# EVALUATION OF *LEUCAENA DIVERSIFOLIA* AS DRY SEASON FEED SUPPLEMENT FOR LACTATING DAIRY CATTLE



BY

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# ABSTRACT

A series of four experiments were conducted in sequel to evaluate the merits of *Leucaena diversifolia* as a dry season feed supplement for lactating dairy cows in Mbeya region. In experiment 1, the biomass yield of *Leucaena diversifolia* was evaluated from 7 500 seedlings established on 1.45 ha of land at ARI-UYOLE. Parameters recorded were length of the tree (LOT), number of branches (NOB) and length of the longest branch (LOLB). Experiment 2 was a rumen metabolism study whereby botanical fractions from bean straw and maize stover were evaluated for degradability characteristics and *in vitro* dry matter digestibility (IVDMD) using Friesian-Boran cattle. Experiment 3 was a feeding trial in which four non-pregnant lactating Friesian cows were offered, 15, 20, 25 and 30 % of *Leucaena diversifolia* as a supplement in a change over arrangement to assess the effects of incremental levels of *Leucaena diversifolia* inclusion on *in vivo* digestibility of maize stover and bean straw diets. In experiment 4, eighteen lactating Friesian cows divided into three treatment groups of six cows each were used to evaluate the effects of increasing rates of offer on feed selectivity, intake and milk yield. *Leucaena diversifolia* was offered as a supplement to nine cows but was not given to the other nine using maize stover and bean straw basal diets. The results showed that 74.04 % of the total variability in edible material yield for *Leucaena diversifolia* trees was accounted for by variation in length of the tree (LOT), number of branches (NOB) and length of the longest branch (LOLB). Yields for edible material and wood in a primary cut stood at 3.5 and 10.1 tons DM/ ha, respectively. The dry matter (DM) potential fermentable contents in maize stover botanical fractions varied significantly (p<0.001) and were 814.1, 754.5, 666.5, 644.6, 622.5 and 572.8 g/kg for maize stover sheath (MS5)>maize stover leaves (MS3)> whole plant maize stover (MS1)> maize stover ear (MS4)> maize stover stalk (MS2)> and maize stover tassels (MS6), respectively. The corresponding ranking for bean straw botanical fractions were 826.1, 626.5 and 425.4 g/kg DM for bean straw pods (BSP2)> whole plant bean straw (WBS3)> and bean straw stem (BSS1), respectively. Dry matter degradability (48 hr incubation) of

*Leucaena diversifolia* was: 433.7 g/kg. With an apparent rumen degradable protein (RDP) of about 600 g/kg DM in *L. diversifolia*, the remaining 400 g/kg DM could arrive as undegradable protein (UDP) for intestinal digestion. In *in vivo* digestibility experiment, dry matter digestibility (DMD) and neutral detergent fibre digestibility (NDFD) were sgnificantly ($p<0.05$) improved with increasing levels of *Leucaena diversifolia* leafmeal supplementation from 15 to 30 % on dry matter basis for both bean straw and maize stover diets. In experiment 4, lactating cattle consumed 82% more of bean straw when offer rate was raised from 30 to 50 g DM/kg $M^{0.75}$. The animals tended to produce somewhat more milk when supplemented with *L. diversifolia* leaf meal and when offered higher offer rates of bean straw i.e. 40 and 50 g DM/kg $M^{0.75}$. Similar trends were apparent for the maize stover based experiment. When supplemented with *L. diversifolia* leaf meal, bean straw and maize stover can be sufficiently metabolized to support 0.7 and 0.5 kg milk /kg DM intake, respectively. The study has shown that *Leucaena diversifolia* can be promoted as a dry season protein supplement for lacatating dairy cattle for high altitude areas in Tanzania.

# DECLARATION

I, **PILIKA ANDREW MWAKILEMBE**, do hereby declare to the Senate of Sokoine University of Agriculture that the thesis presented here is my own original work and that it has not been submitted for a degree award to any other University.

**Signature** ....................................

**Date** 11/october 2004

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# DEDICATION

This thesis is dedicated to my parents Andongwisye Mwakilembe and Jestina Kapesa.

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# LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| ADF | Acid detergent fibre |
| ADG | Average daily gain |
| ADL | Acid detergent lignin |
| a.m. | Before noon (Latin *ante meridiem*) |
| ANIM. | Animal |
| AO1 | Amount of feed offered at 30 g DM/kg liveweight |
| AO2 | Amount of feed offered at 40 g DM/kg liveweight |
| AO3 | Amount of feed offered at 50 g DM/kg liveweight |
| AOAC | Association of Official Agricultural Chemists |
| ARI-UYOLE | Agricultural Research Institute, Uyole |
| ATP | Adenosine triple phosphate |
| BSP2 | Bean straw pods |
| BSS1 | Bean straw stem |
| BW | Body weight |
| °C | Degrees centigrade |
| Ca | Calcium |
| CF | Crude fibre |
| cm | Centimetre |
| Co | Cobalt |
| CP | Crude protein |
| CPD | Crude protein digestibility |
| cv | Cultivar |

| | |
|---|---|
| Diges. | Digestibility |
| DM | Dry matter |
| DMD | Dry matter digestibility |
| DMI | Dry matter intake |
| DOM | Digestible organic matter |
| EE | Ether extract |
| Eff. Degr. | Effective degradability |
| Fac. | Faeces |
| Fe | Iron |
| GE | Gross energy |
| GLM | General Linear Model |
| ha | Hectare |
| hrs | Hours |
| I | Iodine |
| ILCA | International Livestock Centre for Africa |
| INIT. | Initial |
| IVDMD | *In vitro* dry matter digestibility |
| IVOMD | *In vitro* organic matter digestibility |
| K | Potassium |
| kg | kilogramme |
| LACTNO. | Lactation number |
| LACTWK | Lactation week |
| LD1 | *Leucaena diversifolia* (whole leaf) |
| LD2 | *Leucaena diversifolia* (leaflets) |

| | |
|---|---|
| LOLB | Length of the longest branch |
| LOT | Length of tree |
| LRC | Livestock Research Centre |
| LSMEANS | Least square means |
| m | Metres |
| $M^{0.75}$ | Metabolic body weight |
| $M^2$ | Square metres |
| $M^3$ | Cubic metres |
| MAFF | Ministry of Agriculture, Fisheries and Food |
| MB | Maize bran |
| ME | Metabolisable energy |
| Mg | Magnesium |
| MJ | Mega joules |
| MM | Maize meal |
| mm | Millimetre |
| Mo | Molybdenum |
| MOAC | Ministry of Agriculture and Cooperatives |
| MPTs | Multipurpose trees |
| MS | Mean square |
| MS1 | Maize stover, whole plant |
| MS2 | Maize stover, stalk |
| MS3 | Maize stover, leaves |
| MS4 | Maize stover, sheath |
| MS5 | Maize stover, ear |

| | |
|---|---|
| MS6 | Maize stover, tassels |
| MT | Metric tones |
| N | Nitrogen |
| Na | Sodium |
| NAS | National Academy of Sciences |
| NDF | Neutral detergent fibre |
| NDFD | Neutral detergent fibre digestibility |
| NDFN | Neutral detergent Fibre nitrogen |
| NDSN | Neutral detergent soluble nitrogen |
| NFE | Nitrogen free extrcat |
| NOB | Number of branches |
| NORAD | Norwegian Agency for Develpoment |
| NPN | Non protein nitrogen |
| NS | Not supplemented |
| OFI | Oxford Forestry Institute |
| OM | Organic matter |
| P | Phosphorus |
| p.m. | After noon (Latin *post meridiem*) |
| pH | Measure of the acidity or alkalin |
| PhD | Doctor of philosophy (Latin, philosophiae doctor) |
| Pr>F | Probability level (F test) |
| Reten. | Retention |
| S | Sulphur |
| S.e.d. | Standard eror of difference |

| | |
|---|---|
| SAS | Statistical Analysis Systems |
| SD | Standard deviation |
| Se | Selenium |
| SEM | Standard error of the mean |
| SP | Supplemented |
| SS | Sums of square |
| SSC | Sunflower seed cake |
| Std Err | Standard error |
| SUA | Sokoine University of Agriculture |
| Suppl. | Supplement |
| TARP II SUA | Tanzania Agricultural Research Project phase II-SUA |
| TBY | Total biomass yield |
| WBS3 | Bean straw, whole plant |
| Zn | Zinc |

# CHAPTER ONE

## 1.0: INTRODUCTION

The present study was carried out at Agricultural Research Institute Uyole (ARI-UYOLE) in Mbeya region. The region is located in the South Western corner of the Southern Highlands of Tanzania. Mbeya region lies between latitudes 7° and 9° 31 % South of Equator and between longitudes 32° and 35° East of Greenwich (Pratt and Gwyne 1977). According to Mussei et al., (1999), ARI-UYOLE is part of agro-ecological Zone 1, designated as Mbeya stepped plain (10), characterized with undulating rolling lava plain. The altitude at ARI-Uyole is 1850 m.a.s.l. Rains-fall pattern is unimodal type and annual amounts ranges between 1100-1400 mm. The growing period starts from December through to June while the temperature regime is isothermic (12-23 °C), (appendix 2 and 3). Soils are mainly brownish loams (Haplic Andosol). Overall, the land is suitable for the production of maize, beans, wheat, pyrethrum, potatoes and barley. As for livestock production, the climate is highly suitable for dairying, non-ruminants as well as both dairy and beef goats.

According to the Ministry of Agriculture and Cooperatives report (MOAC, 1999), the population of livestock in Tanzania in 1995 was estimated at 15.6 million cattle, 10.7 million goats, 3.5 million sheep, 435,000 pigs and 26 million chickens. Most of this livestock is dominated by local types. In Tanzania, dairy cattle production is dominated by smallholder improved cattle farmers and traditional pastoralists. Total milk production from indigenous/traditional sector is estimated at 643,000 MT (equivalent to 79%) while milk produced from improved cattle is estimated at 171,000 MT (equivalent to 21%). Though the contribution from improved cattle sector is only 21% of the total milk output, it is estimated that it contributes 95 % of the marketed milk. This implies that most of the milk produced by the traditional sector is consumed at home and very little is supplied to the market. With this background, it is clear that still there exists enormous potential to increased milk output from smallholder improved dairy cattle farmers.

According to the Mbeya region socio-economic profile (MRSP, 1997), the dairy cattle population increment between 1991-2000 was estimated at 9.25 % while the national increment during the same period stood at 6.5%. However, despite this superior increment, Mbeya region had a deficit in milk supply of about 11,627,427 litres in 1995. Generally in the Southern Highlands Zone maize stover and bean straw are the most important crop-residues for dry season feeding. Statistics show that Mbeya region produced 221 973 tons of maize grain and 26 024 tons of beans in 1997 (MRSP, 1977). At harvest index of vegetative DM: Grain DM of 3:1 and 4:1 for maize stover and bean straw, respectively as shown by (Kossila 1984), it can be estimated that at least 665 920 tons of maize stover and 104 095 tons of bean straw were garneted as crop residues. These residues constitute the most important feed resources available during the long dry season of June-December.

Smallholder mixed crop-livestock farming is the dominant production system and it is characterized by declining land availability for fodder production due to increasing human population pressure. Under these circumstances, maize stover and bean straw will continue to be the major feed resource base for dry season feeding for improved cattle production by smallholder farmers. However, nutritional deficiencies in crop-residues have been established and documented widely. For instance Owen and Jayasuriya (1989), Nicholson (1984) and Doyle et al. (1986a) have shown that cereal straws and other crop-residues are characterized by low digestibility (< 50 %), hence low metabolisable energy content (< 7.5 MJ / kg DM), low crude protein content (< 60 g / kg DM) and low content of available minerals and vitamins.

According to Tolera (2001), the integration of livestock with crop production is a means of establishing a sustainable production system that aims at optimizing resource use. While livestock greatly influence the ability of farmers to produce food and cash crops through draft power, cash availability and manure, crop-residues play a critical role in ruminants nutrition especially during the dry seasons, a scenario that is likely to increase as more grazing land is put under cultivation due to rapidly increasing human population pressure. Thus strategic research on optimizing the use of locally and abundantly produced feed resources and educating the smallholder farmers on the best ways of utilizing these byproducts will strengthen/improve the feed availability during the dry season.

In Tanzania, several technical approaches have been attempted to improve the nutritive value of low quality roughages including crop-residues and these included chemical treatment of maize stover and maize cobs using sodium hydroxide (Urio, 1977; Kategile, 1979), treatment of maize stover, wheat straw and rice straw with ammonia (Kiangi, 1981). Also, bean straw has been treated with urea by Mgheni et al., (1991) while Msangi (1993) used locally produced "magadi" (sodium-containing compound) to up-grade the feeding value of maize stover. Supplementation of crop-residues has also been researched extensively. Three types of supplementation strategies have been distinguished and studied. Firstly, energy and protein supplementation using conventional concentrate feeding stuffs such as un-decorticated cotton seed cake, maize bran, and maize meal at Mpwapwa Research Center, Tanzania (Goodchild, 1981) and at SUA, Morogoro (Laziga, 1991). Kategile (1981) used a combination of cassava and ammonia to supplement maize cobs and maize stover based rations. Secondly is the use of forage from legume multipurpurpose trees such as *Leucaena leucocephala* (Mero, 1990, Ndemanisho, 1992 and Kimambo et al.1992). Thirdly, multi-nutritional blocks such as those made up of urea-molasses have also been investigated as supplements.

However, farmers up-take of some of these technical packages and in particular application of chemical treatment has been minimal or non-existent in most rural areas in the Southern Highlands Zone. Similarly, use of conventional concentrates such as sunflower seed cake, rice-polish, and maize bran is on only limited scale in most rural areas of Southern Highland because of their high prices. *Leucaena leucocephala* as a protein supplementary feed is now threatened by infestation with *Leucaena* psyllid (*Heteropsylla cubana*) and the plant does not perform well in high altitude areas. Recently, research was initiated on lesser-known and psyllid resistant *Leucaena* species and provenances to overcome the limitations associated with the psyllid problems in *Leucaena leucocephala*. Twenty two accessions of *Leucaena* materials were introduced from the university of Hawaii (Brewbaker materials) for evaluation for environmental adaptability, fodder production potential, forage quality and psyllid tolerance (Ostyssina et al., 1997). Of the 22 accessions, *Leucaena* *diversifolia* shows promise for higher altitude areas in Tanzania. Its growth performance in the field at ARI-UYOLE, has shown promising results. *L. diversifolia* originates from Mexico (Hughes, 1990). Due to this, the tree has been widely distributed in various locations of the southern Highlands mainly for soil stabilization in badly eroded areas and as a source of fodder for small holder dairy cattle. However, its use as a dry season protein supplement for zero-grazed dairy cattle in Mbeya region is almost unknown.

Leguminous trees can constitute a useful source of high quality feed for ruminants (NAS, 1977; Chadhokar, 1982; Jones and Hegarty, 1984; Ademosun et al., 1988). It is well known that legume MPTs have leaves with high protein content (> 180 g CP/kg DM ) and are better able to retain feeding quality than tropical grasses especially during dry periods. Their roles in integrated crop-livestock production systems have been advocated (Kang et al., 1981; Reynolds et al., 1988). Thus *Leucaena diversifolia* in the form of a leaf meal could be a cheap source of nitrogen and a feasible supplement for dry season feeding of smallholder dairy cattle production under the conditions prevailing in Southern highlands of Tanzania.

Animals eating heterogeneous forages e.g. maize stover generally select the more nutritional parts. The intensity of selection depends on the degree of freedom that the animal has in choosing the materials to consume. Studies by Aboud et al., (1993), Dutta et al., (2000), Osafo et al., (1990), and Wahed et al., (1990) have shown that increasing the rate of offer had the twin effects of improved intake and increased rate of wastage.

Many tropical plants exhibit extreme morphological differentiation between tissues e.g. between leaves and stems. No systematic studies have been carried out to evaluate nutritive values of botanical fractions, whole crop residues and adapted legume multipurpose trees for dry season feeding in the Southern Highlands zone. The present study was therefore set-up to evaluate the merits of *L. diversifolia* leaf meal as a dry season feed supplement for lactating dairy cattle using maize stover and bean straw as basal diets and to characterize the potential nutritive value of different botanical fractions of maize stover and bean straw and commonly used concentrate feeds using different feed evaluation techniques for ruminants. The study had the following more specific objectives:

(a) To determine the potential biomass yield of *Leucaena diversifolia* trees

(b) To describe *in sacco* rumen degradation characteristics and estimate *in vitro* metabolisable energy of maize stover and bean straw botanical fractions and concentrate feeds

(c) To assess the effects of different levels of *Leucaena diversifolia* inclusion on digestibility *in vivo* for bean straw and maize stover basal diets

(d) To determine the additive effects of *Leucaena diversifolia* supplementation and rate of offer of bean straw and maize stover on feed selectivity, intake and milk yield by lactating cows

# CHAPTER TWO

## 2.0: LITERATURE REVIEW

### 2.1: Biomass production

**Introduction:**

Biomass yield of forage materials is one of the primary parameters defining feed availability and sustainability. Ideally, biomass yield should be distributed such that there is consistent and continuous supply of feed throughout the animal production calendar. Studies in East Africa have concentrated mainly on estimates of biomass yield from grass species and herbaceous legumes and little attention has been paid on tropical legume trees and browses (Mero, 1997). A few studies on legume trees and browses have focused on established species many of which were recently introduced from the Caribbean. Among them is *Leucaena leucocephala* and *Gliricidia sepium*. *Leucaena leucocephala* has been shown to be widely adaptive in Tanzania, but had been severely attacked by psyllid beetles *(Heteropsylla cubana)*. According to Hughes (1998), total leaf loss and blackened stems are common observations in severe psyllid infestation. Recently another member of the *Leucaena* genus i.e. *Leucaena diversifolia* was introduced in the Southern highlands of Tanzania. Initial adaptive trials in Tanzania have shown that *L. diversifolia* is more tolerant to the psyllid infestation than *L. leucocephala* (Ostyssina et al., 1997). Similar observations were reported by Hughes (1998) and showed psyllid resistance scores of 2-5 that was defined as moderate resistance. However, little has been reported on biomass yield potential for MPTs including *L. diversifolia*. This review discusses aspects of botanical description, ecological distribution, use of *L. diversifolia* and biomass production from selected MPTs and other herbaceous legumes.

### 2.1.1: Botanical description, ecological distribution and use of *L. diversifolia*

*Leucaena diversifolia (Schltdl.) Bentham*) belongs to the family Leguminosae and sub-family Mimosoideae (Brewbaker et al., 1988). *Leucaena diversifolia* contains two sub-species i.e. *L. diversifolia var. diversifolia* (which resembles *L. leucocephala)* by being self-fertile and "tetraploid", (2n = 104) and *L. diversifolia* var. *Trichandra* (sometimes referred to as *L. diversifolia var. Stenocarpa*) that is out-crossing and has half as many chromosomes (diploid) (Hughes, 1998). It is noted that the sub-specific division is important since the breeding methods used to improve each subspecies are very different. *L. diversifolia* grows to a maximum height of 8.20 m attaining this height at 4 years, it is a perennial legume tree with the following leaves characteristics: pinnae (14-) 16-24 (-28) pairs; pinnular rachis (3.5-) 5-7 (-8) cm long, densely covered with white hairs; leaflets (2.9-) 4-5.5 (-7) mm long, (0.6-) 0.8-1 (-1.2) mm wide, (43-) 48-58 (-62) pairs per pinna, linear-oblong, acute at apex, strongly asymmetric at base, glabrous except hairy margins and a deep brown bark (Hughes 1998). According to Brewbaker et al., (1988), the stem may reach up to 50 cm bole diameter at three years, thus it is usually slender with a light but spreading crown. Plate 2.1 shows a stand of *L. diversifolia* at one year of age while Plate 2.2 shows a close-up of a branch.

Plate 2.1: A stand of *L. diversifolia* at one year.

Plate 2.2: A close-up of *L. diversifolia* branch.

Unlike *L. leucocephala*, which frequents hot lowlands altitudes (sea level up to 1000 m), *L. diversifolia* colonizes higher altitudes (700 to 2500 m), cooler and seasonally wetter sites. Its performance in highland trials is good (Brewbaker et al., 1988). *L. diversifolia* is not frost tolerant and is known to be drought sensitive (Bray et al., 1988). It performs best on fertile (maize growing) soils, but also colonizes infertile ones but does not appear to be tolerant of saline or sodic soils. Available records show that the native distribution of *Leucaena diversifolia* extends from Eastern and Central Mexico (Vera Cruz and Puebla) south through Guatemala, Honduras and into Nicaragua (Hughes, 1998). It is also indicated that *L. diversifolia* has been introduced outside its native range in historical times (pre- 1900) into Jamaica, Martinique and Indonesia (Urban, 1900; Adams, 1972). More recently, it has been more widely introduced as a reforestation species for wood and leaf fodder in tropical highland regions to complement the more tropical *Leucaena leucocephala* (Brewbaker and Sorensson, 1994). This legume tree was introduced in Tanzania during 1992 / 93 growing season when twenty two accessions of *Leucaena* Oxford Forestry Institute (OFI) materials including *L. diversifolia* from the university of Hawaii were introduced at Tumbi Research station mainly for environmental adaptability, production potential, forage quality and psyllid tolerance evaluation (Ostyssina et al. 1996). In the present study, biomass determination and use of *L. diversifolia* leaf meal as a dry season proteinous supplement in dairy cattle feeding systems for smallholders are being investigated.

*Leucaena diversifolia* has been cultivated usually as a shade tree over coffee plantations in Guatemala. Unripe pods are occasionally harvested and consumed though not on the same scale as some other species of *Leucaena* (Hughes, 1998). *L. diversifolia* has been used in ways similar to *L. leucocephala* for both fodder and wood. Again due to its light crown, makes it an ideal species for shade over perennial crops such as coffee and this has been one of the main uses in Jamaica and Papua New Guinea. *L. diversifolia* is also a promising parent in artificial hybridization and its hybrid with *L. leucocephala*; designated KX3 by the University of Hawaii is the most widely used seed source (Brewbaker et al., 1988). It is also used for soil improvement and stabilization, alley cropping and agro-forestry, pasture improvement, posts and pulpwood.

### 2.1.2: Biomass yield from selected legume trees and shrubs and herbaceous legume plants

In a preliminary biomass study at Tumbi Tabora, it was reported that fodder production varied significantly among species and hybrids whereby *Leucaena diversifolia* No. 8, *Leucaena* hybrid KX3a (Wainamalo), *Leucaena diversifolia* K 156 and *L. pallida* from Hawaii consistently gave higher fodder yields (4-8 tons DM / ha), Ostyssina et al., (1997). It was further noted that the species and hybrids also showed good coppicing ability and tolerance to repeated cutting. Similarly, Karachi (1997) working also at the same station demonstrated variation in the proportion of leaf in the total dry matter among *Leucaena* lines including *L. diversifolia* and results are summarized in Table 2.1.

**Table 2.1: The proportion of leaf in total dry matter among selected *Leucaena* lines**

| Line | % Leaf |
|---|---|
| ***L. leucocephala*** | |
| cv. Cunningham | 59.2 |
| cv. Peru | 58.5 |
| cv. K8 | 57.3 |
| CPI58396 | 53.6 |
| K1 | 54.9 |
| T1 | 55.6 |
| Korog | 53.4 |
| K88A | 50.6 |
| ***L. diversifolia*** | |
| CPI85312 | 47.9 |
| NO8 | 46.3 |
| NO 156 | 45.9 |
| ***L. esculenta*** | |
| CPI91309 | 47.3 |
| ***L. pallida*** | 44.7 |

**Source: Karachi (1997)**

Table 2.1 shows that *L. leucocephala* lines with leaf content values ranging between 51-59 % were superior to all other *Leucaena* species. Inherently lower values for the leaf proportion in legume foliage will negatively influence the leaf: stem ratio, an index of nutritive value for most forage. In another development, Man et al., (1995) while working in Vietnam investigated on biomass production of some leguminous shrubs and trees and results obtained are presented in Table 2.2. Apart from its superior biomass yield, *Acacia auriculiformis* was shown to be less palatable possibly due to its poor DM digestibility (Bui Xuan An et al., 1992). On the other hand, although *L. leucocephala* performed the poorest on both edible and total biomass yield but is shown to be readily consumed by goats. This suggests that evaluation of legume multipurpose trees and shrubs in the tropics should consider both biomass yield and nutritive value before they can be widely adapted in different farming systems. Chadhokar (1982) highlited that frequent fodder harvests in the early years of *Gliricidia sepium* establishment may reduce biomass yield in later years and recommended that, during the first to three years of establishment, foliage be harvested only once or twice a year.

**Table 2.2: Accumulated (3 harvests) production of edible parts and stem in kg DM/ ha of seven tree legumes for a 16 months period in Vietnam**

| *Legume trees* | Edible leaf | Stem | Total |
|---|---|---|---|
| *Acacia auriculiformis* | 5, 708 | 2,987 | 8,695 |
| *Indigofera teysamii* | 5,250 | 3,173 | 8,423 |
| *Gliricidia sepium* | 4,510 | 1,877 | 6,387 |
| *Acacia mangium* | 4,212 | 1,267 | 5,479 |
| *Flemengia congesta* | 3,386 | 1,358 | 4,744 |
| *Desmodium ransonii* | 3,604 | 1,094 | 4,698 |
| *Leucaena leucocephala* | 2,322 | 1,330 | 3,652 |

**Source: Man et al., (1995).**

According to Ivory (1989), the older the tree at first cutting, the higher the rates of regrowth and biomass yield, since older trees would have thicker stems, more carbohydrate reserves and a deeper and more extensive root system. The variability in biomass yields has also been attributed to modifying effects of factors such as intra-row spacing, fodder species, climate (wet or dry seasons) and production system (wood or leaf). Thus ILCA (1988) reported a fall in *Leucaena* yield from 30.4 tons/ha, when cut at 12 weeks interval, to 10.3 tons/ha when harvested at intervals of

6 weeks, with accompanying plant mortality. The same workers demonstrated the effect of intra-row spacing on *Leucaena* yield that fell from 41 tons/ha at 0.5m to 30 tons/ha at 1 to 2m intra-row spacing. In high altitude areas like those of Southern highlands where emphasis is on fodder production, cutting twice per year would appear suitable for most adapted legume trees and shrubs due to somewhat slower growth rate of the trees. According to Hedge (1983) and ILCA (1988), higher yields of 30-50 tons/ha are possible for *Leucaena leucocephala* under intensive monoculture production systems with tree populations of over 200,000 plants/ha. The effect of planting densities on leaf yield has been investigated (Kang et al., 1981 and Ella, 1988) who reported that, for *Leucaena, Calliandra and Sesbania*, leaf yield per unit area increased with increasing plant density. This suggests that when high leaf yield is targeted for fodder production, high planting densities are recommended. Although varying plant densities ranging from 1 to 13 trees/ $M^2$ have been assayed, the optimum planting densities have rarely been recommended because of the confounding effects of such factors as season, rainfall and plant spacing. Ivory (1989) concluded that it might be difficult to define optimum planting densities for intensive production systems based on existing information.

**2.1.3: Summary**

Trees and shrubs fodder play important roles within the farming systems of tropical Africa, through contributing significantly to soil maintenance and fertility, as well as livestock production, particularly as dry season feed resources. The full potential of some of the introduced species have not been systematically and fully expoited. Little information is available in the literature on *Leucaena diversifolia* as a feeding material. As a results excessive citations were drawn from work reported in

Carribean, West Africa and South East Asia since most pioneering studies on *Leucaena spp* were conducted in those area. Research efforts should be directed towards year-round feed utilization systems that will maximally exploit biomass yields resulting from a better understanding of agronomic features of adapted trees and shrubs. Fitting of adapted legumes MPT's trees into existing farming systems in Sub-Saharan Africa would improve nitrogenous feed resource base for cattle fed on crop residue diets in the dry season.

## 2.2: Techniques for evaluation of feed resources

### 2.2.1: Nylon bag technique (*in-sacco*) and the two-stage Tilley and Terry *in vitro* digestibility: Its application and limitations

**Introductoion:**

Feed evaluation is central to scientific planning of animal's diets. Over the last 100 years wide ranging efforts have been directed towards measurement of feed value. While substantive in-roads have been made on non-ruminant's diets, there are still many black holes for ruminant's feeds. The major reasons behind this, is the diversity of ruminant's feeds and the contrast between what is offered and what the animal actually consumes. The two-compartment digestive system of the ruminants complicates the matter further. Ruminal digestion is essentially independent of the post-ruminal digestion. This review discusses evaluation methods that have shown strong correlation with ruminal microbial digestion a stage that principally prepares feeds for post-ruminal enzymic digestion.

### 2.2.2: Nylon bag technique *in sacco*

According to Aerts et al. (1977) and Wanapat et al. (1986), the data on 48hr *in vitro* incubation has successfully been used for predicting *in vivo* digestibility since strong and positive correlation has been found between these two variables. The technique has made it possible to study the kinetics of rumen digestion for various nutrients such as DM, CP and NDF and is therefore considered a powerful tool for indexing the relative degradabilities of feedstuffs.

The *in-sacco* technique is, however, characterized with low repeatability as is suggested by the diversity of values obtained by different researchers for a similar feed sample (Mehrez and Orskov, 1977; Setale, 1983; Weakley et al., 1983; Lindberg, 1985; Oldham, 1987 and Verite et al., 1990).

The *in sacco* method necessitates availability of cannulated animals, making the method rather unsuitable for routine evaluation of feeds. However, the ability to capture rumen outflow kinetics, makes *in-sacco* method a useful tool especially for evaluation of low quality roughages.

### 2.2.3: The two stage Tilley and Terry *in vitro* dry matter digestibility (IVDMD)

The technique uses simple apparatus and is highly reproducible and therefore many samples can be handled in a single experiment (Tilley and Terry, 1963). Due to these features, it is suitable for routine evaluation of forage samples. According to Michalet-Doreau and Ould-Bah (1992), IVDMD measurements are subject to variations in the nature of the innoculum and thus to variations in microbial synthesis, thus involving the use of controls and an increase in the number of replications necessary to obtain a correct mean value. Need for rumen cannulated animals is an added disadvantage. However, recent trials of using faecal suspension (Aboud, 2003, personal Communication) could help in eliminating the need for cannulated animals.

### 2.2.4: Degradability characteristics and *in vitro* dry matter digestibility of selected feedstuffs

Mgheni and Ndemanisho (2001) working in Tanzania evaluated the degradability characteristics of two tropical crop residues, maize stover, rice straw and their botanical fractions. The findings reported in Table 2.3 suggest that these crop residues had low soluble component (A) but quite high insoluble but fermentable component (B) that were associated with a low rate of degradation, (C). These results clearly demonstrate the differences in degradability constants between different botanical fractions. The findings also corroborate closely with studies by Tuan et al., (2001), Orskov and Ryle (1990) and research findings from Ethiopia by Tolera and Said (1997) and Tolera (2001) whose results are presented in Table 2.3. Similarly, Chakeredza et al. (2002) while working in Zimbabwe revealed the following DM degradation characteristics for maize stover: Soluble component ("A"): 7.07 %; insoluble but fermentable component ("B"): 58.57 %; the asymptote ("A+B"): 65.65 %; Effective degradability: 28.37 % and rate constant ("C"): 0.03.

A study by Tuah et al., (1996) in Ghana showed that the relationship between the *in sacco* dry matter degradability and the *in vitro* gas production values at the various incubation periods was high, positive and significant (r = 0.58 to 0.98). Degradability characteristics for those feed materials are indicated in Table 2.3. The negative values in the water-soluble component (A) for both leaves and husks botanical fractions for the two maize stover varieties are indicative of presence of lag phase that was not measured.

**Table 2.3: Degradability characteristics for selected tropical crop residues and their botanical fractions in g/kg**

| Feed/nutrient | A | B | A+B | C/h | Effect.d egr. | 48hr DM degr | Authors |
|---|---|---|---|---|---|---|---|
| Maize stover | | | | | | | Mgheni and |
| Whole plant | 118 | 678.1 | 796 | 2.53 | 375.6 | | Ndemanisho |
| Leaves | 156 | 715.6 | 872 | 3.09 | 433.5 | | (2002) |
| Leaf sheaths | 132 | 680.2 | 812 | 2.13 | 368.5 | | " |
| Husks | 94 | 779.3 | 873 | 3.42 | 399.3 | | " |
| Stems | 137 | 549.6 | 687 | 2.09 | 326.1 | | " |
| Panicles | 129 | 612.5 | 742 | 2.33 | 344.3 | | " |
| I* | 146 | - | - | 0.0302 | 411 | 584 | Tolera |
| II | 119 | - | - | 0.0273 | 373 | 544 | (2001) |
| III | 112 | - | - | 0.0242 | 363 | 512 | " |
| 1 Whole stover | 54 | 488 | | 0.033 | 9.1 | | Tuah et al., |
| 1Stem | 111 | 356 | | 0.0198 | 14.8 | | (1996) |
| 1Leaves | -49 | 695 | | 0.0381 | 16.8 | | " |
| 1Husks | -20 | 818 | | 0.0206 | 23.1 | | " |
| 2Whole stover | 80 | 511 | | 0.0367 | 18.5 | | " |
| 2Stem | 52 | 342 | | 0.0219 | 9.3 | | " |
| 2Leaves | -38 | 700 | | 0.0288 | 22.7 | | " |
| 2Husks | -52 | 923 | | 0.0243 | 17.1 | | " |
| Maize stover | 220 | 539 | 759 | 0.0380 | 435 | - | Tolera and Said (1997) |
| Rice straw | | | | | | | Mgheni and |
| Whole plant | 171 | 740.5 | 1.29 | 35.23 | | | Ndemanisho |
| Leaves | 149 | 809.6 | 1.37 | 33.95 | | | (2002) |
| Leaf sheath | 142 | 785.7 | 1.12 | 29.79 | | | " |
| Stems | 205 | 659.4 | 1.97 | 42.61 | | | " |
| Panicles | - | - | - | - | | | " |

Key: * Stages I, II and III refer to harvesting of maize crop at grain moisture contents of 28-30; 20-23 and 10-12 %, respectively. 1 and 2 denote maize stover varieties and their botanical fractions

**Table 2.4: DM degradability characteristics for selected tropical MPTs, shrubs and herbaceous legumes in g/kg**

| Feed/nutrient | A | B | A+B | C | Effect.degr. | Authors |
|---|---|---|---|---|---|---|
| *Desmodium intortum* | 329 | 366 | 695 | 0.0690 | 520 | Tolera and) |
| *Stylosanthes guianensis* | 327 | 419 | 746 | 0.0670 | 577 | Said (1997 |
| *Maximum axillare* | 336 | 368 | 704 | 0.0580 | 512 | " |
| *Leucaena leucocephala* | | | | | | Kamatali *et al.*, |
| OM | 307 | 454 | 761 | 0.0330 | - | (1992) |
| CP | 251 | 595 | 846 | 0.0350 | - | " |
| NDF | - | 565 | 565 | 0.0200 | - | " |
| *Seshania sehan* | | | | | | " |
| OM | 442 | 448 | 890 | 0.1500 | - | " |
| CP | 429 | 522 | 951 | 0.1310 | - | " |
| NDF | - | 631 | 632 | 0.1400 | - | " |
| *Calliandra calothyrsus* | | | | | | " |
| OM | 311 | 319 | 630 | 0.016 | - | " |
| CP | 188 | 390 | 578 | 0.012 | - | " |
| NDF | - | 389 | 390 | 0.013 | - | " |
| *Leuceana leucocephala* | 266.6 | 372.1 | 638.7 | 0.063 | 530.7 | Ngwa *et al.*, |
| *Acacia eriobola* | 310.8 | 318.5 | 629.3 | 0.028 | 477.1 | (2000) |
| *Acacia karoo* | 229.5 | 425.9 | 655.4 | 0.026 | 448.3 | " |
| *Acacia nilotica* | 473.4 | 381.7 | 855.1 | 0.022 | 644.2 | " |
| *Acacia sieberiana* | 374.1 | 415.4 | 789.5 | 0.027 | 592.1 | " |
| *Acacia tortilis* | 305.5 | 506.7 | 811.2 | 0.028 | 572.2 | |

The variability in degradability values as reported by different authors has been ascribed to differences in chemical and botanical compositions among botanical fractions as influenced by climate and harvesting conditions.

Sibanda et al., (1993) and Wadhwa et al., (1993) working independently on sunflower seed cakes showed that potentially degradable component (B) ranges from 300-340 g/kg. Addition of the soluble component brings the value to between 630-960 g/kg for the (a+b) component.

Studies from Rwanda by Kamatali et al. (1992) on *in situ* degradability of organic matter, crude protein and cell wall of selected tree forages are presented in Table 2.4 The authors argued that *Sesbania sesban* had lowest cell-wall contents and gave highest ruminal degradability for OM, NDF and CP. In contrast, the authors showed that protein of *Calliandra calothyrsus* was poorly degraded. However, some feed proteins may escape digestion (by-pass protein) in the rumen and provide additional protein for absorption in the small intestine. In fact it is this supplemental protein that promotes high levels of production. According to Shelton and Gutteridge (1994), protection against digestion may be afforded by heat denaturation of proteins during drying or by complexation with tannins during mastication and ruminal metabolism. Where tannin-protein complexes are dissociated in the small intestine, additional protein of high biological value is available for use by the animal (Jones 1994b). Keir et al. (1997) compared DM degradability characteristics between *Gliricidia sepium and Leucaena leucocephala* and the data obtained were: *Gliricidia sepium*: Soluble component ("A"): 45.7 %; insoluble but fermentable component ("B"): 44.5 % and rate constant ("C"): 0.055 and for *Leucena leucocephala*: Soluble component ("A"): 39.4 %; insoluble but fermentable component ("B"): 37.0 % and rate constant ("C"): 0.048.

The potential of legume pods as supplements to low quality roughages was also carried out in the Republic of South Africa by Ngwa et al. (2000) using rumen cannulated Jersey cows. Dry matter degradation of the reference feeds are shown in Table 2.4. The authors indicated that DM and N degradabilities were highest for pods of *Acacia nilotica* and *Acacia sieberiana* respectively and lowest for those of *Acacia karoo*. Walli et al., (1988) ascribed differences in DM loss between fractions of the same straw feed to differences in chemical composition or by variations in physical structure such as distribution of lignified cells within the tissues. Dwayne et al. (1996) showed variability in *in vitro* dry matter disappearance (IVDMD) and neutral detergent fibre (NDF) content of some parental inbred maize lines and data obtained is presented in Table 2.5. The workers noted that non-structural carbohydrate concentration of maize stover is inversely related to grain content of the forage, because non-structural carbohydrates are translocated from the stem to the developing grain. The more grain produced, the more non-structural carbohydrate translocated out of the stems.

**Table 2.5: IVDMD and NDF of parental inbred maize lines in g/kg**

| Inbred line | IVDMD | IVDMD | NDF | NDF |
|---|---|---|---|---|
| | Stover | Whole plant | Stover | Whole plant |
| B57 | 554 | 657 | 672 | 542 |
| E227 | 545 | 648 | 672 | 552 |
| NC258 | 595 | 637 | 608 | 562 |
| Mo 17 | 567 | 648 | 667 | 542 |
| N28 | 544 | 608 | 641 | 587 |
| B94 | 519 | 653 | 679 | 537 |
| NC272 | 537 | 616 | 684 | 596 |
| B52 | 512 | 578 | 670 | 600 |
| B64 | 519 | 597 | 675 | 605 |
| NC262 | 549 | 624 | 657 | 567 |
| B79 | 549 | 650 | 654 | 544 |
| LAN 496 | 577 | 682 | 701 | 562 |
| LSD (0.05) | 21 | 19 | 22 | 25 |

**Source: Dwayne et al. (1996).**

Givens et al., (1989) reported chemical composition, digestibility *in vitro* and *in vivo* and calculated energy value of untreated cereal straws produced in farms throughout England. Table 2.6 shows the exhibited variability. Results obtained illustrated that measurements *in vitro* exhibited considerable variation within cereal straws. For instance, in their study, the pepsin cellulases values were consistently much lower than the rumen fluid and NDF cellusases. Givens et al., (1989) commented that the three *in vitro* methods clearly did not measure the same fractions. The pepsin cellulase method in particular produced much lower values than the NDF cellulase or rumen fluid method. It seems possible that the NDF cellulase method, which involves a heating step with neutral detergent solution, opens up the structure of the cell walls allowing more extensive degradation by cellulase than in the pepsin-cellulase method. These differences point to the fact that *in vitro* measures of digestibility cannot be assumed to provide values which are numerically equivalent to, or even similar to, the corresponding values *in vivo*.

**Table 2.6: Digestible organic matter content in g/kg DM of cereal straw species measured by three *in vitro* methods and the influence of year and county**

| *In vitro* method | Wheat straw | | Barley straw | | Oat straw | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | + year | + county | + Species |
| Rumen fluid Tilley and Terry | 417 | 63.9 | 426 | 54.7 | 493 | 60.3 | ** | * | ** |
| NDF cellulase | 367 | 38.1 | 372 | 46.6 | 435 | 45.8 | * | NS | NS |
| Pepsin cellulase | 170 | 32.1 | 182 | 30.8 | 211 | 11.1 | NS | NS | * |

**Source: Givens et al. (1989).**

Research studies from Germany by Flachowsky et al., (1991) on botanical fractions of straw of 51 cereal varieties and *in sacco* degradability of various fractions revealed that the rumen DM loss was the lowest for internodes (26.5-46.0%), followed by nodes (28.3-51.1 %), chaff (31.4-68.2 %) and leaves (38.2-67.8%). It was further argued that the higher lignin concentration of internodes and nodes may be responsible for the lower degradability of both fractions compared with leaves and chaff. In a very related work, Shand et al. (1988) while evaluating rumen degradation of straw in United Kingdom demonstrated that there exists large differences between degradation characteristics of leaf and stem and indicated that the 48-hr degradability varied from 570 to 650 g/kg for wheat leaf plus leaf sheath and from 300 to 380 g/kg for wheat stem. The respective ranges for oat straw were from 480 to 530 and from 250 to 280 g/kg for leaves and stems, respectively.

Orskov and Ryle (1990) contended that the soluble component may be much more dependent on environmental conditions than the insoluble but degradable part. Heavy rainfall when the straw is mature may cause leaching out of the soluble matter. On the other hand, in a dry year, rapid ripening may decrease the translocation of solubles to the kernel so that more soluble matter remains in the straw. To what extent does this hold true under tropical conditions whereby all plants exhibit C4 photosynthetic pathway, is not yet verified. These authors further added that the leaf to stem ratio can make important differences and may well be influenced by environmental and harvesting conditions. Since degradability of leaf may sometimes be more than twice that of stem, the leaf to stem ratio is an important parameter to determine whenever utilization of crop-residues is being investigated.

Capper et al., (1986) and Wales (1990) while working independently showed that the characterization of feeds for ruminants by using the factors of the exponential equation relating degradation and time as outlined by Orskov and McDonald (1979) most accurately represent the value of crop-residues in so far that it can even predict intake and performance of animals far better than chemical and other biological measurements.

### 2.3: Effect of different levels of *Leucaena diversifolia* on *in vivo* digestibility for bean straw / maize stover based diets by lactating dairy cattle

### 2.3.1: *In-vivo* digestibility as a method for estimating nutritive value of forages

### 2.3.2: Definition of digestibility:

The term digestibility as used in animal nutrition has a definite and limited meaning. It denotes the percentage of a nutrient in a feed, which is acted on in the entire digestive tract and assumed to be absorbed and thus put at the disposal of the body cells (Schneider and Flatt, 1975). Algebraically, digestibility of any of the nutrients of the feed is expressed as:

$$Da = \frac{Qi - Qr}{Qi}$$

**Whereby:**

Da= Digestibility of a nutrient

Qi = The average daily intake

Qr = The average quantity of undigested nutrient voided daily (Van Soest, 1982).

### 2.3.3: Apparent and true digestibility coefficients

According to Schneider and Flatt (1975), digestibility coefficients are referred to as apparent digestion coefficients because it is assumed that the faeces are composed entirely of undigested feed substances but contain endogenous debris coming from the body itself. For instance part of the faecal nitrogen had been digested previously and already had served a purpose in the body. Thus the digestion coefficient is only apparent. At the outset of the 20 $^{th}$ century, Jordan and Hall (1900) distinguished faecal nitrogen to be consisted of two major fractions: (a) Nitrogen of dietary origin and (b) Nitrogen of body origin. A varying proportion of nitrogen that is not undigested nitrogen of feed origin is present in the faeces, and is commonly referred to as metabolic nitrogen of the faeces. The latter is related to the amount of DM consumed. Van Soest (1994) illustrated that in total diets, protein and lipids always have a faecal metabolic loss. Fibre and carbohydrates have no metabolic faecal loss and thereby apparent digestibility is assumed equal to the true digestibility.

### 2.3.4: Factors affecting forage digestibility

#### 2.3.4.1: Feed factors

It has been cited that the mean DMD coefficient of temperate grass is higher by 130 g/kg than that of tropical grasses (Minson and Mcleod, 1970). In contrast, only a small difference (40 g/kg) occurs between the mean DMD of temperate legumes and tropical legumes (Minson, 1990). It is argued that the lower digestibility of tropical grasses is caused by differences in anatomical structure associated with the different photosynthetic pathways (Laetsch, 1974) and the temperature at which tropical grasses are normally grown. Leaf blades of tropical grasses have been noted to have more vascular bundles per unit cross-sectional area and hence more sites for lignifications, a closely packed cell structure and suberized, thick walled bundle sheaths that have a high resistance to penetration by rumen micro flora (Minson, 1990). All these anatomical factors are known to lead to a low potential digestibility of the leaves of tropical grasses and stems. Similarly, tropical grasses are normally grown in climates with high temperatures and high potential transpiration rates, which is associated with a lower soluble carbohydrate concentration in tropical grasses and hence declining DMD.

As pasture matures, there is an increase in the proportion of fibre and a decrease in the protein content and of the digestibility of the dry matter (Minson, 1974 as cited by Morley, 1981). It is evident that the effect of maturity is indirectly an effect of the ratio cell content to cell walls and the chemical composition of the cell walls. The cell content is more or less 100% digestible irrespective of the maturity. Amount of cell walls and the composition, especially lignification, will determine NDF degradability. These changes occur in both tropical and temperate pasture species but there are large differences in the rate of fall in digestibility of the dry matter in the tropical than in temperate forages. Tropical grasses generally decrease in DM digestibility at a daily rate of 100 to 200 g/kg digestibility units (Minson, 1971) compared with 50 g/kg units for temperate grasses (Minson et al., 1960). Many experiments have illustrated that the decrease in digestibility of plants as they become mature is due largely to an increase in lignin that is poorly digested even by ruminants. Moreover, cell walls of mature plants become encrusted with lignin and thus decrease the digestibility of the nutrients inside the cell-walls (Schneider, 1955; Hogan, 1967 and Reid, 1957). An additional factor in decreasing digestibility with increased maturity possibly is the depression in the leaf: stem ratio caused by shattering of the leaves. In tropical forages, the leaf botanical fraction become too brittle with advanced maturity and depending on the weather, valuable nutrients may lose through leaching. The leaves are rich in cell contents and therefore more highly digestible than stems. This is what happens when grazing is deferred until after the plants are mature and growing little or not at all. This explains why the digestibility and content of nutrients are so low in cereal crop-residues.

Applying fertilizer nitrogen has been shown (Minson, 1990) to increase DM yield, protein and water content of forage and reduces the proportion of leaf. To what extent is this valid, has not been verified. These changes might be expected to have a major effect on DMD, but most studies have shown only small differences of DMD at low N and High N fertilizer application regimes (Reid et al., 1966a; 1966b; Blaxter et al., 1956). Minson (1990) noted that the higher CP in the N-fertilized forage is offset by a reduction in the level of soluble carbohydrates. However, these findings are in contrast to those reported by Morley (1981) who revealed that fertilizer nitrogen reduces the mean level of cell wall constituents (hemi-cellulose, cellulose and lignin) and that this reduction in cell-wall lead to a mean increase of 22 g/kg in the digestibility of DM. It appears therefore there is no consistent pattern in the response to fertilizer nitrogen on DMD among different reports.

The digestibility of a feed will be reduced if the activity of the rumen micro flora is below optimum. Low levels of available soil sulphur reduce dry matter digestibility (Rees et al., 1974 as cited by Minson, 1990). These workers illustrated that application of fertilizer sulphur to sulphur-deficient *Digitaria decumbens* increased DMD by 50 g/kg units and energy digestibility by 100 - 120 g/kg units. It was substantiated that the effect was due to enhanced fibre-digesting capability of the rumen microorganisms and not to any change in the anatomy of the forage. The extent of the improvement in DMD varies with the extent of the sulphur deficiency in the animal, sheep being more susceptible to sulphur deficiency than cattle.

One of the most significant factors, that affect digestibility, is the chemical composition of the feeds under consideration. If protein rich feeds are added to balance a low protein ration, the microorganisms seem to be stimulated and thus attack the fibre more vigorously. Early in the 19$^{th}$ century, Schulze and Maercker (1871), as cited by Schneider and Flatt (1975) added a gluten protein to a Meadow hay ration fed to sheep and concluded that this favorably affected all nutrients especially the CF. They concluded that the larger the percentage of protein in the ration, the greater the digestibility of all nutrients. An increase in the fibrous or cell wall components namely cellulose, hemicelluloses and lignin is associated with low intake of digestible energy caused by low intake and low digestibility.

### 2.3.4.2: Animal factors

The plane of nutrition is one of the many factors affecting digestibility of feed nutrients. Haenlein and Holdrein (1965) worked with sheep having maximum daily

DM intakes varying from 32 to 88 g per M $^{0.73}$ kg. Digestibility of the several nutrients regressed inversely with the level of hay intake. The regressions of intake level on digestion coefficients were –0.143, -0.134, -0.129, -0.257, -0.099 and –0.091 for DM, OM, GE, CF, CP and NFE, respectively. Most other experiments have illustrated that farm animals usually digest a larger percentage of the nutrients in their feed when fed a little ration than when they receive a full ration (Andersen, 1959; Brown, 1966; Flatt, 1966; Reid, 1956; 1962; Reid et al., 1966a and Wagner and Loosli, 1967). Due to this phenomenon, there is a general belief that published digestion coefficients are too high for use at productive levels of feeding by at least 50 g/kg units because they have been obtained at maintenance or only slightly super maintenance levels of feeding. Thus under normal feeding conditions, liberally fed dairy cows will not obtain from their rations quite as much digestible nutrients as shown in feed tables. When an animal is subjected to a higher plane of nutrition, movement of feed materials in the gastro-intestinal tract is relatively faster than if fed a small ration thus allowing less time for digestion or absorption. This explains why as the level of feed intake increases, the digestibility of nutrients tend to decrease.

### 2.3.5: Nutritive characteristics for crop-residues

Analysis of crop-residues by detergent procedures (Goering and Van soest, 1970 as cited by Musimba 1981) has shown that they are high in lignocelluloses contents (lignin, cellulose, hemicelluloses and cutins) but low in nitrogen and nitrogen free extracts. Silica content of cereal straws and stovers varies with crop species and location.

Table 2.7 shows findings obtained in Tanzania by Kimambo et al., (1990). It can be observed that *in sacco* 48 hrs DMD of five varieties of maize stover ranged from 530 to about 645 g/kg. "Short season" rapid maturing variety had apparently lower DMD values compared to the "long season" varieties. This corroborates similar comparisons between tropical and temperate grasses where rapid maturity has been cited (Minson 1990) as one reason for inferior DMD values of the tropical species.

**Table 2.7: Nutritive value of crop-residues and other feeds from Kilimanjaro and Arusha regions, Tanzania**

| Sample name | N | DM g/kg as fed | CP g/kg of DM | 48hr DM degrad., g/kg | Calculated ME, MJ/kg DM |
|---|---|---|---|---|---|
| MS Kitale | 3 | 866 | 24 | 637 | 9.6 |
| MS Zimbabwe | 1 | 902 | 24.5 | 605 | 9.2 |
| MS 622 | 2 | 910.5 | 44 | 530 | 8.4 |
| MS Staha | 4 | 898 | 41 | 579 | 9.0 |
| MS Local | 2 | 898 | 49 | 645 | 9.7 |
| MS Kilima | 1 | 910 | 40.9 | 636 | 9.6 |
| BS Canadian Wonder | 1 | 900 | 78 | 573 | 8.9 |
| BS Local | 2 | 907 | 66 | 548 | 8.64 |
| BS Belabela | 1 | 910 | 52 | 572 | 7.6 |
| Rice straw | 1 | - | 56.4 | 579 | 9.0 |

**Source: Kimambo et al., (1990).**

**Legend: MS = maize stover varieties**

**BS = bean straw varieties**

Research on the utilization of crop-residues has quite a long history in Tanzania. Urio and Kategile (1987) summarized research findings reported by different authors. Chemical composition information is shown in Table 2.8.

**Table 2.8: Chemical composition of maize cobs and stover in g/kg DM**

| Parameters | MS H631/32 | MS Ilonga composite | MS Ilonga composite | Maize cobs Ilonga comp. |
|---|---|---|---|---|
| DM | 934 | - | 906 | 881 |
| ASH | 121 | 81 | 60 | 39 |
| CP | 23 | 35 | 24 | 22 |
| CF | 453 | 394 | - | - |
| EE | 18 | 6 | - | - |
| NFE | 384 | 484 | - | - |
| NDF | - | 807 | - | - |
| Ca | - | 3.2 | - | - |
| P | - | 2.8 | - | - |
| GE, MJ/KG DM | - | 16.6 | 16.3 | 17.3 |
| | Musimba, 1980 | Biwi, 1986 | Urio, 1981 | Urio, 1981 |

**Source: Urio and Kategile (1987)**

**Key: MS= Maize stover**

**MS H631/32 and MS Ilonga composite refer to the maize crop varieties**

These workers noted that both maize stover and cobs are high in lignocelluloses content and that they would probably require a source of readily available carbohydrate for optimum utilization. In a maize stover / cobs based *in vivo* digestibility study, Urio and Kategile (1987) showed that with appropriate supplementation strategies, digestibility of various nutrients could be elevated from

565 to 698 g/kg as fed for DM, 717 to 835 g/kg DM for CP and DM intake from 43.7 to 93.6 g/kg $M^{0.75}$.

In another research development, Theander and Åman (1984) determined chemical composition of some Swedish cereal crop-residues and forages for feeding value evaluations. The data reported by these workers is shown in Table 2.9. It is evident that although some chemical nutrients such as nitrogen content and others are missing, almost all crop-residues had higher values for cell walls. Morley (1981) demonstrated that major changes are associated with changes in the proportion of leaf to stem and in the composition of both leaf and stem. It has been established that as the plant matures there is an increase in the fibrous or cell wall components namely cellulose, hemicelluloses and lignin on dry matter basis but a decrease in CP (N x 6.25), soluble carbohydrates, most soluble ash constituents and carotene.

**Table 2.9: Chemical composition of some roughage as determined by the Detergent Fibre Analysis Scheme (g / kg DM)**

| Roughage | Cell walls | Hemicelluloses | Cellulose | Lignin |
|---|---|---|---|---|
| Barley straw | 810 | 270 | 440 | 70 |
| Oat straw | 730 | 160 | 410 | 110 |
| Paddy straw | 790 | 260 | 330 | 70 |
| Wheat straw | 800 | 360 | 390 | 100 |
| Sorghum stover | 740 | 300 | 310 | 110 |
| Chickpea straw | 620 | 200 | 300 | 100 |
| Lucerne straw | 690 | 190 | 380 | 110 |
| Cotton seed hulls | 910 | 150 | 590 | 130 |

**Source: Theander and Åman (1984).**

A study on mineral composition (% DM) of various roughages were carried out by Coombe (1987) as cited by Morley (1981), (see Table 2.10) and revealed that for the major minerals, crop residues appear to be better sources of calcium, magnesium, potassium, and in some cases sodium. The same crop residues were noted to be rather low in contents of phosphorus and sulphur. However, extent of availability of the various minerals to the ruminant animals was not shown.

**Table 2.10: Mineral composition (g/kg DM) of various crop-residues**

| Residue | P | S | Ca | Mg | Na | K |
|---|---|---|---|---|---|---|
| Straw[1] | 0.5-1.1 | 0.4-1.5 | 1.1-3.4 | 0.5-1.8 | 0.2-0.35 | 4-24.4 |
| Rice straw | 0.9-1.6 | 1.0-2.0 | 2.4 | 1.2 | 0.5 | 13.2-17.7 |
| Corn straw | 0.8-1.5 | 1.0-1.5 | 3.0-4.1 | 0.8 | 0.5 | 15 |
| Sorghum stalks | 1.3 | - | 3.4 | - | - | - |

**1= Derived from wheat, oats and barley**

**Source: Coombe (1987) as quoted by Morley (1981).**

**2.3.6: Summary**

The *in vivo* digestibility method is highly suited for estimating the extent to which feeds are digested. From this review, it is evident that the main distinguishing feature between the *in vivo* and *in sacco* techniques is that the latter is more informative in that it provides apart from extent of digestibility, the rate at which different feeds are degraded. The major limitation of the conventional *in vivo* digestibility method is that it is measured at a rather restricted level of feeding while in practice animals are fed at varied levels of intended production. However, the balance of matter lost in the passage through the digestive tract, is the most reproducible measurement for a given feedstuff, (Van Soest, 1994).

Crop-residues are widely used in tropical animal production. Crop-residues from graminae family such as rice, maize and sorghum generally appeared to contain comparatively high levels of indigestible fibre and consequently lower DMD than those derived from leguminous family. Despite their reasonable levels of ME, the utilization of crop-residues is limited by their low N content. The mineral content in crop-residues is variable, the levels being a function of soil conditions on which the crops were produced. However mineral content is generally low and there is paucity of information on the nutritional availability of the minerals.

### 2.3.7: Nitrogen metabolism in ruminants

Crop-residues constitute a big proportion of dairy cattle rations during the dry seasons in most smallholder dairy cattle production units in Sub-Saharan Africa. The primary limiting nutrients for production in crop-residues based diets are both fermentable nitrogen and bypass protein and as a result varied protein supplementation regimes are practised. In this section, aspects related to fate of dietary protein in the rumen, effect of substrate on degradation of dietary protein and the significance of recycling of urea on nitrogen economy and metabolism in ruminants are briefly reviewed.

#### 2.3.7.1: Fate of dietary protein in the rumen

Three major changes occur to dietary CP in the rumen:

(a) Degradation of dietary CP to ammonia. If the ammonia produced is present in high concentrations, it is absorbed, leading to a net loss of CP

(b) Microbial protein is synthesized from non-protein nitrogen and sulphur present in the rumen. This can lead to a net gain of amino acids and true protein due to microbial protein production.

(c) Microbes synthesize protein, which has a different amino acid profile from that of the degraded dietary protein (Weston, 1971 and Beever et al., 1986 as quoted by Minson, 1990).

**2.3.7.2: Effect of substrate on degradation of dietary protein**

Ganev *et.al.* (1979) as quoted by Ørskov (1982) incubated a series of protein supplements in the rumen of sheep fed on barley hay or grass. The results obtained are presented on Table 2.11 and clearly demonstrate that the disappearance was faster when different protein sources were incubated with grass than with barley hay, which appeared to be less favorable for cellulolysis.

**Table 2.11: Effect of type of substrate in the rumen on disappearance of protein from nylon bags incubated in the rumen of sheep in g/kg DM**

| Incubation time | Soybean meal | | Groundnut meal | | Sunflower meal | | Fishmeal | |
|---|---|---|---|---|---|---|---|---|
| | Barley | Grass | Barley | Grass | Barley | Grass | Barley | Grass |
| 3 | 229 | 384 | 275 | 361 | 326 | 521 | 428 | 413 |
| 6 | 306 | 506 | 409 | 608 | 437 | 640 | 472 | 478 |
| 9 | 397 | 592 | 498 | 652 | 534 | 775 | 557 | 503 |
| 15 | 474 | 787 | 659 | 897 | 657 | 845 | 620 | 556 |
| 24 | 617 | 890 | 820 | 951 | 799 | 919 | 715 | 680 |

**Source: Ganev et. al., (1979) as quoted by Ørskov, (1982).**

This study has shown that the rate at which protein supplements are degraded can differ according to whether the rumen environment can support a higher or a lower rate of cellulose degradation. These authors have emphasized that this phenomenon is particularly important for protein supplements of vegetable origin and less important for protein supplement of animal origin. It has also been elaborated that the rate of protein degradation from vegetable sources of protein is affected when the proportion of cereals in the diet is such that the resultant rumen PH is inhibiting cellulolysis. The observed differences in the disappearance values between barley hay and grass are difficult to explain due to the many contributory factors such as variations in the content of readily available carbohydrates and rumen environment (pH).

#### 2.3.7.3: Recycling of urea via saliva

It has been established for quite a long time that urea can be recycled and used as a source of N for the rumen micro-organisms (Harris and Phillipson, 1962). The extent to which urea is returned via saliva appears to be directly proportional to the blood urea concentration and to the amount of saliva secreted (Nolan and Leng, 1972). In another work, Kay (1966) observed that the amount of saliva secreted can be greatly influenced by the physical structure of the diet i.e. it increases with increasing proportion of long fibres. The blood urea concentration is influenced by the extent to which absorbed amino acids are oxidized and also on the absorption of ammonia from the rumen. Blood urea concentration to a large extent reflects the extent to which the diet is balanced in N, both, as far as the requirement of the rumen microorganisms is concerned and as far as the host animal is concerned. Blood levels of ammonia normally remain low because the liver rapidly converts ammonia back to urea, a conversion that costs the animal about 12 kcal/g of nitrogen (Van Soest, 1982).

According to Ørskov et.al. (1980), rumen epithelium is constantly shed into the lumen of the rumen, and this can act as a source of N. In experiments with ruminants sustained entirely by intragastric nutrition, the quantities of N leaving the rumen in forms other than ammonia was determined with lambs, steers and cows and are shown in Table 2.12.

**Table 2.12: The outflow of non-ammonia N from the rumen of lambs, calves and cows given N-free infusates**

| Animal | Live weight, kg | Non-$NH_3$ N leaving rumen g /d |
|---|---|---|
| Lambs | 25 | 1.4 |
| Calves | 200 | 5.1 |
| Cows | 600 | 8.3 |

**Source: Ørskov et al. (1980).**

In this research work, the nitrogenous component appeared from microscopic examination to be mainly in the form of abraded epithelial cells from the rumen wall. Thus, it is an addition that must be taken into account when a balance is made between dietary nitrogen intake and flow at the abomasums.

### 2.3.7.4: Summary

The amount of amino acids absorbed by ruminants is not directly related to the quantity of CP in the forage but is modified during passage through the rumen. The extent of the change depends on the degradability of the feed and whether the amino acids and ammonia released into the rumen from the forage and saliva exceed the energy available to the microbes (Minson, 1990). It is further illustrated that the main features of these changes are a loss of CP from diets high in CP and an increase in N when the forage is low in CP.

#### 2.3.7.5: Performance of ruminant animals supplemented with leguminous trees/ shrubs to tropical forages

Reed et al. (1990) working in Ethiopia determined intake, growth and digestibility in sheep fed forage produced from four African multi-purpose trees in combination with teff straw and the effect of poly-phenolics on nitrogen utilization. Results reported are presented in Table 2.13. Reed et al., (1990) concluded that there were large differences in the nutritive value of the four African fodder trees when fed in combination with straw and that tannins and related poly-phenolic compounds in *acacias* had negative effects on intake, digestibility and nitrogen utilization. *Acacia seyal* has the highest organic matter true digestibility. *Acacia cyanophylla* has a significant negative effect on digestibilities compared to all the other supplements. However, studies from Central Tanzania by Mero et al., (1990) on the effect of supplementing mature grass hay with dried *Leucaena* leaves on OM digestibility and voluntary intake by sheep indicated that *Leucaena* supplementation failed to improve grass OM and NDF intakes at the high feeding level although there was improvement in grass CP intake. The same study revealed significant improvements in total OM and CP intakes that were attributed to the intake of the *Leucaena* supplement

**Table 2.13: Apparent and True Digestibility of OM, NDF and ADL for sheep consuming seven feeds in combination with teff straw (*Eragrotis abyssinica*) in g/kg DM**

| Parameters. | *Acacia sieberana* | *Acacia seyal* | *Acacia cyanophylla* | *Sesbania sesban* | *Vicia dasycarpa* | Noug cake | Urea | SEM |
|---|---|---|---|---|---|---|---|---|
| Apparent OM | 540 $^{bc}$ | 540 $^{bc}$ | 410 $^{a}$ | 540 $^{bc}$ | 531 $^{bc}$ | 573 $^{c}$ | 507 $^{b}$ | 11 |
| True OM | 640 $^{c}$ | 701 $^{d}$ | 544 $^{a}$ | 664 $^{dc}$ | 636 $^{c}$ | 671 $^{dc}$ | 608 $^{b}$ | 11 |
| NDF | 370 $^{b}$ | 419 $^{b}$ | 290 $^{a}$ | 517 $^{cd}$ | 490 $^{c}$ | 571 $^{d}$ | 528 $^{cd}$ | 20 |
| Lignin | 358 $^{b}$ | -37 $^{c}$ | -611 $^{a}$ | 154 $^{c}$ | 6 $^{c}$ | 149 $^{c}$ | 95 $^{c}$ | 55 |

Means followed by different superscripts are significantly different

**Source: Reed et al. (1990).**

Research findings reported by Ash (1990) while studying effect of supplementing Guinea grass hay (1.08 % nitrogen) with leaves from the fodder trees *Sesbania grandiflora*, *Albizia chinensis* and *Gliricidia sepium* on intake and digestibility in goats, illustrated that supplementation with *gliricidia* and *sesbania* significantly increased total dry-matter intake (g/d) from 498 (Control) to respectively 597 and 626. In this study the supplementation rate was 100 g for each of the fodder trees while the Guinea grass was offered at ad-libitum level. Ash (1990) also indicated that *Albizia* supplementation had no effect on total dry-matter intake but nitrogen digestibility was significantly improved in all supplementation treatments. It is notable also from these experiments that both *Gliricidia* and *Albizia* contained moderate levels of condensed tannins yet *Gliricidia* was extensively degraded in the rumen which suggests that condensed tannins differ in type and behavior between plant species. The author concluded that legume supplements are usually most effective when fed with roughages containing < 20 g N per kg DOM because they increase the rumen ammonia concentration by providing ruminally fermentable N.

In another digestibility experiment, Banda and Ayoade (1986) while working in Malawi and using Malawian Local goats investigated the effects of *Leucaena Leucocephala* leaf hay (919 g/kg as fed and 258 g/kg DM CP) supplementation on the voluntary intake and digestibility of maize stover (931 g/kg as fed and 44 g/kg DM CP). The results indicated that daily water intake increased significantly with increasing levels of *leucaena* supplementation. Total DM intake increased from 176.4 to 393.0 g/d, daily CP intake increased from 7.5 to 66.2 g/d while daily maize stover DM intake decreased from 176.4 to 163.0 g/d. The authors argued that this depression was due to substitution effects. However, increased *leucaena* hay supplementation significantly raised the total daily DM intake by goats fed maize stover. Nutrient digestibilities of chopped maize stover by goats as affected by *Leucaena* leaf hay supplementation are shown in Table 2.14

**Table 2.14: Digestibility coefficients of maize stover with increasing levels of *leucaena* leaf hay supplementation**

| Parameters | Levels of *leucaena* leaf hay supplementation | | | |
|---|---|---|---|---|
| | 0 g | 100 g | 200 g | 300 g |
| DM , g/kg | 457.7a | 508.6a | 479.7a | 542.6a |
| OM, g/kg DM | 592.3b | 718.2b | 665.2b | 759.4a |
| CP, g/kg DM | 505.8b | 369.1a | 420.2a | 554.0a |

**Means followed by different letters in the same row differ significantly ($P < 0.05$).**
**Source: Banda and Ayoade (1986)**

These data demonstrated that *Leucaena* leaf hay supplementation had no effect on DM digestibility but had an effect on OM and CP digestibility with increasing leaf hay supplementation. However, this is an uncommon phenomenon since nitrogenous supplements have been documented to improve both DMD and CPD. Gutteridge and Shelton (1994) summarized *in vivo* digestibility and voluntary feed intake of ruminants given forage tree legume species (Table 2.15). Values are for fresh forages.

The authors cautioned that no specific conclusions could be drawn since the data were collected under a range of conditions. However, they show comparative values of the different species.

**Table 2.15: *In-vivo* digestibility and voluntary feed intakes**

| Species | DM digest.,g/kg | N digest., g/kg DM | Intake g/kg LW/d | Animal species | Reference |
|---|---|---|---|---|---|
| *Acacia aneura* | 392 | - | 14.2 | Sheep | Mcleod (1973) |
| *Acacia aneura* | 527 | 631 | 15.8 | Sheep | Norton etal., (1972) |
| | 468 | - | 21.3 | Sheep | McMeniman (1976) |
| *Albizia chinensis* | 435 | 384 | - | Cattle | Gohl (1981) |
| | 376 | 323 | - | Sheep | Ahn et al., (1989) |
| *Albizia lebbeck* | 573 | - | 17.7 | Goat | Lowry (1989) |
| | 643 | 822 | 23.2 | Sheep | Lowry (1989) |
| | 425 | 445 | 35.2 | Sheep | Gohl (1981) |
| | 463 | 645 | - | Cattle | Gohl (1981) |
| *Cajanus cajan* | 648 | 690 | - | Cattle | Gohl (1981) |
| | 509 | 600 | - | Sheep | Gohl (1981) |
| | 473 | 618 | 25.7 | Goat | Whiteman and Norton (1980) |
| | 509 | 618 | 21.7 | Sheep | Whiteman and Norton (1980) |
| | 546 | 688 | 25.1 | Cattle | Whiteman and Norton (1980) |
| *Desmanthus v.* | 477 | 440 | - | Cattle | Gohl (1981) |
| *Gliricidia sepium* | 548 | - | 25.8 | Sheep | Mahyudalin (1983) |
| | 563 | 846 | 32.6 | Goats | Murugan et.al., (1985) |
| *Leucaena leucoc.* | 680 | - | 35.6 | Goats | Yates (1982) |
| | 632 | - | 31.9 | Sheep | Yates (1982) |
| | 548 | 650 | - | Cattle | Gohl (1981) |
| *Sesbania grand.* | 627 | 740 | - | Sheep | Gohl (1981) |

**Source: Gutteridge and Shelton (1994)**

Ahn (1990) noted significant increases in intake and digestibility of barley straw fed to sheep (from 13.2 to 22.6 g per kg per day) when dried *gliricidia* were offered as supplements. Drying increased feed N degradability; it increased protein absorbed and N retention. Devendra (1983) measured intake and digestibility of chopped rice straw when supplemented with varying levels of *Leucaena leucocephala* leaves. Results reported are shown in Table 2.16. The data suggest that DMI, CP, Energy digestibility and N retention were all improved with *L. leucocephala* supplementation. Minson (1990) noted that positive responses to supplementing ruminant animals with CP are generally restricted to forages containing less than 62 g CP / kg DM.

**Table 2.16: Performance of animals fed chopped rice straw with varying levels of *Leucaena leucocephala***

| Parameters | RS + Control | RS+ 10% *Leucaena* | RS+ 20 % *Leucaena* | RS+ 30 % *Leucaena* | RS+ 40 % *Leucaena* | RS+ 50 % *Leucaena* | RS+ 60 % *Leucaena* |
|---|---|---|---|---|---|---|---|
| Daily intake g | 741.3a | 890.7ab | 967.7ab | 1158.7ab | 1446.06c | 1475.7bc | 1300.7bc |
| DMI/kg $M^{0.75}$ g/day | 59.9a | 58.9a | 53.2a | 59.9a | 68.5b | 70.7b | 59.9a |
| DMI as % BW | 2.7a | 2.6a | 2.6a | 2.8a | 3.1a | 3.1a | 2.7a |
| DMD, g/kg | 424a | 485b | 467b | 495b | 505b | 532c | 496b |
| OMD, g/kg DM | 509a | 513a | 495a | 525b | 533b | 555b | 524b |
| CPD, g/kg DM | 197a | 405b | 472c | 496c | 520c | 662d | 505c |
| Energy digest., g/kg DM | 404a | 464b | 463b | 521c | 515c | 547c | 462b |
| N retention as % of intake | -1a | 202b | 164b | 236b | 315c | 275c | 308c |

**abc= Means on the same row with different letters differ (P<0.05).**

**RS= Rice straw**

**Source: Devendra (1983).**

Preliminary investigations on fodder quality of psyllid-tolerant *Leucaena* species and provenances at Tabora, Tanzania indicated that CP content and *in vitro* dry matter digestibility for *L. diversifolia* ranged between 218 - 232 g/kg DM and 491 – 558 g/kg DM, respectively (Ostyssina et al., 1997). Nutrient content of selected fodder trees and shrubs compared to *Panicum maximum* were determined by Smith (2003) and findings indicated in Table 2.17. The data suggested that on average, fodder trees and shrubs are richer in protein and lower in fibre and ash than tropical grasses. In fact the differences are even more striking when dry season values are compared. Crude protein content, for instance of the majority of crop-residues often falls below the minimum 6 % required for maintenance, while most fodder trees remain green with high protein contents.

**Table 2.17: Nutrient content of selected fodder trees and shrubs (compared to Panicum maximum) in g/kg DM**

| Fodder species | OM | CP | CF | ADF | NDF | Total Ash |
|---|---|---|---|---|---|---|
| *Albizia lebbeck* | 850 | 217 | 366 | 246 | 354 | 73 |
| *Gliricidia sepium* | 900 | 230 | 207 | 287 | 428 | 97 |
| *Leucaena leucocephala* | 890 | 224 | 130 | 289 | 420 | 94 |
| *Sesbania grandiflora* | 882 | 235 | - | 217 | 271 | 100 |
| *Panicum maximum* | 884 | 120 | 300 | 559 | 760 | 130 |

**Source: Smith (2003)**

### 2.3.7.6: Secondary Compounds in Leguminous Trees / Shrubs

Leguminous trees and shrubs are known to produce chemicals, which are not directly involved in the process of plant growth and sometimes referred to as "secondary compounds" (Gutteridge and Shelton, 1994). They are known to be defense mechanisms, which assist in their survival. However, these compounds also affect animals and the nutritive value of forages. Distribution of secondary compounds found in some forage tree legumes is presented in Table 2.18. The most common secondary compounds found in tropical legume trees and shrubs include tannins, cyanogenic glycosides and saponins (Table 2.18). Tannins have been studied much more extensively than any other secondary compounds and therefore the present literature review will dwell more on tannins.

### 2.3.7.7: Nutritional effects of tannins

Tannins are water-soluble phenolic metabolites of plants with a molecular weight of above 500 and with the ability to precipitate gelatin and other proteins from aqueous solution (Mehanso et al., 1987a). Tannins are formed in two different ways to give condensed and hydrolysable tannins and the two are differentiated by their structure and reactivity towards hydrolytic reagents. According to Kumar and Vaithiyanathan (1990), hydrolysable tannins are readily hydrolysed by acids, bases or certain enzymes while condensed tannins, that are also referred to as proanthocyanidins do not depolymerize and are not absorbed and therefore may protect soluble protein from rumen fermentation. Generally tree leaves and browse contain both types of tannins and the two may differ in their nutritional significance and toxic effects. The present literature review gives an overview of the most prevalent nutritional effects of tannins from commonly used tropical feedstuffs including MPTs and shrubs for ruminants' production

**Table 2.18: Distribution of secondary compounds found in some forage tree legumes**

| Species | Plant part | Compound | Reference |
|---|---|---|---|
| Acacia aneura | Leaf | C. tannins, oxalate | Gartner et al., (1976) |
| *Acacia cambagei* | Leaf | C. Glycosides, C. hydrolase, Oxalate | Cunningham et al., (1981) |
| *Acacia cana* | Leaf, Stem | Selenium | Cunningham et al., (1981) |
| *Acacia doratoxylon* | Leaf, Stem | C.glycosides | Cunningham et al., (1981) |
| *Acacia georgina* | Leaf, Stem | C.glycoside, Fluoroacetate | Cunningham et al., (1981) |
| *Acacia salicina* | Leaf, bark, pods | Tannins, Saponins | Hail et al., (1972) |
| *Albizia chinensis* | Bark, leaf | Echinocystic acid, glycosides, Oleanolic acid, C.tannins | Rawat et al., (1989) |
| *Albizia lebbeck* | Floweres, | Various Sterols | Asif et al. (1986) |
| | Leaf | Pipe colic acid derivatives | Romeo, (1984) |
| *Calliandra calothyrsus* | Leaf | C. tannins | Ahn et al., (1989) |
| *Calliandra haematocephala* | Leaf | Pipecolic acid derivative | Marlier et al., (1979) |
| *Calliandra partoricensis* | Leaf | Tannins, saponins, flavonoids, glycosides | Aguwa and Lawal (1987) |
| *Gliricidia sepium* | Leaf | Pinitol | Calle et al., (1987) |
| | Leaf | Condensed tannins | Ahn et al., (1989) |
| | Leaf | Coumarins, melitotic acid | Griffiths, (1962) |
| | Leaf | Cyanogenic, glycosides, nitrate | Manidool, (1985) |
| | Seed | Canavanine, heat stable toxin | Sotelo et al. (1986) |
| *Leucaena leucocephala* | Leaf | Mimosine | Hergarty et al., (1964) |
| | Leaf | Condensed tannins | Ahn et al. (1989) |
| | Leaf | Flavanol glycoside | Lowry et al (1984) |
| Sesbania grandiflora | Leaf, seed | C.tannins, glycosides | Andal and Sulochana (1986) |
| | Floweres | Methyl oleanolate | Kalyanaguranathan et al., (1985) |
| *Sesbania sesban* | Leaf | Saponin | Dorsaz et al., (1988) |
| | Leaf | Saponin, heat labile toxin | Shqueir et al., (1989) |
| | Seed | Saponin | Kholi (1988) |

Donnelly and Anthony (1969) reported that the tannin level required for rejection by grazing animals is approximately 20 mg/g DM and also indicated that a high level of tannins could depress the feed intake in three ways: (1) They may slow down the digestion of DM in the rumen, react with the outer cellular layer of the gut and thus diminish the permeability of the gut wall, all of which would give signals of physical distension- an important feedback in the ruminant for controlling feed intake. (2) There is some evidence suggesting that tannins may influence hormone levels. Cholecystokinin, a peptide hormone released from the duodenum, has been observed to suppress feeding and the peptide bombesin has been implicated in reducing feed intake in sheep (Schneider et al., 1983). Whether the intake of tannins influences the release of hormones or neuropeptide secrections is not known. (3) The depression of intake could also be due to unpalatability (Burns and Cope, 1974). The tannins in plant tissue may precipitate salivary proteins, causing an astringent taste in the mouth. The astringency or protein precipitating capacity of the tannins depends on the molecular weight and increases progressively from 576 up to 1134 (Bate-Smith, 1973). However, when the molecular weight is very large (>5000), the condensed tannins become rather insoluble in physiological solutions and lose their protein-precipitating capacity. The palatability of 14 species of woody plants in Southern Africa savannas to browsers (goats) was closely related to the concentration of condensed tannins. There was a threshold of tannin content, approximately 5 %, below which there was no effect (McNaughton, 1987).

There are indications that when the tannins of tree leaves interact with dietary protein they form indigestible protein-tannin complexes and also inactivate the enzymes and as a result the digestion of fibre and proteins is depressed in the ruminants (Kumar and Singh, 1984a).

Van Hoven (1984) observed the decrease in IVDMD of *Lucerne* with tannin concentration and some of the results demonstrated in Table 2.19.

**Table 2.19: IVDMD in g/kg of *Lucerne* (*Medicago sativa*) in the presence of tannins**

| Tannin, g/kg | Condensed tannins | Tannic acid |
|---|---|---|
| 0 | 497 | 485 |
| 100 | 384 | 424 |
| 150 | 374 | 406 |
| 250 | 138 | 294 |
| 350 | 0 | 203 |
| 450 | - | 0 |

**Source: Van Hoven (1984).**

The author demonstrated that both the hydrolysable and the condensed tannins had a negative influence on IVDMD, but the latter was more pronounced. Similarly, Reed et al., (1985) observed that condensed tannins affected the NDF degradability in a negative relationship. However, Robbins et al., (1987b) reported that the tannins had no effect on NDF digestibility in deer. Gartner and Hurwood (1976) reported that the availability of sulphur was decreased in sheep fed with mulga (*Acacia aneura*) leaves containing tannin. However, when they were supplemented with both soluble (Na2SO4) and insoluble (CaSo4) salts of sulphur, the increase in intake was approximately 500 g/kg, but no responses were obtained with calcium salts that did not contain sulphur. This observation was more or less supported by Fuller et al., (1967) who said that the sulphur-containing amino acids, are reported to counteract certain adverse effects of tannic acid in chickens through donating methyl group to inactivate tannis, but the role of sulphur was not elaborated. Ahn et al. (1989) found that there was poor correlation between nitrogen digestibility and total condensed tannin content measured either by Vanillin- HCL or Butanol-HCL assay.

Sandusky et al., (1977) indicated that condensed tannins readily combine with dietary proteins, salivary protein, digestive enzymes and rumen microbes, and these proteins bound with tannins are most unlikely to undergo normal metabolism. However, it was cautioned that a continued consumption of tannin can cause gastritis and irritation, and also oedema of the intestine and that once tannin has crossed the intestinal membrane, a myriad of possible harmful interactions could result. According to Van Hoven (1984), hydrolysable tannins may also exert similar toxic effects. In addition, as they can be hydrolysed in the rumen to yield gallic acid, hexahydroxydiphenic acid that can be absorbed, several other toxic manifestations would be reflected. Baloyi et al., (2001) while researching on tannins and saponin content in selected herbaceous legumes revealed that there were more condensed tannins in the mature leaves than in the younger leaves of the forages. This was in agreement with findings by Makkar and Singh (1991) who suggested that there are more tannin complexes in the mature leaves. Generally, the NDF, ADF, ADL, cellulose, hemicellulose and lignin contents increase with leaf maturity, as does the content of insoluble tannins. This suggests that, as the leaves mature, the insoluble (condensed tannins) tannins are becoming bound to the cell wall and to proteins, which decreases the digestibility of the lignocellulose moiety. The lower levels of condensed tannins in the young leaves may be offset by the presence of hydrolysable tannins (Makkar et al., 1988). These results also suggest that the young leaves might be fed to livestock without risking deleterious effects.

### 2.3.7.8: Protective response to dietary tannins

In an excellent review, Mehanso et al., (1987a) proposed that the increased secretion of proline-rich proteins (PRPs) in saliva constitutes the first line of defense against ingested tannins. Similarly, Hagerman and Butler (1981) supported this contention when they indicated that PRPs have very high affinities for tannins and that both condensed and hydrolysable tannins were found to induce this response. It appears therefore that PRPs may function as tannin-binding proteins and can reverse the detrimental effects of tannins in the diet. It is Robins et al., (1987b) who reported the presence of PRPs in the saliva of ruminants for the first time. Size differences in ruminant parotid salivary glands are best explained by the range in tannin intake and the requisite production of salivary proteins, glyco-proteins for lubrication and proline-rich salivary proteins to bind tannins.

In addition, it has been hypothesized that high-proline salivary proteins have two other essential roles in permitting ingestion of tanniferous forages (Robbins et al., 1987b). The author mentioned that the non-precipitating nature of these proteins coupled with the high binding capacity of proline-rich proteins relative to other proteins may permit a much more efficient binding of tannins per unit of protein. However, depending on the nature of the tannin: plant protein complex ratio, the tannin-plant protein complex may dissociate in the acidic abomasums with both the protein and tannin, if hydrolysable, being absorbed (Driedger and Hatfield, 1972 and Jones and Mangan, 1977). The nutritional consequences of the dissociated tannin depends on whether it can be absorbed or whether it is toxic. Although ruminants are less susceptible to tannin toxicity than many other animals, domestic cows and sheep are more susceptible than are browsing ruminants (Nastis and Malechek, 1981).

There is also evidence that some ruminal micro-organisms are able to metabolise tannins or remain active in a high tannin environment, and therefore may be used as inoculants to overcome the detrimental effects of tannins in ruminants (Shelton and Gutteridge, 1984). Palmer and Schlink (1992) have reported that wilting (25° C for 24 h) *Calliandra calothyrsus* depressed feed intake in sheep when given as sole diet over an 8-day period. On contrary, Ahn et al., (1989) showed that drying decreases extractable tannin content of tree legumes including *Caliandra*. In their work, drying alone increased straw intake and the digestibility of NDF. These workers further illustrated that drying the browse at 60 °C in a force- draught oven resulted in variable losses in both total phenolics and condensed tannins content in all species. In particular, *Glirircidia sepium* and *Tipuana tipu* lost all apparent tannin content during oven drying. As expected, the scale of reduction was very variable. The rapid distengration of leaf cell walls and passage from the rumen are essential features for tree and shrub leaves to be useful feeds for ruminants. This contention was also reported by Hungate (1959) who indicated that higher rumen fermentation rate in browsers and mixed feeders relative to grazers is a pre-requisite to consume more of tannins-containing feeds.

**2.3.7.9: Summary**

The review has shown that legume tree leaves maintain high protein content during their growth and hence useful as dry season protein supplement. Whilst there is considerable information in the literature on supplementation value of ***Leucaena leucocephala*** and others like *Gliricidia sepium* and certain *acacia spp.*, less is known about other species in the genus *Leucaena* that have been identified as psyllid resistant such as *L. diversifolia* and thus merits further investigation. The literature suggests that where legume foliage are used as supplement, the quantities given or the regime of feeding will vary depending on the nature of the basal diet, the nutritive properties of the foliage and the desired level of performance of the animals fed. It is thus suggested that any evaluation of new forage trees should investigate the effects of increasing levels of supplement on animal performance so that minimum quantity-maximum effect responses can be determined. The present study was therefore designed to investigate the value of *Leucaena diversifolia* as a dry season protein supplement to beans straw and maize stover based basal diets.

## 2.4: Effect of rate of offer of basal diets (maize stover and beans straw) and *L. diversifolia* leafmeal supplementation on intake, selectivity, and milk yield and its composition by lactating dairy cows

**Introduction:**

Generous offer under stall-feeding provides opportunities for selective consumption in a manner that mimmicks free range grazing. Through selection animals improve both intake and digestibility of the materials consumed as evidenced by Wahed et al., (1990) and Tanner et al., (1993). Although it is not well documented what internal mechanisms are responsible in controlling diet selection, but there is ample evidence that ruminants are capable of making nutritionally wise choices between foods or even if offered a heterogenous single food, (Forbes, 1998). This section reviews past research and development works on effect of selective consumption of heterogenous feeds on improving production performance of ruminant animals.

### 2.4.1: Effect of rate of offer of basal feed on performance of ruminant animals

Table 2.20 summarizes the literature on influence of rates of offer on selected studies. This table demonstrates the effectiveness of selective consumption strategy in improving production performance of ruminants when wide ranging offer rates systems were being evaluated with such animals. It is evident that in most cases offer rates were set on the basis of expected target refusal amounts or rates (Wahed and Owen, 1986; Bhargava et al., 1988; Wahed et al., 1990; Fernandez-Rivera et al., 1994; Biswal et al., 2000 and Dutta et al., 2000). In other cases, offer rates have been worked out on the basis of intended percentage of live weight as feed allowance (Gibb and Treacher, 1976; Wahed et al., 1990; Aboud et al., 1991; 1993; Bosman et al., 1995; Tanner et al., 1995; Methu et al., 1996 and Osafo et al., 1997).

**Table 2.20: Inventory of previous research reports for selective consumption studies for selected feeds, criteria used to set offer rates, levels of amount offered investigated and type of response measurements recorded**

| Authors | Basal feed | Rate of offer | Animal species | Response measurements |
|---|---|---|---|---|
| Aboud et al., 1993 | Sorghum stover | 25, 50, 75 g/kg M.d | Sheep, Goats | ADG, feed selectivity |
| Aboud et al., 1991 | Sorghum stover | 25, 50, 75 g/kg M.d | Sheep | Intake, selectivity, ADG |
| Bhargava et al., 1988 | Barley straw | 0.2, 0.3, 0.4, 0.5, 0.7 kg of refusal | Sheep | Intake, digestibility, selectivity |
| Biswal et al., 2000 | Wheat straw | 75, 100, 125, 150 % of *adlibitum* intake | Goats | Intake, selectivity, passage kinetics |
| Bosman et al., 1995 | G. sepium, L. leucocephala | 60, 70, 80, 90, 100, 110, 120 g DM/kg M $^{-0.75}$ | Goats | Intake, digestibility, ADG |
| Brown et al., 1988 | Napier grass, pigeon pea | 200 % intake | Goats | Intake, digestibility |
| Dutta et al., 2000 | Maize fodder | 20, 35, 50 % of refusal | Goats | Intake, digestibility |
| Fernandez-Rivera et al., 1994 | Pearl millet stover leaves | 100, 300, 500, 700 g DM/ day | Sheep | Intake, selectivity, digestibility |
| Gibb and Treacher, 1976 | Rye grass and red clover swards | 20, 28, 44, 73, 127 g DM/ kg M.d | Goats | Intake |
| Methu et al., 1996 | Maize stover | 2.9, 5.7, 8.7 % Of M | Cattle | Intake, selectivity |
| Osafo et al., 1997 | Sorghum stover | 25, 50 g/kg M.d | Sheep, Cattle | Intake, selectivity |
| Subba Rao et al., 1994 | Finger millet straw | 60, 80, 100, 120, 140, 160 % of energy | Cattle | Intake, digestibility |
| Tanner et al., 1995 | Axonopus compressus (indigenous forage), rice bran | 25, 50, 75 g DM/kg m.d | Sheep | ADG, intake |
| Wahed and Owen, 1986 | 1.Lucerne 2. Barley straw | 200 g/kg refusal | Sheep and goats | Intake selectivity |
| Wahed et al., 1990 | Barley straw | 200, 500 g/kg DM refusal | Goats, sheep | Intake, selectivity |

Subba-Rao et al., (1994) employed energy requirements for 300 g gain in crossbred heifers as a criterion for setting offer rates. Irrespective of the approach used, generous feeding strategy has shown improvement in intake, gain and milk yield. In addition, Aboud et al., (1991) argued that for highly differentiated forages such as sorghum stover it might not be very appropriate to set offer rates on the basis of target refusal rates. This has been supported by Methu et al., (1996) who showed that stem intake was not affected by rate of offer while sheath intake tended to decrease with increasing rate of offer when maize stover was offered to lactating cattle. In the present study, offer rates for bean straw and maize stover were set on the basis of live-weight in order to obtain reliable estimates for judging feeds selectivity. Both bean straw and maize stover are largely dominated by the stem fractions. Botanical composition for various cereal straws/stovers from different experiments is presented in Table 2.21.

There is paucity of information in the literature illustrating combined effects of selective consumption and legume leaf meal supplementation on feed selectivity and the resultant animal productivity. It is common knowledge that the legumes have in their leaves a high protein content and are better able to retain feeding quality than tropical grasses especially during dry periods. It might be postulated that better animal performance can be registered if the benefits of selective feeding are enhanced with a legume supplement. In the present study it is intended to observe the responses when lactating cows are offered varied rates of either bean straw or maize stover as single feed or in combination.

**Table 2.21: A summary of botanical composition for selected cereal straws/ stover**

| Cereal crop residue | Botanical fraction | Composition g/kg DM | Author |
|---|---|---|---|
| **Sorghum straw** | | | Aboud et al., 1991 |
| | Leaf | 168-258 | |
| | Sheath | 213-254 | |
| | Stem | 424-493 | |
| **Sorghum stover** | | | Osafo et al., 1997 |
| | Leaf | 33-94 | |
| | Sheath | 211-263 | |
| | Stem | 695-704 | |
| **Maize stover** | | | Methu et al., 1996 |
| | Leaf | 123-175 | |
| | Sheath | 133-153 | |
| | Ear | 236-247 | |
| | Stem | 423-505 | |
| **Wheat straw** | | | Bhargava et al., 1988 |
| | Leaf-blade | 128 | |
| | Leaf-sheath | 314 | |
| | Stems | 500 | |
| | Chaff | 58 | |
| **Barley straw** | | | Theander and Aman, 1984 |
| | Internode | 580 | |
| | Node | 70 | |
| | Leaf | 350 | |
| **Oat straw** | | | Theander and Aman, 1984 |
| | Internode | 530 | |
| | Node | 40 | |
| | Leaf | 430 | |

This holds a significant bearing in improving smallholder dairy cattle production since legume leaf meal is a cheap nitrogen source and may reduce feed costs and therefore improve the gross margins in dairy production. Although generous feeding strategy has been proved to be superior in promoting total feed intake, digestibility and the resultant increased animal productivity, it is, however associated with some disadvantages. Firstly, are the large feed quantities required to allow for selectivity. This disadvantage may have serious effects notably under cut and carry feeding management system that is predominant in smallholder dairy cattle production in Tanzania. Also generous feeding inevitably produces large quantities of refusals and it can only be regarded rational if other uses can be found for refusals. For instance, according to Tanner et al., (1995), Javanese farmers (Indonesia) persist in offering excess levels of forage to their livestock in order to maximize manure compost yield since the latter is ranked by Javanese farmers alongside offspring as the most important outputs from livestock production. Experience from Southern highlands of Tanzania support this contention since farmers hitherto conserve composted manure in specially erected and well roofed manure barns while awaiting for the planting season. Under such circumstances high offer rates may optimize nutrient recycling.

Response on animal performance in selective consumption studies have varied both with basal feeds under investigation and offer-rates on test. For instance investigations by Aboud et al., (1991) while investigating influence of sorghum stover varieties and rate of offer reported intake by Ethiopian rams of 46.3, 59.3 and 58.6 g DM/kg $M^{0.75}$ at offer rates of 25, 50 and 75 % on the basis of live-weight of sheep. The corresponding rate of gain in g/d for the same treatments were 39.4, 66.5

and 76.6, respectively. The authors noted that rams consumed significantly more sorghum stover from both varieties as the rates of offer was raised from 25 to 75 g/kg M.d. Similarly, Methu et al., (1996) recorded total stover DM intakes of 8.3, 11.5 and 13.2 kg for 2.9, 5.7 and 8.7 % rates of offer of maize stover on the basis of liveweight of lactating dairy cows while milk yields were 11.2, 11.3 and 13.0 kg per cow per day, respectively. These authors also observed an increase in the intake of both stem and leaves fractions with increasing rate of offer of maize stover. Overall, the authors concluded that offering large amounts of maize stover could be used as a strategy to increase intake and milk production.

Studies by Osafo et al., (1997) while investigating effects of amount offered and chopping on intake and selection of sorghum stover by Ethiopian sheep and cattle reported average gain of 30.5 and 56.0 g/d (for unchopped stover) at 25 or 50 g/kg M, respectively. The corresponding gains for chopped stover were 45.8 and 70.5 g/d respectively. The trends in gain for cattle were 0.25 and 0.43 kg/d for the 25 and 50 g/kg M., respectively for the unchopped stover material while the corresponding gain for the chopped material were 0.36 and 0.44 kg/d for 25 and 50 g/kg M, respectively. Stover intake were 3.7 and 4.7 kg DM/d for 25 and 50 g/kg M. per day, respectively for unchopped material and 3.6 and 3.9 kg DM/d for chopped stover, respectively. Intake of leaf were 0.5 and 0.8 kg DM/d for 25 and 50 g/kg M, respectively for the unchopped stover and 0.5 and 0.6 kg DM/d for the chopped stover, respectively. The reported sheath fraction intake were 0.9 and 1.2 kg DM/d at 25 and 50 g/kg M, respectively for the unchopped stover and 0.9 and 1.3 kg DM/d for the chopped stover, respectively. The observed stem intake were 2.4 and 2.8 kg DM/d (unchopped) for the 25 and 50 g/kg M, respectively while the corresponding stem intake for the chopped stover were 2.2 and 1.9 kg DM/d stover, respectively.

Bosman et al., (1995) researched on the effect of amount offered on intake, digestibility and value of *Gliricidia sepium* and *Leucaena leucocephala* using West African dwarf goats. Feed was offered at levels varying from 60 to 120 g DM/kg $M^{0.75}$ .d with increments of 10 g. In this experiment, two combinations of *G.sepium* and *L. leucocephala* were studied (100 % *Gliricidia*-G1` and 50 % *Gliricidia*/50 %*Leucaena*-GL1). Maximum DMI reported were 72.5 and 90.7, g/ kg $M^{0.75}$ .d for G1 and G2, respectively.

Examination of selective consumption studies carried out in temperate countries suggest that nature of responses for selectivity and the corresponding animal productivity are in most cases consistent with what has been documented under tropical environment. Bhargava et al., (1988) evaluated selection and degradation of morphological components of barley straw by sheep at the Rowett research institute (Aberdeen) in which sheep were allowed to leave uneaten feed proportionately 200, 300, 400, 500 and 700 g/kg of the straw on offer. The authors noted that the selection of leaf sheath was less apparent but that the amount of leaf blade in the material consumed increased in largely a linear fashion with the amount of excess allowance while the proportion of stem eaten varied conversely. Similarly, Wahed and Owen (1986) reported more or less similar observations while evaluating comparison of sheep and goats under stall-feeding conditions and measuring roughage intake and selection. In this study, feed was offered ad-libitum allowing refusals of about 200 g/

kg of long *Lucerne* hay. The results obtained are shown in Table 2.22. The authors concluded that both sheep and goats are selective feeders under stall-feeding conditions.

**Table 2.22: Intake and chemical composition of *Lucerne* hay**

| | | | Sheep | Goat | s.e.d |
|---|---|---|---|---|---|
| **No. of animals** | | | 10 | 10 | |
| **Initial age (months)** | | | 21 | 21 | |
| **Mean live weight** | | | 51.8 | 42.5 | 4.1 |
| **Intake** | | | | | |
| **Dry matter (DM) offered (g/day)** | | | 1884 | 1744 | |
| **DM intake (g/day)** | | | 1474 | 1373 | 122.3 |
| **DM intake (g/kg M per day)** | | | 28.3 | 33.2 | 2.1 |
| | **Hay offered** | | **Hay refused** | | |
| **Chemical composition** | Mean | s.e | | | s.e.d |
| **DM (g/kg)** | 805 | 3.2 | 765 | 786 | 1.0 |
| **Nitrogen (g/kg DM)** | 28 | 1.0 | 16 | 23 | 2.1 |
| **Acid detergent fibre (g/kg DM)** | 391 | 4.6 | 466 | 449 | 20.0 |
| **Ash (g/kg DM)** | 91 | 1.1 | 69 | 77 | 5.2 |

Source: Wahed and Owen (1986).

### 2.4.2: Effect of legume forage supplementation on animal performance

Cereal straws and leguminous tree forage are valuable feed resources for ruminant livestock in the tropical world. The straws are usually deficient in protein, vitamins and critical minerals. Animals fed exclusively on these feeds are unlikely to meet their nutritional requirements, consequently resulting in low production (Leng, 1990). The converse appears to be true in the leaves of most browse and tree species (Le

Houerou, 1980). However, most leguminous browses and trees contain tannins and related polyphenols (Reed, 1986; Glyphis and Puttick, 1988). Due to these factors, the supplementary value of various browses and trees will vary with species of plant materials and animals. The present review evaluates the role of legume leaf meal or forages in improving the utilization of cereal straws or stovers and other poor quality tropical forages for ruminants' production. Although the present study is centered on maize stover and bean straw as basal feeds and *Leucaena diversifolia* leaf meal as a nitrogen supplement, the following literature review, however, will not be limited to these feeds only but also includes other commonly used tropical ruminant feeds.

Different measurements including basal feed intake, average daily gain (ADG), degradability characteristics, $NH_3$ levels in the rumen, milk yield and its composition and apparent digestibility have been used to assess the supplementary value of legume forages. Responses on these variables are used as a criterion in judging the value of legume leaf meals.

In an effort to evaluate supplementary value of legume tree forage, Ebong (1995) worked on *Acacia nilotica*, *Acacia seyal* and *Sesbania sesban* as supplements to tef (*Eragrostis tef*) straw fed to sheep and goats. The results obtained are shown in Tables 2.23 and 2.24.

**Table 2.23: Intake (g per kg $M^{0.75}$ daily) and digestibility (g/kg intake) in sheep and goats fed tef straw in combination with iso-nitrogenous (7.2 g N/d ) amounts of *A.nilotica, A. seyal and S. sesban***

| | Goats | | | Sheep | | |
|---|---|---|---|---|---|---|
| | A.nilotica | A. seyal | S. sesban | A.nilotica | A.seyal | S. sesban |
| Straw intake | 36.2a | 40.7b | 37.7ab | 43.7b | 43.1b | 51.6c |
| Total DMI | 60.4b | 64.7c | 55.5a | 70.2d | 69.3d | 69.0d |
| Digestibility | | | | | | |
| DM | 643c | 606bc | 551a | 589ab | 569a | 552a |
| OM | 639c | 594bc | 541a | 576ab | 544a | 544a |
| NDF | 527ab | 517ab | 488a | 494ab | 494ab | 562b |
| Digest. DMI | 38.8b | 39.3b | 41.4b | 41.4b | 37.6b | 38.1b |

*Source: Ebong, (1995).*

Based on this information, Ebong, (1995) commented that apparent N digestibility and N retention were consistently lower in animals fed *Acacia seyal* than when animals were fed *Acacia nilotica* and *Sesbania sesban.* It was further argued that differences in intake between sheep and goats could be attributed to differences in retention times and hence digestibility of DM and NDF. Differences between browse species were attributed to types and levels of tannin and related polyphenols in the leaves and their effect on N metabolism in the rumen. It is apparent from these results that N excretion in faeces differed between the legume browses whereby sheep and goats fed *Acacia seyal* voided more N in faeces than their contemporaries fed on *A. nilotica* and *S. sesban,* hence the lower N digestibility in animals fed *A. seyal.* A similar pattern was observed in the urinary N excretion and N retention where proportionally less N was excreted or retained in urine and tissues, respectively, in animals fed *A. seyal* than in those fed *A. nilotica* and *S. sesban*. Reduced apparent nitrogen digestibility and urinary N excretion are typical features in ruminants fed protected proteins. Similar patterns have been observed in animals fed on tannin containing feeds (Nastis and Malechek, 1981).

**Table 2.24: Nitrogen intake (g/d), excretion (g/d and proportions of intake) pattern in faeces and urine, and retention in the body in sheep and goats fed tef straw in combination with isonitrogenous (7.2 g N/day) amounts of *A. nilotica, A. seyal and S.sesban***

| | Goats | | | Sheep | | |
|---|---|---|---|---|---|---|
| | *A.nilotica* | *A.seyal* | *S.sesban* | *A.nilotica* | *A.seyal* | *S.sesban* |
| **Intake** | 8.2 | 9.0 | 9.8 | 9.3 | 9.1 | 10.7 |
| **Faecal excr.** | 3.2a | 5.0b | 3.1a | 3.9a | 5.9b | 5.2b |
| **App. Diges.g /kg** | 661d | 441ab | 688d | 582cd | 354a | 514bc |
| **Fae.NDFN, g/d** | 0.6a | 1.3c | 0.6a | 0.8b | 1.6d | 0.6a |
| **% N intake** | 5.8a | 14.4d | 5.6a | 8.6c | 17.6d | 6.1a |
| **Fae.NDSN, g/d** | 2.7a | 3.7b | 2.5a | 3.1a | 4.3bc | 4.6c |
| **% N intake** | 28.1a | 41.0b | 25.6a | 33.3ab | 47.9c | 42.5bc |
| **Urine N, g/d** | 3.2c | 2.3ab | 4.0d | 2.8bc | 1.6a | 3.2a |
| **Urine N % N intake** | 35.2bc | 25.2a | 40.3c | 29.8b | 18.1a | 30.1b |
| **N reten. g/d** | 1.7 | 1.7 | 2.6 | 2.6 | 1.6 | 2.3 |

**Key: NDFN= Fibre bound nitrogen**

**NDSN = Neutral detergent soluble N**

**FAE.= faeces**

**Source: Ebong, (1995).**

Recent studies by Ondiek et al., (2000) on cross bred dairy goat in Kenya have shown that goats fed on *Gliricidia* based concentrate recorded superior intake and daily gain than those given commercial based concetrate and *Leucaena* based concentrate. In contrast, Richards et al., (1994) while also investigating replacement value of *L. leucocephala* and *G. sepium* leafmeal for concentrates in *Pennisetum purpureum* based diets for lactating goats in Jamaica showed that faecal nitrogen production was greater for legumes supplemented diets than conventional concentrate supplemented diets (control) leading to lower nitrogen digestibility for the legume leaf meal supplemented diets. No reason were outlined for this lowered digestibility but probably legume based supplements were more fibrous than the conventional concentrate. The observations further indicated that OM intake was greatest for the control diet and least for the *Gliricidia* supplemented diet but milk production characteristics were similar for all treatments. The authors recommended that for iso-energetic diets, up to 50 % of the concentrate nitrogen might be replaced by the tropical tree legumes *Gliricidia* and *Leucaena* without a reduction in milk production. This proposition is in conformity with observations by Khalili and Varvikko (1992); Yates and Panggahean (1988) who demonstrated that direct replacement of concentrates by legumes may result in reduced productivity because energy in concentrate feeds is not adequately replaced by legume forages. Abdulrazak et al., (1996) evaluated the effects of incremental levels of *Gliricidia sepium* and *Leucaena leucocephala* in a Napier grass based diets using *Bos Taurus-Bos indicus* crossbred steers. The findings showed increase in total DMI but intake of Napier grass was depressed linearly with *Gliricidia* supplementation while supplementation with *Leucaena* increased the total DMI linearly without depressing the intake of Napier grass. Egan, (1986) indicated that legume supplements are usually most effective when offered with roughages containing less than 20 g N per kg DOM because they increase the rumen ammonia concentration by providing ruminally fermentable nitrogen. Other workers have suggested that when readily consumed the *Gliricidia* distends the rumen and thereby reducing intake of the basal diet (Smith and van Houtert, 1987).

Topps (1992) showed that majority of legume shrubs and trees is low in phosphorus while only a few are rich in calcium. Further more, this worker indicated that the calcium to phosphorus ratio was very large (up to 21.3: 1) and for the species investigated, the sodium content was very low.

**2.4.3: Summary**

It is increasingly being realized that, high feed allowances is one way to increase the performance of ruminants offered heterogenous roughages under stall-feeding production system. Research and development over the last three decades has demonstrated that ruminants are capable of making nutritionally wise choices both between and within feeds depending on level of botanical tissues differentiation. Owing to the fact that ruminants' feeding is highly diversified, there is need to determine responses of animals to increasing levels of feed allowances based on locally available feed resources in different locations.

Forages from legume trees growing in the tropics can be used as cheap nitrogen sources to supplement low-N feed resources. However, interpretation of literature data on the feeding value of these legume forage trees and shrubs has been confounded with the presence of secondary compounds such as tannins which exert varied nutritional effects upon consumption.

# CHAPTER THREE

## 3.0: MATERIALS AND METHODS

### 3.1: Experiment 1: Biomass evaluation for *Leucaena diversifolia*

The aim of this study was to test the hypothesis that it is possible to estimate and predict biomass yield for *L. diversifolia* based on plant height, number of branches and length of the longest branch characteristics of the tree. Estimation of biomass is a necessary step in feed budgeting. However, plant species differ in their indicator parameters, calling for investigations on the most practical predictive models for all forages especially those native to the location.

#### 3.1.1: Site of the experiment

The present study was carried out at the Agricultural Research Institute Uyole (ARI-UYOLE), in Mbeya region in the Southern Highlands of Tanzania (8° 55' S, 35° 32' E; altitude 1800 m above sea level). Average annual rainfall ranges between 1200 – 1400 mm. The rainy season runs from December to April whereas the dry season usually lasts from June to November. The coolest month is June with an average temperature of 10.51 °C. The warmest month is November with an average temperature of 24.2 °C. The soils are brownish loams (Haplic Andosol). Soil fertility has declined greatly over the past years due to continuous cultivation of crops, lack of soil fertility restoration strategies and also leaching by rains.

### 3.1.2: Planting of trees

First batch of *Leucaena diversifolia* trees was planted in January 1999. Some 7,500 tree seedlings that had earlier been established in a nursery were transplanted into a 1.45 ha plot soon after the onset of the rainy season. This first batch of *Leucaena diversifolia* trees grew quite well and no visible problems. The second batch of *L. diversifolia* seedlings were transplanted into the remaining un-planted portion of the same field during January 2000 and also soon after the start of the rain season. However, this second batch of the trees had to be irrigated during July / August 2000 (dry season) in order to enhance growth of the trees because of the unusually short rainy season that ended in April instead of May (Appendix 2). The planting configurations was 2 x 0.5 m between and within rows, respectively. No fertilization was practised but weeding was done to ensure that the growing trees were free from weeds infestation.

### 3.1.3: Biomass Determination

A plot of *Leucaena diversifolia* that consisted 8 trees spaced at 2 m x 0.5 m configuration, was used as a sampling unit for evaluation of biomass productivity of *Leucaena diversifolia* trees. For sampling purposes, only 4 trees per plot that were chosen at random were used for recording the data. Total number of plots used for this exercise was 40 and altogether about 160 trees were used for data recording. Coppicing of trees was done at the age of 12 months when the trees were fully established. The trees were cut 15 cm above the ground for biomass determination, as illustrated in Plate 3.1. The sampled trees were separated into edible proportions, which included leaflets, petioles, pods and young twigs (<100 mm). The remaining component was the wood part. For DM determination, 200 g was drawn from each botanical fraction. The dried samples were ground and placed in the oven at 105 °C for the conventional dry matter determination procedures as described by AOAC (1990).

Plate 3.1: Trees coppiced at one year.

### 3.1.4: Chemical composition analyses

The proximate composition of the leaf meal was analyzed according to the standard procedures as described by (AOAC, 1990). NDF was determined following the procedure as outlined by Van Soest (1982). Condensed tannins were determined by the Butanol-HCL method as described by Mueller-Harvey et al. (1987).

### 3.1.5: Data analysis

Multiple Linear Regression Analysis Procedure was used for data analysis on biomass yield (edible material and total biomass yield). This analysis tool was used because it was assumed that biomass determination in a perennial tree at an age of one year from planting time falls within a range whereby the relationship could be adequately described by a straight line for a range of independent variables that was measured in this study and which included: Length of the tree (LOT), Number of branches (NOB) and Length of the longest branch (LOLB). The data for biomass evaluation were analyzed according to the model:

$$Y = a + B_1 x_1 + B_2 x_2 + B_3 x_3$$

Where by:

Y = Represents either total biomass or edible material yield

a = Represents the intercept

$B_1$ = Partial regression coefficient for the Length of the tree (LOT)

X 1 = Represents Length of the tree as an independent variable

B 2 = Partial regression coefficient for the Number of branches (NOB)

X 2 = Represents Number of branches as the second independent variable

B 3 = Partial regression coefficient for the Length of the Longest Branch (LOLB).

X 3 = Length of the Longest branch as the third independent variable

This model was used since is one of the descriptive statistical tools and was considered appropriate in this experiment because the interest was to describe and predict biomass yield for *L. diverfolia* based on selected plant component.

While using the above model, the most important assumptions considered were:

(a) For each particular set of values of LOT, NOB and LOLB, there exists a population of either total biomass yield or edible material yield for *L. diversifolia*

(b) Each population of either total biomass or edible material yield (dependent variables) are normally distributed

(c) The variances of either total biomass yield or edible material yield are equal (Dunn and Clark, 1974).

## 3.2: Experiment 2: *In-sacco* degradability and *in-vitro* digestibility characterization of maize stover and bean straw

This experiment was designed to test the hypothesis that there exists substantial variation in *in sacco* degradability characteristics and estimated *in vitro* ME contents between bean straw and maize stover botancal fractions and *L.diversifolia* leaf meal. Maize bran and sunflower seed cake were used as positive controls.

### 3.2.1: Site of the study and description of feeds

The present study was carried out at the University's livestock research farm, Magadu, Sokoine University of Agriculture (SUA), Morogoro. However, feeds were produced at the Agricultural Research Institute Uyole (ARI-UYOLE), in Mbeya region located in the Southern Highlands zone and samples taken to SUA for *in sacco* and *in vitro* digestibility evaluations. The University is well facilitated with rumen cannulated animals.

Feeds for this study included botanical fractions from maize stover namely, whole plant (MS1), Stalk (MS2), leaves (MS3), Sheath (MS4), Ear (MS5) and Tassels

(MS6) and for bean straw fractions were stem (BSS1), pods (BSP2) and whole plant (WBS3). Other feeds included commonly used concentrate feeds i.e. maize bran and sunflower seed cake. Also included in this study was leaf meal from *Leucaena diversifolia* (leguminous multipurpose tree), which is a new protein supplement currently being adapted in different locations in Southern Highlands of Tanzania. Maize meal is not a common concentrate but was included for comparative reasons. Maize stover and bean straw was produced by the Farm Production Department at ARI-UYOLE following normal husbandry practices for the two crops and were collected from the field soon after grain harvesting. *Leucaena diversifolia* leaf meal was obtained after sun-drying the coppiced trees established in a pure stand field at ARI-UYOLE. Maize bran and sunflower seed cake were purchased while maize meal was supplied by the Farm Production Department at ARI-UYOLE.

### 3.2.2: Determination of botanical fractions

Two representative samples of 500 grammes each of maize stover and bean straw were separated manually into respective fractions as mentioned above. The different fractions for each type of the crop-residues were weighed in order to determine proportional distribution of the different fractions in the respective crop-residues and thereafter samples were taken for the *in-sacco* and *in-vitro* digestibility experiments.

### 3.2.3: *In sacco* degradability

Three, Friesian-Boran crossbred cows weighing on average 347.0 kg that were in 1$^{st}$ lactation, fitted with large and permanent rumen cannulae (internal diameter 10 cm) were used in a complete randomised design to describe *in sacco* degradation characteristic of the experimental feeds. The cows were kept individually in pens with concrete floor and fitted with permanent automatic drinkers. The animals were fed *Brachiaria brizantha* hay at approximately 80 % of the ad-libitum. They were also provided with 2 kg/head/day of concentrate mixture. The feeds were given daily in two equal meals at 09.00 and 16.00 hrs. Composition of the feeds used is presented in Table 3.1.

**Table 3.1: Composition of concentrate mixture and basal feeds for animals for *in sacco* experiment**

| Feed ingredients | CP composition g/kg | Proportion in g/kg DM | Calculated CP contribution in diet g/kg DM |
|---|---|---|---|
| Maize bran | 103.5 | 400 | 41.4 |
| Cotton seed cake | 347.5 | 400 | 139.0 |
| Maize meal | 95.0 | 200 | 19.0 |
| Total | | 1000 | 199.4* |

***Brachiaria brizantha* hay composition**

| | DM g/kg | ASH g/kg DM | CP g/kg DM | NDF g/kg DM |
|---|---|---|---|---|
| | 819 | 93 | 64 | 748 |

*** Laboratory analysis for the concentrate mixture had CP of 177.5 g/kg DM**

Nylon bags measuring 7.5 x 10 cm with pore size of 36 x 36μm were used in incubating the feed samples for DM, CP and NDF degradability characteristics. The air-dried feed samples were ground to pass a 2.5 mm screen. Each feed material was incubated separately in the rumens of three cows for each of the incubation periods. Duplicate samples of feed material were placed in the rumen of each cow. About 1 gm of air-dry feed materials was incubated in the rumen of each cow. The bags were anchored to a 25 cm plastic tube and withdrawn from the rumen after 2, 4, 8, 16, 24, 48, 72, 96, 120, 144 or 168 hrs of incubation. After withdrawal of the bag containing the undegraded residues of the samples, they were washed in cold water for about 18 minutes in order to suppress microbial action. The immediately solubility or washing loss was determined by soaking samples of each feed material in water at 38°C for one hour followed by the washing procedure as described above. Samples for DM and N were filtered through N-free filter paper of known weight. The residue was dried in an oven at 100°C for 20 hrs. Residues for NDF degradability were not dried but transferred directly to glass filter crucibles of known weight for NDF analysis. The loss of DM was determined for each incubation period and the data for each feed material were described by the exponential equation of Orskov and McDonald (1979), $P = a + b\,(1 - e^{-ct})$,

whereby:

P = degradation at time t

a = represents the intercept. If fermentation commences with no lag phase, then "a" represents the immediately soluble material, otherwise if "a" value is negative it will indicate a lag phase.

b = represents the water insoluble but degradable material.

c = Is the rate constant of "b".

("a + b") = is the potential degradability of the feed material, and a measure of its nutritive value.

Thus in presenting the results in tables, the parameters included are the constants "a", "b" and "c", the potential degradability (a + b) and the residual standard deviation of the equation (RSD).

### 3.2.4: *In vitro* digestibility

*In vitro* DM, OM digestibility and the estimated metabolisable energy (ME) of the same feedstuffs used for the *in sacco* experiment were determined by using the modified Tilley and Terry (1963) method as outlined by Goering and Van Soest (1970) which involves the use of neutral detergent solution in the second stage of the fermentation. Animals used for the *in sacco* experiment were also used as donor animals for the rumen liquor for the *in vitro* digestibility in a complete randomized design experment. Feeding and management of animals was as described under the *in sacco* experiment. Estimations of metabolisable energy values of forage based feed materials and concentrates were predicted from *in-vitro* digestibility values by using the formulae: **ME (MJ/kg DM) = 0.15 DOMD %**, whereby DOMD % was obtained from *in vitro* laboratory results. For concentrate feeds and *Leucaena diversifolia* leaf meal, the coefficient 0.15 was replaced by 0.16 for improved precision in estimating ME values of different classes of feeds as suggested by MAFF (1975).

### 3.2.5: Statistical analysis

The analysis of variance for DM, CP and NDF degradability characteristics of the various feed materials was done using the General Linear Model (GLM) in SAS (1990), according to the following model:

$Yij = \mu + Ai + Bj + eij$

Whereby: Yij = disappearance of DM, CP or NDF

$\mu$= Mean

Ai = Feed effect

Bj = Animal effect

eij = Residual error, assumed to be normally and independently distributed.

### 3.3: Experiment 3: The effect of *L. diversifolia* supplementation on *in-vivo* digestibility for beans straw / maize stover based diets by lactating dairy cattle

This experiment was set up to test the hypothesis that the optimum inclusion level for *L. diversifolia* leaf meal in either bean straw or maize stover basal diets ranges between 15 to 30% on dry matter basis. The choice for 15, 20, 25 and 30% levels of *L. diversifolia* with CP content of 224 g/kg DM was assumed to meet the minimum CP requirements i.e. 60 g/kg DM for the rumen microbes when lactating cows are fed on a basal diet of either bean straw or maize stover.

#### 3.3.1: Site of the experiment and description of experimental animals

The experiments were carried out at the Agricultural Research Institute Uyole (ARI-UYOLE) in Mbeya region and its location is as described under section 3.1. Four lactating Friesian breed cattle (Newzealand-origin) were used for this experiment. Body weight of experimental animals ranged between 286-352 kg with a mean of 309.8 kg at the beginning of the experiment. Mean milk yield of the animals was 3.5 litres per cow per day and ranged between 2.5- 5.0 litres per cow per day at the beginning of the first period. The cows were in mid-late stage of lactation but were not pregnant.

Before commencement of the experiment, the cows were drenched with an injectable anthelmintic drug, ALFAMISOLE 10 % (ALFASAN) at a dose rate of 1 ml per 20 kg body weight. They were also sprayed with an acaricide (TIKTAK) once per week in order to control tick borne diseases. All animals were confined in individual well-ventilated stalls. They were weighed at the beginning of the experiment and also at the beginning of each period. The experimental animals had been previously trained to confinement in metabolism cages.

### 3.3.2: Feed description and preparation

**Basal feeds:**

Bean straw variety DRK (UYOLE 94) was used in this experiment. This bean variety is the most popular in the Southern Highlands and is leafier than others (Madata, pers. comm.) and therefore was recommended for detailed evaluation in dairy cattle feeding systems for smallholder farmers. The bean straw was collected from Research Institute's farm during July / August 2000 and was stored under shed until it was required for digestibility experiments. Similarly maize stover H6302 which also is the most popular and specially bred for the cooler high altitude areas (Lyimo, pers. comm.) was collected from the same source during September 2000 and stored under shade until when it was required for the digestibility experiment.

***Leucaena diversifolia:***

*Leucaena diversifolia* trees were established in a 1.45 ha field and were coppiced after one year for production of leaf meal for the feeding experiments. The trees were harvested during January 2001 and dried under the sun. Stems thicker than 100 mm were sorted out and removed during the drying process. The leaf meal with more or less uniform composition was then packed in clean and dry containers until when it was required for the feeding experiments.

### 3.3.3: Feeding allowance

Dry matter allowance for the basal feeds and *Leucaena diversifolia* supplement was computed according to the formula:

**DMA = 0.025W + 0.1Y.**

Whereby: DMA= Dry matter allowance, kg / day,

W= Body weight of the animal, kg,

Y= Mean daily milk yield of the animal, kg / day (MAFF, 1975).

This equation was used since it was assumed that the total (maintenance plus production) DM requirements of lactating dairy cows in mid-late stage of lactation could be approximately met by such feed allowance.

### 3.3.4: Feeding plan

Table 3.2 shows the feeding plan used for the two *in-vivo* digestibility experiments i.e. 3a (bean straw) and 3b (maize stover) as basal feeds, respectively.

**Table 3.2: Feeding plan for the digestibility experiments**

| Periods | Cow Numbers | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| I | T1 | T2 | T3 | T4 |
| II | T2 | T3 | T4 | T1 |
| III | T3 | T4 | T1 | T2 |
| IV | T4 | T1 | T2 | T3 |

**Legend: T1 – T4 denotes supplementation levels of *Leucaena diversifolia* and defined as follows:**

T1: 15 % DM inclusion of *Leucaena diversfolia*.

T2: 20 % DM inclusion of *Leucaena diversifolia*

T3: 25 % DM inclusion of *Leucaena diversifolia*

T4: 30 % DM inclusion of *Leucaena diversifolia*.

### 3.3.5: Feeding

*Leucaena diversifolia* leaf meal was provided first during morning milking at around 8.00 a.m. The whole treatment allowance was given at once in order to stimulate simultaneous release of nitrogen and energy for the microbes. The daily basal feeds (bean straw and maize stover) allowances were divided into two equal parts and fed at 9.00 a.m.and 3.00 p.m. Drinking water was accessible to the animals all the time using automatic drinkers fitted into metabolism stalls. Similarly, animals had free access to mineral block licks whose composition is given in Table 3.3.

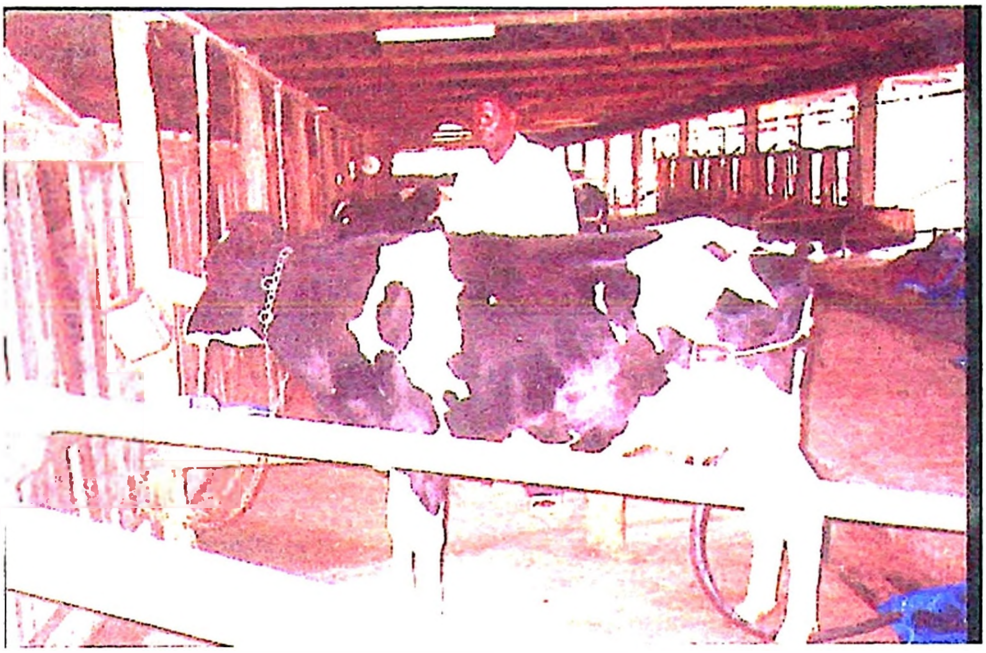

Plate 3.2: Feeding stalls for metabolism experiments

**Table 3.3: Guaranteed Analysis Of Macklik Super (KBS 4), g/kg**

| | |
|---|---|
| Nacl | 270.0 |
| Ca | 185.1 |
| P | 110.0 |
| Mg | 308.0 |
| Fe | 5.0 |
| Cu | 1.6 |
| Mn | 4.0 |
| Zn | 5.0 |
| S | 4.0 |
| Co | 0.2 |
| I | 0.2 |
| Se | 0.015 |
| Mo | 0.002 |
| Ca: P | 1.68: 1 |

### 3.3.6: Faeces collection

In this study, total collection approach was employed i.e. both urine and faeces were collected separately, sampled and stored for various analysis. Faeces were collected for the determination of nutrients digestibility coefficients. Faeces were collected into plastic bags and approximately 10 % of the daily collection were sampled and kept frozen until required for analysis. The sampling function for faeces was done routinely daily at 8.00 a.m.

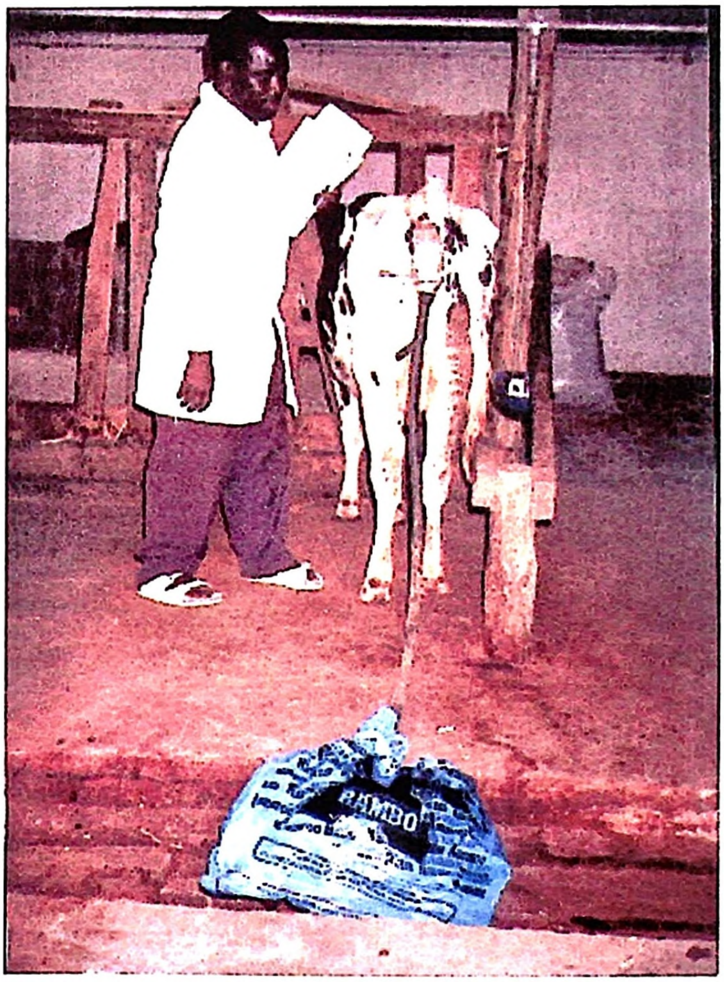

Plate 3.3: Separation of faeces from urine during *in-vivo* digestibility experiment

### 3.3.7: Experimental design and treatments

Both experiments (i.e. bean straw and maize stover based) were carried out in a 4 x 4 Latin square layout since there were four treatments that were investigated using four lactating cows. Experimental treatments included incremental levels of *Leucaena diversifolia* inclusion on DM basis as explained under section 3.3.5 above.

In executing this experiment, 14 days were used for adjustment purposes (preliminary period) and 7 days was for collection. The two weeks preliminary period was considered sufficient to account for any carry over effects because the basal feeds could not vary during the four periods except for levels (amounts) of *Leucaena diversifolia* inclusions from 15 % to 30 %. The "periods " variable would account for the differences in digestibility due to advancing stage of lactation in experimental animals.

### 3.3.8: Laboratory analysis

The feed and faeces samples were analyzed for DM, Ash and CP according to standard procedures (AOAC, 1990). Samples analyzed for NDF were done according to the methods described by Van Soest et al. (1991).

### 3.3.9: Calculations for digestibility coefficients

The calculated digestibility coefficients were for the total rations. Owing to the fact that the amount of feed refusals were negligible in this experiment, digestibility coefficients for DM and NDF were calculated according to the formula:

$$\textbf{Digestibility, \%} = \frac{\textbf{(Amount in feed – Amount in faeces) x 100}}{\textbf{Amount in feed}}$$

The apparent digestion coefficient of protein (CPD) was calculated as follows:

$$\textbf{Apparent CPD} = \frac{\textbf{(CP intake} - \textbf{total faecal CP)} \times 100}{\textbf{CP intake}}$$

In this case faecal CP includes both undigested feed CP and metabolic faecal CP since the latter was not measured and therefore not debited in this study.

### 3.3.10: Data analysis

Statistical analysis was done by the General Linear Model (GLM) procedure of SAS (1990) according to the model:

Y ijk = U + Ai + Bj + Ck + (AB)ij + eijk

Whereby:

U = Overall mean

Yijk = Observed output e.g. DM digestibility in %

Ai = Effect of the treatment (I = 1, 2, 3, 4)

Bj = Effect of the period (j = 1, 2, 3, 4)

Ck = Effect of the animal (k = 1, 2, 3, 4)

(AB) ij = Effect of A X B interaction

eijk= Random error.

## 3.4 Experiment 4: Effect of rate of offer of basal feeds (bean straw and maize stover) and *L. diversifolia* leaf meal supplementation on milk yield and its composition

This experiment was set up to test the hypothesis that *L. diversifolia* leaf meal supplementation to either bean straw or maize stover basal diets and increasing the rate of offer of the latter will sustain acceptable level of milk yield during the dry season.

### 3.4.1: Location

The present studies were also carried out at Agricultural Research Institute (ARI-UYOLE) and whose location is as shown in section 3.1 above.

### 3.4.2: Experimental design

In the first experiment, bean straw offered at 30, 40 and 50 g DM/ kg $M^{0.75}$ daily, designated as AO1, AO2 and AO3 were used as the basal diet for 18 New-Zealand Friesian breed origin lactating cows with mean live-weight 419.7 kg and which ranged between 342.5- 477.5 kg in early to mid stage of lactation over a period of 10 weeks. In addition, the basal diets were either supplemented (SP) or not supplemented (NS) with *Leucaena diversifolia* leaf meal in a 3 x 2 factorial experimental layout. There were therefore six treatment combinations (Table 3.4) with three randomly allocated lactating cows per treatment combination. Since experimental animals differed widely in stage of lactation (week of lactation), parity number, initial milk yield and body weights, these parameters were thoroughly recorded for each individual animal and were used as co-variates upon data analysis. A different set of other eighteen lactating cows that were also in early-mid lactation stage and of the same breed with mean liveweight of 349.8 kg were used for experiment 4b. Experimental layout and design was as explained for experiment 4a.

### 3.4.3: Feeding and management of animals

The experimental animals were placed in well-ventilated individual feeding stalls fitted with automatic drinkers. Feeding troughs used for each animal were of the same size and measured '2.13 x 1.2 x 0.65 m'. The feeding stalls were designed in such a manner that feed wastage is highly minimized. Experimental animals were accessible to clean drinking water all the time. They were also provided with a flat rate of 3 kg of conventional concentrate whose composition is presented in Table 3.5. One half of this concentrate was provided per every milking and animals were milked twice per day through out the experimental period. The morning milking was done routinely at 06.00 a.m. while afternoon milking was conducted daily at 03.00 p.m.

The daily basal feed allowance was divided into two to four lots depending on amount on offer per individual animal and these were fed at 08.00 a.m., noon, 04.00p.m. and or 06.00 p.m. The basal feed was provided to experimental animals in a long form as it was collected from the field in order to enhance feed selectivity. The *L. diversifolia* leaf meal, where pertinent was provided at a rate of 1 kg/cow/day at around 07.30 a.m.

All animals were treated against gastro-intestinal parasites prior to the commencement of the experiment by use of injectable ALFAMISAN drug following manufacturer dosage recommendation. Animals were subjected to a 21 days adaptation period so that they become accustomed to confinement and feeds under test before intake measurements were recorded. Animals were weighed at the beginning of the experiment and towards the end. Plate 3.4 shows a close-up of one of the experimental animals.

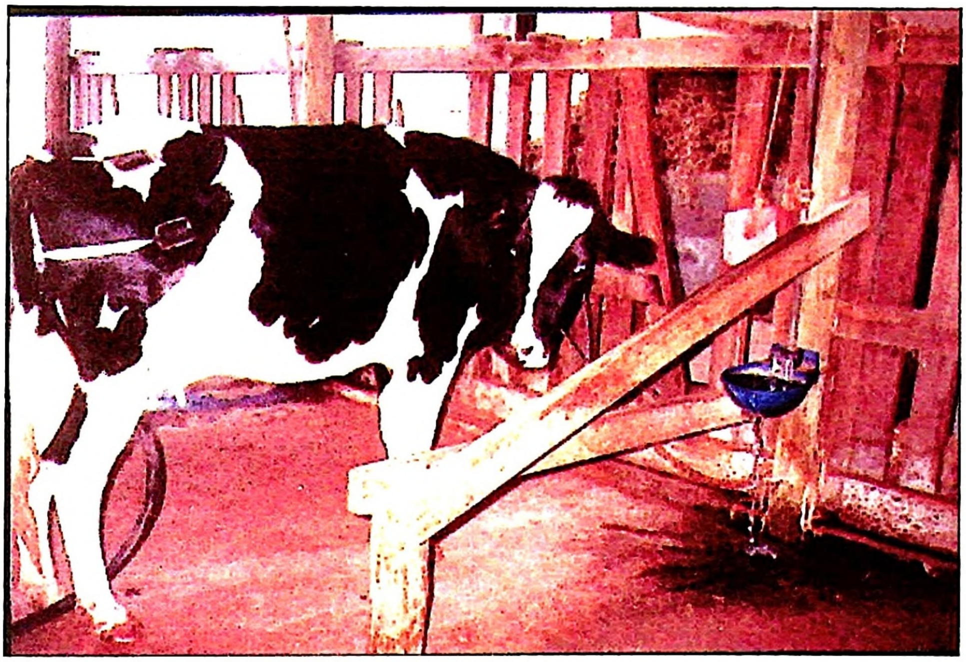

Plate 3.4: A close-up of one of the experimental animals

### 3.4.4: Sampling and measurements

**Botanical fractionation of basal feed and refusals:**

About 4 kg of fresh bean straw was measured and fractionated manually daily into pods, stems and branches. Each botanical fraction was weighed separately in order to determine percentage proportion for each category. The weights for stems and branches were pooled since they appeared to be very similar in the morphological structure and chemical composition. About 500 g of each fraction i.e. pods and (stems + branches) were sampled and bulked for a week and thereafter sub-sampled to obtain a representative sample for chemical composition analyses.

Before each meal, the refusals from the previous meal were weighed. The difference between amount offered and amount refused was assumed to be the quantity consumed. Each daily sample of the refusal was added to the previous days sample for one week for every experimental animal. At the end of each week, the pooled sample was divided into two parts, one for chemical analysis and the remaining one for botanical fractionation. The proportion kept for chemical analysis from each animal were then mixed by treatment groups and sub-sampled to form a single sample per week from each treatment group. Similar procedure used for the determination of botanical fractions in the offered basal feed were used for botanical fractionation of the refusals and the proportions were expressed as g / kg of sample and averaged for each treatment group per week. There were no refusals for the legume leaf meal as well as the conventional concentrate.

### 3.4.5: Chemical analyses

Proximate composition analysis (DM, Ash, CP) for both offered feed, refusals and milk constituents were performed as described by AOAC (1990) while NDF was determined according to the detergent analysis system as described by Van Soest (1991). The *in-vitro* DM and OM digestibility of both feed on offer and refusals were done by standard procedures as outlined by Tilley and Terry, (1963).

### 3.4.6: Milk yield and its composition

Both morning and afternoon milk yields were recorded separately and summed later to obtain daily milk yield per individual animal. Milk sampling for compositional analysis was done twice i.e. during second and last weeks of the experimental period of ten weeks for each experiment i.e. for bean straw and maize stover based experiments. Only two samplings were made for milk composition evaluations because very little day-to-day variation was expected since animals were maintained on same feeding regime apart from advancing week of lactation. Parameters measured for milk composition included dry matter, milk fat and milk protein.

### 3.4.7: Data analysis

Analysis of variance using General Linear Models (GLM) of Statistical Analysis Systems Institute (SAS, 1990) was done for all data. The data for milk production and feed intake were analyzed according to an analysis of covariance model using initial milk yield, week of lactation (stage of lactation), parity and body weight as the co-variate factors. However, for feed intake analysis, only body weight was used as a covariate. Offer rates of basal diets and *L. diversifolia* supplementation regime were the main factors. Where treatment means were different, they were separated using LSD criterion (Steel and Torrie, 1980). The model used is indicated below:

$$Y_{ijklm}=\mu + B_i + Sj + (BS)_{ij} + b_1 (X_{1(ijklm)} - \overline{X}_1) + b_2 (X_{2(ijkm)} - \overline{X}_2) + b_3 (X_{3(ijklm)} - \overline{X}_3)$$
$$b_4 (X_4(_{ijklm}) - \overline{X}_4) + e_{ijklm}$$

Whereby:

$Y_{ijklm}$ = Observation of $m^{th}$ animal in $l^{th}$ parity, $k^{th}$ week of lactation, assigned to $i^{th}$ offer rate of a basal diet, and $j^{th}$ supplementation level

$\mu$ = Overall mean

$B_i$= Effect of $i^{th}$ offer rate

Sj= Effect of $j^{th}$ supplementation level

$(BS)_{ij}$= Effect of interaction between offer rates and supplementation regime

$X_{1(ijklm)}$ = Initial milk yield of an individual

$b_1$ = Regression of $X_{1(ijklm)}$ on $Y_{ijklm}$

$\overline{X}_1$= Overall mean for initial milk yield

$X_{2(ijkm)}$ = Initial body weight of an individual

$b_2$ = Regression of $X_{2(ijklm)}$ on $Y_{ijklm}$

$\overline{X_2}$= Overall mean for initial body weight

$b_3$= Regression of $X_{3(ijklm)}$ on $Y_{ijklm}$

$\overline{X_3}$= Overall mean for week of lactation

$b_4$= Regression of $X_{4(ijklm)}$ on $Y_{ijklm}$

$\overline{X_4}$= Oveall mean for parity

$e_{ijk}$= Error term

**Table 3.4: Treatment combinations for the evaluation of effect of offer rate of either bean straw or maize stover with or without *Leucaena diversifolia* leaf-meal supplementation experiments**

| Basal feeds | Offer levels | *Leucaena diversifolia* supplementation levels | |
|---|---|---|---|
| | | SP= Supplemented | NS=Unsupplemented |
| **Bean straw** | | | |
| BS | AO1 | BSAO1SP | BSAO1NS |
| | AO2 | BSAO2SP | BSAO2NS |
| | AO3 | BSAO3SP | BSAO3NS |
| **Maize stover** | | | |
| MS | AO1 | MSAO1SP | MSAO1NS |
| | AO2 | MSAO2SP | MSAO2NS |
| | AO3 | MSAO3SP | MSAO3NS |

**Table 3.5: Composition of concentrate mixture for the effects of offer rate of either bean straw or maize stover with or without *Leucaena diversifolia* leaf meal supplementation experiment in g/kg DM**

| Feed ingredient | CP content | Proportion | Calculated CP |
|---|---|---|---|
| Maize bran | 103.5 | 400 | 41.4 |
| Sunflower seed cake | 272.0 | 400 | 108.8 |
| Rice polish | 121.5 | 200 | 24.3 |
| Total | | 1000 | 174.5* |

**Laboratory analysis for the concentrate mixture had CP of 18.35 %.**

# CHAPTER FOUR

## 4.0: RESULTS

### 4.1: Biomass yield for *L. diversifolia*

Mean biomass production on an individual tree basis is presented in Table 4.1. Wood production per tree was the highest while edible material yield represented about 25 % of the total biomass yield. All the measured variables that included length of the plant (LOT), number of branches (NOB) and length of the longest branch (LOLB) scored substantially wide ranges between minimum-maximum values for the same. Visual observation of the trees in the field indicated that *Leucaena diversifolia* remained green during the dry season. Insect-pest infestation in the trees was not observed for the last three years since establishment. However, growth of the trees was somewhat depressed during the dry season but resume vigorously during the rain season. The re-growth in coppiced trees started 2-3 weeks after cutting the trees for biomass determination. Persistence of trees from coppicing stress appeared to be good as there were no mortalities of the trees thereafter. In this study, edible material included leaflets, pods, petioles, twigs and slender stems.

**Table 4.1: Biomass production performance on individual tree basis**

| Parameters | Min. | Max. | Mean | Std. Dev. |
|---|---|---|---|---|
| TBY, kg DM | 0.134 | 6.275 | 1.3616 | 0.8223 |
| LOT, cm | 73.0 | 365.0 | 196.6 | 52. 56 |
| NOB, count | 9.0 | 450.0 | 202.0 | 17.0 |
| LOLB, cm | 16.0 | 238.0 | 113.92 | 43.61 |
| EDIBLE, kg DM | 0.039 | 2.572 | 0.3469 | 0.4056 |
| WOOD, kg DM | 0.046 | 3.702 | 1.0124 | 0.7236 |

Key: **TBY** = total biomass yield, **LOT** = length of the tree, **NOB** = number of brances, **LOLB** = length of the longest branch.

Table 4.2 shows biomass productivity for *Leucaena diversifolia* trees when expressed on an area (ha) unit basis. The results revealed that production of edible material stood at about 3 500 kg DM / ha and this represented about 25 % of the total biomass yield while wood production from *L. diversifolia* trees was 10. 150 kg DM / ha, which represented about 75 % of total biomass yields.

**Table 4. 2: Biomass production from *L. diversifolia* trees on a unit area basis, Kg DM / ha**

| Parameters | Yield | % |
|---|---|---|
| Edible Material | 3, 469.3 | 25.5 |
| Wood | 10, 146.8 | 74.5 |
| Total | 13, 616.1 | 100.0 |

Regression parameters and corresponding statistics obtained are shown in Tables 4.3 and 4.4 for prediction of total biomass and edible material yield, respectively.

**Table 4.3: Regression parameters and corresponding statistics when total biomass yield is regressed on LOT, NOB, and LOLB for *Leucaena diversifolia***

| Parameters | Partial Regression Coefficients | Standard Deviation | Level of Significance |
|---|---|---|---|
| **Intercept** | - 0.87631 | 0.2281 | 0.0002 |
| **LOT** | 0.006945 | 0.0016 | 0.0001 |
| **NOB** | 0.000611 | 0.0001 | 0.0001 |
| **LOLB** | 0.00658 | 0.0017 | 0.0002 |

**$R^2$: = 63.05 %**

**r: = 79.4 %**

The estimated Multiple Linear Regression model was:

**Y = - 0.8763 + 0.006945 LOT + 0.00061075 NOB + 0.00658 LOLB**

Whereby:

Y = Total biomass yield per tree on DM basis

**Table 4.4: Regression parameters and corresponding statistics when edible material was regressed on length of the tree (LOT), number of branches (NOB) and length of the longest branch (LOLB) for *L. diversifolia***

| Parameters | Partial Regression Coefficients | Standard Deviation | Level of Significance |
|---|---|---|---|
| **Intercept** | - 0.5258 | 0.0733 | 0.0001 |
| **LOT** | 0.003195 | 0.0005 | 0.0001 |
| **NOB** | 0.000305 | 0.0001 | 0.0001 |
| **LOLB** | 0.001607 | 0.0005 | 0.0037 |

**$R^2$: = 74.04 %**

**r:= 86.05 %**

The estimated Multiple Linear Regression model was:

**Y = - 0.5258 + 0.0031953 LOT + 0.00030528 NOB + 0.001607 LOLB**

**Whereby:**

Y = Predicted edible material yield on DM basis

This actually means almost 20 % of all variation in biomass yield could not be accounted by the parameters listed in the model. There is room therefore to include additional variables to improve the models' predictability.

## 4.2: *In sacco* degradability characteristics

### 4.2.1: DM degradability

The degradability pattern for DM is shown in figures 4.1 and 4.2 while Least Square Means for degradability constants are shown in Tables 4.5 and 4.6. The degradation profiles (Figures 4.1 and 4.2) followed different courses for different crop-residues botanical fractions and concentrate feeds. Although the botanical fractions were degraded in the rumen at different rates and extents, all forages showed high rates at the beginning up to 70hrs then increased at a decreasing rate up to 120hrs and then formed a plateau an indication that the asymptotes have been achieved. Concentrate feeds, however, showed high rates only up to 25hrs while the plateau was achieved after 50hrs of incubation. The ranking in water-soluble component for maize stover botanical fractions were MS3> MS1> MS2> MS4> MS5> MS6. The corresponding ranking order for bean straw fractions were BSP2>BSS1>WBS3. The content of water-soluble fraction of DM in *Leucaena diversifolia* leaf meal was more or less intermediate among the feeds studied.

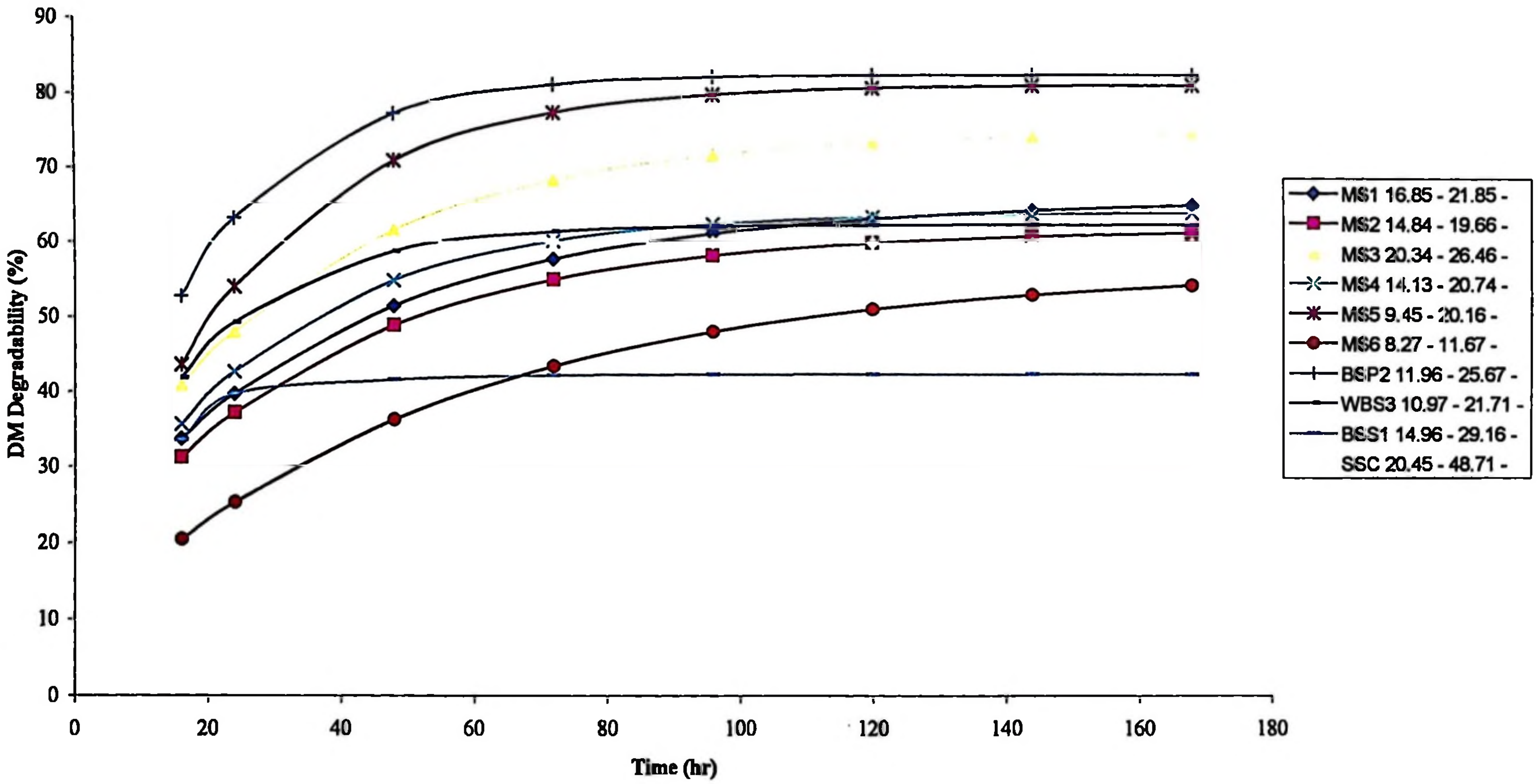


**Figure 4.1: DM degradability pattern for bean straw and maize stover botanical fractions**

Wide differences were observed in the content of the insoluble but fermentable component "b". The ranking order for bean straw botanical fractions were BSP2> WBS3> BSS1 and differed significantly (P>0.001) among themselves. Trends in maize stover botanical fractions for the "b" component were MS5> MS3> MS4> MS1> MS6> MS2. Maize stover ear (MS5) had the highest insoluble but fermentable component and differed significantly (P<0.0001) from all other maize stover botanical fractions. The amount of insoluble but fermentable fraction in *Leucaena diversifolia* was comparatively lower. Overall, the data suggested that maize stover leaves (MS3), ear (MS5) and sheath (MS4) and bean straw pods (BS2) were superior with respect to content of the insoluble but fermentable fraction.

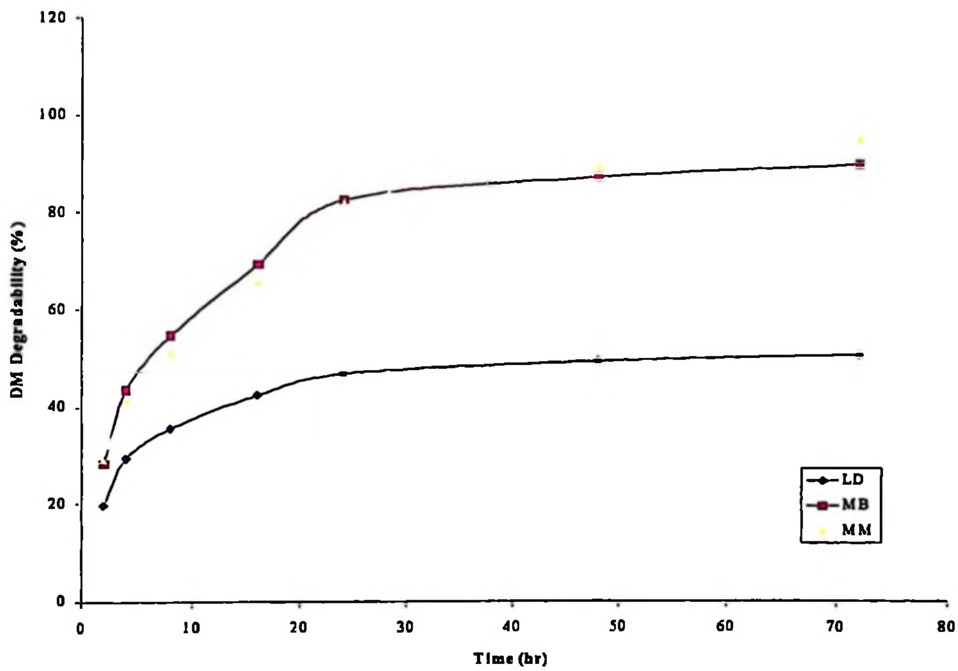


**Figure 4.2: DM degradability pattern for concentrate feeds**

The variability between feeds in the asymptote (a + b) was quite high. The ranking within bean straw fractions for (a + b) component were BSP2> WBS3> BSS1 and differed significantly (P<0.001) from each other while the trends in maize stover botanical fractions were MS5> MS3> MS1> MS4> MS2> MS6. Feed materials MS5 and MS3 differed significantly ($P<0.0001$) between themselves and each also differed significantly ($P<0.05$) from all other maize stover botanical fractions. MS6 (tassels) had the lowest values and differed significantly ($P=0.0001$) from all other maize stover botanical fractions. Again bean straw pods (BSP2), maize stover leaves (MS3), ears (MS5) and sheath (MS4) were superior in the amount of (a + b). *Leucaena diversifolia* and sunflower seed cake that represent the protein supplements had intermediate values.

Degradation rate constant "c" was lowest in tassels (MS6) and highest in sunflower seed cake. Degradation rate constant was similar ($P>0.05$) between *Leucaena diversifolia* and maize bran. Degradation rate constant for *Leucaena diversifolia* was observed to be relatively higher than values for maize stover and bean straw botanical fractions.

Similarly there was substantial variability in effective degradability between feed materials. The ranking within bean straw specie was BSP2> WBS3> BSS1 and differed significantly ($P=0.0001$) between themselves. The trend in the content of effective degradability for maize stover botanical fractions were MS5> MS3> MS4> MS1> MS2> MS6. The data further showed that MS2 and MS6 differed significantly ($P=0.001$) from each other and also from all other maize stover botanical fractions. The content of effective degradable fraction in *Leucaena diversifolia* was similar to that contained in maize stover ear (MS5) and maize stover leaves (MS3).

**Table 4.5: LSMEANS for DM degradability characteristics for different botanical fractions**

| Feed | A, g/kg | STD Err | B, g/kg | STD Err | A+B, g/kg | STD Err | C | STD Err | EFF degr, g/kg | STD Err | RSD | STD Err |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BSP2 | 119.6 | 11.141 | 706.5 | 16.747 | 826.1 | 17.685 | 0.0543 | 0.00857 | 485.7 | 1.0939 | 4.23 | 0.3581 |
| BSS1 | 119.1 | | 306.4 | | 425.4 | | 0.0517 | | 274.7 | | 2.29 | |
| MS1 | 168.5 | | 498.0 | | 666.5 | | 0.0273 | | 337.3 | | 2.95 | |
| MS2 | 148.4 | | 474.1 | | 622.5 | | 0.0270 | | 313.0 | | 3.68 | |
| MS3 | 203.4 | | 551.1 | | 754.5 | | 0.0293 | | 406.3 | | 2.93 | |
| MS4 | 141.3 | | 503.3 | | 644.6 | | 0.0363 | | 348.3 | | 3.78 | |
| MS5 | 94.5 | | 719.6 | | 814.1 | | 0.0407 | | 415.3 | | 1.94 | |
| MS6 | 82.7 | | 490.0 | | 572.8 | | 0.0180 | | 211.3 | | 2.11 | |
| SSC | 204.5 | | 396.0 | | 600.6 | | 0.3160 | | 546.0 | | 3.17 | |
| WBS3 | 109.7 | | 516.8 | | 626.5 | | 0.0583 | | 384.3 | | 2.18 | |

**Key:**

BSP2= Bean straw pods, BSS1= Bean straw stem, MS1= Maize stover whole plant

MS2= Maize stover stalk (stem), MS3= Maize stover leaves, MS4= Maize stover sheath, MS5= Maize stover ear

MS6= Maize stover tassels, SSC= Sunflower seed cake and WBS3= Bean straw, whole plant.

**Table 4.6: LSMEANS for DM degradability characteristics for concentrates**

| Feed | A, g/kg | STD Err | B, g/kg | STD Err | A+B, g/kg | STD Err | C | STD Err | EFF degr, g/kg | STD Err |
|---|---|---|---|---|---|---|---|---|---|---|
| LD | 198.9 | 11.141 | 306.6 | 16.747 | 505.5 | 17.685 | 0.0967 | 0.00857 | 433.7 | 1.093 |
| MB | 283.8 | | 613.9 | | 897.7 | | 0.1190 | | 733.4 | |
| MM | 292.5 | | 662.3 | | 954.8 | | 0.0883 | | 734.0 | |

**Key:**

LD= *Leucaena diversifolia* leaf-meal

MB= Maize bran

MM= Maize meal

### 4.2.2: Crude protein degradability

Tables 4.7 and 4.8 present CP degradability constants of different feed materials while figures 4.3 and 4.4 show the corresponding degradability pattern for the same. All botanical fractions exhibited different degradation profiles and showed high rates of nitrogen degradation at the beginning up to 20hrs then increased at a decreasing rate up to 30 hrs. Concentrate feeds showed relatively shorter high rate of nitrogen degradation i.e. up to 10hrs while the asymptote was achieved just after 22hrs. The results showed substantial variation in the immediate soluble fraction (A) of the protein. The tassels (MS6) contained significantly ($p<0.0001$) higher water-soluble fraction compared to other fractions including the leaves.

Overall the data suggest that BSP2 had the highest insoluble but fermentable component of the crude protein while MS6 had the least content. Trends in insoluble but fermentable component for CP in bean straw botanical fractions were BSP2> WBS3> BSS1. Differences between the three fractions were highly significant ($P=0.0001$). The corresponding ranking in insoluble but fermentable component for maize stover botanical fractions in declining order were MS2> MS1> MS3> MS5> MS4> MS6. When protein supplements are compared, data indicated that sunflower seed cake had higher "b" value than *Leucaena diversifolia.*

The asymptote, defined as "a + b" differed markedly between the feed materials. Ranking for maize stover based fractions with respect to "a + b" content for CP was MS3> MS1> MS5> MS2> MS4> MS6. The corresponding ranking for bean straw based fractions in declining order were BSP2>WBS>BSS1. Similarly, the ranking for the concentrate feeds with respect to the asymptote for CP was SSC> MM> MB.

Variability in degradation rate constant "c" for CP was somewhat moderate. *Leucaena diversifolia* was characterized with comparatively high degradation rate constant and stood at 0.069.

A wide range in effective degradability for CP between feed materials was exhibited. The ranking for bean straw botanical fractions in the content of effective degradability was BSP2> WBS3> BSS1 and the three fractions differed significantly (P=0.0001) from each other. The corresponding ranking in effective degradability content for CP in maize stover fractions were MS1> MS5> MS3> MS2> MS6> MS4. Effective degradability for CP in *L. diversifolia* was relatively moderate.

Residual standard deviation (RSD) ranged between 0.500 for sunflower seed cake to 7.243 for maize stover ear (MS5). All other feedstuffs had intermediate values for RSD.

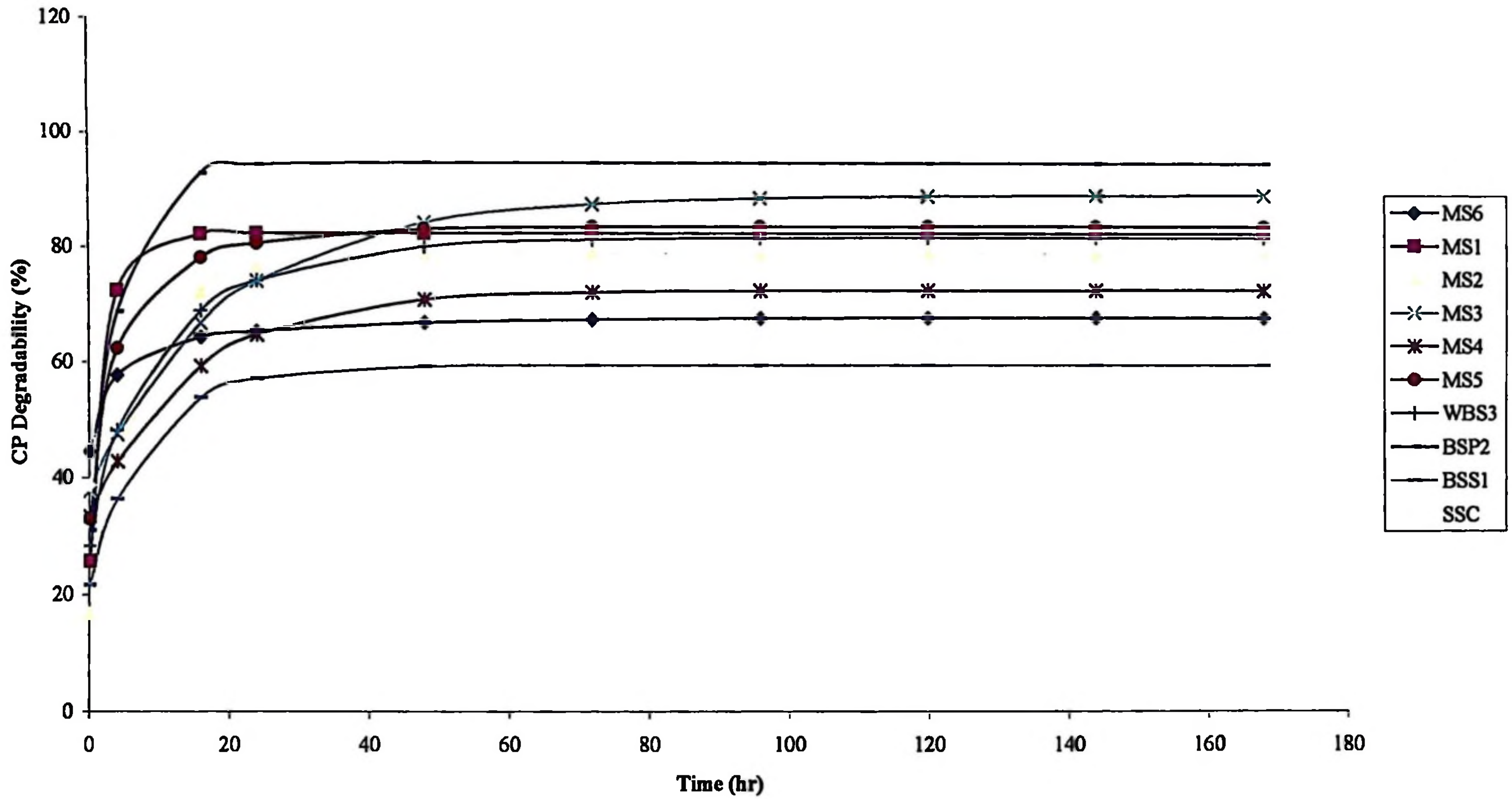


**Figure 4.3: CP degradability pattern for bean straw and maize stover botanical fractions**

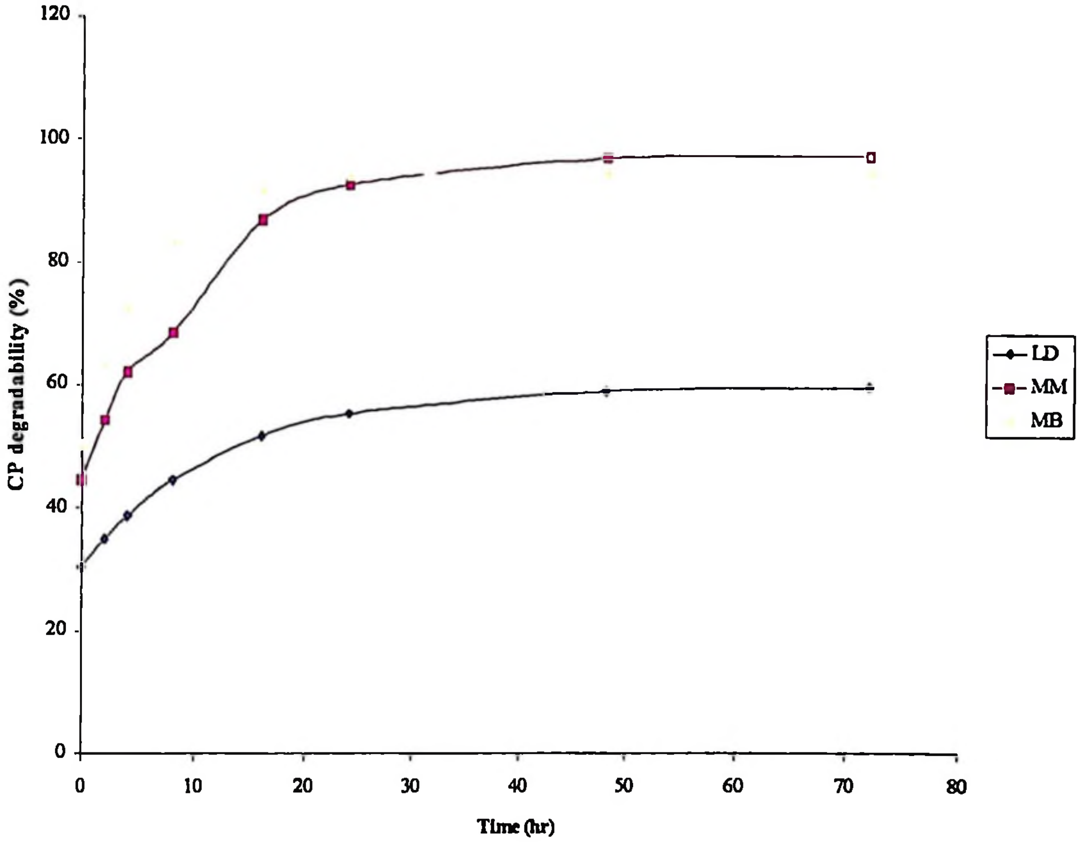


**Figure 4.4: CP degradability pattern for concentrate feeds**

**Table 4.7: LSMEANS for CP degradability constants of different feedstuffs**

| FEED | A, g/kg | STD Err | B, g/kg | STD Err | A+B, g/kg | STD Err | C | STD Err | EFF degr, g/kg | STD Err | RSD | STD Err |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BSP2 | 309.8 | 8.954 | 636.7 | 12.248 | 946.5 | 8.462 | 0.0227 | 0.0313 | 830.3 | 13.850 | 5.07 | 0.3477 |
| BSS1 | 217.2 | | 377.4 | | 594.6 | | 0.0123 | | 484.0 | | 3.11 | |
| MS1 | 247.1 | | 576.3 | | 823.4 | | 0.0457 | | 764.3 | | 2.81 | |
| MS2 | 167.5 | | 621.9 | | 789.4 | | 0.0143 | | 624.7 | | 2.53 | |
| MS3 | 377.2 | | 514.3 | | 891.5 | | 0.054 | | 638.7 | | 4.92 | |
| MS4 | 334.8 | | 390.2 | | 725.0 | | 0.069 | | 559.3 | | 4.19 | |
| MS5 | 301.7 | | 505.9 | | 807.6 | | 0.0713 | | 723.7 | | 7.24 | |
| MS6 | 446.0 | | 231.7 | | 677.7 | | 0.2287 | | 620.0 | | 3.32 | |
| SSC | 387.7 | | 589.9 | | 977.6 | | 0.0517 | | 923.0 | | 0.50 | |
| WBS | 229.3 | | 532.9 | | 762.2 | | 0.1297 | | 634.7 | | 5.97 | |
| 3 | | | | | | | | | | | | |

Key:

BSP2= Bean straw pods, BSS1= Bean straw stem, MS1= Maize stover, whole plant

MS2= Maize stover stalk (stem), MS3= Maize stover leaves, MS4= Maize stover sheath, MS5= Maize stover ear

MS6= Maize stover tassels, SSC= Sunflower seed cake and WBS= Bean straw, whole plant.

**Table 4.8: LSMEANS for CP degradability constants for concentrates**

| FEED | A, g/kg | STD Err | B, g/kg | STD Err | A+B, g/kg | STD Err | C | STD Err | EFF degr. g/kg |
|---|---|---|---|---|---|---|---|---|---|
| LD | 303.6 | 8.954 | 295.8 | 12.248 | 599.5 | 8.462 | 0.069 | 0.0313 | 486.7 |
| MB | 501.7 | | 447.7 | | 949.4 | | 0.1753 | | 849.0 |
| MM | 446.1 | | 530.7 | | 976.9 | | 0.101 | | 800.0 |

**Key:**

LD= *Leucaena diversifolia* leaf-meal

MB= Maize bran

MM= Maize meal

### 4.2.3: NDF degradability

The degradability pattern for NDF is presented in Figures 4.5 and 4.6 while Least Square Means for degradation constants for different feed materials are shown in Tables 4.9 and 4.10. The degradation profiles suggest that although fibre was degraded at different rates and extents for different botanical fractions, all feed materials showed high rates at the beginning up to 50hrs then increased at a decreasing rate up to 140hrs and then formed a plateau suggesting that no more rumen degradation was in progress. The ranking in insoluble but fermentable fraction for maize stover based botanical fractions was such that MS5> MS3> MS1> MS4> MS2> MS6. The corresponding trend for bean straw botanical fractions indicated that BSP2> BSS1> WBS3 and these fractions differed significantly ($P<0.0001$) from each other.

The degradation rate constant was relatively faster for feed materials BSP2, LD and SSC.

The observed trends in effective degradability for bean straw botanical fractions revealed that BSP2> BSS1> WBS3 while the corresponding pattern for maize stover botanical fractions were MS5> MS3> MS4> MS2> MS6>MS1. *Leucaena diversifolia* had significantly ($P<0.0001$) lower content of effective degradability than SSC.

**Table 4.9: LSMEANS for NDF degradability characteristics for different botanical fractions**

| Feed | B, g/kg | STD Err | C | STD Err | EFF degr, g/kg | STD Err | RSD | STD Err |
|---|---|---|---|---|---|---|---|---|
| BSP2 | 587.7 | 21.7 | 0.0470 | 0.00439 | 444.7 | 14.877 | 3.87 | 0.2685 |
| BSS1 | 432.0 | | 0.0619 | | 437.7 | | 5.83 | |
| MS1 | 560.7 | | 0.0238 | | 184.7 | | 2.44 | |
| MS2 | 510.7 | | 0.0297 | | 225.3 | | 1.52 | |
| MS3 | 738.3 | | 0.0392 | | 291.7 | | 4.77 | |
| MS4 | 545 3 | | 0.0256 | | 248.3 | | 1.83 | |
| MS5 | 783.0 | | 0.0135 | | 301.0 | | 3.24 | |
| MS6 | 459.0 | | 0.0083 | | 201.3 | | 2.24 | |
| SSC | 214.3 | | 0.0394 | | 280.7 | | 2.72 | |
| WBS3 | 363.3 | | 0.0295 | | 279.3 | | 1.57 | |

**Key:**

BSP2= Bean straw pods, BSS1= Bean straw stem, MS1= Maize stover whole plant

MS2= Maize stover stalk (stem), MS3= Maize stover leaves, MS4= Maize stover sheath, MS5= Maize stover ear

MS6= Maize stover tassels, SSC= Sunflower seed cake, WBS3= Bean straw whole plant

**Table 4.10: LSMEANS for NDF degradability characteristics for concentrates**

| Feed | B, g/kg | STD Err | C | STD Err | EFF degr, g/kg | STD Err | RSD | STD Err |
|---|---|---|---|---|---|---|---|---|
| LD | 206.3 | 21.7 | 0.0450 | 0.00439 | 214.7 | 14.877 | 1.15 | 0.2685 |
| MB | 817.3 | | 0.0220 | 0.00439 | 432.0 | | 8.63 | |

**Key:**

LD= *Leucaena diversifolia* leaf-meal

MB= Maize bran

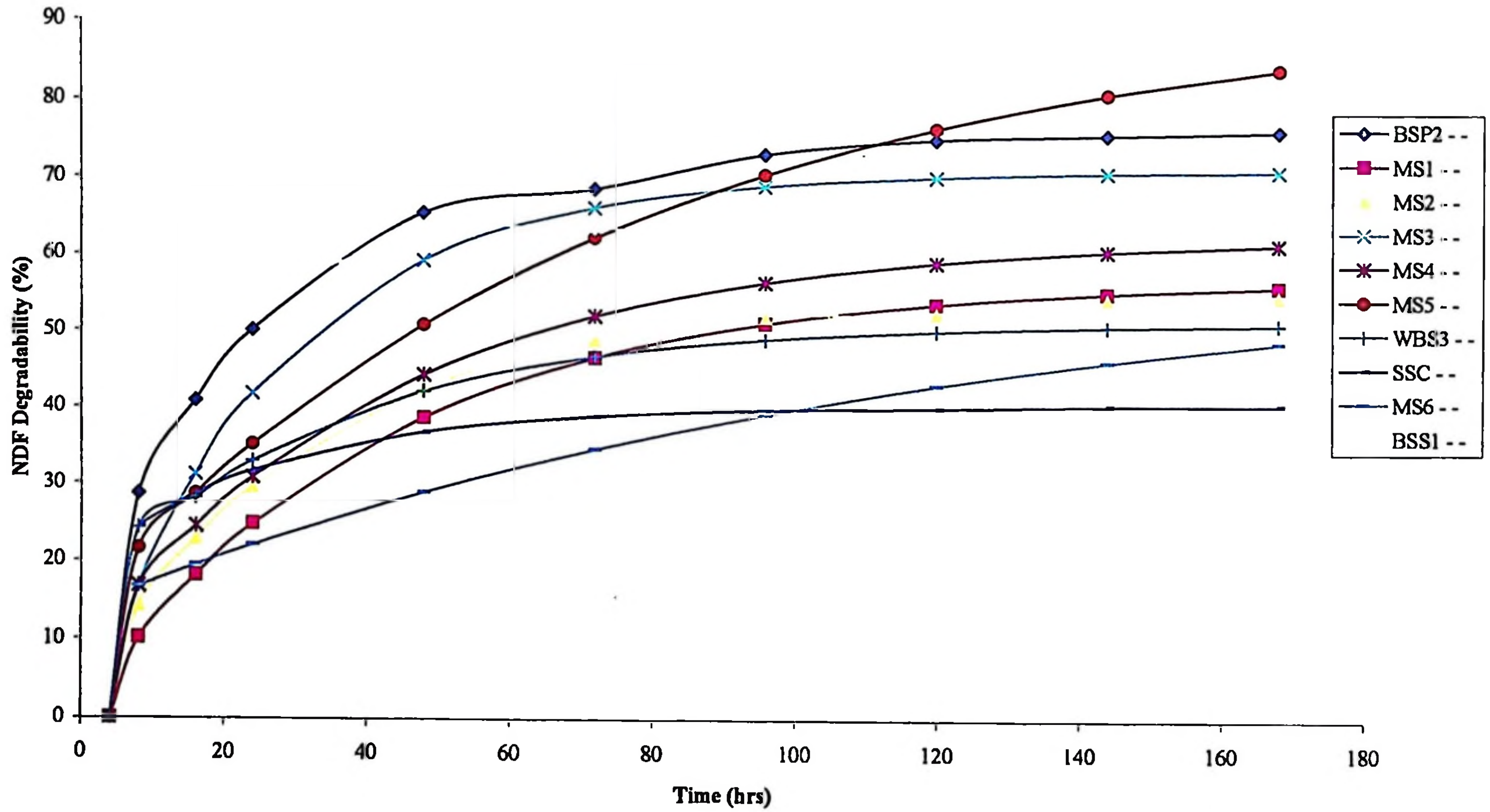


**Figure 4.5: NDF degradability pattern for bean straw and maize stover botanical fractions**

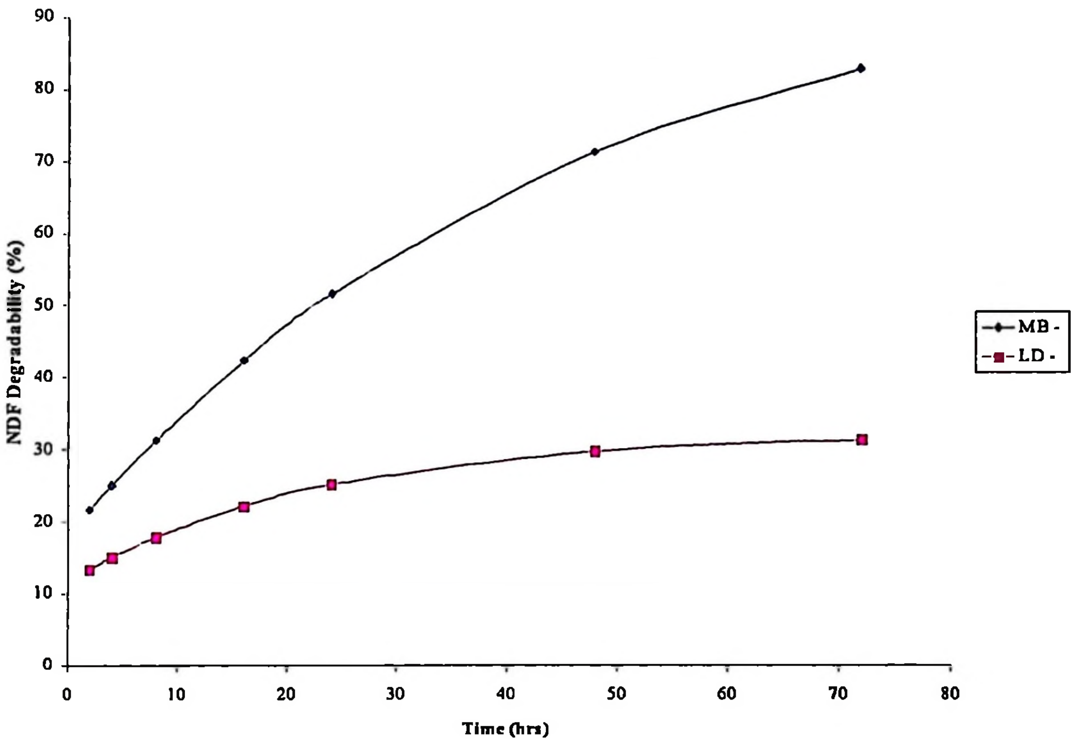


**Figure 4.6: NDF degradability pattern for concentrate feeds**

### 4.2.4: *In vitro* DM digestibility

Table 4.11 presents *in vitro* DM and OM digestibility values and the estimated *in vitro* metabolisable energy for the various feed materials studied. The same information is depicted in figure 4.7. Within maize stover species botanical fractions, IVDMD were in the order: MS3> MS5> MS1> MS4> MS2> MS6. The corresponding ranking for bean straw botanical fractions with respect to IVDMD was BSP2> BS3> BSS1. When protein sources are compared, *Leucaena diversifolia* leaf meal scored higher IVDMD value than sunflower seed cake. It was also observed that IVOMD and the estimated *in vitro* ME of the same feed resources followed a similar pattern with IVDMD trends.

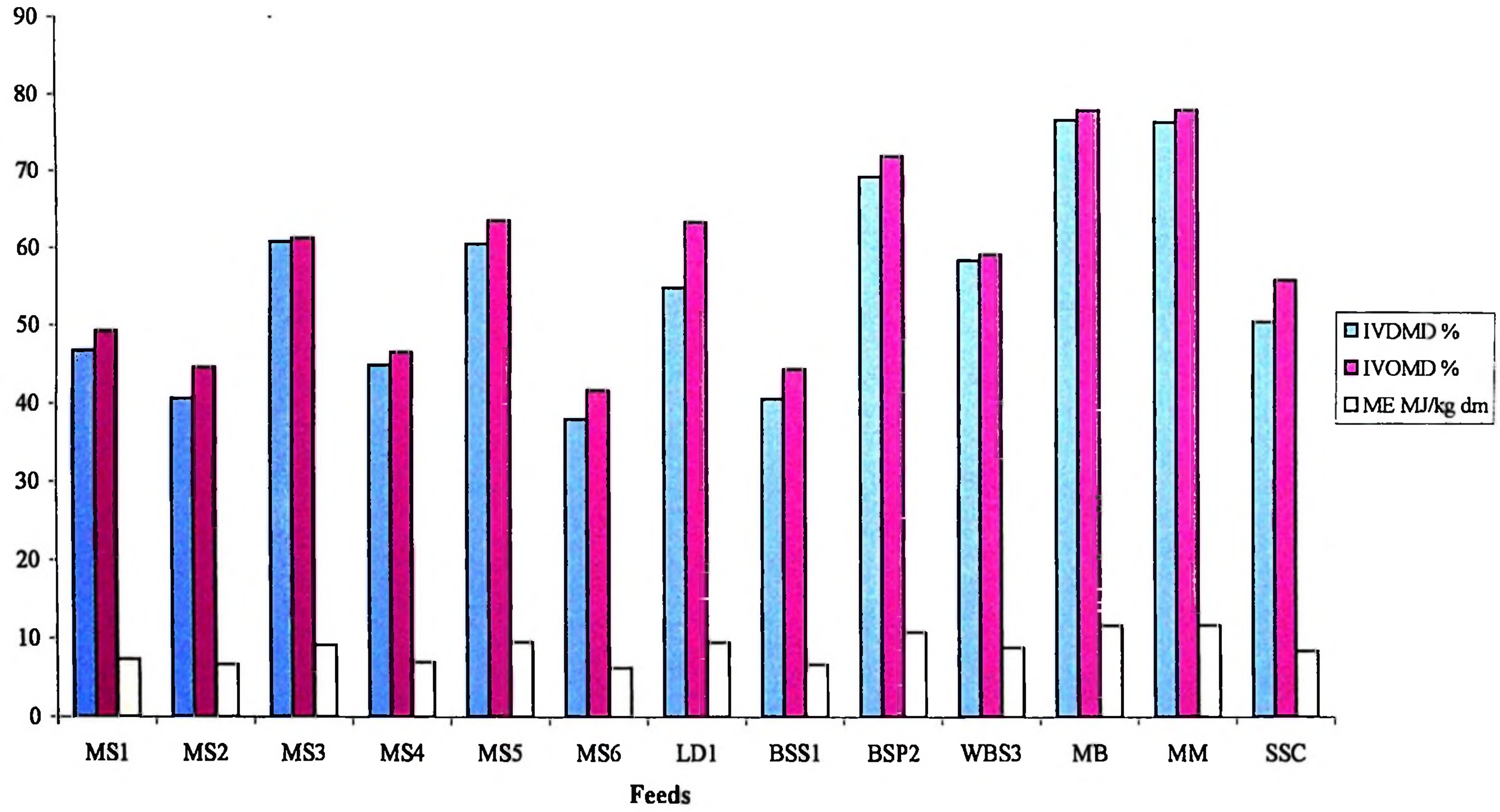


**Figure 4.7:** ***In vitro*** **digestibility pattern for different feeds**

**Table 4.11:** ***In vitro* DMD, OMD and the estimated ME values for different feedstuffs**

| Feed materials | MEAN IVDMD, g/kg | MEAN OMD, gkg DM | ME, MJ/ KG DM |
|---|---|---|---|
| MS1 | 467.5 | 493.4 | 7.40 |
| MS2 | 406.4 | 447.0 | 6.71 |
| MS3 | 608.3 | 613.4 | 9.20 |
| MS4 | 449.3 | 466.2 | 7.00 |
| MS5 | 606.3 | 636.9 | 9.55 |
| MS6 | 380.5 | 417.7 | 6.27 |
| LD | 550.0 | 635.1 | 9.53 |
| BSS1 | 406.4 | 445.2 | 6.68 |
| BSP2 | 694.5 | 721.6 | 10.82 |
| WBS3 | 586.2 | 594.6 | 8.92 |
| MB | 768.8 | 781.9 | 11.73 |
| MM | 766.9 | 782.6 | 11.74 |
| SSC | 507.5 | 562.4 | 8.44 |

## 4.3: Effect of different levels of *Leucaena diversifolia* on *in vivo* digestibility for bean straw / maize stover based diets by lactating cattle

### 4.3.1: Health of animals

The animals generally remained healthy during execution of the first experiment i.e. bean straw experiment. No abnormal health disorders were observed among the experimental animals for the whole experimental period. However, during execution of the second experiment (maize stover experiment), one cow that was subjected to treatment T2 (20 % supplementation level of *Leucaena diversifolia*) had diarrhea during the first period (between dates 3 / 11 / 2001- 5 / 11 / 2001). Initially, blood-stained faeces were noted for the first two days. However, this animal recovered after treatment with sulphurdimidine tablets. Data from this animal while undergoing treatment were omitted from the analysis.

### 4.3.2: Chemical composition of experimental feeds

The chemical composition of feeds used in this experiment is presented in Table 4.12.

**Table 4.12: Chemical composition of feeds for the digestibility experiment**

| Feed resources | DM, g/kg feed | ASH, g/kg DM | CP, g/kg DM | NDF, g/kg DM | Tannins, % |
|---|---|---|---|---|---|
| Bean straw 1 | 919 | 75.3 | 53 | 632.4 | - |
| Maize stover 1 | 916 | 90.8 | 47 | 670 | - |
| *L. diversifolia* leaf meal | 889 | 74.5 | 225.3 | 299 | 6.504 |

**1 =Values for the whole plant crop residues**

The data indicated that dry matter content as fed was comparable between bean straw and maize stover. *Leucaena diversifolia* had slightly less DM content when compared with the crop residues. Table 4.12 revealed that there were a marked difference in CP content between *L. diversifolia* and the crop residues. NDF was higher in maize stover than bean straw, but *L. diversifolia* had the lowest content. Ash content was almost comparable among the forages. The Level of condensed tannins in *L. diversifolia*. was fairly high.

### 4.3.3: Digestibility coefficients for bean straw experiment

Apparent nutrients digestibility coefficients for bean straw basal diet experiment are indicated in Table 4.13 and the same is depicted in Figure 4.8. The findings showed that DMD and NDFD were significantly (P= 0.0207) increased with increasing levels of *L. diversifolia* leaf meal supplementation from 15 to 30 % on dry matter basis.

**Table 4.13: Effect of increasing levels of *Leucaena diversifolia* supplementation on nutrient digestibility of bean straw, g/kg**

| Nutrients | Levels of *L. diversifolia* supplementation | | | | StdErr | Level of |
|---|---|---|---|---|---|---|
| | 15 % | 20 % | 25 % | 30 % | LSMEAN | sign. |
| DMD | 487.3b | 575.5a | 595.3a | 638.9a | 22.1213 | 0.0058 |
| CPD | 880.4 | 899.9 | 907.4 | 915.7 | 7.8173 | 0.0543 |
| NDFD | 323.4b | 413.2ab | 434.7a | 485.0a | 29.0534 | 0.0207 |

**Means with different letters in a row are significantly different.**

**Key: DMD = dry matter digestibility**

**CPD = crude protein digestibility**

**NDF = neutral detergent fibre digestibility**

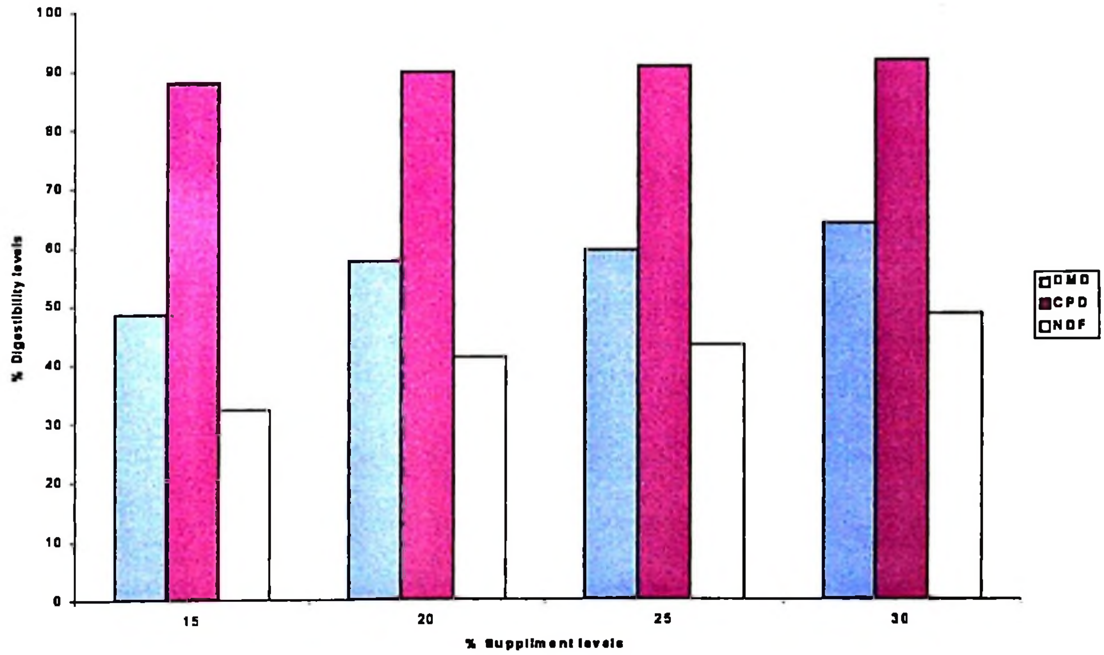


**Figure 4.8: Effect of incremental levels of *L. diversifolia* on nutrients digestibility of bean straw**

### 4.3.4: Digestibility coefficients for maize stover based experiment

Table 4.14 summarizes apparent nutrients digestibility for the maize stover based experiment and the same is depicted in figure 4.9.

**Table 4.14: Effect of increasing levels of *Leucaena diversifolia* supplementation on nutrient digestibility of maize stover, g/kg**

| Levels of Supplementation | DMD | Std Err | CPD | Std Err | NDFD | Std Err |
|---|---|---|---|---|---|---|
| 15 % | 440.8c | 12.1505 | 847.1c | 4.8897 | 218.4b | 19.3860 |
| 20 % | 477.6bc | | 880.1b | | 261.8bc | |
| 25 % | 503.3b | | 893.0b | | 293.0ac | |
| 30 % | 546.6a | | 914.6a | | 344.9a | |
| Level of significance | 0.0011 | | 0.0001 | - | 0.0079 | - |

**Means with different letters in a column are significantly different.**

There were significant (P=0.0011) differences in DMD, CPD and NDFD with increasing levels of *L. diversifolia* supplementation from 15 to 30 % on dry matter basis. The increasing digestibility coefficients for CPD with increasing level of supplement was probably reflecting increasing intake of CP.

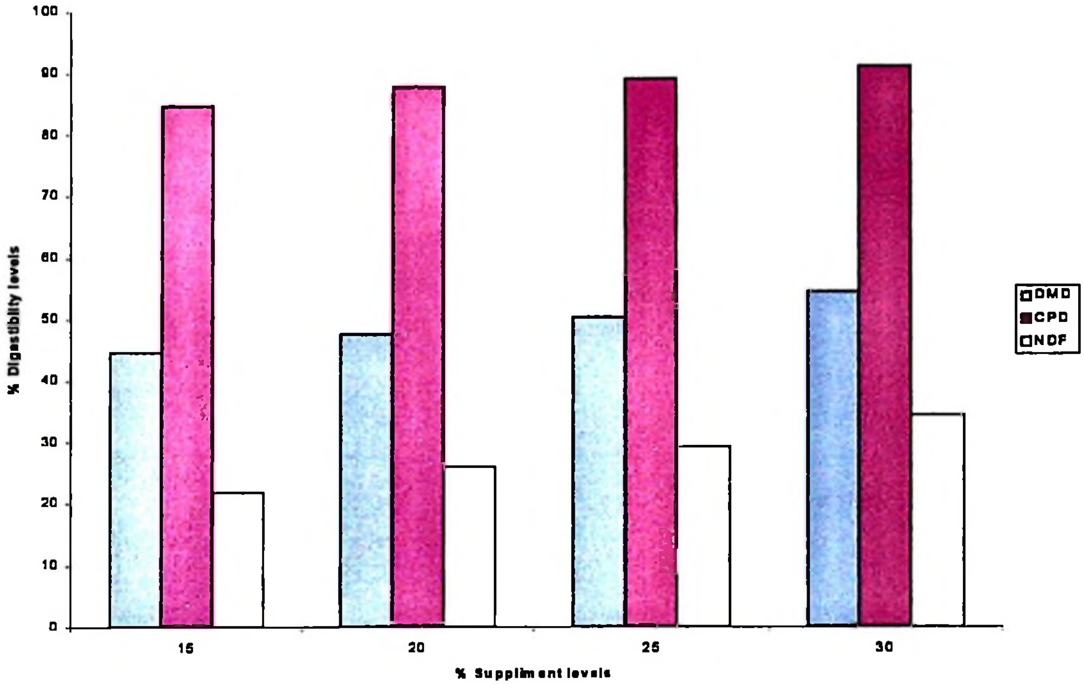


**Figure 4.9:** **Effect of incremental levels of *L. diversifolia* on nutrients digestibility of maize stover**

### 4.4: Experiment 5: Effect of offer rate of basal feeds and *L. diversifolia* leaf meal supplementation on milk yield and its composition

#### 4.4.1: Bean straw diet based experiment

##### 4.4.1.1: Chemical and botanical composition

Tables 4.15 and 4.16 present chemical and botanical composition of experimental feeds, respectively.

**Table 4.15: Chemical composition and the estimated IVOMD and ME content of bean straw offered and other feeds used in experiment 4a**

**Chemical Composition:**

| Feed/ Botanical Fraction | DM (g/kg feed) | ASH | CP | NDF | IVOMD | ME MJ/kg DM |
|---|---|---|---|---|---|---|
| | | | g/kg DM | | | |
| Bean straw Whole plant | 919.0 | 75.3 | 53.0 | 632.4 | 594.6 | 8.92 |
| Bean straw Stem | 941.3 | 54.1 | 40.2 | 760.0 | 445.2 | 6.68 |
| Bean straw Pods | 921.8 | 87.6 | 77.0 | 540.0 | 721.6 | 10.8 |
| *Leucaena Diversifolia* | 889.0 | 74.5 | 225.3 | 298.6 | 635.1 | 9.53 |

**Table 4.16: Distribution of botanical fractions composition for beat straw**

| Botanical fraction | Content g / kg straw | Range g / kg straw | % contribution |
|---|---|---|---|
| Bean straw pods | 557 | 545-575 | 56 |
| Bean straw stem + branches | 443 | 450- 455 | 44 |

The findings indicated that bean straw pods contained higher CP, estimated IVOMD and ME than either whole bean straw or stems and constituted about 11.4 % more of the total weight of whole bean straw compared to a pooled value for bean straw stems and branches. Differences in CP content between *L. diversifolia* leaf meal and bean straw botanical fractions were highly remarkable. Results also indicated that content of NDF in *L. diversifolia* leaf meal was comparatively lower than that contained by bean straw botanical fractions.

4.4.1.2: **Intake of bean straw**

There was no significant interaction between offer rate of basal diet and *L. diversifolia* leaf meal supplementation regime on intake of bean straw by lactating cattle. However, significant (P=0.001) linear improvements in intake of bean straw were observed when offer rates of basal diet were elevated from 30, 40 to 50 g DM/kg $M^{0.75}$ (Table 4.17). Overall, lactating cattle consumed about 82 % more of bean straw when offer rate was raised from 30 to 50 g DM/kg $M^{0.75}$ while they consumed 43 % more when offer rate was increased from 30 to 40 g DM/kg $M^{0.75}$. About 39 % increment in intake of bean straw was recorded when offer rate was changed from 40 to 50 g DM/kg $M^{0.75}$. Relatioship between amount of DM offered, consumed and that refused is depicted in Figure 4.10. Table 4.17 further revealed that the supplementation regime had had no profound effect on amount of dry matter consumed by lactating cattle. Dry matter intake in dairy cows varies with metabolic body weight ($M^{0.75}$). Table 4.18 shows changes in metabolic body weight after a 70 days experimental period. On average, lactating cattle lost 98.6 g/d of metabolic body weight for an extended period of ten weeks.

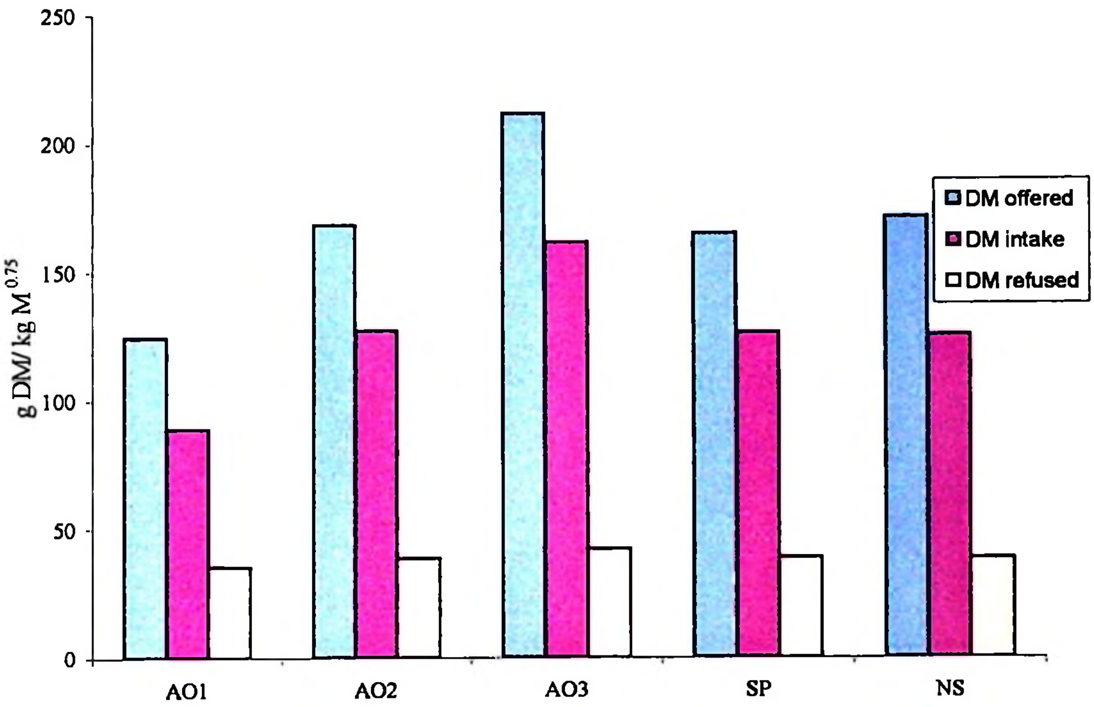


**Figure 4.10: Relationship of amount of DM offered, consumed and that refused in g DM/ kg M $^{0.75}$in a bean starw basal diet experment (4a)**

**Table 4.17: Effect of main factors (offer rates and *L. diversifolia* supplementation regime) on intake of bean straw in g DM/kg M$^{0.75}$**

| Main factors | INTAKE LSMEANS | Std Err LSMEANS |
|---|---|---|
| **Offer rates** | | |
| AO1 | 89.04c | 1.3651 |
| AO2 | 127.45b | 1.3727 |
| AO3 | 162.19a | 1.3722 |
| **Supplementation regime** | | |
| NS | 125.73 | 1.1146 |
| SP | 126.72 | 1.1146 |

**Means marked with different superscripts in a column are significantly different (P=0.001).**

**Table 4.18: Changes in metabolic body weight of experimental animals – bean straw basal diet over a ten weeks period**

| BASAL | SUPPL. | $M^{0.75}$ – At start | $M^{0.75}$ – At end |
|---|---|---|---|
| AO3 | SP | 87.4 | 82.3 |
| AO1 | NS | 92.3 | 84.4 |
| AO1 | SP | 100.0 | 93.6 |
| AO2 | SP | 104.6 | 98.5 |
| AO2 | NS | 80.4 | 87.8 |
| A03 | NS | 104.3 | 78.8 |
| A01 | SP | 84.5 | 76.9 |
| A03 | NS | 95.6 | 82.3 |
| A03 | NS | 91.1 | - |
| A02 | SP | 93.9 | 96.6 |
| A01 | NS | 95.9. | 92.3 |
| A02 | NS | 101.5 | 86.7 |
| A03 | SP | 102.2 | 91.1 |
| A01 | NS | 87.1 | 84.4 |
| A02 | NS | 80.9 | 71.2 |
| A02 | SP | 83.0 | 81.6 |
| A03 | SP | 79.6 | 76.2 |
| A01 | SP | 93.9 | 86.1 |

#### 4.4.1.3: Rate of refusals and feed selectivity

In the present investigation, botanical fractionation and chemical composition analyses of the refused feed were used to assess rate of refusals and thus extent of feed selectivity. Effects of offer rate and *L. diversifolia* supplementation regime on amount of refused bean straw botanical fractions are presented in Table 4.19. There were no significant differences (P > 0.05) between the main factors on the quantity of refused bean pods and pooled stems and branches. However, the quantity of refused bean straw stem and pods tended to decrease somewhat with *L. diversifolia* leaf meal supplementation. No clear pattern was discernible on the effect of rate of offer of the basal diet on the amount of botanical fractions refused. The effects of main factors on quantity of DM refused is demonstrated in Table 4.20. Although there were no significant (P>0.05) differences between offer rate and *L. diversifolia* leaf meal supplementation regime on the quantity of DM refused, but there was a tendency to increase in a linear manner from AO1 to AO3 offer rate of the basal feed. Table 4.20 also shows that *L. diversifolia* leaf meal supplementation had no apparent effect on amount of DM refused.

**Table 4.19: Effect of main factors (offer rates and *L. diversifolia* supplementation regime) on amount of refused bean straw botanical fractions in g DM/Cow/day**

| Parameters | AO1 | AO2 | AO3 | NS | SP |
|---|---|---|---|---|---|
| **Refused stem** | 3550 | 3540 | 3560 | 3550 | 3540 |
| StdErr LSMEANS | 17.7 | | | 14.5 | |
| **Refused pods** | 170 | 180 | 160 | 170 | 160 |
| StdErr LSMEANS | 16.8 | | | 13.8 | 13.0 |

**Table 4.20: Effect of main factors (offer rate and *L. diversifolia* supplementation regime) on quantity of DM refused in g DM/kg $M^{0.75}$**

| Main factors | LSMEANS DM refused | Std Err LSMEANS |
|---|---|---|
| **Offer rates** | | |
| AO1 | 35.32 | 2.2459 |
| AO2 | 38.66 | 2.2957 |
| AO3 | 42.41 | 2.2254 |
| **Supplementation levels** | | |
| SP | 38.76 | 1.8332 |
| NS | 38.73 | 1.8332 |

The effects of offer rates and *L. diversifolia* leaf meal supplementation regime on proximate composition for the measured nutrients and both the estimated IVOMD and ME contents for the refused bean straw botanical fractions is indicated in Tables 4.21 and 4.22. No significant interaction between the main factors on the refused bean straw pods and stems were detected. Although significant differences (P=0.0275) were observed in NDF content in the refused bean straw pods between varied offer rates of the basal feed, but no clear pattern was defined. A similar phenomenon was exhibited with ash content in refused bean pods. Contents for DM, CP and estimated IVOMD and ME in refused bean straw pods were similar for all levels of offer rates of the basal diet. The findings also indicated that estimated IVOMD and ME contents in the refused bean pods increased significantly (P=0.0088) and (P=0.0086) when lactating cows were supplemented with *L. diversifolia* leaf meal, respectively. However, contents for DM, ash, CP and NDF were similar irrespective of *L. diversifolia* leaf meal supplementation regime.

**Table 4.21: Effect of main factors (rate of offer and *L. diversifolia* supplementation regime) on Estimated IVOMD in g/ kg DM and ME in MJ/ kg DM in refused bean straw pods and stems**

| | AO1 | AO2 | AO3 | NS | SP |
|---|---|---|---|---|---|
| **Pods** | | | | | |
| IVOMD | 691.03 | 697.39 | 690.93 | 687.19b | 699.04a |
| StdErr | 3.2206 | 3.2327 | 3.2235 | 2.6316 | 2.6316 |
| ME | 10.37 | 10.46 | 10.36 | 10.31b | 10.49a |
| Stderr | 0.0481 | 0.0482 | 0.081 | 0.0393 | 0.0393 |
| **Stems** | | | | | |
| IVOMD | 428.60 | 378.85 | 409.48 | 411.54 | 399.75 |
| StdErr | 16.7886 | 16.8513 | 16.8035 | 13.7180 | 13.7180 |
| ME | 6.43 | 5.68 | 6.14 | 6.17 | 6.00 |
| Stderr | 0.2520 | 0.2529 | 0.2522 | 0.2059 | 0.2059 |

**Means marked with different superscripts in a row are significantly (P=0.0088) different.**

**Table 4.22: Effect of main factors (offer rate and *L. diversifolia* supplementation regime) on chemical composition for refused bean straw pods and stems**

| Botanical fraction/Main factors | DM, g/kg straw | StdErr, LSMEANS | ASH g/kg DM | StdErr, LSMEANS | CP, g/kg DM | StdErr, LSMEANS | NDF, g/kg DM | StdErr, LSMEANS |
|---|---|---|---|---|---|---|---|---|
| **Pods:** | | | | | | | | |
| AO1 | 917.92 | 2.8754 | 77.08b | 1.1085 | 50.27 | 2.2586 | 567.94ab | 8.6327 |
| AO2 | 913.67 | 2.8862 | 84.72a | 1.1127 | 48.97 | 2.2671 | 550.47a | 8.6650 |
| AO3 | 912.68 | 2.8780 | 82.58ab | 1.1095 | 51.01 | 2.2606 | 589.45b | 8.6404 |
| Level of supplement: | | | P=0.0014 | | | | P=0.0275 | |
| NS | 916.49 | 2.3495 | 82.66 | 0.9058 | 52.02 | 1.8455 | 571.73 | 7.0538 |
| SP | 913.02 | 2.3495 | 80.26 | 0.9058 | 48.14 | 1.8455 | 566.84 | 7.0538 |
| **Stems+branches:** | | | | | | | | |
| AO1 | 938.97 | 3.5786 | 56.93 | 1.3564 | 37.42a | 0.3117 | 766.24 | 8.1102 |
| AO2 | 931.51 | 3.5920 | 57.37 | 1.3615 | 38.21a | 0.3129 | 776.36 | 8.1405 |
| AO3 | 938.25 | 3.5818 | 55.65 | 1.3576 | 39.72b | 0.3120 | 774.13 | 8.11.74 |
| Level of supplement | | | | | P=0.0009 | | | |
| NS | 934.22 | 2.9241 | 55.64 | 1.1108 | 38.44 | 0.2547 | 777.22 | 6.6269 |
| SP | 938.27 | 2.9241 | 57.66 | 1.1108 | 38.45 | 0.2547 | 767.27 | 6.6269 |

**Means marked with different superscripts in a column are significantly different.**

There was a significant (P=0.0009) increasing trend in the content of CP for the refused bean straw stem when the rate of basal feed was raised from minimum (AO1) to the maximum level (AO3), although incremental differences between AO1 and AO2 appeared to be similar. Tables 4.21 and 4.22 show that contents for DM, ASH, NDF and the estimated IVOMD and ME in the refused bean straw stem were similar at all rates of offer of bean straw. Similarly, legume leaf meal supplementation had no effect (P>0.05) on the content of measured chemical composition parameters and both the estimated IVOMD and ME for the refused bean straw stem.

#### 4.4.1.4: Milk yield and its composition

Summaries of analysis of variance for milk yield and its composition as influenced by varied offer rates of bean straw and *L. diversifolia* leaf meal supplementation regime are given in Tables 4.23 and 4.24. There was no significant interaction between offer rates of the basal diet and *L. diversifolia* leaf meal supplementation regime on milk yield by lactating cows. However, animals tended to produce somewhat more milk when supplemented with *L. diversifolia* leaf meal and when offered higher offer rates of bean straw i.e AO2 and AO3. Similarly milk composition was neither affected by varying offer rates of bean straw nor by supplementing lactating cows with or without *L. diversifolia* leaf meal (Table 4.24). However, there was a general tendency for the CP content in milk to increase with increasing offer rates of bean straw. From Table 4.24 it is evident that almost all parameters (total solids, fat and CP) tended to improve when animals were supplemented with a legume leaf meal.

**Table 4.23: Effect of main factors on milk yield (kg/cow/day) in a bean straw based experiment (4a)**

| Main factors | LSMEANS milk yield | Std Err LSMEANS |
|---|---|---|
| **Offer rates** | | |
| AO1 | 7.7 | 0.3754 |
| AO2 | 8.0 | 0.3675 |
| AO3 | 7.8 | 0.3680 |
| **Supplementation levels** | | |
| NS | 7.6 | 0.2991 |
| SP | 8.1 | 0.2991 |

**Table 4.24: Effect of main factors (offer rate and *L. diversifolia* supplementation regime) on un-adjusted milk composition in g/kg**

| Factors | DM | Std Err LSMEAN | FAT | Std Err LSMEAN | CP | Std Err LSMEAN |
|---|---|---|---|---|---|---|
| **Offer rates** | | | | | | |
| AO1 | 128.4 | 3.847 | 41.9 | 2.041 | 39.4 | 2.702 |
| AO2 | 133.9 | | 39.8 | | 39.9 | |
| AO3 | 132.3 | | 40.3 | | 40.3 | |
| **Supplement level** | | | | | | |
| NS | 128.5 | 3.141 | 39.8 | 1.667 | 37.0 | 2.207 |
| SP | 134.6 | | 41.4 | | 42.7 | |

### 4.4.2: Maize stover as the basal diet (experiment 4b)

#### 4.4.2.1: Chemical and botanical composition

Chemical and botanical composition and the estimated IVOMD and ME of maize stover offered and other feeds used are presented in Tables 4.25 and 4.26.The results indicated that there was not much variability in DM content between the different maize stover botanical fractions. However, botanical fractions differed substantially in the content of CP with leaves, tassels and ears constituting at least 50 g/kg DM while all other botanical fractions contained less than this amount. Stalk (stem) fraction contained the least amount of CP. The findings in Table 4.25 have demonstrated the superiority of *L. diversifolia* leaf meal in CP content over maize stover botanical fractions. It was observed that leaves and ears contained higher values of both estimated IVOMD and ME than other botanical fractions while NDF content was highest in ears followed by both stalk and sheath. Table 4.26 shows that stalk is the predominant botanical fraction in maize stover while tassels constituted the least. The data indicated that leaves represent about a quarter of the whole maize stover plant.

**Table 4.25: Chemical composition and the estimated IVOMD and ME contents for maize stover botanical fractions**

| Chemical composition | DM, g/kg stover | ASH, g/kg DM | CP, g/kg DM | NDF, g/kg DM | IVOMD, g/kg DM | ME, MJ/kg DM |
|---|---|---|---|---|---|---|
| Fractions | | | | | | |
| Maize stover, whole plant | 915.5 | 90.8 | 46.6 | 669.8 | 493.4 | 7.40 |
| Stalk | 922.9 | 51.9 | 30.1 | 724.0 | 447.0 | 6.71 |
| Leaves | 927.6 | 60.7 | 69.6 | 586.7 | 613.4 | 9.20 |
| Sheath | 915.8 | 120.4 | 39.1 | 724.6 | 466.2 | 7.00 |
| Ears | 932.6 | 45.4 | 56.0 | 800.0 | 636.9 | 9.55 |
| Tassels | 914.5 | 54.8 | 60.2 | 486.6 | 417.7 | 6.27 |

**Table 4.26: Distribution of maize stover botanical fractions composition in g/kg stover**

| Botanical fraction | Content | Range | % Composition |
|---|---|---|---|
| Sheath | 170.8 | 150-184 | 17.1 |
| Tassels | 36.6 | 32-42 | 3.7 |
| Leaves | 258.6 | 245-266 | 25.9 |
| Ears | 124.6 | 120-133 | 12.5 |
| Stalk | 409.4 | 386-433 | 40.9 |

**4.4.2.2: Intake of maize stover**

There was no significant (P>0.05) interaction between offer rates of basal diet and *L. diversifolia* leaf meal supplementation regime on intake of maize stover. Lactating cows, however, consumed significantly (p=0.0001) higer amount of maize stover when offer rates of basal diet were varied from 30, 40 to 50 g DM/kg $M^{0.75}$ (AO1-AO3). It can be shown from Table 4.27 that at a full spectrum range of offer rates (AO1-AO3), an overall improvement in intake of maize stover was 83%. Between AO1-AO2 offer rates, intake of maize stover was increased by 43% while it increased by 28% when offer rate was elevated from AO2-AO3. Table 4.27 further shows that intake of maize stover were similar between lactating cows irrespective of *L. diversifolia* leaf meal supplementation regime. Relatioship of amount of DM offered, consumed and that refused is depicted in Figure 4.11. Table 4.28 shows changes in metabolic body weight after a 70 days experimental period. The results suggest that mean metabolic body weight was 17.1 g/d.

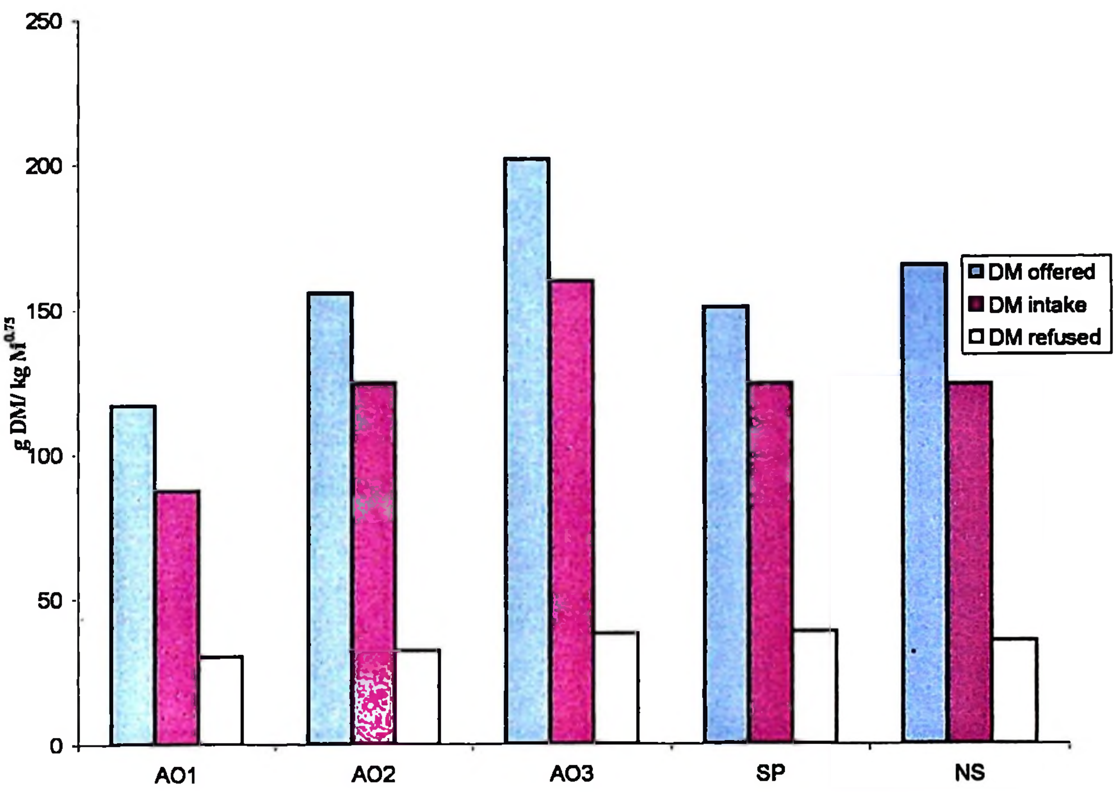


**Figure 4.11: Relationship of amount of DM offered, consumed and that refused in g DM/kg $M^{0.75}$**

**Table 4.27: Effect of main factors (offer rates and *L.diversifolia* leaf meal supplementation regime) on daily intake of maize stover in g DM/kg $M^{0.75}$**

| Factors | LSMEANS INTAKE | Std Err LSMEANS |
|---|---|---|
| **Offer rates** | | |
| AO1 | 87.59c | 1.2728 |
| AO2 | 124.90b | 1.2752 |
| AO3 | 159.93a | 1.2867 |
| **Supplementation regime** | | |
| SP | 124.40 | 1.0974 |
| NS | 123.88 | 1.0974 |

**Means marked with different superscripts in a column are significantly (P=0.0001) different**

**Table 4.28: Changes in metabolic body weight of experimental animals over a ten weeks period – maize stover basal diet**

| BASAL | SUPPL. | $M^{0.75}$ - Start | $M^{0.75}$ - end |
|---|---|---|---|
| AO1 | NS | 73.9 | 72.7 |
| AO2 | NS | 76.0 | 75.7 |
| AO3 | SP | 82.1 | 80.7 |
| AO2 | SP | 93.1 | 92.2 |
| AO2 | SP | 76.5 | 75.7 |
| AO1 | NS | 86.1 | 84.3 |
| AO3 | SP | 89.9 | 88.5 |
| AO3 | SP | 71.5 | 69.8 |
| AO1 | SP | 77.4 | 76.6 |
| AO2 | NS | 79.5 | 79.2 |
| AO2 | NS | 83.0 | 82.2 |
| AO3 | NS | 70.8 | 68.5 |
| AO2 | SP | 83.2 | 80.9 |
| AO1 | NS | 69.5 | 68.4 |
| AO3 | NS | 87.8 | 86.3 |
| AO3 | NS | 70.8 | 68.5 |
| AO1 | SP | 90.4 | 89.1 |
| AO1 | SP | 91.9 | 91.1 |

#### 4.4.2.3 Rate of refusals and feed selectivity

There was no significant interaction (P>0.05) between the main factors on the quantity of DM refused. Table 4.29 shows amount of DM refused as influenced by main factors. The proportion of DM refused per cow per day tended to increase slightly from AO1 to AO2 offer rates but was significantly (P=0.006) increased from both AO1 and AO2 to AO3 offer rates. Apparently, *Leucaena diversifolia* leaf meal supplementation regime had no marked effect on quantity of maize stover DM refused (P>0.05) (Table 4.29). There was no interaction effect (P>0.05) between the main factors on the quantity of refused maize stover botanical fractions. Similarly, there were no treatment differences between the main factors on the quantity of refused maize stover botanical fractions as exemplified in Table 4.30. Results suggest that out of the maize stover offered, leaves and tassels were all consumed and therefore the refused botanical fractions included stem, ear and sheath. It is further illustrated from Table 4.30 that maize stover refused was predominated by stem and to a lesser extent sheath. Maize stover ears were refused the least.

**Table 4.29: Effect of main factors (offer rate of maize stover and *L. diversifolia* leaf meal supplementation regime) on amount DM refused in g DM/kg $M^{0.75}$ per day in a maize stover based (4b) experiment**

| Factors | LSMEANS DM REFUSED | Std Err LSMEANS |
|---|---|---|
| **Offer rates** | | |
| AO1 | 30.48a | 1.0955 |
| AO2 | 32.44a | 1.0939 |
| AO3 | 38.10b | 1.1456 |
| **Supplementation regime** | | |
| SP | 31.87 | 0.9180 |
| NS | 35.70 | 0.9948 |

**Table 4.30: Effect of main factors (rate of offer of maize stover and *L. diversifolia* leaf meal supplementation regime) on quantity of refused botanical fractions in g DM/cow/day**

| Rate of offer | LSMEANS Ears refused, | LSMEANS Stem refused, | LSMEANS Sheath refused, |
|---|---|---|---|
| AO1 | 231 | 3815 | 562 |
| AO2 | 234 | 3814 | 559 |
| AO3 | 235 | 3775 | 597 |
| StdErr LSMEANS | 23.4 | 38.3 | 22.6 |
| **Level of suppl.** | | | |
| NS | 237 | 3786 | 584 |
| SP | 230 | 3816 | 562 |
| StdErr LSMEANS | 19.1 | 31.2 | 18.5 |

In this study, chemical composition of the refused maize stover was carried out for the different refused botanical fractions i.e. ears, stem and sheath. Table 4.31 presents chemical composition and the estimated IVOMD and ME contents for the refused maize stover sheath. The findings indicated that there was no significant (P>0.05) interaction between the main factors on any of the measured proximate composition variables and the estimated IVOMD and ME contents. However, there was a tendency for NDF content in the refused maize stover sheath to decline linearly with increasing offer rates of the basal feed as summarized in Table 4.31. A similar pattern was observed with the CP content in the refused maize stover sheath. No clear pattern was discernible for DM, ASH and both estimated IVOMD and ME contents for the refused maize stover sheath.

**Table 4.31: Effect of main factors (rate of offer of maize stover and *L. diversifolia* leaf meal supplementation regime) on chemical composition and estimated IVOMD and ME in the refused maize stover sheath**

| | AO1 | AO2 | A03 | SEM | NS | SP | SEM |
|---|---|---|---|---|---|---|---|
| DM, g/kg stover | 919.93 | 919.21 | 920.66 | 17.230 | 920.75 | 919.12 | 14.240 |
| ASH, g/kg DM | 98.43 | 97.73 | 98.21 | 1.6820 | 100.49a | 95.75b | 1.3910 |
| CP, g/kg DM | 33.20 | 33.05 | 32.83 | 1.3150 | 33.19 | 32.86 | 1.0872 |
| NDF, g/kg DM | 817.27 | 810.50 | 801.97 | 10.046 | 809.69 | 810.13 | 8.31 |
| IVOMD, g/kg DM | 325.08 | 321.76 | 339.80 | 2.2574 | 322.65 | 335.11 | 18.67 |
| ME, MJ/kg DM | 4.88 | 4.83 | 5.10 | 0.3391 | 4.84 | 5.03 | 0.2804 |

**Means marked with different superscripts in a row are significantly different (P=0.0367)**

Table 4.32 presents chemical composition and the estimated IVOMD and Me contents for the refused maize stover stem. Observations show that main factors i.e offer rates and *L. diversifolia* leaf meal supplementation regime had no marked effect on the various proximate variables measured and the estimated IVOMD and ME contents for the refused maize stover stem. However, significant (P=0.0033) differences were observed in the DM content of the refused maize stover stem between offer rates of the basal diet, but no clear trends were demonstrated.

**Table 4.32: Effect of main factors (rate of offer of maize stover and *L. diversifolia* leaf meal supplementation regime) on chemical composition and estimated IVOMD and ME of the refused maize stover stem**

| | AO1 | AO2 | A03 | SEM | NS | SP | SEM |
|---|---|---|---|---|---|---|---|
| DM, g/kg stover | 932.01a | 926.23b | 929.32ab | 0.9275 | 928.85 | 929.58 | 0.7675 |
| ASH, g/kg DM | 70.41 | 65.72 | 69.79 | 5.1211 | 68.47 | 68.81 | 4.2373 |
| CP, g/kg DM | 26.62 | 23.65 | 23.93 | 1.7154 | 24.87 | 24.59 | 1.4106 |
| NDF, g/kg DM | 843.69 | 851.59 | 838.92 | 17.1231 | 844.02 | 845.45 | 14.1679 |
| IVOMD, g/kg DM | 345.53 | 343.83 | 293.33 | 32.7042 | 328.84 | 326.28 | 27.0599 |
| ME, MJ/kg DM | 5.18 | 5.16 | 4.39 | 0.4942 | 4.93 | 4.89 | 0.4088 |

**Means marked with different superscripts in a row are significantly different (P=0.0033).**

#### 4.4.2.4: Milk yield and its composition

There were no significant (P>0.05) interactions between rate of offer of maize stover and *L. diversifolia* leaf meal supplementation regime on both milk yield and milk composition. Tables 4.33 and 4.34 show the Least Square means for unadjusted milk yield and its composition, respectively. The results showed that milk yield production per cow per day and its composition were similar between the main factors studied.

**Table 4.33: milk yield in kg / cow / day as affected by main factors (offer rates of basal diet and *L. diversifolia* leaf meal supplementation regime)**

| | AO1 | AO2 | A03 | NS | SP |
|---|---|---|---|---|---|
| Milk yield LSMEANS | 4.6 | 4.8 | 4.7 | 4.6 | 4.9 |
| Std Err LSMEANS | 0.2539 | 0.2593 | 0.2491 | 0.2075 | 0.2075 |

**Table 4.34: Milk composition in g/kg as influenced by main factors (offer rates and *L. diversifolia* leaf meal supplementation regime)**

| Parameters | AO1 | AO2 | AO3 | NS | SP |
|---|---|---|---|---|---|
| DM | 125.3 | 135.0 | 127.0 | 127.9 | 130.3 |
| Std Err LSMEANS | 4.7745 | | | 3.8984 | |
| FAT | 38.5 | 43.2 | 41.7 | 39.6 | 42.7 |
| Std Err LSMEANS | 2.0817 | | | 1.6997 | |
| CP | 35.0 | 38.2 | 37.3 | 37.3 | 36.3 |
| Std Err LSMEANS | 1.5782 | | | 1.2886 | |

# CHAPTER FIVE

## 5.0: DISCUSSION

### 5.1: Description of biomass production

The aim of this experiment was to test the hypothesis that it is possible to estimate and predict biomass yield for *L. diversifolia* based on plant height, number of branches and length of the longest branch characteristics of the tree. The results obtained supported this hypothesis. The potential minimum biomass yield for *L. diversifolia* trees for highland areas in Tanzania has been determined. The value presented here is rather conservative as it is estimated from primary cuts of established *L. diversifolia* trees. Edible fodder yields exhibited in the present work i.e. approximately 3.5 tons / ha were only slightly lower compared with values ranging from 4-8 tons / ha reported by Ostyssina et al. (1997) in Tabora (Tanzania) for lesser-known *Leucaena* species including *L. diversifolia.* However, the data for edible fodder yields in the present research work is for 1 $^{st}$ cut which was done at an age of one year after establishment while values reported by Ostssyina were averages for three different cuttings. The estimated prediction equations for both edible material yield and total biomass yield were significant (P= 0.0001) and thus this suggests that the combined linear effects of length of the tree (LOT), number of branches (NOB) and length of the longest branch (LOLB) contributed significantly to the variability in both edible material and total biomass. The estimated prediction model for edible material was better than that for total biomass.

**5.2: Chemical and botanical composition characteristics of experimental feeds**

The content of CP obtained in this study for *L. diversifolia* (22.53 %) was similar to that reported by other workers in Tanzania (Ostsyina et al., 1997) and is conceived high enough to be warranted as a protein supplement especially with crop residues based diets. The levels of condensed tannins in the leaf meal from *L. diversifolia* trees were 60.5 g/kg DM which compares poorly with other *Leucaena* species. The nature of tannins in *L. diversifolia* is unknown. The present studies could not indicate the nutritional influence the *Leucaena diversifolia* tannins may have.

DM, NDF and CP contents for bean straw and maize stover is in general agreement with previous research reports in Tanzania (Kimambo et al., 1990; Urio and Kategile, 1987 and Musimba, 1991). However, NDF values for maize stover in the present experiment are somewhat lower than those reported by Urio and Kategile (1987). This could probably be attributed to differences in growing conditions, varieties, proportions of botanical parts and magnitude of stover deterioration during storage. The content of CP in maize stover botanical fractions i.e. 30 to 69.6 g/kg DM could not meet the critical level of dietary CP i.e. 70 g/kg DM that is recommended for acceptable voluntary feed intake by ruminant animals as argued by Van Soest (1982).

The study has shown that maize stover is more heterogeneous as it contains more botanical fractions namely leaf, sheath, ear, stalk and tassels compared to bean straw that was composed of pods and a combination of branches and stems.

## 5.3: Description of rumen degradability and *in-vitro* digestibility characteristics of feeds

This particular experiment was designed to test the hypothesis that there exists substantial variation in *in sacco* degradability characteristics and *in vitro* ME contents for bean straw and maize stover botanical fractions and *L. diversifolia* leaf meal. Maize bran and sunflower seed cake were used as positive controls. The results obtained are discussed in relation to this hypothesis. A wide variation in *in sacco* degradation parameters and *in vitro* ME contents between the different feed materials studied were exhibited. In practise, this could be considered advantageous in terms of choices that can be made for efficent utilisation of the available feed resources. However, in this study, the relative ranking of botanical fractions and concentrate feeds was similar between the *in sacco* and *in vitro* digestibility feeds evaluation methods.

Overall, the data showed that both maize stover and bean straw botanical fractions are characterized by high DM potential degradability ("a + b") that was contributed mainly by the water-insoluble but fermentable fraction ("b") and therefore could be used extensively as energy sources during the dry seasons by small holder dairy cattle farmers. Tolera and Said (1997), Mgheni and Ndemanisho (2001) and Chakeredza et al (2002) reported similar observations while evaluating *in-sacco, in-vitro* and *in-vivo* digestibilities and supplementary values of some tropical forages and roughages.

The consistency in superiority for maize stover leaves, ears and sheath and bean straw pods for various degradation constants and IVDMD coefficients was similar to the findings reported by Flachowsky et al (1991), Tuah et al. (1996), Walli et al. (1988), Shand et al (1988), Orskov et al. (1990) and by Mgheni and Ndemanisho (2001). Since degradability of leafy materials may sometimes be more than twice that of stem, then the leaf: stem ratio may be used as an index in optimizing the utilization of heterogeneous crop-residues for smallholder dairy cattle production. Orskov and Ryle (1990) argued that the soluble component which is high in leafy materials may be much more dependent on environmental conditions than the insoluble but degradable part. For instance, heavy rainfall may cause leaching out of the soluble matter in the matured straw. On the other hand, rapid ripening of the crop while in the field may decrease the translocation of solubles to the kernel on a drier year, so that more soluble matter remains in the straw/stover.

Degradation characteristics for DM in sunflower seed cake in the present study is generally in close agreement with data reported by Sibanda et al. (1993). Tuan et al. (2001) while working in Ghana and Wadhwa et al. (1993) working in India reported more or less similar findings on degradation constants for sunflower seed cake. The sunflower seed cake is the single most important protein supplement available to the majority of smallholder dairy cattle farmers in Southern highlands of Tanzania. Its high ruminal degradation as illustrated in this study suggest that it is a good source of ammonia and can have positive effect when used as a supplement to either maize stover or bean straw based diets during the dry season.

Overall, with potential degradability ("a + b") for CP in *L. diversifolia* with a value of 599.5 g/kg DM, suggests that it was not extensively degraded in the rumen. With an apparent rumen degradable protein (RDP) of about 600 g/kg DM in *L. diversifolia*, the remaining 400 g/kg DM could arrive as undegradable protein (UDP) for intestinal digestion. This could not be demonstrated, however. This amount of undegradable protein (UDP) in *L. diversifolia* is just slightly above 350 g/kg DM, a level recommended by NRC for lactating dairy cattle. Tannins have been shown to depress degradability in certain legume forages such as *Calliandra calothyrsus* (Shelton and Gutteridge, 1994). In the present study amount of condensed tannins in *L. diversifolia* was 60.5 g/kg DM, a level high enough to depress ruminal degradation of CP. However, this was not measured.

The study has shown that the content of *in vitro* ME in *L. diversifolia* leaf meal was 9.53 MJ/kg DM and thus apart from its use as a protein supplement, it can also contribute fermentable energy to the rumen in the form of available cellulose and hemicellulose that are known to stimulate fibre digestion. On the other hand, if *L. diversifolia* leaf meal will be used liberally by small holder farmers in feeding dairy cattle animals, it will have an energy sparing effect when used with either maize stover or bean straw.

### 5.4: *In vivo* digestibility measurements

This experiment was set up to test the hypothesis that the optimum inclusion level for *L.diversifolia* leaf meal in either bean straw or maize stover basal diets ranges between 15-30% on dry matter basis. The effects of incremental levels of *Leucaena* *diversifolia* leaf meal supplementation on apparent digestibility of nutrients for both bean straw and maize stover diets are reported for the two successive experiments. The response in nutrients digestibility due to *L. diversifolia* leaf meal supplementation was positive and ranged from 487.3 to 638.9 g/kg (DMD); 880.4 to 915.8 g/kg DM (CPD) and from 323.4 to 485.7 g/kg DM (NDFD) when levels of *L. diversifolia* were elevated from 15 to 30 % on DM basis for the bean straw experiment. A similar trend was noted for the maize stover experiment. However, since the responses were linear, further experiments are required to quantify the nutrients digestibility to higher levels of *L. diversifolia* supplementation to either bean straw or maize stover. The present results suggest that an optimum inclusion level for *L. diversifolia* is above 30% on dry matter basis and therefore do not support the hypothesis as stated above. In implementing this experiment and also experiments 4a and 4b an opportunity was taken to monitor the health of experimental animals consuming *L. diversifolia* for extended periods up to ten weeks. There were no apparent indications of antinutritional effects in the experimental animals from the two experiments.

*L. diversifolia* compares variably to other commonly used legume trees. Ash (1990) noted significant improvements in nitrogen digestibility in Guinea grass hay based diets by goats. The latter worker used *Sesbania grandiflora, Albizia chinensis and Gliricidia sepium*. Similarly, Reed et al., (1990) observed improvements in OMD and NDFD when three *Acacia* spps, *Sesbania sesban* and *Vicia dasycarpa* leaf meal were used to supplement teff straw with sheep. However, Banda and Ayoade (1986) found no improvements in maize stover DM digestibility when *Leucaena leucocephala* was used as a supplement to goats.

An ideal forage supplement should maintain or increase intake of the basal diet rather than substitute for it, a phenomenon that has been frequently observed in animals fed on legumes or legume straws. In the present study, intakes of both bean straw and maize stover were not significantly depressed by incremental levels of *L. diversifolia* supplementation.

The improved nutrients digestibility with increasing *L. diversifolia* leaf meal supplementation in both bean straw and maize stover basal diets could be attributed to improved ruminal environment and hence efficient microbial degradation of either bean straw or maize stover. However, this remains a proposition since ruminal parameters were not measured in this study. Evidence from numerous feeding studies shows that the most frequent nutrient deficiency in crop residues based diets is probably nitrogen whose ratio to digestible organic matter decreases from 39 to 3 g/kg as crop residues become senescent. Thus supplementation with small quantities of proteinous forages can improve the ruminal environment and enhance utilization of crop residues.

### 5.5: Feed intake, selectivity and animal performance

Bean straw diet based experiment was carried out during the dry season (July-September 2002) while that on maize stover diet was started during the peak of the dry season through to the beginning of the rain season (November 2002- February

2003). As shown earlier, bean straw and maize stover form a major proportion of improved dairy cattle rations during the dry season that usually commences in June through to December in the Southern Highlands of Tanzania. Implementation of the present study was therefore designed to mimic the feeding management system practised by smallholder dairy cattle farmers during the dry season under Southern highlands conditions. In these investigations the main hypothesis that was being tested was that combined *L. diversifolia* leaf meal supplementation to either bean straw or maize stover diets and increasing the amount on offer of the latter will sustain milk yield production by lactating cattle during the dry season. There were no significant interaction effects between the main factors (offer rates and *L. diversifolia* leaf meal supplementation regime) on milk yield for both bean straw and maize stover based experiments. The results obtained therefore do not support this hypothesis since various levels of the main factors exerted influence on milk yield independently.

Microbial protein supply to the small intestine was not measured in this study, but it could be possible that lactating cows supplemented with *L. diversifolia* leaf meal improved microbial protein supply resulting to somewhat better performance in milk yield (8.1 vs 7.6 kg/cow/day) in a bean straw based trial. A similar trend was also exhibited in a maize stover based experiment. In another experiment under the same study, degradability characteristics ("A" and "B") values for water soluble component and water-insoluble but fermentable component, respectively for *L. diversifolia* were: DM degradability: A: 198.9 g/kg (s.e.d 11.141); B: 306.6 g/kg (s.e.d 16.747) and for CP degradability values were: A: 303.6 g/kg DM (s.e.d 8.954) and B: 295.8 g/kg DM (s.e.d 12.248). These factors suggest that a substantial CP proportion (400.6 g / kg DM) is not rumen degradable and perhaps is made available for digestion in the small intestine. The tendency for improved performance in lactating cattle supplemented with *L. diversifolia* leaf meal could probably partly be attributed to these factors. Observations from an *in vivo* digestibility study showed that nutrients digestibility were improved linearly with increasing *L. diversifolia* leaf meal supplementation and probably this also explains the observed higher milk yields tendency for the supplemented lactating cows. Similarly, higher live-weight gains in steers have been reported when they were supplemented with tropical forages rich in bypass protein (Abdulrazak et al., 1996).

In a bean straw experiment, basal feed intake in g DM / $M^{0.75}$ per cow per day was increased from 89.04 to 162.19 as rate of offer was changed from 30-50 g DM/kg $M^{0.75}$. This was also associated with a proportional increase in DM refused of 35.32, 38.66 and 42.41 g DM/kg $M^{0.75}$ per cow per day at 30, 40 and 50 g DM/kg $M^{0.75}$offer rates, respectively. Respective basal feed DM intake by supplementation regime was similar and stood at 125.73 and 126.72 g DM/kg $M^{0.75}$for the un-supplemented and supplemented category of animals, respectively. This shows that a great part of improvement in intake was due to increasing amount on offer of the basal diet. The improved intake with increasing offer rate of the basal diet is in general in close agreement with previous studies using sorghum stover (Aboud et al., 1991, 1993; Osafo et l., 1997), barley straw (Wahed et al., 1986, 1990; Bhargava et al., 1988), maize stover (Methu et al., 1996), wheat straw (Biswal et al., 2000) and finger-millet straw (Subba-Rao et al., 1994). In this study, however, response on milk yield due to increased DM intakes with increasing offer rates of basal diets was non-significant. However, changes in metabolic body weight after a 70-days experiments indicate that lactating experimental cows lost on average 98.6 and 17.1 g/d of metabolic body weight for bean straw and maize stover based experiments, respectively. It is suggestive from this fact that part of improved DM intakes with increasing offer rates reduced the rate of metabolic body weight loss. It has long been established that intake in dairy cows varies with metabolic liveweight ($M^{0.75}$). In the present studies, for every 10 g DM/kg $M^{0.75}$ interval of offer rates, the mean response in intake was 36.17 and 36.58 g DM/kg $M^{0.75}$ for maize stover and bean straw, respectively, when offer rates were increased from 30 to 50 g DM/kg $M^{0.75}$ (AO1-AO3). Mean DM intake for a bean straw based experiment was 11.98 kg while mean milk yield was 7.84 kg and thus mean metabolizability characteristic for this experiment was 0.7 kg milk/ kg DM intake. A corresponding metabolizability for a maize stover experiment was 0.5 kg milk/ kg DM intake. Average ME intakes were 106.9 and 74.37 MJ/ kg DM per cow per day for bean straw and maize stover experiments respectively. The observed discrepancy in milk yields for bean straw and maize stover experiments could probably be attributed to differences in ME intake by lactating cows.

In the refused bean straw, the pods to stem ratio were 1: 20.9, 1:19.7 and 1: 22.25 for AO1, AO2 and AO3 offer rates, respectively and this clearly shows that the improved intake with increasing offer rate, contained more pods than stems. Pods were characterized by higher CP (77.0 g/kg DM) and both the estimated IVOMD (721.6 g/ kg DM) and ME (10.8 MJ/ kg DM). The pattern of refused DM in maize stover experiment, followed a similar trend but the quantity of refused botanical fractions were in the order Stem> Sheath> Ears.

Feed selectivity in the two experiments was judged by the post-feeding changes in botanical and chemical composition of the offered and refused materials. For bean straw, chemical composition of refused bean pods and stems contained less CP, ASH, and lower IVOMD and ME than the offered material. Conversely NDF values were higher in the refused than the offered materials. Similar trends were evident in maize stover.

Cows receiving liberal quantities of bean straw showed slight increase in milk yield, the highest response being recorded at AO2. With maize stover the response was similarly positive albeit at a rate lower than that of bean straw. Lactating cows supplemented with *L. diversifolia* leaf meal tended to produce more milk than those in the unsupplemented category.

In both experiments milk composition was unaffected by varying offer rates of bean straw or maize stover with or without a legume leaf meal supplementation.

The respective observed refusal rates were 3.58 and 2.72 kg DM/cow/day for bean straw and maize stover based diets, respectively. Experience from Southern Highlands zone shows that smallholder dairy cattle farmers consider manure compost production as one of the most valuable by-products in the mixed crop-livestock farming system that is the most predominant in the area. Thus the observed rates for the refused feed should not be considered as wasteful; rather it will enhance nutrient recycling through soil fertility restoration.

The present results have shown that offer rates of basal diets and *L. diversifolia* leaf meal supplementation regime did not interact positively. However, main factors tended to improve milk yield independently and therefore the results did not support the hypothesis that combined *L. diversifolia* leaf meal supplementation to either bean straw or maize stover based diets and increasing the amount on offer of the latter will sustain acceptable level of milk yield during the dry season.

# CHAPTER SIX

## 6.0: CONCLUSION AND RECOMMENDATIONS

### 6.1: Conclusions

From the present study, the following conclusions can be drawn:

- The biomass yield has shown that *L. diversifolia* can be promoted as a dry season protein supplement for lactating dairy cattle for high altitude areas in Tanzania.
- The *in vivo* digestibility study has shown that the optimum inclusion level for *L. diversifolia* is above 30% on dry matter basis for either bean straw or maize stover basal diets
- When supplemented with *L. diversifolia*, bean straw and maize stover can be sufficiently metabolized to support 0.7 and 0.5 kg milk/ kg DM, respectively.
- Ruminal degradation study showed that *L. diversifolia* was characterized by higher bypass CP than sunflower seed cake, suggesting a possibility of higher supply of amino acids at tissue level.

- *Leucaena diversifolia* leaf meal can be incorporated as a protein supplement in lactating dairy cattle rations without deleterious effects on milk composition.

## 6.2: Recommendations

- *L. diversifolia* was shown to contain a substantial level of rumen undegradable protein (RUDP). Therefore, further research is recommended to elucidate bypass protein characteristics in *L. diversifolia* leaf meal.

- The accompanied increment in refused feed due to generous feeding strategy should be recycled back into the farming system through manure composting for soil fertility improvement. Experience from Southern highlands zone shows that farmers consider manure production as secondary after milk production. Thus the generous feeding strategy can be advocated among mixed farming smallholder farmers.

- It is recommended that further research be conducted to determine potential maximum biomass yield from *L. diversifolia* trees by including apart from primary cuts, secondary and where possible tertiary cuts.

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# 8.0: APPENDICES

**Appendix 8.1: Extraction of crop-residues for Mbeya Region according to Kossila (1984)**

| | 1991/92 | 1992/93 | 1993/94 | 1994/95 | 1995/96 | 1996/97 | 1997/98 |
|---|---|---|---|---|---|---|---|
| Maize yield in 000' tones | 287.7 | 286.6 | 213.0 | 315.9 | 218.1 | 214.8 | 252.6 |
| Maize stover yield in 000' Tonnes | 460.3 | 458.6 | 340.8 | 505.4 | 349.0 | 343.7 | 404.2 |
| Beans yield in 000' tones | 22.1 | 23.5 | 11.1 | 28.8 | 33.4 | 26.7 | 28.0 |
| Beans straw yield in 000' tones | 88.4 | 94.0 | 44.1 | 113.6 | 133.6 | 106.8 | 112.0 |

**Extraction rate: Vegetative dry mater: Grain DM (3: 1) for maize and 4:1 for beans.**

**Source: Kossila (1984).**

**Appendix 8.2: Mean monthly rainfall and temperature distribution during 1999/2000 season**

| Month | Rainfall, mm | Temperature, °C |
|---|---|---|
| January | 235.6 | 19.0 |
| February | 132.1 | 18.9 |
| March | 353.5 | 18.1 |
| April | 271.7 | 17.2 |
| May | 68.1 | 15.5 |
| June | Nil | 14.4 |
| July | Nil | 14.3 |
| August | 3.3 | 16.0 |
| September | 10.1 | 17.5 |
| October | 11.3 | 18.8 |
| November | 21.0 | 19.8 |
| December | 85.2 | 18.9 |

**Source: ARI-UYOLE meteorological station.**

**Appendix 8.3: Mean monthly rainfall and temperature distribution during 2000/2001 season**

| Month | Rainfall, mm | Temperature, °C |
|---|---|---|
| January | 341.6 | 17.8 |
| February | 92.1 | 19.0 |
| March | 163.8 | 18.8 |
| April | 150.7 | 17.6 |
| May | 74.7 | 16.2 |
| June | Nil | 14.2 |
| July | Nil | 14.0 |
| August | Nil | 15.6 |
| September | Nil | 17.2 |
| October | 19.2 | 19.4 |
| November | 40.6 | 19.9 |
| December | 168.7 | 19.3 |

**Source: ARI-UYOLE meteorological station.**

**Appendix 8.4: Fitted values for *in sacco* dry matter degradability**

| FEED | ANIM | A | B | A + B | C | EFFdeg | RSD |
|---|---|---|---|---|---|---|---|
| MS1 | 1 | 15.79 | 46.15 | 61.94 | 0.0378 | 35.7 | 2.42 |
| | 2 | 17.63 | 55.84 | 73.47 | 0.0163 | 31.4 | 3.92 |
| | 3 | 17.14 | 47.41 | 64.55 | 0.0279 | 34.1 | 2.52 |
| MS2 | 1 | 14.82 | 48.4 | 63.22 | 0.021 | 29.1 | 3.97 |
| | 2 | 14.4 | 48.43 | 62.83 | 0.029 | 32.2 | 3.22 |
| | 3 | 15.31 | 45.39 | 60.7 | 0.0306 | 32.6 | 3.84 |
| MS3 | 1 | 21.58 | 50.12 | 71.7 | 0.0249 | 38.2 | 3.65 |
| | 2 | 19.31 | 55.71 | 75.02 | 0.0372 | 43.1 | 2.78 |
| | 3 | 20.13 | 59.51 | 79.64 | 0.0262 | 40.6 | 2.36 |
| MS4 | 1 | 13.18 | 53.27 | 66.45 | 0.0308 | 33.5 | 3.78 |
| | 2 | 12.84 | 47.56 | 60.4 | 0.0434 | 34.9 | 3.6 |
| | 3 | 16.36 | 50.17 | 66.53 | 0.035 | 36.1 | 3.95 |
| MS5 | 1 | 8.57 | 74.63 | 83.2 | 0.0417 | 42.5 | 1.27 |
| | 2 | 9.11 | 69.53 | 78.64 | 0.0428 | 41.2 | 2.61 |
| | 3 | 10.68 | 71.71 | 82.39 | 0.0365 | 40.9 | 1.94 |
| MM | 1 | 26.1 | 69.72 | 95.82 | 0.0883 | 76.4 | 7.95 |
| | 2 | 30.89 | 65.63 | 96.52 | 0.081 | 71.5 | 9.69 |
| | 3 | 30.77 | 63.33 | 94.1 | 0.0956 | 72.3 | 9.75 |
| MB | 1 | 25.71 | 61.75 | 87.46 | 0.1192 | 74.5 | 9.73 |
| | 2 | 30.94 | 59.95 | 90.89 | 0.108 | 71.9 | 10 |
| | 3 | 28.48 | 62.48 | 90.96 | 0.1304 | 73.6 | 9.35 |
| SSC | 1 | 20.57 | 41.2 | 61.77 | 0.2664 | 55.3 | 3.7 |
| | 2 | 20.39 | 39.41 | 59.8 | 0.3536 | 54.9 | 3.37 |
| | 3 | 20.4 | 38.2 | 58.6 | 0.3281 | 53.6 | 2.45 |
| LD1 | 1 | 17.21 | 31.57 | 48.78 | 0.0961 | 44.4 | 5.34 |
| | 2 | 19.64 | 30.63 | 50.27 | 0.097 | 43.3 | 4.84 |
| | 3 | 22.83 | 29.78 | 52.61 | 0.0969 | 42.4 | 5.84 |
| LD2 | 1 | 21.81 | 31.74 | 53.55 | 0.0891 | 42.1 | 5.3 |
| | 2 | 16.53 | 26.8 | 43.33 | 0.0889 | 39.8 | 5.39 |
| | 3 | 17.31 | 25.91 | 43.22 | 0.0886 | 39.4 | 4.92 |
| WBS | 1 | 8.83 | 53.93 | 62.76 | 0.0741 | 41 | 2.34 |
| | 2 | 11.24 | 51.79 | 63.03 | 0.0402 | 34.3 | 1.46 |
| | 3 | 12.84 | 49.33 | 62.17 | 0.0612 | 40 | 2.75 |
| BSS | 1 | 8.24 | 34.36 | 42.6 | 0.0622 | 27.3 | 2.83 |
| | 2 | 14.37 | 27.81 | 42.18 | 0.0381 | 26.4 | 1.98 |
| | 3 | 13.11 | 29.74 | 42.85 | 0.055 | 28.7 | 2.06 |
| BSP | 1 | 13.87 | 68.23 | 82.1 | 0.0545 | 49.4 | 3.6 |
| | 2 | 10.54 | 72.03 | 82.57 | 0.0497 | 46.4 | 4.12 |
| | 3 | 11.46 | 71.7 | 83.16 | 0.0577 | 49.9 | 4.98 |

Appendix 8.5: Fitted *in sacco* values for crude protein degradability

| FEED | ANIM | A | B | A+B | C | EFFdeg | RSD |
|---|---|---|---|---|---|---|---|
| MS1 | 1 | 24.68 | 57.74 | 82.42 | 0.058 | 77.8 | 2.65 |
| MS1 | 2 | 24.74 | 58.66 | 83.4 | 0.0375 | 76.5 | 2.81 |
| MS1 | 3 | 24.7 | 56.49 | 81.19 | 0.0409 | 75 | 2.97 |
| MS2 | 1 | 16.68 | 60.66 | 77.34 | 0.01455 | 61.8 | 2.2 |
| MS2 | 2 | 16.81 | 62.8 | 79.61 | 0.01362 | 62.7 | 3.16 |
| MS2 | 3 | 16.77 | 63.1 | 79.87 | 0.01361 | 62.9 | 2.22 |
| MS3 | 1 | 39.06 | 51.61 | 90.67 | 0.0393 | 61.8 | 5.09 |
| MS3 | 2 | 36.3 | 50.94 | 87.24 | 0.0766 | 67.1 | 5.01 |
| MS3 | 3 | 37.79 | 51.75 | 89.54 | 0.0463 | 62.7 | 4.66 |
| MS4 | 1 | 32.45 | 41.85 | 74.3 | 0.0577 | 54.9 | 2.53 |
| MS4 | 2 | 32.02 | 39.75 | 71.77 | 0.0848 | 57 | 4.71 |
| MS4 | 3 | 35.97 | 35.47 | 71.44 | 0.0644 | 55.9 | 5.33 |
| MS5 | 1 | 30.17 | 50.47 | 80.64 | 0.0721 | 68.5 | 7.1 |
| MS5 | 2 | 30.1 | 49.59 | 79.69 | 0.0698 | 73.7 | 7.77 |
| MS5 | 3 | 30.24 | 51.71 | 81.95 | 0.0719 | 74.9 | 6.86 |
| MB | 1 | 48.61 | 47.09 | 95.7 | 0.2006 | 86.3 | 4.02 |
| MB | 2 | 49.61 | 45.34 | 94.95 | 0.1836 | 85.2 | 4 |
| MB | 3 | 52.3 | 41.88 | 94.18 | 0.1413 | 83.2 | 4.51 |
| LD1 | 1 | 31.29 | 29.19 | 60.48 | 0.068 | 48.1 | 2.2 |
| LD1 | 2 | 29.11 | 29.16 | 58.27 | 0.0711 | 49.6 | 2.28 |
| LD1 | 3 | 30.69 | 30.41 | 61.1 | 0.0683 | 48.3 | 1.86 |
| LD2 | 1 | 31.19 | 30.87 | 62.06 | 0.0811 | 50.3 | 2.13 |
| LD2 | 2 | 31.64 | 28.56 | 60.2 | 0.0522 | 46.2 | 3.29 |
| LD2 | 3 | 32.21 | 26 17 | 58.38 | 0.0826 | 48.5 | 2.78 |
| BSP | 1 | 30.98 | 63.69 | 94.67 | 0.02191 | 82.8 | 4.79 |
| BSP | 2 | 30.56 | 63.25 | 93.81 | 0.0258 | 83.6 | 5.29 |
| BSP | 3 | 31.4 | 64.07 | 95.47 | 0.02 | 82.7 | 5.13 |
| BSS | 1 | 21.03 | 40.63 | 61.66 | 0.01 | 48.2 | 2.64 |
| BSS | 2 | 22.97 | 35.02 | 57.99 | 0.011 | 47 | 3.12 |
| BSS | 3 | 21.15 | 37.57 | 58.72 | 0.0164 | 50 | 3.57 |
| SSC | 1 | 38.78 | 58.72 | 97.5 | 0.03861 | 90.8 | 0.92 |
| SSC | 2 | 38.77 | 59.3 | 98.07 | 0.0476 | 92.4 | 0.26 |
| SSC | 3 | 38.77 | 58.95 | 97.72 | 0.0678 | 93.7 | 0.32 |
| MM | 1 | 42.82 | 54.89 | 97.71 | 0.1146 | 81 | 4.12 |
| MM | 2 | 44.15 | 54.3 | 98.45 | 0.0884 | 78.8 | 3.02 |
| MM | 3 | 46.87 | 50.03 | 96.9 | 0.0999 | 80.2 | 4.83 |
| WBS | 1 | 21.9 | 55 | 76.9 | 0.0684 | 61.2 | 5.34 |
| WBS | 2 | 23.7 | 55.3 | 79 | 0.2613 | 70.1 | 5.64 |
| WBS | 3 | 23.2 | 49.57 | 72.77 | 0.0597 | 59.1 | 6.93 |

Appendix 8.6: Fitted *in sacco* values for NDF degradability

| FEED | ANIM | B | C | EFDEGR | RSD |
|---|---|---|---|---|---|
| MS4 | 1 | 55.4 | 0.0290 | 24.6 | 0.96 |
| MS4 | 2 | 53.3 | 0.0212 | 24.8 | 1.73 |
| MS4 | 3 | 54.9 | 0.0268 | 25.1 | 2.79 |
| MS3 | 1 | 81.0 | 0.0483 | 28.3 | 4.87 |
| MS3 | 2 | 73.3 | 0.0383 | 28.8 | 4.28 |
| MS3 | 3 | 67.2 | 0.0310 | 30.4 | 5.15 |
| MS2 | 1 | 50.8 | 0.0317 | 23.5 | 1.67 |
| MS2 | 2 | 52.6 | 0.0310 | 21.8 | 1.52 |
| MS2 | 3 | 49.8 | 0.0265 | 22.3 | 1.36 |
| MS1 | 1 | 57.0 | 0.0232 | 18.5 | 2.30 |
| MS1 | 2 | 54.1 | 0.0260 | 18.8 | 2.04 |
| MS1 | 3 | 57.1 | 0.0222 | 18.1 | 2.99 |
| MB | 1 | 82.4 | 0.0235 | 43.9 | 9.04 |
| MB | 2 | 80.8 | 0.0199 | 42.2 | 8.44 |
| MB | 3 | 82.0 | 0.0225 | 43.5 | 8.42 |
| LD | 1 | 20.1 | 0.0498 | 21.5 | 0.95 |
| LD | 2 | 20.9 | 0.0381 | 21.0 | 1.28 |
| LD | 3 | 20.9 | 0.0471 | 21.9 | 1.23 |
| BSP | 1 | 63.1 | 0.0362 | 39.1 | 3.03 |
| BSP | 2 | 63.8 | 0.0381 | 39.7 | 4.32 |
| BSP | 3 | 49.4 | 0.0668 | 54.6 | 4.24 |
| BSS | 1 | 43.0 | 0.0653 | 44.2 | 5.83 |
| BSS | 2 | 42.9 | 0.0662 | 44.3 | 5.95 |
| BSS | 3 | 43.7 | 0.0544 | 42.8 | 5.71 |
| MS6 | 1 | 41.8 | 0.0088 | 19.2 | 2.49 |
| MS6 | 2 | 43.4 | 0.0091 | 20.8 | 1.87 |
| MS6 | 3 | 52.5 | 0.0072 | 20.4 | 2.37 |
| SSC | 1 | 20.6 | 0.0349 | 27.7 | 2.55 |
| SSC | 2 | 21.7 | 0.0531 | 28.3 | 3.17 |
| SSC | 3 | 22.0 | 0.0303 | 28.2 | 2.45 |
| WBS | 1 | 39.0 | 0.0280 | 26.9 | 1.57 |
| WBS | 2 | 36.8 | 0.0328 | 27.9 | 1.81 |
| WBS | 3 | 33.2 | 0.0278 | 29.0 | 1.32 |
| MS5 | 1 | 80.4 | 0.0118 | 30.0 | 3.23 |
| MS5 | 2 | 78.9 | 0.0129 | 29.9 | 3.67 |
| MS5 | 3 | 75.6 | 0.0157 | 30.4 | 2.82 |

**Appendix 8.7: Average DM consumption of animals by periods for *in vivo* digestibility trial (bean straw basal feed)**

| TREATMENT | PERIOD | Basal feed consumption, kg DM/cow/day | Supplement consumption, kg DM/cow/day | Total DM consumed/cow/day, kg |
|---|---|---|---|---|
| T1 | 1 | 6.02 | 1.08 | 7.10 |
| T2 | 1 | 5.31 | 1.32 | 6.63 |
| T3 | 1 | 6.36 | 2.07 | 8.43 |
| T4 | 1 | 4.88 | 2.05 | 6.93 |
| T1 | 2 | 5.73 | 0.99 | 6.72 |
| T2 | 2 | 5.78 | 1.42 | 7.20 |
| T3 | 2 | 4.95 | 1.60 | 6.55 |
| T4 | 2 | 5.51 | 2.22 | 7.73 |
| T1 | 3 | 6.55 | 1.12 | 7.67 |
| T2 | 3 | 5.36 | 1.32 | 6.68 |
| T3 | 3 | 5.26 | 1.70 | 6.96 |
| T4 | 3 | 4.37 | 1.81 | 6.18 |
| T1 | 4 | 5.35 | 0.92 | 6.27 |
| T2 | 4 | 5.84 | 1.51 | 7.35 |
| T3 | 4 | 4.84 | 1.69 | 6.53 |
| T4 | 4 | 4.78 | 2.00 | 6.78 |

**Appendix 8.8: Average DM consumption of animals by periods for *in vivo* digestibility trial (maize stover basal feed)**

| TREATMENT | PERIOD | Basal feed consumption, kg DM/cow/day | Supplement consumption, kg DM/cow/day | Total DM consumed/cow/day, kg |
|---|---|---|---|---|
| T1 | 1 | 4.29 | 0.89 | 5.18 |
| T2 | 1 | 3.30 | 1.16 | 4.46 |
| T3 | 1 | 4.31 | 1.69 | 6.00 |
| T4 | 1 | 3.76 | 1.96 | 5.72 |
| T1 | 2 | 5.68 | 1.25 | 6.93 |
| T2 | 2 | 4.20 | 1.25 | 5.45 |
| T3 | 2 | 3.96 | 1.42 | 5.38 |
| T4 | 2 | 4.39 | 2.05 | 6.44 |
| T1 | 3 | 4.84 | 1.07 | 5.91 |
| T2 | 3 | 4.43 | 1.25 | 5.68 |
| T3 | 3 | 3.96 | 1.51 | 5.47 |
| T4 | 3 | 4.47 | 2.22 | 6.69 |
| T1 | 4 | 4.61 | 1.07 | 5.68 |
| T2 | 4 | 4.73 | 1.33 | 6.06 |
| T3 | 4 | 4.53 | 1.51 | 6.04 |
| T4 | 4 | 3.90 | 1.69 | 5.59 |

## Appendix 8.9.0: ANOVA summaries

### Appendix 8.9.1: Maize stover based *in-vivo* digestibility experiment-DMD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 237.60 | 79.20 | 0.0011 |
| Period | 3 | 61.93 | 20.64 | 0.0630 |
| Error | 9 | 53.15 | 5.91 | |

### Appendix 8.9.2: Maize stover based *in-vivo* digestibility experiment -CPD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 95.75 | 31.92 | 0.0001 |
| Period | 3 | 1.75 | 0.58 | 0.6262 |
| Error | 9 | 8.60 | 0.96 | |

### Appendix 8.9.3: Maize stover based *in-vivo* digestibility experiment -NDFD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 339.92 | 113.31 | 0.0079 |
| Period | 3 | 526.17 | 175.39 | 0.0019 |
| Error | 9 | 135.29 | 15.03 | |

### Appendix 8.9.4: Bean straw based *in-vivo* digestibility experiment-DMD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 487.65 | 162.55 | 0.0058 |
| Period | 3 | 433.62 | 144.54 | 0.0085 |
| Error | 9 | 176.17 | 19.57 | |

### Appendix 8.9.5: Bean straw based *in-vivo* digestibility experiment-CPD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 27.34 | 9.11 | 0.0543 |
| Period | 3 | 13.80 | 4.60 | 0.2031 |
| Error | 9 | 21.99 | 2.44 | |

### Appendix 8.9.6: Bean straw based *in-vivo* digestibility experiment-NDFD

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Treatment | 3 | 550.94 | 183.65 | 0.0207 |
| Period | 3 | 823.38 | 274.46 | 0.0063 |
| Error | 9 | 303.88 | 33.76 | |

### Appendix 8.9.7: DM intake in g DM/kg $M^{0.75}$ per cow per day-bean straw based, milk production experiment

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| BW | 1 | 950.58 | 950.58 | 0.0001 |
| Basal feed | 2 | 15996.72 | 7998.36 | 0.0001 |
| Supplement feed | 1 | 4.41 | 4.41 | 0.5426 |
| Basal*Supplement | 2 | 51.58 | 25.79 | 0.1457 |
| Error | 11 | 122.99 | 11.18 | |

**Appendix 8.9.8: DM intake in g DM/M$^{0.75}$ per cow per day-maize stover based, milk production experiment**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| BW | 1 | 745.16 | 745.16 | 0.0001 |
| Basal feed | 2 | 15294.87 | 7647.44 | 0.0001 |
| Supplement feed | 1 | 0.9866 | 0.9866 | 0.7554 |
| Basal*Supplement | 2 | 7.28 | 3.64 | 0.6947 |
| Error | 11 | 106.39 | 9.67 | |

**Appendix 8.9.9: Milk yield-Bean straw based experiment**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| INITMILK | 1 | 13.36 | 13.36 | 0.0027 |
| LACTNO | 1 | 1.1809 | 1.1809 | 0.2545 |
| LACTWK | 1 | 0.1769 | 0.1769 | 0.6488 |
| BASAL | 2 | 0.2244 | 0.1122 | 0.8706 |
| SUPPL | 1 | 0.8213 | 0.8213 | 0.3366 |
| BASAL*SUPPL | 2 | 0.5625 | 0.2812 | 0.7120 |
| Error | 9 | 7.1752 | 0.7972 | |

**Appendix 8.9.10: Milk yield-Maize stover based experiment**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| INITMILK | 1 | 3.4866 | 3.4866 | 0.0129 |
| LACTNO | 1 | 0.3351 | 0.3351 | 0.3625 |
| LACTWK | 1 | 2.2777 | 2.2777 | 0.0338 |
| Basal feed | 2 | 0.1721 | 0.0861 | 0.7943 |
| Supplement Feed | 1 | 0.4474 | 0.4474 | 0.2965 |
| Basal*Supplement | 2 | 0.1679 | 0.0839 | 0.7988 |
| Error | 9 | 3.2787 | 0.3643 | |

**Appendix 8.9.11: DM in refused bean straw pods**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.4156 | 0.4156 | 0.3793 |
| Basal | 2 | 0.9275 | 0.4640 | 0.42 |
| Suppl. | 1 | 0.5410 | 0.5410 | 0.32 |
| Basal*Suppl. | 2 | 0.2990 | 0.1490 | 0.7453 |
| Eror | 11 | 5.4490 | 0.4954 | |

**Appendix 8.9.12: ASH in refused bean straw pods**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.4214 | 0.4214 | 0.0357 |
| Basal | 2 | 1.8517 | 0.9258 | 0.0014 |
| Suppl. | 1 | 0.2576 | 0.2576 | 0.0882 |
| Basal*Suppl. | 2 | 0.1096 | 0.0548 | 0.4975 |
| Error | 11 | 0.8099 | 0.0736 | |

## Appendix 8.9.13: CP in refused bean straw pods

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.4800 | 0.4800 | 0.2361 |
| Basal | 2 | 0.1270 | 0.0635 | 0.8160 |
| Suppl | 1 | 0.6750 | 0.6750 | 0.1660 |
| Basal*Suppl. | 2 | 0.1023 | 0.0540 | 0.8480 |
| Error | 11 | 3.3620 | 0.3056 | |

## Appendix 8.9.14: NDF in refused bean straw pods

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.6490 | 0.6490 | 0.7103 |
| Basal | 2 | 45.2600 | 22.6300 | 0.0275 |
| Suppl. | 1 | 1.0698 | 1.0698 | 0.6840 |
| Basal*Suppl. | 2 | 6.8970 | 3.4480 | 0.4850 |
| Error | 11 | 49.1150 | 4 4650 | |

## Appendix 8.9.15: IVOMD in refused bean straw pods

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 5.7091 | 5.7091 | 0.0114 |
| Basal | 2 | 1.6210 | 0.8104 | 0.3103 |
| Suppl. | 1 | 6.2815 | 6.2815 | 0.0088 |
| Basal*Suppl. | 2 | 0.0435 | 0.0218 | 0.9657 |
| Error | 11 | 6.8360 | 0.6215 | |

## Appendix 8.9.16: ME in refused bean straw pods

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.1287 | 0.1287 | 0.0111 |
| Basal | 2 | 0.0362 | 0.01811 | 0.3093 |
| Suppl. | 1 | 0.1407 | 0.1407 | 0.0086 |
| Basal*Suppl. | 2 | 0.00126 | 0.000631 | 0.9556 |
| Error | 11 | 0.1523 | 0.0138 | |

## Appendix 8.9.17: DM in refused bean straw stem

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.02497 | 0.02497 | 0.8601 |
| Basal | 2 | 2.01044 | 1.0052 | 0.3088 |
| Suppl. | 1 | 0.7354 | 0.7354 | 0.3486 |
| Basal*Suppl. | 2 | 0.5672 | 0.2836 | 0.6993 |
| Error | 11 | 8.4400 | 0.7670 | |

## Appendix 8.9.18: ASH in refused bean straw stem

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.04713 | 0.0471 | 0.527 |
| Basal | 2 | 0.0948 | 0.0474 | 0.661 |
| Suppl. | 1 | 0.1829 | 0.1829 | 0.224 |
| Basal*Suppl. | 2 | 0.7109 | 0.3554 | 0.079 |
| Error | 11 | 1.2125 | 0.1100 | |

**Appendix 8.9.19: CP in refused bean straw stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.01183 | 0.01183 | 0.182 |
| Basal | 2 | 0.16490 | 0.08250 | 0.0009 |
| Suppl | 1 | 0.00000152 | 0.00000152 | 0.987 |
| Basal*Suppl. | 2 | 0.00588 | 0.00294 | 0.617 |
| Error | 11 | 0.06400 | 0.00582 | |

**Appendix 8.9.20: NDF content in refused bean straw stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 13.05 | 13.05 | 0.0961 |
| Basal | 2 | 3.38 | 1.69 | 0.662 |
| Suppl. | 1 | 4.42 | 4.42 | 0.312 |
| Basal*Suppl. | 2 | 10.02 | 5.01 | 0.319 |
| Error | 11 | 43.35 | 3.94 | |

**Appendix 8.9.21: IVOMD content in refused bean straw stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 61.76 | 61.76 | 0.0822 |
| Basal | 2 | 74.82 | 37.41 | 0.1554 |
| Suppl. | 1 | 6.22 | 6.22 | 0.5562 |
| Basal*Suppl. | 2 | 56.62 | 28.31 | 0.2315 |
| Error | 11 | 185.76 | 16.89 | |

**Appendix 8.9.22: ME content in refused bean straw stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 1.3887 | 1.3887 | 0.0825 |
| Basal | 2 | 1.6763 | 0.8382 | 0.1568 |
| Suppl. | 1 | 0.1393 | 0.1393 | 0.5574 |
| Basal*Suppl. | 2 | 1.2844 | 0.642 | 0.2295 |
| Error | 11 | 4.185 | 0.3800 | |

**Appendix 8.9.23: DM content in refused maize stover stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 1.032 | 0.516 | 0.0033 |
| Suppl. | 1 | 0.0227 | 0.0227 | 0.5205 |
| Cows | 1 | 0.00005 | 0.00005 | 0.9757 |
| Basal*Suppl. | 2 | 1.3291 | 0.6646 | 0.0013 |
| Error | 11 | 0.5676 | 0.0516 | |

**Appendix 8.9.24: ASH content in refused maize stover stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 0.7780 | 0.3890 | 0.785 |
| Suppl. | 1 | 0.0048 | 0.0048 | 0.957 |
| Cows | 1 | 0.4550 | 0.4550 | 0.601 |
| Basal*Suppl. | 2 | 0.5690 | 0.2843 | 0.837 |
| Error | 11 | 17.302 | 1.5730 | |

**Appendix 8.9.25: CP content in refused maize stover stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 0.3231 | 0.1615 | 0.429 |
| Suppl. | 1 | 0.0033 | 0.0033 | 0.894 |
| Cows | 1 | 0.0634 | 0.0634 | 0.561 |
| Basal*Suppl. | 2 | 0.0028 | 0.0014 | 0.992 |
| Error | 11 | 1.9393 | 0.1763 | |

**Appendix 8.9.26: NDF content in refused maize stover stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 4.911 | 2.4600 | 0.8712 |
| Suppl. | 1 | 0.0874 | 0.0874 | 0.9451 |
| Cows | 1 | 28.706 | 28.706 | 0.2277 |
| Basal*Suppl. | 2 | 19.350 | 9.6770 | 0.5919 |
| Error | 11 | 193.44 | 17.590 | |

**Appendix 8.9.27: IVOMD content in refused maize stover stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 105.51 | 52.760 | 0.465 |
| Suppl. | 1 | 0.281 | 0.281 | 0.948 |
| Cows | 1 | 41.68 | 41.680 | 0.437 |
| Basal*Suppl. | 2 | 4.614 | 2.307 | 0.965 |
| Error | 11 | 705.65 | 64.150 | |

**Appendix 8.9.28: ME content in refused maize stem**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Basal | 2 | 2.438 | 1.2191 | 0.461 |
| Suppl. | 1 | 0.0044 | 0.0044 | 0.957 |
| Cows | 1 | 0.9379 | 0.9379 | 0.441 |
| Basal*Suppl. | 2 | 0.0952 | 0.0476 | 0.968 |
| Error | 11 | 16.11 | 1.46 | |

**Appendix 8.9.29: DM content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.0798 | 0.07980 | 0.5795 |
| Basal | 2 | 0.1116 | 0.05578 | 0.7998 |
| Suppl. | 1 | 0.0697 | 0.06967 | 0.6042 |
| Basal*Suppl | 2 | 0.0318 | 0.01592 | 0.9374 |
| Error | 11 | 2.6917 | 0.24470 | |

**Appendix 8.9.30: ASH content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.9116 | 0.9116 | 0.0768 |
| Basal | 2 | 0.0489 | 0.02449 | 0.9035 |
| Suppl. | 1 | 0.8570 | 0.8570 | 0.0849 |
| Basal*Suppl. | 2 | 0.1528 | 0.0764 | 0.733 |
| Error | 11 | 2.6299 | 0.2391 | |

**Appendix 8.9.31: CP content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.1747 | 0.17469 | 0.2833 |
| Basal | 2 | 6.2495 | 3.1248 | 0.0001 |
| Suppl. | 1 | 0.5379 | 0.5379 | 0.0734 |
| Basal*Suppl. | 2 | 0.3244 | 0.1622 | 0.343 |
| Error | 11 | 1.5104 | 0.13731 | |

**Appendix 8.9.32: NDF content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.0315 | 0.0315 | 0.8056 |
| Basal | 2 | 40.4649 | 20.2324 | 0.0001 |
| Suppl. | 1 | 8.5961 | 8.5961 | 0.0016 |
| Basal*Suppl. | 2 | 5.4854 | 2.7427 | 0.0216 |
| Error | 11 | 5.4439 | 0.4949 | |

**Appendix 8.9.33: IVOMD content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 20.4255 | 20.4255 | 0.5447 |
| Basal | 2 | 3.4427 | 1.7213 | 0.9677 |
| Suppl. | 1 | 39.2879 | 39.2879 | 0.4045 |
| Basal*Suppl. | 2 | 101.9073 | 50.9537 | 0.4077 |
| Error | 11 | 575.15 | 52.2864 | |

**Appendix 8.9.34: ME content in refused maize stover ear**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.4379 | 0.4379 | 0.5558 |
| Basal | 2 | 0.07319 | 0.03659 | 0.9697 |
| Suppl. | 1 | 0.9046 | 0.90460 | 0.4011 |
| Basal*Suppl. | 2 | 2.3357 | 1.16785 | 0.4042 |
| Error | 11 | 13.0467 | 1.18610 | |

**Appendix 8.9.35: DM content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.0128 | 0.0128 | 0.7937 |
| Basal | 2 | 0.0631 | 0.0315 | 0.8400 |
| Suppl. | 1 | 0.1135 | 0.1135 | 0.4411 |
| Basal*Suppl. | 2 | 0.2569 | 0.1285 | 0.5071 |
| Error | 11 | 1.9554 | 0.1778 | |

**Appendix 8.9.36: ASH content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.9467 | 0.9467 | 0.0376 |
| Basal | 2 | 0.0155 | 0.00776 | 0.9554 |
| Suppl. | 1 | 0.9581 | 0.9581 | 0.0367 |
| Basal*Suppl. | 2 | 0.0135 | 0.0067 | 0.9612 |
| Error | 11 | 1.8648 | 0.1695 | |

**Appendix 8.9.37: CP content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.4048 | 0.4048 | 0.0736 |
| Basal | 2 | 0.0041 | 0.00203 | 0.981 |
| Suppl. | 1 | 0.00472 | 0.00472 | 0.835 |
| Basal*Suppl. | 2 | 0.0963 | 0.0482 | 0.640 |
| Error | 11 | 1.1391 | 0.1036 | |

**Appendix 8.9.38: NDF content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.1721 | 0.1721 | 0.869 |
| Basal | 2 | 7.045 | 3.522 | 0.575 |
| Suppl. | 1 | 0.00796 | 0.00796 | 0.972 |
| Basal*Suppl. | 2 | 32.6165 | 16.3083 | 0.1114 |
| Error | 11 | 66.509 | 6.05 | |

**Appendix 8.9.39: IVOMD content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 3.8757 | 3.8757 | 0.728 |
| Basal | 2 | 11.054 | 5.527 | 0.837 |
| Suppl. | 1 | 6.622 | 6.622 | 0.651 |
| Basal*suppl. | 2 | 91.579 | 45.780 | 0.266 |
| Error | 11 | 335.84 | 30.530 | |

**Appendix 8.9.40: ME content in refused maize stover sheath**

| Source | DF | SS | MS | Pr>F |
|---|---|---|---|---|
| Cow | 1 | 0.0889 | 0.0889 | 0.726 |
| Basal | 2 | 0.2506 | 0.1253 | 0.836 |
| Suppl. | 1 | 0.1497 | 0.1497 | 0.650 |
| Basal*Suppl. | 2 | 2.071 | 1.0355 | 0.265 |
| Error | 11 | 7.576 | 0.6887 | |