia.

International Council for Research in Agroforestry (ICRAF) Annual Report., 1989.

Jones R. J., 1979. The value of *Leucaena leucocephala* as a feed for ruminants in the Tropics. World Animal Review 31: 12-22.

Jones R.J., and Hegarity, M.P., 1984. The effect of different proportions of *Leucaena leucocephala* in the diet of cattle

on growth feed intake, Thyroid function and urinary excretion of 3-hydroxy-4(1H)-pyrodone. Australian Journal of Agricultural Research 35: 317-25.

Jones R.J., Blunt C.G. and Nurnberg., 1978. Toxicity of *Leucaena leucocephala*. The effect of iodine and mineral supplements on penned steers fed sole diet of leucaena. Aust. Vet. J. 54 (8): 387-392.

Jones, R.J. and Megarity, R.G., 1983. Comparative toxicity responses of goats fed *leucaena Leucocephala* in Australia and Hawaii. Australian Journal of Agricultural Research 34: 781-790.

Jones R.J. and Megarity, R.G., 1986. Successful transfer of DHP degrading bacteria from Hawaiian goats to Australian ruminants to over come the toxicity of leucaena. Australian Veterinary Journal 63: 259-63.

Joshi, D.C and Upadhyay R.B., 1976. *Leucaena leucocephala* an ever green protein rich tree fodder and the possibility of using it in the dietary animals 1. Sheep Indian Vet. J. 53: 606-608.

Kang H. S., Yoo T. S and Choi S. Y., 1982. A study on the nitrogen metabolism and energy digestibility with the Korean native

goats fed acacia leaf hay. Nutrition abstracts and reviews Series B 52 (9): 553.

Kempton, T.J. and R.A. Leng., 1979. Protein nutrition of growing lambs, Response in growth and rumen function of supplementation of Low - Protein - Cellose Diet with Either Urea, Casein or Formaldehyde treated Casein.Br. J. Nut., 42: 289.

Klopfenstein, T., Owen F.G., 1981. Value and potential use of crop residues and by products in dairy rations. J. Dairy Sci. 64: 1250-1268.

Lance, R. D., D. C Foss, C. R. Krueger, B. R. Baumgardt and R. P. Niedermeir., 1963. Evaluation of corn and sorghum silages on the basis of milk production and digestibility. J. Dairy Sci. 47: 254.

Le Fevre, C. F. and L. D. A. Kamstra., 1960. Comparison of cellulose digestion in vitro and invivo. J. Anim. Sci. 19: 867.

Leng R.A and Peston T.R., 1976. Sugarcane for cattle production: present constraints, Perspective and Research Priorities. Tropical Animal Production. 1 (1): 1-22.

Lindahal, 1959. Methods employed in Nutrition research. Techniques and Procedures in animal production research. Soc. Anim. Prod. 117

Little, D.A., 1985. The dietary mineral requirements: Implication for the utilization of Tropical fibrous agricultural residues. In: The utilization of fibrous agricultural residues as animal feeds. (Ed. Doyle, P.T.) . Australian Government Printing Services, Canberra.

Minson D.J.,1967. The voluntary intake and digestibility in sheep, of chopped and pelleted *Digitaria decumbers* (Pangola grass) following a late application of fertilizer nitrogen. Brit. J. Nutr. 21: 587.

Ministry Agricultural Annual report, 1989. Lusaka, Zambia

Megarity R.G and Jones R.J., 1983. Toxicity of *Leucaena leucocephala* in ruminant: The effect of supplemental Thyroxine on goats fed on sole diet of leucaena. Aust. J . Agric. Res. 34: 791-8.

Mosi A. K and Butterworth M. H., 1983. The use of *Trifolium tembense* to enhance crop residue utilization by ruminants. ILCA News letter 2(4): 5-6.

Mosely, G., 1974. The nutritive value of dried red clover as supplement for perennial ryegrass hay. Brit. J. Nutr. 32: 317-325.

Moxon A.L. and O.G. Bently, 1953. Some discrepancies in AOAC crude fibre and nitrogen-free extract values in roughages. J. Anim. Sci. 12: 925.

National Academy of Science, 1977. Leucaena: Promising forage and Tree crop for the Tropics. National Academy of Science Washington, DC.

National Academy of Science Press, 1983. Calliandra. A versatile Small Tree for the Humid Tropics. Washington, DC.

National Research Council. Nutrient requirements of dairy cattle. Sixth Revised Edition Update 1989.

N'gambi, J.W. (1988) Evaluation of sodium hydroxide treated straw for cattle. Ph.D. Thesis University of London.

Owen, E., 1976. Farm wastes; Straw and other fibrous materials. In: A.N. Duckham, J.G.W Jones and H.E Roberts (Ed.). Food Production and Consumption: The Efficiency of Human Food Chains and Nutrient Cycles pp 299-318. North Holland Publ Co., Amsterdam

Paterson, J.A., Klopfenstein T.J and Britton R.A., 1982.

Digestibility of sodium hydroxide treated crop residues when fed with alfalfa hay. J. Anim. Sci. 54: 1056-1066.

Pratchett, D., Capper, B.G., Light, D.E.,Miller, M.D., Rutheford, A.S., Rennie, T.W., Buck, N.G. and Trail, J.C., 1977. Factors limiting live weight gain on rangelands in Botswana. Journal of Range Management 30: 442-445.

Preston T.R and Leng R.A., 1986. Matching livestock production systems to available resources, ILCA, Ethiopia.

Research Branch Agriculture Canada, 1988. Canadian Farm Buildings Handbook. Publication 1822E.

Saenger P.F., Lemenager and Hendrix K.S., 1982. Anyhydrous ammonia treatment of corn and its effect on digestibility, intake and performance of beef cattle. J. Anim. Sci. 54: 419.

Smith G.A., 1966. Studies on hyporrhenia veld of Zambia. VII. The effect of grazing veld and dambo at different stocking rates. Journal of Agricultural Science, Cambridge 66: 49-56.

Smith O.B., 1987. Utilization of crop residues in the nutrition of sheep and goats in the humid tropics of West Africa. In: Sheep and goat production in the humid tropics of West

Africa, FAO Animal Production Health paper 70.

Sing H.K and Mudgal V.D., 1967. Chemical composition and nutritive value of *Leucaena glauca* (white popinac). Indian J. Dairy Sci., 20: 191-195.

Satter L.D. and B.R. Baumgardt, 1962. Changes in digestive physiology of the bovine associated with various feeding frequencies. J. Anim. Sci. 21: 897.

Steel R.G. and J.H. Torrie. 1980. Principles and procedures of statistics. A biometrical approach. 2nd Edition. McGraw-Hill Book Co. New York.

Thomas D.and Addy B.L., 1977. Tropical pasture legumes and animal production in Malawi. World-Rev-Anim-Prod. 13 (3): 47-52.

Ulyatt, M.J., 1973. The feeding value of herbage In: Buttler, G.W and Bailey, R.W. (Eds). Chemistry and Biochemistry of herbage Vol 3, Pg 131-178 London Academic Press.

Upadhyay V.S., Rekib A and Pathak P.S., 1974. Nutritive value of *Leucaena leucocephala* (Lam.) De wit. Indian Vet. J. 51: 534-537

van Eys J.E., Mathius I.W, Pongsapan P. and Johnson, 1986. Foliage of tree legumes gliricidia, leucaena and sesbania as supplements to growing goats. J. Agric. Sci., Camb. (1986) 107: 227-233.

Vander Noot, G. W., R. H. Cordts and R. Hunt, 1965. Comparative nutrient digestibility of silages by cattle and sheep. J. Anim. Sci. 24: 47

Van Soest, P.J., 1962. A rapid method for determination of fibre and lignin using detergent. USDA mimeo.

Van Soest, P.J., 1967. Development of comprehensive system of feed analysis and its application to forages. J. Anim. Sci. 26: 119-128.

Van Soet P.J., D. R. Mertens, 1977. Analytical parameters as guides to forage quality. Proceed. Internat. Meet. on animal production from Temperate grasslands.

Van Soet, P.J. 1982. Nutritional Ecology of the Ruminant. O and B Books, Inc., Oregon, USA 374 p.

Vearasilp T., 1981. Digestibility of rice straw Rations supplemented with *Leucaena leucocephala* and *Gliricidia maculata,* 1981. Thai J. Agric. Sci. 14: 259-264.

APPENDICES

APPENDIX 1. CUMULATIVE WEIGHT GAIN FOR THE INDIVIDUAL GOATS

Table 1.1 Cumulative weight gain of goats fed maize plus urea

	Animal number					
Days	537	508	210	213	230	530
1	9.5	10.0	9.0	10.5	10.0	11.0
7	9.5	10.0	9.5	10.5	10.0	11.0
14	9.0	10.0	9.5	9.5	9.5	11.0
21	9.0	10.0	9.5	9.5	10.0	11.0
28	9.5	9.5	9.0	10.0	10.0	10.0
35	9.5	9.5	9.0	10.0	10.0	10.5
42	9.0	10.0	9.0	9.5	9.5	11.5
49	9.0	10.0	9.5	10.0	10.0	11.5
56	9.5	9.5	9.5	10.0	10.5	10.5
63	9.5	9.5	9.5	10.0	10.0	11.0
70	9.5	10.0	9.5	10.0	10.5	11.5
77	9.5	9.5	9.0	10.0	10.5	10.5
84	10.0	10.5	9.5	10.5	10.5	10.5

Table 1.2 Cumulative weight gain of goats fed maize husk mixed with leucaena

	Animal number					
Days	538	506	504	529	170	534
1	11.0	9.0	10.0	10.5	10.0	10.0
7	11.0	9.5	10.0	10.5	10.0	10.5
14	11.0	9.5	10.0	10.5	10.0	10.5
21	11.5	9.5	10.5	11.0	10.0	10.5
28	11.5	9.5	10.5	11.0	10.0	11.0
35	11.0	10.0	10.5	11.0	10.5	10.5
42	11.5	10.0	10.5	11.5	10.5	10.5
49	11.5	10.0	11.0	11.0	11.0	11.0
56	12.0	10.5	10.5	11.5	11.0	11.5
63	12.0	11.0	11.0	11.5	10.5	11.5
70	12.5	11.0	11.5	11.5	11.5	11.5
77	12.5	11.5	11.5	12.0	12.0	12.0
84	13.0	11.5	12.0	12.5	12.0	12.0

Table 1.3 Cumulative weight gain of goats fed maize husk mixed with calliandra

	Animal no.					
Days	516	518	514	530	515	533
1	9.0	10.5	10.0	9.5	11.0	10.0
14	9.0	10.5	10.0	9.5	11.0	10.0
21	9.5	10.5	10.0	9.5	11.0	11.0
28	9.0	11.0	10.5	9.5	11.5	10.5
35	9.5	11.0	11.0	9.5	11.5	11.5
42	9.5	10.5	11.0	10.0	11.5	10.5
49	9.5	10.5	11.0	10.0	11.5	10.5
56	10.0	11.0	10.5	10.0	11.5	10.5
63	9.5	11.0	12.0	10.5	11.5	10.5
70	10.0	11.5	12.0	10.5	12.0	11.0
77	10.5	11.5	12.5	10.5	12.0	11.5
84	10.5	12.0	12.5	11.0	12.5	11.5

Table 1.4 Cumulative weight gain of goats fed maize husk mixed with leucaena and calliandra

	Animal no.					
Days	529	503	522	517	180	240
1	10.0	11.0	10.5	9.5	9.0	10.0
7	10.0	11.0	10.5	9.5	10.0	10.0
14	10.0	11.0	11.0	9.5	9.0	10.0
21	10.0	11.0	11.0	10.0	9.5	10.5
28	10.5	11.5	11.5	10.0	9.5	10.5
35	10.5	11.5	11.5	10.0	10.0	10.5
42	10.2	11.5	11.5	10.5	10.0	10.5
49	10.5	12.0	12.0	10.0	10.5	11.0
56	11.0	12.0	12.0	10.0	10.5	11.5
63	11.0	11.5	11.5	10.5	10.5	11.0
70	10.5	12.0	12.5	11.0	11.0	11.0
77	11.0	12.0	12.5	11.0	11.0	11.0
84	11.0	12.5	12.5	11.0	11.0	12.0

APPENDIX 2. WEEKLY CHEMICAL COMPOSTION OF MAIZE HUSK, LEUCAENA AND CALLIANDRA

Table 2.1 The weekly chemical composition of maize husk, *Leucaena leucocephala* and *Calliandra calothyrsus*

	Maize husk			Leucaena			Calliandra		
Time (weeks)	Ash	CP	ADF	Ash	CP	ADF	Ash	CP	ADF
1	3.9	4.0	30.0	10.6	28.0	22.6	7.8	24.4	46.2
2	3.9	4.0	30.0	10.6	28.1	22.6	7.7	24.4	46.2
3	3.9	4.0	30.2	10.7	28.1	22.6	7.7	24.4	46.2
4	3.9	3.8	30.1	10.6	28.1	22.6	7.9	24.8	46.2
5	3.9	4.0	30.0	10.8	27.8	22.6	7.8	24.4	46.2
6	4.0	4.0	30.0	10.7	27.9	22.6	7.8	24.4	46.3
7	3.9	4.0	30.0	10.7	27.8	22.6	7.8	24.4	46.3
8	3.9	4.0	30.0	10.7	27.9	22.7	7.7	24.4	46.3
9	3.9	4.0	30.0	10.7	28.0	22.5	7.8	24.4	46.3
10	3.9	4.0	30.0	10.7	28.0	22.7	7.8	24.4	46.3
11	3.9	4.0	30.0	10.7	28.0	22.7	7.8	24.8	46.2
12	3.8	4.2	29.7	10.6	28.3	22.9	7.8	24.4	46.3

APPENDIX 3. VOLUNTARY FEED INTAKE BY THE GOATS

Table 3.1 Mean daily intakes of (gm day^{-1}) of maize husk (period 1 & 2 EXPT 1)

period 1		period 2	
mixture	separate	mixture	separate
200.8	208.7	267.0	265.9
198.4	197.8	277.6	268.8
200.7	206.1	274.0	271.8
206.8	206.1	274.4	273.8
201.6	203.0	277.9	278.0
mean ± SD	201.7 ± 3.1	204.2 ± 4.3	273.6 ± 3.5	271.6 ± 4.8

mixture = maize husk plus leucaena (3:2) fed as a mixture

separate = maize husk plus leucaena (3:2) offered in separate troughs but at the same time.

SD = Standard deviation

Table 3.2 Mean daily intakes(gm day-1) of diet dry matter (period 1 & 2 EXPT 1)

period 1		period 2	
mixture	separately	mixture	separately
360.8	360.7	348.0	347.4
366.4	365.2	353.3	348.9
308.7	374.1	356.5	355.4
374.8	374.1	356.7	356.4
370.6	369.8	351.9	358.5
mean ± SD	368.3 ± 3.1	368.8 ± 5.4	353.3 ± 3.5	353.3 ± 4.8

mixture = maize husk plus leucaena (3:2) fed as a mixture

separate = maize husk plus leucaena (3:2) offered in separate troughs but at the same time.

SD = Standard deviation

Table 3.3 The means of average maize husk daily dry matter intakes expressed as g/day (Expt 2).

	Blocks				
Treatment	1	2	3	4	Mean ± SD*
husk/urea	250.4	250.5	245.8	251.4	249.7 ± 2.5a
husk/leucaena	150.3	150.1	148.4	147.9	149.2 ± 1.2b
husk/calliandra	149.2	145.9	147.5	146.2	147.2 ± 1.4b
husk/leu/cal	150.2	147.2	151.8	148.3	149.4 ± 2.0b

* means followed by the same later are not significantly different

SD Standard Deviation

Table 3.4 The means of average total daily dry matter intakes expressed as g/day (Expt 2).

	Blocks				
Treatment	1	2	3	4	Mean ± SD*
husk/urea	250.4	250.5	245.8	251.4	249.7 ± 3.9c
husk/leucaena	328.1	334.1	330.4	383.9	331.6 ± 2.8a
husk/calliandra	317.2	313.9	315.5	314.2	315.2 ± 1.9b
husk/leu/cal	318.2	315.2	319.8	316.3	317.4 ± 2.0b

* means followed by the same later are not significantly different

SD Standard Deviation

APPENDIX 4. DIGESTIBILITY VALUES FOR INDIVIDUAL GOATS IN EXPERIMENT 1

Table 4.1 Dry matter digestibility values for maize husk plus leucaena (3:2) fed as a mixture and separately (Period 1 and period 2)

	period 1		period 2	
	mixture	separate	mixture	separate
	62.0	61.3	64.5	64.9
	64.9	64.0	61.5	60.7
	62.2	60.3	61.6	61.9
	62.2	61.7	60.7	61.1
	64.4	64.7	60.6	61.1
mean ± SD	63.1 ± 1.4	62.2 ± 1.8	61.8 ± 1.5	61.9 ± 1.7

mixture = maize husk plus leucaena (3:2) fed as a mixture

separate = maize husk plus leucaena (3:2) offered in separate troughs but at the same time.

SD = Standard deviation

Table 4.2 Organic matter digestibility values for maize husk plus leucaena (3:2) fed as a mixture and separately (Period 1 and period 2)

	period 1		period 2	
	mixture	separate	mixture	separate
	64.0	62.8	66.2	66.7
	65.8	65.4	63.7	63.0
	64.0	62.1	62.7	63.9
	63.5	63.5	63.0	62.5
	66.2	66.1	63.2	62.8
mean ± SD	64.7 ± 1.2	64.0 ± 1.7	63.7 ± 1.4	63.8 ± 0.8

mixture = maize husk plus leucaena (3:2) fed as a mixture

separate = maize husk plus leucaena (3:2) offered in separate troughs but at the same

SD = Standard deviation

Table 4.3 Acid detergent fibre digestibility values for maize husk plus leucaena (3:2) fed as a mixture and separately (Period 1 and period 2)

	period 1		period 2	
	mixture	separate	mixture	separate
	51.5	48.6	52.1	57.3
	58.0	49.6	61.8	50.0
	49.8	50.2	55.0	55.1
	48.4	51.7	53.6	55.5
	54.1	57.0	52.1	55.8
mean ± SD	52.4 ± 3.7	51.4 ± 3.3	55.9 ± 3.7	55.9 ± 0.8

mixture = maize husk plus leucaena (3:2) fed as a mixture

separate = maize husk plus leucaena (3:2) offered in separate troughs but at the same

SD = Standard deviation

APPENDIX 5. DIGESTIBILITY VALUES FOR INDIVIDUAL GOATS (EXPT 2) Table 5.1 The means of average diet dry matter digestibility (Expt 2).

	Blocks				
Treatment	1	2	3	4	Mean ± SD*
husk/urea	54.3	45.6	43.2	43.5	46.7 ± 5.1c
husk/leucaena	63.4	62.6	62.3	65.2	63.4 ± 1.2a
husk/calliandra	60.5	59.9	57.9	58.5	59.2 ± 1.2b
husk/leu/cal	60.6	60.0	59.0	59.2	59.7 ± 0.7ab

* means followed by the same later are not significantly different

SD Standard deviation

Table 5.2 The means of average organic matter digestibility (Expt 2).

	Blocks				
Treatment	1	2	3	4	Mean ± SD*
husk/urea	57.3	53.5	53.6	51.2	53.9 ± 2.5c
husk/leucaena	65.0	64.2	63.8	66.9	64.9 ± 1.3a
husk/calliandra	61.7	61.4	59.0	60.0	60.7 ± 1.2b
husk/leu/cal	62.2	62.0	60.7	62.5	61.9 ± 0.7b

* means followed by the same later are not significantly different

SD Standard Deviation

Table 5.3 The means of average acid detergent fibre digestibility (Expt 2).

	Blocks				
Treatment	1	2	3	4	Mean ± SD
husk/urea	51.2	32.1	48.6	40.4	43.0 ± 8.6
husk/leucaena	52.8	49.0	51.4	55.5	52.2 ± 2.7
husk/calliandra	54.8	52.9	50.6	51.3	52.4 ± 1.9
husk/leu/cal	54.9	54.2	57.1	54.5	54.5 ± 1.5

SD Standard Deviation

APPENDIX 6. ANALYSIS OF VARIANCE TABLES

Table 6.1 Analysis of variance for husk dry matter intake

source	df	ss	ms	F	P>F
Total	15	30621.86			
Block	3	7.74	2.58	0.67	0.59
Treatment	3	30579.28	10193.09	2633.84****	0.0001
Error	9	34.83	3.87		

**** Significant at (P<0.0001)

Table 6.2 Analysis of variance for diet dry matter intake

Source	df	ss	ms	F	P>F
Total	15	15797.01			
Block	3	9.37	3.12	0.35	0.79
Treatment	3	15706.72	5235.57	582.34	0.0001
Error	9	80.91	8.99		

**** Significant at (P<0.0001)

Table 6.3 Analysis of variance for dry matter digestibility

Source	df	ss	ms	F	P>F
Total	15	730.44			
Block	3	36.81	12.27	2.01	0.18
Treatment	3	638.55	212.18	37.79****	0.0001
Error	9	55.06	6.11		

**** Significant at (P<0.0001)

Table 6.4 Analysis of variance for organic matter digestibility

Source	df	ss	ms	F	P>F
Total	15	291.83			
Block	3	10.40	3.46	1.50	0.27
Treatment	3	260.63	86.87	37.60****	0.0001
Error	9	20.79	2.31		

**** Significant at (P<0.0001)

Table 6.5 Analysis of variance for Acid Detergent Fibre digestibility

Source	df	ss	ms	F	P>F
Total	15	1230.55			
Block	3	477.01	159.00	2.76	0.10
Treatment	3	234.61	78.20	1.36	0.31
Error	9	518.92	57.65		

Table 6.7 Analysis of variance for weight gain

Source	df	ss	ms	F	P>F
Total	23	13.65			
Block	5	0.59	0.11	4.89***	0.0075
Treatment	3	42.69	4.23	174.14****	0.0001
Error	15	0.36	0.0024		

**** Significant at (P<0.0001)