THE POTENTIAL OF ENSILED BROWSE/MAIZE FORAGE MIXTURES OF *CALLIANDRA, GLIRICIDIA* AND *LEUCAENA* FOR DAIRY CATTLE FEEDING

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DECLARATION

I declare that the work presented in this thesis is my own and that it has not been submitted for a degree in any other University.

------------------------------ 11/3/2005

HABIB KATO Date

This thesis has been submitted with our approval as the University supervisors.

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DEDICATION

Dedicated to my parents, the late Yohana Kyanda and the late Mastura Mugizi, whose memories are a convergence of our love and respect in the family, and to my family, brothers and sisters for giving me a sense of security and belonging.

ABSTRACT

The potential of ensiled browse/maize fodder mixtures of *Calliandra calothyrsus, Gliricidia sepium or Leucaena leucocephala* for dairy cattle feeding was assessed in five experiments. Experiment 1 examined the fermentation characteristics, and the effect of fermentation on the chemical composition and rumen degradation of the browses and maize silage. Maize silage fermented best with higher ($P \leq 0.05$) levels of lactic acid (4.98% DM) and lower ($P \leq 0.05$) pH values compared to browse silages. The level of NH_3-N (% Total N) was higher ($P \leq 0.05$), in maize silage than in browse silages. Degradation of dry matter, organic matter and nitrogen was highest with *Gliricidia* followed by maize, *Leucaena* and *Calliandra* was least degraded. Fermentation increased rumen microbial protein synthesis with *Gliricidia, Leucaena* and maize forage but not with *Calliandra.*

Experiment 2 assessed the fermentation characteristics, chemical composition and rumen degradation of ensiled browse/maize fodder mixtures in proportions of 0 to 50% browse (DM basis). Butyric acid and lactic acid levels and pH were low at all levels of browse addition. The levels of NH_3-N were lower ($P \leq 0.05$) with browse addition levels above 10% indicating less proteolysis with higher levels of browse addition. Maximum degradation of DM, OM and N occurred at 10 – 20% levels of browse addition. Estimated RMP synthesis consistently decreased with higher levels of *Calliandra* and *Leucaena* addition to the silage, but increased with higher levels of *Gliricidia* addition.

Experiment 3 investigated intake and digestibility of the browse/maize silages containing 0 or 30% browse (DM basis). The silages were fed to weaned dairy calves. Dry matter intake (g/kgW¾) was higher ($P \leq 0.05$) with browse/maize silages, probably as a result of higher DM, and CP contents, less acetic acid and NH_3-N contents. All the silages had similar DM digestibility, but CP digestibility was higher ($P \leq 0.05$) with *Gliricidia*/maize silage and lower ($P \leq 0.05$) with *Leucaena*/maize silage. Weight gains of the calves on all the silages were low indicating need for supplementation even when maize silage is enriched with browse addition.

In Experiment 4 the milk producing ability of browse/maize silages containing 0 or 20% browse (DM basis) were investigated. The silages were fed to lactating dairy Friesian cows supplemented with dairy meal in a 4 x 4 Latin square design. The DMI (g/Wkg¾) was higher ($P \leq 0.05$) for *Calliandra*/maize silage but was lower ($P \leq 0.05$) and similar between *Leucaena*/maize silage and maize silage. Apparent nutrient digestibility coefficients were higher ($P \leq 0.05$) for *Leucaena*/maize silage. Milk yield was higher ($P \leq 0.05$) with *Calliandra*/maize and *Gliricidia*/maize silages and was lower ($P \leq 0.05$) for the control maize silage. Milk protein % and total solids % were higher ($P \leq 0.05$) for cows fed maize silage but % BF was similar for all silages.

In Experiment 5 browse/maize silages were compared with maize silage treated with urea (0.5%). All the silages were treated with molasses (5%). The treatments were silages containing 0 or 20% browse (DM basis) and were fed to lactating cows of Friesian x local cattle crosses supplemented with maize bran in a 4x4 Latin square design. Molasses improved lactic acid levels and lowered the pH. Urea raised CP content of maize silage to a comparable level with the browse silages. Silage DMI (g/kg$W^{3/4}$) was higher ($P \leq 0.05$) with *Calliandra*/maize silage and was lower ($P \leq 0.05$) with *Gliricidia*/maize silage. Digestibility of DM and OM were similar with all the silages, but crude protein digestibility was lower ($P \leq 0.05$) with *Calliandra*/maize. Milk yield was higher ($P \leq 0.05$) with the browse/maize silages compared to the control maize silage. Rumen NH_3 levels were within the expected range (30-35 mg/litre) while blood glucose levels were at the minimum levels. Blood total protein and plasma albumin levels were above the expected normal levels, but plasma urea levels were much lower than the expected normal levels.

The results of the five experiments show that browse/maize mixture, especially *Gliricidia*/maize can result in good silages that can be utilized well by animals. A level of 20 –30% browse addition (DM basis) would make good silage with 9-12% CP. However, for maximum benefit, the browse/maize silages should be supplemented with concentrate when fed to growing calves and lactating cows.

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ADF	Acid detergent fibre
ADF-AA	Acid detergent fibre amino acids
ADF N	Acid detergent fibre nitrogen
ADI N	Acid detergent insoluble nitrogen
ADL	Acid detergent lignin
AOAC	Association of official analytical chemists
BF	Butter fat of milk
BW	Body weight
CP	Crude protein
C:N	Carbon:nitrogen ratio
DHP	3-Dihydroxy – 4(1H) Pyridone
DIP	Degradable intake protein
DM	Dry matter
DMI	Dry matter intake
DOMD	Digestible organic matter in dry matter
ED	Effective degradability
EDTA	Ethylene diamine tetra acetic acid
FAO	Food and Agricultural Organisation of the United Nations
FCM	Fat corrected milk
GDP	Gross domestic product
GE	Gross energy
GLM	General linear model procedures of SAS
g	Gram
HCI	Hydrochloric acid
IGAD	Inter-Governmental Authority on development
ILCA	International livestock center for Africa
IVOMD	Invitro organic matter digestibility
J	Joule
kg	Kilogram
MAFF	Ministry of Agriculture, Fisheries and Food of Scotland

MCal	Mega calories
ME	Metabolisable energy
MEF	Metabolisable energy of feed
MJ	Mega joule
MP	Metabolisable protein
MUARIK	Makerere University Agricultural Research Institute, Kabanyolo
N	Nitrogen
NAARI	Namulonge Agricultural and Animal Research Institute, Uganda
NARO	National Agricultural Research Organisation, Uganda
NDF	Neutral detergent fibre
NDF-AA	Acid detergent fibre amino acids
NDFN	Neutral detergent fibre nitrogen
NH_3	Ammonia
NH3-N	Ammonia nitrogen
NPN	Non-protein nitrogen
ODA	Overseas Development Administration, UK
OM	Organic matter
PD	Potential degradability
PEG	Polyethylene glycol
RDP	Rumen degradable protein
RMP	Rumen microbial protein
RUP	Rumen undergradable protein
SAS	Statistical Analysis Systems, Inc., USA
SE	Standard error
SNF	Solids not fat in milk
S-SA	Sub-Saharan Africa
TDN	Total digestible nutrients
TRMP	Total rumen microbial protein
UDP	Undegradable protein
VFA	Volatile fatty acids
Wkg ¾	Metabolic body weight

CHAPTER I

General Introduction

1.1 Background

Livestock production in Uganda contributes 10% of total Gross Domestic Product (GDP) and 17% of agricultural GDP (Mukiibi (2001). The smallholder producers operating mixed crop/livestock farms own the majority (95%) of the cattle and 100% of the small ruminants and produce most of the domestic milk and slaughter animals while large scale commercial ranches and dairy farms make up only 5% of the cattle population (Uganda Government, 2000; Twinamasiko, 2001). It is the same pattern else where in tropical or Sub-Saharan Africa (S-SA) that, smallholder farmers own the majority of the cattle often operating a grazing system (ILCA, 1989; IGADD, 1990). The future perspectives in Uganda include development and adoption of high-yielding technologies aimed at the smallholder farmers. The liberalization of the dairy sub-sector has led to the development of private milk processing which gives impetus for increased milk production by the smallholder farmers (Uganda Government, 2000; Twinamasiko, 2001).

The demand and supply projections for livestock products show that Uganda is in short supply with regard to all livestock products except goat meat. The self-sufficiency ratio in the case of beef is below 60%. However, the binding constraint to livestock production in the medium term is effective demand and not supply due to low per capita income that translates into low purchasing power of the majority of the Uganda population (Uganda Government, 1998). Nevertheless, with growth in the economy and improvement in the per capita income there should be growing demand for livestock products. Uganda's per capita income grew from US$ 200 in 1990 to $296 in 1998 (Uganda Government, 1999).

Inadequate nutrition of the livestock, however, is one of the most serious constraint to livestock production in S-SA and arid and semi-arid regions of Africa. Since forage is the cheapest source of nutrients, improvement of forage production and feeding systems is imperative for the improvement of livestock production in these regions. Studies have been undertaken to screen "best bet" forages, their management, use and the farming systems in which they would be used (ILCA, 1989). This is particularly essential in the smallholder grazing system, which is most common in the tropics and where forages constitute the sole diet for the grazing animals.

In Uganda it has long been observed that herbage quality and digestible energy intake were among the most important factors limiting production by foraging cattle (Mugerwa, *et al*., 1973; Mugerwa, 2001). However, it is also now acknowledged that animal production in the tropics is limited by a deficiency of protein particularly in areas with long dry seasons when green feed is limited (Jones, 1982; Kabirizi, *et al*., 2000; Sabiiti, 2001) and crude protein (CP) content falling below the 7% level considered critical to provide the minimum ammonia level required for optimal rumen microbial activity (Jones, 1982; Hoover, 1986; Kabirizi, *et al*., 2000; Sabiiti, 2001) and therefore reduces DMI.

Practices to address the problem of low CP content of the pastures have been application of nitrogen (N) fertilizers, use of grass/legume mixed pastures, use of protein supplements and legume tree foliages (Horrell and Tiley, 1970; Otim, 1973; Sabiiti, 2001). Fast growing nitrogen-fixing trees have been found to have a lot of potential for use in mixed crop/livestock production system (Reynolds and Adeoye, 1986; Jones *et al.*, 1992; Topps, 1992; Sabiiti and Cobbina, 1992). They provide high quality fodder and improve and maintain soils fertility and productivity. They remain green throughout the year and have a medium to high content of CP ranging from 120 to 298g/kg dry matter (DM) (Topps, 1992; El hassan *et al.*, 2000). This makes them a valuable source of high quality fodder and protein to supplement the low CP content of the grass pastures particularly in the small holder grazing systems. Further advantage of tree legumes as sources of supplementary protein is evidenced by studies that have indicated well-balanced forage based diets to have higher efficiency of microbial protein synthesis in the rumen than diets containing high levels of concentrate (Verbic, 2002).

Thus, the practice of growing fodder trees and shrubs is being advocated for and adopted in the smallholder grazing systems (Jones, 1982; Sabiiti, 2001). In Uganda, *Calliandra, Gliricidia* and *Leucaena* tree species have been identified and recommended as the most suitable species for supplementation of indigenous goats under tethering or free range grazing conditions in the sub-humid zones of Uganda (NARO, 1999; Sabiiti, 2001). Tree forages, however contain toxic constituents whose effects need to be countered if greater utilization and productivity of these forages are to be realised (Lowry, 1990; Hammond, 1995). Methods for alleviating effects of antinutritional factors and toxicity associated with the fodder trees include supplementation, dilution, detoxication, feeding the tree forages in combination and treatments such as wilting, heating and drying (Lowry, 1990; Topps, 1992). Ensiling alters the chemical composition of ensiled materials (Bareeba, 1997; Weiss *et al*., Mahana, 1997) and could therefore, be used to store and at the same time process the browses to improve their utilization by farm animals. The purpose of this study was to investigate the ensiling characteristics of *Calliandra calorthyrsus*, *Gliricidia sepium* and *Leucaena leucocephala*, and their feeding value when ensiled with maize forage.

1.2 Objectives

The specific objectives of the study were to determine:

1. The ensiling characteristics and nutrient composition of the browses ensiled alone or with maize.
2. Rumen DM, OM and N degradability of the browses ensiled alone or with maize.
3. The feeding value of the browses ensiled with maize forage and fed either to growing or lactating dairy cattle.

CHAPTER II

Literature Review

2.1.0 Potential of browses as feedstuffs

Browses are tender shoots and twigs of shrubs and woody plants, fruits and pods forming a component of the diet for a variety of herbivores. They have been used as fodder for domesticated livestock in Asia, Africa and the Pacific. They become increasingly important in the arid and semi-arid regions where inadequate feeds are a major constraint to the survival and production of livestock (Topps, 1992; Sabiiti and Cobbina, 1992; Kaitho, 1997). As animal feeds, particularly for ruminants they are a major source of supplemental nitrogen to the low quality roughages.

Browses have nutritional diversity between and within species and even when prepared as feeds. These nutritional differences have been attributed to age, presence and concentration of anti-nutritional factors, methods of harvest (leaf, leaf and petiole, leaf and soft shoots) and form of presentation (fresh, wilted or dried). These factors determine their chemical composition, palatability, intake, extent and rate of degradation, digestibility and nutrient utilization by the animals. The most commonly used species come from the genera *Acacia, Albizia, Calliandra, Desmanthus, Desmodium, Gliricidia, Leucaena, Prosopis and Sesbania* (Bennison and Paterson, 1993; Paterson, 1994; Kaitho, 1997; Maasdorp, *et al.*, 1999).

Dzowela *et al*., (1995) and Bareeba and Aluma (2000) evaluated nutritional and anti-nutritional characteristics and degradability of DM and N for some of the browse species with potential for agroforestry in Zimbabwe and Uganda respectively. The results show that the browses studied are able to maintain their CP content for a considerable time of regrowth, over 12 weeks (Dzowela *et al*., 1995). The leaf materials had high CP content ranging from 189g kg^{-1} DM in *Flemingia macrophylla* to 292g kg^{-1} DM in *Acacia angustissima* (Dzowela *et al*., 1995) and 212g kg^{-1} DM in *Acacia tortilis* and *Prosopis juliflora* to 292g kg^{-1} DM in *Faidherbia albida* (Bareeba and Aluma, 2000). The ADF content increased growth (6-12 weeks) perhaps as a result of increased cellulose content and lignification with advancing maturity of foliage material (Dzowela *et al*., 1995). Results from both studies also show that while the browses studied had high CP content, they also had low NDF ranging from 321g kg^{-1} DM in *Sesban sesban* to 580g kg^{-1} DM in *Acacia tortilis* (Bareeba and Aluma, 2000) and ADF ranging from 155g kg^{-1} DM in *S.sesban* to 355g kg^{-1} DM in *S.goetzei* (Bareeba and Aluma, 2000) and 98-99g kg^{-1} DM in *S.sesban* to 254-301g kg^{-1} DM in *Flemingia congesta* (Dzowela *et al*., 1995).

The high CP content, though very varied, makes browses good protein supplements. However, the presence of tannins in some of the species could limit their efficient utilization by the animals. Condensed tannins precipitate protein to form stable complexes at rumen pH, which adversely affect protein and fibre degradation in the rumen (Lowry,1990). The materials with detectable amounts of condensed tannins, *Accacia.angustissima*, *C.calothyrsus* and *Flemingia congesta* (with 9.3-11.2, 8.4-27.4 and 0.8-6.0g kg^{-1} DM of condensed tannins respectively) had the lowest degradability ranging from 42 to 57% for DM and 26-50 for N (Dzowela *et al.*, 1995). Bareeba and Aluma (2000) also reported tannin–induced depression of *in vitro* organic matter degradability (IVOMD) for *Accacia tortilis, C.calothyrsus* and *Sesban goetzei*. Maasdorp *et al.* (1999) supplemented Holstein-Friesian lactating cows with *A.boliviana, C.calothyrsus* and *Leucaena leucocephala*. Despite being fed a commercial polyethylene glycol which preferentially binds the tannins and containing a digestive modifier (Browse Plus), it was concluded that anti-nutritional factors were operative with *A. boliviana* and *C. calothyrsus*. Maasdorp *et al.* (1999) also reported that amongst the tree forages, L.*leucocephala* has the lowest and *C.calothyrsus* the highest content of soluble polyphenolics and condensed tannins.

2.2.0 Utilisation of browses by animals

In Uganda, the genera *Calliandra* and *Leucaena* have species that have been identified and recommended as the most suitable species for supplementing indigenous goats under tethering or free range grazing conditions in the sub-humid zones of the country (NARO, 1999). Animal productivity assessment ranked *C.calothyrsus* as the most important in potential as a browse followed by *L.divesifolia*, *Gliricidia.sepium* and *S.sesban.* However, evaluation of *Calliandra* for milk production with farmers showed that milk yields increased only when cows were fed *Calliandra* leaf meal mixed with a concentrate (NARO, 1999).

Work from elsewhere shows that *Calliandra* is a good browse in terms of CP and other nutrient entities but it cannot support weight gain or other productivity (Topps, 1992).

Kaitho (1997) reported *C.calothyrsus* and *G.sepium* to have medium palatability ranking. Maasdorp *et al.* (1999) supplemented Holstein-Friesian cows with 1.5 kg of air-dried fodder of *A.boliviana*, *C.calothyrsus* or *L.leucocephala* or Rhodes grass as control, while receiving a basal diet of maize silage, cotton seed cake, and crushed maize grain. *C.calothyrsus* showed no beneficial effect. The highest ($P \leq 0.001$) milk yeild of 13.19 kg/day, was produced by cows receiving *L.leucocephala*. The lack of response to C. *calothyrsus* was attributed to the presence of soluble polyphenolics, which were hightest in *Calliandra* and lowest in *Leucaena.* The results further indicated poor nutritional value of *C.calothyrsus* when it is fed dry. Reports cited by Kaitho (1997) indicate that in terms of 48h DM disappearance using the nylon bag technique, there were no significant differences between forms of drying (sun, oven and freeze) of the browse materials investigated. However, the 48h DM disappearance, for all the drying treatments were significantly lower than those obtained from fresh material for *Calliandra.*

Kaitho (1997) argued that drying increases the amount of protein bypassing the rumen as well as decreasing the content of anti-nutritional factors. Similar reports and arguments were cited by Maasdorp *et al.* (1999). Comparatively, *Calliandra* could be an inferior browse to *Leucae*na and *Gliricidia* and would compare with *Acacias*, in supporting weight gain and other productivity (Maasdorp *et al*., 1999; Jones *et al*., 1992). However, Ebong *et al*., (1999) reported highest growth rate with most efficient feed utilization in goat kids fed a ration mixture of equal quantities of soybean meal and *Calliandra* leaf meal. They concluded that *Calliandra* leaf meal is a potentially valuable substitute for soybean meal in compound feeds.

Utilisation of the browses by animals is improved when they are fed in combination with other feeds rather than as sole diets. Chadhokar (1979) fed *Gliricidia.maculata* with *Bracharia brizantha* in proportions ranging from 0 to 100% to Jersey milking cows for a month. There were no adverse effects observed on the cows' health or their milk production or the fat and solids not fat (SNF) content of the milk. Diets combining *Gliricidia* and *Leucaena* have been used particularly to offset *Leucaena* toxicity while at the same time maintaining the high quality of the diet. Supplementation with a 1:1 mixture of *Leucaena* and *Gliricidia* diet to sheep with a daily intake of up to 450g DM/head raised productivity by 55% compared with sheep offered unrestricted amounts of *Panicum maximum* (Reynolds and Adeoye, 1986; Chadhokar, 1979).

Leucaena is highly palatable among browses (Kaitho, 1997), but has the disadvantage of being toxic at high intake levels because of the amino acid mimosine. Animals fed a pure diet of *Lecaena* do not make sustained weight gains. The animals either maintain or lose weight throughout the experimental period or gain weight acceptably to begin with and lose weight subsequently. This phenomenon could be associated with the toxic effect of *Leucaena* (Anon, 1982; Jones and Bray, 1982; Quirk *et al.,* 1988; Hammond, 1995). Therefore, *Leucaena* is generally offered as a component of the diet rather than as a sole feed. Also, the risk of its' toxicity is reduced by combining it with another browse. This strategy maintains the high protein quality of the feed and decreases mimosine intake. In a combination of *Leucaena* and *Gliricidia* in the ratio of 1:3, animals ate almost all the *Leucaena* whereas with a ratio of 1:1 animals were not selective (Reynolds and Adeoye, 1986).

Experimental results confirm the value of Leucaena as a supplement to roughages low in protein for increased animal production. Levels of supplement have ranged between 15 to 35% of the diet although levels of up to 60% have given good liveweight gains and higher diet efficiency with cattle, goats or sheep. Higher levels have shown limited benefits (Flores *et al.,* 1979; Jones, 1982; Chee and Devendra, 1982; Kaitho, 1997). Similarly, studies have shown that supplementary grazing of *Leucaena* substantially improves liveweight gains over that from pure grass pasture (Jones and Bray, 1982; Kaitho, 1997). The results of experiments in which *Leucaena* was fed to dairy cows show that *Leucaena* supplementation increases milk yield (Jones, 1982; Maasdorp *et al*., 1990). The benefits of feeding *Leucaena* arise from its high CP content (183-291g kg^{-1} DM), and when added to a roughage with low CP content, it improves DM intake and digestibility, thereby, resulting in higher productivity and feed efficiency.

2.3.0 Toxicity in browses and its alleviation

2.3.1 The toxic agents in plants

Toxic agents in plants act as anti-nutritional factors in grazing animals such that they interfere with the optimum nutrition of the animals. Anti-nutritional factors include amino acid derivatives such as mimosine in *Leucaena,* toxic terpenoids such as lantadenes in *Lantana camara,* hydrolyzable tannins, phenolics, steroids, and glycosides such as cyanogenic glycosides and saponins (Lowry, 1990; Kaitho, 1997).

Toxic agents in forages cause direct as well as indirect losses in livestock production. Indirect losses occur due to inadequate utilization of the forages. A wide range of accessible woody plants which, would be good feed particularly in herding systems are not utilized. The protein and fibre levels of such forage plants often show that they would otherwise make good quality feeds (Reed *et al.*, 1990; Topps, 1992; Dzowela *et al.,* 1995; Kaitho, 1997; Maasdorp *et al.,* 1999; Bareeba and Aluma, 2000).

The visible toxicity of a plant is one end of a continum of effects. There may be simple aversion where the animal shows reluctance to eat the plant but when induced to do so, the plant proves to be non-toxic and of high quality. On the other hand, the animal may not reject the plant completely, but voluntary intake will be low as well as digestibility and animal performance. Toxins could also induce deficiencies of minerals and therefore show positive response to mineral supplementation even when these minerals are not deficient in the plant.

Phenolics are the most widespread, abundant, and varied plant secondary compounds in tropical woody species. They occur at levels of 10-20% leaf dry weight in tropical shrubs and range from 13-50% in many species that are valued East African browse plants (Kaitho, 1997; Bareeba and Aluma, 2000). Phenolics have varied possible effects, but overall, they form the major constraint on the use of shrubs for browse through their effects on intake and digestibility. They can be those that precipitate protein (tannins) or those that do not. Tannins can be hydrolyzable or condensed tannins. Apart from hydrolyzable tannins, phenolics have low mammalian toxicity although some have antimicrobial activity and therefore could affect rumen fermentation rate, and some are enzyme inhibitors. Tannins can precipitate digestive enzymes, adversely affect intake and digestibility at high levels above 10% leaf dry weight, but are tolerated up to 5%. (Lowry, 1990; Dzowela *et al.*, 1995; Kaitho, 1997)

Phenolics that are metabolized are absorbed and finally, excreted as conjugates with glycine, glucuronic acid, or sulphate. Therefore they put pressure on nitrogen, energy and mineral metabolism. In nutritionally stressed animals, this would limit use of high-phenolic forages. Condensed tannins, which cannot be degraded and are not absorbed could have an advantageous role in protecting soluble protein from fermentation in the rumen and make it available in the lower gut (Reed *et al.*, 1990; Somda *et al.*, 1993; Reynolds and de Leeuv, 1993; Fernandez-Rivera *et al.,* 1993). This could be the case with *Calliandra,* which has a high level of condensed tannins (Dzowela *et al.*, 1995).

Calliandra is characterised by high levels of phenolic compounds, including tannins. Total phenolics could be as high as 18.18% and condensed tannins 11.07% when measured by the vanillin-HCl technique (Paterson, 1994). Bareeba and Aluma (2000) reported a tannin acid equivalent of 19.2 g/kg DM in *C.calothyrsus*. Tannins have been associated with low digestibilities of the browses containing high tannin levels. Thus, the presence of tannins limits the utilization of the browses by the animals.

Besides, although toxic compounds such as alkaloids and cyanogenic glycosides may not occur in *Calliandra*, a range of insecticidal, non-protein, sulfur containing amino acids and rare imino acids may occur in seeds and seedlings of a number of *Calliandra* species (Paterson, 1994). These compounds play a protective role against leaf and seed-eating insects, which is essential for the survival of the species. However, adverse effects of these compounds on higher animals have not been reported.

There are aversive, non-toxic agents in plants that cause livestock to have a low preference for the plants that are otherwise non toxic and have high feed quality, such as *G. sepium*. It is quite unpalatable yet its foliage is high in N and it is highly digestible. Aversion of livestock to it could be due to its "mousy" smell (Kaitho, 1997). Potentially toxic substances that have been isolated from various parts of *Gliricidia* include coumarin and o-coumaric acid from leaves, hydrocyanic acid, alkaloids and tannins (Smith and Van Houtert, 1978; Bennison and Paterson, 1993). Also *Gliricidia* may be a nitrate accumulator plant in much the same way that some other plants have been reported to be selenium accumulators. Toxicity in *Gliricidia* has been mainly reported in non-ruminants such as rodents, horses and poultry, thus, making it unsuitable for feeding non-ruminants (Smith and Van Houtert. 1978). In ruminants conclusive evidence of *Gliricidia* toxicity under normal feeding is lacking although it has a mousy smell that initially limits intake. The risks of feeding high levels of *Gliricidia* to ruminants for long periods however, need to be fully investigated.

According to Lowry *et al.* (1985) the toxic constituent in Leucaena is the non-protein amino acid, mimosine, present in high concentrations (3-12%) in actively growing leaves and its derivative compound, 3- dihydroxy–4 (IH) pyridone (DHP). Mimosine is a very strong depilatory agent that cannot be degraded after absorption although it is extensively broken down to DHP in the rumen particularly when the animals are gradually conditioned to high levels of *Leucaena.* Faecal concentrations of both compounds are usually low because both compounds are readily absorbed. They are also readily excreted and the urinary concentration of DHP sometimes exceeds 0.8%. Their analysis in urine indicates not only the extent but also the nature of the toxic load, i.e. acute cytotoxic, chronic or goitrogenic (Lowry *et al.* 1985).

The toxic effects of mimosine are therefore through its breakdown product, DHP, which reduces feed intake, weight gain and is goitrogenic. When pregnant ewes were fed *ad lib Leucaena* for 30 days or 90 days, they could not maintain weight and produced light-weight and goitrous lambs than did comparable ewes fed lucerne (Jones and Bray, 1982). Steers that alternately grazed grass and leucaena/grass pastures made better gains than those permanently on leucaena pastures. Steers fed diets with 10% or 20% young leucaena/grass pastures made better gains than those permanently on leucaena pastures. Steers fed diets with 10% or 20% young leucaena shoots showed none of the clinical signs associated with leucaena toxicity after prolonged feeding. Dietary levels of 40%, 80% and 100% leucaena depressed serum iodine levels and steers lost weight on the 80% and 100% leucaena (Jones and Bray, 1982). These observations indicated that *Leucaena* was better utilized mixed with other feeds, but not as a sole diet.

2.3.2 Alleviation methods

A number of methods can be used to alleviate toxicity of browses in animals. These include using supplements, “dilution” as mixtures of browse species, treatments, adapted rumen micro-organisms, and the recognition that the fore gut fermentation of the ruminant provides a powerful method for detoxifying forages (Lowry, 1990; Kaitho, 1997). Appropriate supplements can greatly improve animal performance on certain forages that otherwise have toxic agents. Tannin-rich leaves have been fed in combination with concentrate rations without any adverse effects (Kaitho, 1997). Supplements enable toxic agents to be excreted as conjugates with other nutrients such as glycine, glucuronic acid or sulphate. However, the processes deprive the body of these nutrients. Positive response to sulphur supplementation has been observed with *Acacia aneura,* which has high levels of phenolics (Lowry, 1990). Supplements may also prevent absorption of secondary compounds from the gut as in the case of calcium hydroxide which gave a positive effect when supplemented to goats fed a high tannin shrub, *Clidemia hirta* in Indonesia (Lowry, 1990). Ferric salts have been used to reduce the uptake of mimosine and DHP from *Leucaena.* They also have a positive effect on the use of high-tannin sorghum by poultry (Lowry, 1990).

Polyethylene glycol (PEG) is effective in counteracting the effect of condensed tannins by complexing with them (Reynolds and Adeoye, 1986; Kaitho, 1997). Therefore, proteins are excluded from complexing with the tannins, which would otherwise make the protein unavailable. However, the current price of PEG makes it uneconomical as a supplement.

“Dilution” as a means of reducing toxicity involves feeding the toxic plants in a mixture with other plants such that the effective level of each toxic compound is reduced (Lowry, 1990). This is because many compounds have an acceptable level below which no adverse effects are observed and can be fed safely at certain proportions of the diet. Leucaena can be fed safely provided intake is kept below 40% of the total diet (Lowry, 1990). Chickens fed a diet containing leaf meal mixture of cassava, *Gliricidia, Sesbania, Leucaena* and *Calliandra* performed better than when the same level of leaf meal from any of the individual species was used in the diet (Lowry, 1990). Similarly a combination of *Gliricidia* and *Leucaena* can be used to reduce the risk of *Leucaena* toxicity. At a ratio of 1:1, animals can eat *Gliricidia* and *Leucaena* unselectively (Reynolds and Adeoye, 1986).

Wilting, drying, heat treatment and maceration of plants prior to feeding also reduces toxicity. Drying is reported to decrease tannin content or even remove it all together such as in *Gliricidia* and *Tipuana tipu* (Kaitho, 1997). Maceration and wilting raptures the plant tissues and cells bringing into contact the toxic agents and the enzymes capable of degrading them. These measures have been shown to work with cassava leaves and *Leucaena*. Wilting of cassava leaves makes the cyanogenic glycoside come into contact with hydrolases, and free hydrogen cyanide is formed and lost by diffusion from the leaf (Lowry, 1990). In *Leucaena,* enzymic hydrolysis of mimosine to DHP eliminates the acute but not the chronic mimosine toxicity (Lowry, 1982).

Enzymic detoxification of *Leucaena* is possible although it may not be used extensively. It proceeds by hydrolysing mimosine to DHP, pyruvic acid and ammonia (Lowry, 1982). The enzyme is present in leaflets and lamina of the green pod but not in the petiole, rachis or rachillae. It is not present in the stems or mature seeds although all these tissues contain mimosine. Enzyme and substrate occur together in the same cells which can be shown by autolysis of mimosine under treatments that break cell membranes without grossly disrupting the tissue such as freezing and thawing. Autolysis is also brought about by maceration of the tissue, which brings enzyme and substrate in contact. Maceration at 40°C with an equal weight of buffer at pH 7-8 brings about hydrolysis of mimosine within 2 minutes (Lowry, 1982). By maceration of leaves and stems together, all the mimosine can virtually be converted to DHP. Thus any mechanical damage in harvesting and handling Leucaena will affect the mimosine and DHP levels. Even when fresh Leucaena is ingested, the conditons of maceration, temperature, addition of slightly alkaline saliva favour rapid autolysis of mimosine and as much as 30% mimosine conversion can occur before the ingesta reaches the rumen (Lowry, 1982).

However, drying and sudden heating to temperatures higher than 70°C and contact with acid inhibited autolysis (Lowry,1982). Therefore, sun drying under clear conditions as in commercial production of leaf meals leaves the mimosine intact. Whereas, if conditions are humid, temperature elevated, and drying delayed, autolysis can occur. Mimosine in a heap of fresh leucaena heating up by its own respiration will undergo rapid change.

Microbial detoxification of Leucaena can be achieved by using DHP degrading microbes that may occur in the rumen (Jones, 1981; Jones and Bray, 1982). Jones and Magarrity (1986) successfully transferred DHP-degrading bacteria from Hawaiian goat to Australian ruminants to overcome the toxicity of leucaena by culturing rumen fluid and infusing it in uninfected goats and steers. Also, animal to animal transfer occurs in small paddocks and the introduced bacteria persist in the animal for at least six months after removal from Leucaena feeding (Jones *et. al.,* 1985). Pratchett *et al.* (1991) controlled mimosine toxicity by dozing heifers with rumen fluid containing bacteria capable of degrading DHP. Within 4 weeks of dozing, excretion of DHP in the urine of treated heifers almost ceased, serum thyroxine levels returned to normal and clinical signs of toxicity were absent. Dosed heifers were 15 kg heavier than the controls after 12 weeks. By the 12th week after dosing, the bacteria had spread to the control group and those heifers then recovered from the toxicity and overall weight gains at 20 weeks after dosing were similar to the dosed group. Quirk *et al.* (1988) reported increased growth rate from dosing rumen bacteria capable of degrading DHP to cattle grazing on Leucaena pasture from 0.52 kg/her per day when not dosed, to 1.03 kg/head per day when dosed in the period 6-19 weeks after treatment. The introduced bacteria spread naturally to untreated cattle after 19 weeks post-dosing.

2.4.0 Ensiling as a technology for improving utilisation of browses

2.4.1 Ensiling technology

Ensiling is a means of storing green crops or forage as silage. Silage is a product of anaerobic fermentation and acidification in the stored crop material. Available carbohydrates in the stored crop are fermented and produce organic acids principally lactic acid, which ultimately prevent deterioration of the stored crop by undesirable micro-organisms (Mahana, 1997). The principal purpose of ensiling is storage with minimum loss of nutrients. Making consistent, high-quality silage requires sound management decisions and attention to details such as speed of harvest, moisture content, chop length, silage distribution and compaction. These factors greatly influence the fermentation process and stability of the silage in storage. Management decisions include forage maturity and moisture at harvest, harvesting and ensiling methods, type of storage structure, use of silage additives and feed bunk management.

According to Mahana (1997) good quality silages are low in ammonia-nitrogen (NH_3-N) and have higher levels of amino acids and peptides in the non protein nitrogen (NPN) fraction. Lower quality silages range between two extremes, high moisture silages with less than 35% DM and high DM silages with over 45% DM. High moisture silages ferment longer and develop increased levels of ammonia (NH_3), amines and butyric acid. In high DM silages, fermentation activity is reduced and replaced by a potential for moulds and heating leading to higher levels of acid detergent insoluble nitrogen (ADIN). Poorly fermented silages have high concetration of NPN, butyric acid or acetate. Mahana (1997) has given goals for stable silage; a pH range of 4.0–4.5, the upper range being for legume and wilted silages and the lower range for grass, corn, cereals and direct-cut silages; lactic acid levels of 6-8% DM for lower DM silages and 3-4% DM for higher DM silages; acetic acid levels of less than 2%; butyric acid level of less than 0.1% DM and propionic acid levels of 0-1% DM; NH_3-N (% of Total N) levels of less than 5% for corn and cereals and less than 10-15% for grass or legumes.

Ammonia nitrogen content has been used as a measure of proteolysis particularly in grass silages (Bareeba, 1979). High NH_3-N indicates extensive fermentation and protein breakdown by proteolytic enzymes contained within the crop. Also, high NH_3-N silages are associated with proteolytic activity by clostridial secondary fermentation (Mahana, 1997). A ratio of fibre-bound protein to CP of less than 12% would indicate fermentation that has proceeded normally, while a ratio of over 15% would indicate considerable heat damage to have occurred (Mahana, 1997).

2.4.2 Effect of ensiling on chemical composition

Preparation practices of the material for ensiling, such as chopping and wilting prior to ensiling, have an effect on the composition of the resulting silages. Chopping and wilting of the material bring active plant proteases and protein substrates together and proteolysis occurs (Givens and Rulquin, 2003). Protein N, particularly that in cell organelles, such as chloroplasts and mitochondria, is solubilized extensively and the process is enhanced by moist conditions. Wilting under good weather or dry conditions will therefore, largely prevent the activity of plant proteases (Tamminga *et al.,* 1991; Charmley and Veira, 1990). Charmley and Veira (1990) found that silages from heat-treated material prior to ensiling contained more protein N, less soluble protein N, less NPN and less NH_3-N than the control silage. Thus, the N fraction is affected more than other components during the period prior to ensiling by extensive proteolytic activity immediately after cutting.

However, Charmley and Veira (1990) observed close similarity in chemical composition of alfalfa at cutting and ensiling indicating that the major compositional changes associated with ensiling occur in the silo. Also, it is the N fraction that is affected most in the silo. Fibre constituents, for example, are not affected by normal fermentation with the exception of losses in hemicellulose. The neutral detergent fibre (NDF) and cellulose remain fairly constant among silages and fresh herbage although lignin and acid detergent fibre (ADF) may be elevated (Weiss *et al*., 1986). Cushnahan and Gordon (1995) found that conservation of herbage as silage increased modified ADF and reduced NDF concentrations. Cushnahan *et al*. (1995) found that extensive fermentation by inoculation with Ecosyl, Zeneca Bioproducts, led to the silages having higher ADF and lower hemicellulose concentrations than fresh grass. However, ensilage had no significant effect on the gross energy concentration of the silage.

The content and distribution of N as available and fibre bound N is not altered greatly by normal fermentation, however there is increased NPN and reduced amino acid N (Weiss *et al*., 1986; Charmley and Veira, 1990). Cushnahan and Gordon (1995) reported increased levels of NH_3-N and soluble N in grass after 41 or 51 days of ensiling.

Weiss *et al.* (1986) found that ensiling solubilizes cell wall protein or NDF amino acids (NDF – AA) preferentially over NPN components associated with NDF fraction. Normal ensiling had little effect on concentration of amino acids insoluble in acid detergent (ADF-AA) or ADIN. Heat damage (over 60°C) in the silo has more impact on N distribution than does normal ensiling as found out by Weiss *et al.* (1986). In heat damaged silages, N is isolated in the lignin fraction with the resulting increase in ADIN and lignin fraction. There is a substantial increase in ADFN in heat-damaged silages such that almost all the NDFN is also ADFN. Also, fermentation is limited in heat-damaged silages as indicated by low levels of volatile fatty acids (VFAs) and elevated pH.

2.4.3 Rumen degradation of ensiled feed material and microbial protein synthesis

Ruminants derive their energy supply from rumen fermentation and degradation of storage and structural carbohydrates. They obtain their protein supply from microbial and bypass protein. Studies have been carried out on degradation of feeds in the rumen using the nylon bag incubation technique among others (Orskov *et al.,* 1980). Degradation is measured as the loss in weight of DM of the feed sample in the bag incubated in the rumen. Degradation constants of DM, organic matter (OM), N or NDF are estimated by fitting the degradation data to the exponential equation; $p=a+b\ [1-e^{-c\ (t-tl)}]$ where a, b and c are degradation constants (Mc Donald , 1981). The constant p is the actual degradation after time "t"; a is the intercept of the degradation curve at time zero representing the component that is rapidly degraded or washable; b is the component that will slowly be degraded in time and c is the rate for the degradation of "b". Orskov and Shand (1997) agree that the nylon bag technique is a very robust and useful tool with which to study and describe degradation characteristics of protein and roughages.

However, Tamminga *et al.* (1991) observed that the rate of degradation may be influenced by contamination with microbial cells adhering to undegraded fibre and negatively influencing measurement of degradation. Also, lignin and tannins have the ability to form complexes with numerous types of molecules including carbohydrates, protein, polysaccharides, bacterial cell membranes and enzymes such that high concentrations of lignin and tannins in feed materials would influence negatively measurement of their degradation (Zahedifar, 1997; Fahey *et al.,* 1980; Navas–Camacho *et al.,* 1993; Moya-Rodriguez *e. al.*, 2002).

Therefore, the rate of degradation of feeds in the rumen depends on the intrinsic characteristics of the feed such as the proportion of readily fermentable carbohydrates, the extent of lignification of the cell wall and the proportion of degradable nitrogen required by the micro-organisms for their growth and multiplication (Preston and Leng, 1987). An important extrinsic factor therefore, is the supply of fermentable N. The simplest form of fermentable N preferred by the rumen micro-organisms being NH_3-N (Bareeba, 1979; Nagadi *et al.*, 2000). The level of NH_3-N that supports the largest population of micro-organisms, and therefore, maximum digestibility in the rumen varies among diets. The critical NH_3-N level must be higher for fibrous diets low in N or diets in which carbohydrates is largely soluble than for protein-rich feeds (Preston and Leng, 1987). Therefore, NH_3-N concentration needed for maximum microbial growth and fermentation process has been variously reported ranging from 20 to 200 mg/l of rumen liquor (Preston and Leng, 1987; Nagadi *et al.*, 2000).

For silage, protein degradation during the ensiling process results in increased levels of soluble and degraded intake protein and reduces the level of undegraded intake protein compared to unfermented feeds (Mahana, 1997). Ensiling therefore, influences the supply of fermentable N essential for microbial degradation of feeds in the rumen. Excessive solubilisation of plant protein in silages increases rumen microbial degradation and production of ammonia, which results in increased urinary N excretion and reduced N retention, which losses can be offset by increasing digestible energy (DE) content of the diet (Bareeba, 1979). Tamminga *et al.* (1991) compared silages and hays and found that ensiling increased washable N and rate of degradation of degradable N. The rate of degradation increased with increasing protein content but decreased with increasing DM. Also N escape from the rumen in hays was substantially higher than in silages mainly because a large proportion of N compounds in silage become soluble during the ensiling process. Verbic *et al.* (1999) reported lower protein degradability in hay than in silages. It was lower in wilted than in unwilted silages and it was also reduced by formic acid treatment prior to ensiling. Verbic *et al.* (1999) also reported considerably higher protein synthesis in hay and highly wilted silage. The protein value of hay was better than of silages and that of the wilted silages better than the unwilted. Kokkonen *et al.* (2000) reported higher effective degradabilities of DM and protein in direct-cut silage, but wilted silage had higher content of rapidly degradable protein. Also wilting of silages increased the passage rate of small particles from the rumen, which could affect silage digestibility negatively.

Cushnahan and Gordon (1995) reported a significant increase in the **a** fraction of DM of silages made in round bales while hay had a lower fraction than either fresh or ensiled forage. However, ensiling reduced the **b** fraction of DM and this effect increased with length of time the herbage was ensiled. Conserving the forage as hay led to an increase in the **b** fraction. However, **c** was lower for hay than for fresh or ensiled forage. Ensiling irrespective of length of time of ensiling led to an increase in the effective degradability of DM while the converse was observed for hay. Cushnahan *et al.* (1995) made similar observations on the effect of ensiling on effective degradability of DM, N and ADF. However, grass which had undergone extensive fermentation as a result of inoculation with Ecosyl, tended to have lower DM and N degradation rate than fresh grass or restricted fermented silage, which could have been a reflection of differences in fibre concentration between treatments. From these reports, it is apparent that rumen degradation of DM is higher for silage than for fresh herbage. Protein is more extensively degraded in the silages than in green fodder or hay.

Heat damage to the silage in the silo reduces digestibility. Digestion of fibre fractions and lignin tend to be reduced by heating. However, the most pronounced effect of feeding heat-damaged forage is reduced N digestibility including NPN whereas it is usually normal with silages that have fermented normally (Weiss *et al.* 1986). The concentrations of ADF and lignin are increased in ensiled feed material by heating. This is ascribed to formation of Maillard polymers according to Van Soest (1965). These compounds would differ in composition and structure and therefore in digestibility from native ADF and lignin (Weiss *et al.*, 1986).

Microbial protein is the major source of amino acids with grass silage and cereal grain based diets. However, diets containing a large proportion of silage have been thought to have a low efficiency of microbial protein synthesis in the rumen compared with grass or hay-based diets, which results in inadequate post-ruminal flows of protein and reduced milk yields (Bareeba, 1979; Kokkonen *et al.,* 2000b). Petit and Flipot (1992) observed that body weight gain in beef steers was improved more by N supplementation for silage than by that for hay which suggested that hay was a better protein feed than silage. Treatment of silage with urea exerts a protein sparing effect on natural protein or it promotes bacterial protein synthesis and a combination of elevated ammonia from added urea with organic acids form ammonium salts which have been found to improve utilization of the silages and N retention (Bareeba, 1979).

2.5.0 Utilisation of silages

2.5.1 Intake and digestibility

Literature with regard to effects of ensiling on intake is varied. Cushnahan and Mayne (1995) found no significant differences in DMI between fresh grass or grass silage with either extensive or restricted fermentation. However, when corrected for losses of volatile compounds, animals on silage with restricted fermentation consumed their feed at a higher rate of intake. Cushnahan and Gordon (1995) reported depressed dry matter intake, corrected for losses of volatile compounds, with period of ensiling up to 20 days after ensiling. Regression analysis showed that the reductions in intake with ensiling were mainly due to increase in ammonia N, soluble N, n-butyric acid concentration and modified acid detergent fibre. These are silage fermentation products, which are quite variable and could account for the varied literature with regard to silage intake. According to Mahanna (1997), silage is always in a dynamic state depending on the extent of anaerobic conditions, the remaining level of fermentable substrate, the level and types of fermentation acids present in the silage and silage "face" management during the unloading of silos. Various ensiling practices are employed to improve silage quality and subsequently silage intake, digestibility and utilization. There are also feeding practices aimed at improving intake, digestibility and utilization of the silage.

According to Curan (1998) plant density has an influence on the fibre content of corn silage and therefore influences animal intake, digestion and performance. Percent ADF and NDF increases with increasing plant densities (21,000 to 37,000 plants/acre) so that higher DMI and milk production are associated with lower plant densities, while lower apparent digestibilites and reduced average daily gain have been found with high silage plant populations (Curan, 1997). Chop length of between 75-150 mm is desirable for proper silage compaction, ease of unloading from the silo and adequate effective fibre to meet the rumen function demands (Mahanna, 1997). Wilting the silage material prior to ensiling increases silage DMI, but reduces digestibility and energy content (Kokkonen *et al.*, 2000a). Verbic *et al.* (1999) found that wilting and formic acid treatment prior to ensiling decreased protein degradability and although protein degradability of hay was lower than of silages, microbial protein synthesis for hay and highly wilted silage was considerably higher. The protein value for hay was better than for silages and that of the wilted silage better than the unwilted silage. These reports indicated the benefits of wilting silage materials prior to ensiling.

Ensiling itself and period of ensiling could also influence digestibility. Cushnahan and Gordon (1995) reported that while hay reduced apparent digestibility of DM, N and gross energy (GE), ensiling in round bales up to 21 days had little effect on digestibility of DM, OM or GE but showed gradual increase in N digestibility. Bunker silages ensiled for 56 days had higher digestibility of DM, OM, N and GE. Yahaya *et al.* (2001) reported decreased hemicellulose and increased cellulose digestibilities after 21 and 56 days lucerne silage than in the harvested lucern grass. The explanation was that araban, a component of hemicellulose is consistently digested. Therefore, the readily digested fraction of araban was degraded during ensiling, and the remaining hemicellulose was less digestible. Increased digestibility of cellulose could have been due to shortening of the cellulose chain length by the action of cellulases from silage microflora (Yahaya *et al.*, 2001).

2.5.2 Milk yield and composition

Intake and digestibility has a direct bearing on milk yield. Increased intake and digestibility usually results in increased milk yields. Kokkonen *et al.* (2000a) observed higher milk yield with direct-cut silages than with wilted silage due to reduced digestibility and energy content of the wilted silages. However, there was no difference in milk compostion between milk from animals fed wilted or direct-cut silages. There are also, reports of reduced milk producing potential of silage from fresh grass due to reduced digestible energy intake and efficiency of N utilization (Cushnahan *et al.,* 1995). Cushnahan *et al.* (1995) observed higher urinary N outputs expressed as a proportion of N intake with animals offered extensively fermented silage inoculated with Ecosyl than those offered fresh grass indicating low efficiency of N utilization with extensively fermented silage. However, Cushnahan and Mayne (1995) found no significant difference either in DMI, apparent digestibility or milk yield between animals offered fresh or ensiled grass. However, they found that milk protein fat and protein concentration were significantly higher with fresh grass and silage with restricted fermentaion than with silage with extensive fermentation. These observations on milk composition were possible because Cushnahan *et al.* (1995) reported less urinary N loss with animals offered fresh grass or silage with restricted fermentation. This indicated better utilization of N with fresh grass. Hence, the higher milk protein concentration associated with feeding fresh grass or silage with restricted fermentation. Also, Cushnahan *et al.* (1995) reported higher proportions of rumen propionate and lower proportions of acetate with animals offered extensively fermented silage. Therefore, the higher proportions of rumen acetate gave rise to the higher milk butter-fat of the animals offered fresh or restricted fermented silage. However, it is to be noted that silage fermentation patterns achieved are quite variable (Cushnahan and Gordon, 1995; Mahana, 1997) and therefore, reports on the effect of silage fermentation on milk yield and compostion are also quite varied.

Silage is often fed supplemented with a rumen-fermentable energy and/or N source to improve its utilization by animals. Murphy (1999) obtained a significant linear increase in DMI, milk yield, protein yield and concentration of protein and casein with increasing level of molasses inclusion in a grass-silage based diet for dairy cows. Huhtanen (1988) observed that molasses-containing diets had a higher OM digestibility, higher quantity of microbial N entering the small intestine and a trend towards a higher efficiency of microbial N synthesis in cattle given a silage diet. It is possible that these effects of molasses supplentaiton increases milk yield and milk protein yield and concentration as observed by Murphy (1999). It is possible, molasses supplementation acts as a source of energy for general body metabolism, thus, sparing the protein for milk protein synthesis. Sutton *et al.* (1994) supplemented grass silage with concentrate and found that efficiency of coverting food N to milk N was unaffected by extra CP in the concentrate but was increased by extra energy. Dewhurst *et al.* (1996) observed a strong relationship between metabolisable protein (MP) supply and milk protein yield with a significant effect of metabolisable energy (ME) supply on this relationship. At low ME/MP ratios, the efficiency of conversion of MP into milk protein was reduced.

Supplementation of silage with CP, degradable intake protein (DIP) or undegradable protein (UDP) has been found to influence intake, degradability, digestibility and subsequently milk production. Small and Gordon (1990) examined the influence of protein sources containing small and higher levels of rumen undegradable protein on lactation response of cows given grass silage and found that source of protein did not influence milk output or composition, but increasing total protein intake significantly increased milk yield. However, blood urea levels were significantly influenced by both protein source and level. Sutton *et al.* (1994) found that extra CP in a fixed ration of concentrates often increases silage intake and therefore appears to be a more attractive strategy for enhancing the contribution of grass silage to milk production. Sutton *et al.* (1996) concluded that the strategy of reducing the concentrate ration while maintaining concentrate CP intake causes only small reductions in milk solids production. However, this was dependent for success on supplies of high quality grass silage to substitute for the concentrates.

2.5.3 Weight gain in cattle

Petit and Flipot (1992) investigated feed utilization of beef steers fed grass as hay or silage with or without N supplementation and found that feed utilization was better with silage than with hay and was increased by N supplementation. Petit and Flipot (1992) found that while N supplementation increased body weight gain of steers fed silage, it had no effect on body weght gain of steers fed hay diets suggesting that hay was a better protein feed than silage. Newbold and Rust (1990) determined growth in holstein cattle given high-moisture maize grain in which CP concentration in diets was increased using rumen degradable protein (RDP) or rumen undegradable protein (UDP) and found that live weight gain and feed conversion efficiency were not affected by form of protein. Similar observations were made by Devant *et al.* (2000) with rapidly growing heifers. These reports suggest that animals can utilize silage adequately for weight gain and N supplementation either in the RDP or UDP form improves feed efficiency.

CHAPTER III

3.1.0 EXPERIMENT 1: Fermentation characteristics, nutrient composition and rumen degradability of ensiled *Calliandra calothyrsus*, *Gliricidia sepium*, *Leucaena leucocephala* and maize forage

3.1.1.0 Introduction

Inadequate energy and N intake are the major nutritional limiting factors to livestock production in the tropics particularly in the dry seasons when green feed is extremely limited (Preston and Leng, 1987; Mugerwa, 2001; Sabiiti, 2001). Inclusion of leguminous browses such as *Calliandra, Gliricidia* and *Leucaena* in the farming systems in these regions is a technology that would add N in the crop/livestock systems (Mpairwe, 2003; Sabiiti, 2001). The browses would not only fix N in the soil for use by the crops but, would also be used as a high protein supplement for animals. (Topps, 1992; Mpairwe, 2003; Sabiiti, 2001). However, the browses have anti-nutritional factors that hinder livestock from deriving maximum nutritional benefit from the browses.

Ensiling is a means of storing green fodder by acidification in the stored material. However, it also has profound effects on the chemical and nutrient composition of the stored feed material (Bareeba, 1979; Weiss *et. al.* 1986; Charmley and Veira, 1990; Mahanna, 1998). Ensiling could therefore, ameliorate the effects of anti-nutritional factors associated with browses. The objective of the study was to determine the fermentation pattern and the effect of fermentation on the chemical composition and degradation of ensiled *Calliandra, Gliricidia*, *Leucaena* and maize forage.

3.1.2.0 Materials and methods

3.1.2.1 Ensiling

The experiment was carried out at Makerere University Agricultural Research Institute, Kabanyolo (MUARIK). *Calliandra, Gliricidia* and *Leucaena* foliage (leaf and petiole) and maize at milk stage were used. The DM of the materials at ensiling was determined by drying in triplicate 500 g samples to constant weight at 60°C in a forced air oven. The DM determined was 38.7, 24.4, 24.2 and 25.0% for *Calliandra, Gliricidia, Leucaena* and maize respectively. The dried samples were composited for each browse and the maize. They were then reserved for chemical analysis and degradation experiment.

The browse materials and maize materials for ensiling were chopped (<5cm) to facilitate packing. Each browse and maize material were tightly packed separately to ensile in triplicate in 2 kg lots in polythene bags, and kept in the laboratory. They were allowed to ferment for 30 days. The experiment was set up in a Completely Randomized experimental design.

3.1.2.2 Data collection and chemical analyses

The fermented silos (bags) were weighed to obtain fermented weights of the materials and subsequently the DM losses during fermentation. The DM of the silages was determined by drying to constant weight at 60°C in a forced-air oven. Water extracts of the silage for determination of the volatile fatty acids, pH and ammonia N (NH_3-N) were prepared by shaking on a mechanical shaker 100g of the silages in 800ml of water in a 1000ml flask for two hours. After shaking, water was added to the mark. The extracts were filtered through two layers of cheesecloth. The pH of the water extracts was determined using a pH meter. Lactic, butyric and acetic acids were determined by fractional distillation and titration using standard procedures of the Department of Animal Science, Makerere University. Ammonia nitrogen (NH_3-N) was determined by distillation into boric acid and titration.

Dried samples of the silages and the reserved dried unfermented samples were ground through a 2 mm sieve and thereafter were lanalysed and used for the degradation experiment. The samples were analysed for organic matter (OM) crude protein (CP), calcium (Ca) and phosphorus (P) according to AOAC (1990) procedures and carbon (C) according to Walkley and Black (1934) procedure. Non-protein nitrogen (NPN) was determined by the trichloro acetic acid method according to Gaines (1977). Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to procedures of Van Soest and Robertson (1985). Neutral detergent fibre nitrogen (ADFN) and acid detergent fibre nitrogen (ADFN) were obtained by determining N in the NDF and ADF residues respectively according to procedures by Lacitra et tal. (1996).

3.1.2. 3 Degradation of fermented and unfermented browses and maize forage

The study was carried out at Namulonge Agricultural and Animal Research Institute (NAARI). Degradation characteristics of ground fermented and unfermented browses

Calliandra, Gliricidia, Leucaena and maize forage from the fermentation experiment were studied using two fistulated *Bos indicus* steers. The steers were fed on fresh chopped elephant grass (25%DM) offered twice daily at 8 and 14 hrs. feeding. Water was offered *ad lib*. Degradation of DM, OM and N was determined using the nylon bag method. The bags (pore size 37.5μm and measuring 6 x 12cm) containing the material (2-2.5g) were incubated in the rumen of the steers for 0, 3, 6, 12, 18, 24, 36, 48, 60 and 72 hours. The steers were given a rest period of 3 days between incubations. On removal of the bags at the end of each incubation time, the bags washed under tap water until they clean of all sticking rumen material and the water having become clear. They then be rinsed with distilled water. The zero hour bags were similarly washed. After washing, the bags were dried at 60°C for 72 hours in a forced-air oven. On removal from the oven, they were cooled in a desiccator and weighed. After weighing, the residues were pooled by incubation time and analysed for DM, OM and N (AOAC, 1990). Degradation constants for DM, OM and N were estimated by fitting the exponential equation of McDonald (1981) model with lag time to the data using the non-linear procedure in Statistical Analysis Systems (SAS, 1999). The model being;

$Y = a + b\,[1 - e^{-c\,(t-tl)}]$ where

Y = the potential degradability of either DM, OM or N at time t,

a = the zero time intercept (i.e. the rapidly soluble fraction).

b = the slowly degradable fraction (the amount that will be degraded in time).

c = the rate of degradation at fraction b that will be degraded per hour.

tl = lag time in hours

pd = potential degradability (a+ b)

The constants obtained were used to determine the lag time (tl) and the effective degradability (ED) according to the equation of Orskov and McDonald (1979) as follows;

$$tl = (-1/c) \times \ln\{[(a+b) - w]/b\}$$

$$ED = w + \{(a+b - w) \times [c/(c+0.03)]\}$$

Where: w = the washing value (solubility) at 0 hour as the disappearance estimated by washing in tap water and oven drying in a similar manner and the factor of 0.03 as the outflow rate.

3.1.2. 4 Estimation of rumen microbial protein yield

Estimation was done according to the procedure described by Muia *et. al.* (2001). It was assumed that 150g of rumen microbial protein (RMP) are synthesized per kg of fermentable organic matter (FOM). Total yield (g/kg DM) of RMP was estimated as:

TRMP = (FOM/1000) x 150, where TRMP is total rumen microbial protein,

FOM = (ED x OM/1000) x OM, where ED is effective degradability and OM is organic matter composition of the sample.

3.1.2. 5 Statistical analysis

The data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (1999). Where significant differences were obtained, means were separated using standard error (SE) at probability level of 5%.

3.1.3.0 Results

3.1.3.1 Fermentation characteristics of the browse and maize forage silages

The fermentation characteristics of the browse and maize silages are given in Table 1. *Calliandra* silage had the highest ($P \leq 0.05$) DM content while *Gliricidia* had the lowest. Lactic acid content was higher ($P \leq 0.05$) and the pH lower ($P \leq 0.05$) in maize compared to browse silages. Of the browses, *Gliricidia* silage had higher ($P \leq 0.05$) lactic acid content than either *Leucaena* or *Calliandra* silages. All the browse silages had similar but higher ($P \leq 0.05$) pH levels than maize silage. Levels of NH_3-N were higher ($P \leq 0.05$) in maize silage compared to the browse silages. Levels of NH_3-N were lowest ($P \leq 0.05$) in *Calliandra* silage..Dry matter losses were similar in all the silages except *Leucaena* which had the loest.

Table 1: Fermentation characteristics of the browse and maize forage silages

	Maize	Calliandra.	Gliricidia.	Leuceana.	SE
DM (%)	25.91^{b}	35.55^{a}	23.46^{c}	24.38^{b}	0.73
Acetic acid (% DM)	2.69^{a}	0.52^{c}	0.85^{bc}	1.73^{ab}	0.30
Butyric acid (% DM)	0.09	0.09	0.04	0.10	0.04
Lactic acid (% DM)	4.98^{a}	0.94^{d}	2.81^{b}	1.86^{c}	0.21
pH	3.86^{b}	5.38^{a}	5.08^{a}	5.30^{a}	0.24
NH_3-N (% Total N)	10.28^{a}	1.27^{c}	5.57^{b}	7.33^{b}	0.03
DM Losses (%)	9.27^{a}	8.29^{a}	9.65^{a}	6.06^{b}	2.58

^{abc}Values having different superscripts in a row are significantly ($P \leq 0.05$) different.

3.1.3.2 Chemical composition of the fermented and unfermented browses and maize forage

The chemical composition of the fermented and unfermented browses and maize forage are given in Table 2. *Calliandra* had the highest ($P \leq 0.05$) OM and fermentation had no effect on OM composition of the silages except in *Leucaena* where OM content was lower in its' fermented form. Fermented *Leucaena* had higher ($P \leq 0.05$) CP content, while fermented maize had the lowest ($P \leq 0.05$) CP content. The content of CP was higher ($P \leq 0.05$) in fermented than in unfermented *Gliricidia*. The C:N ratio was narrower in fermented than in unfermented *Gliricidia.* Maize silage had the highest ($P \leq 0.05$) NPN content, while *Calliandra* had the lowest ($P \leq 0.05$) level of NPN.

Table 2: Chemical composition (%DM) of fermented and unfermented browses and maize forage

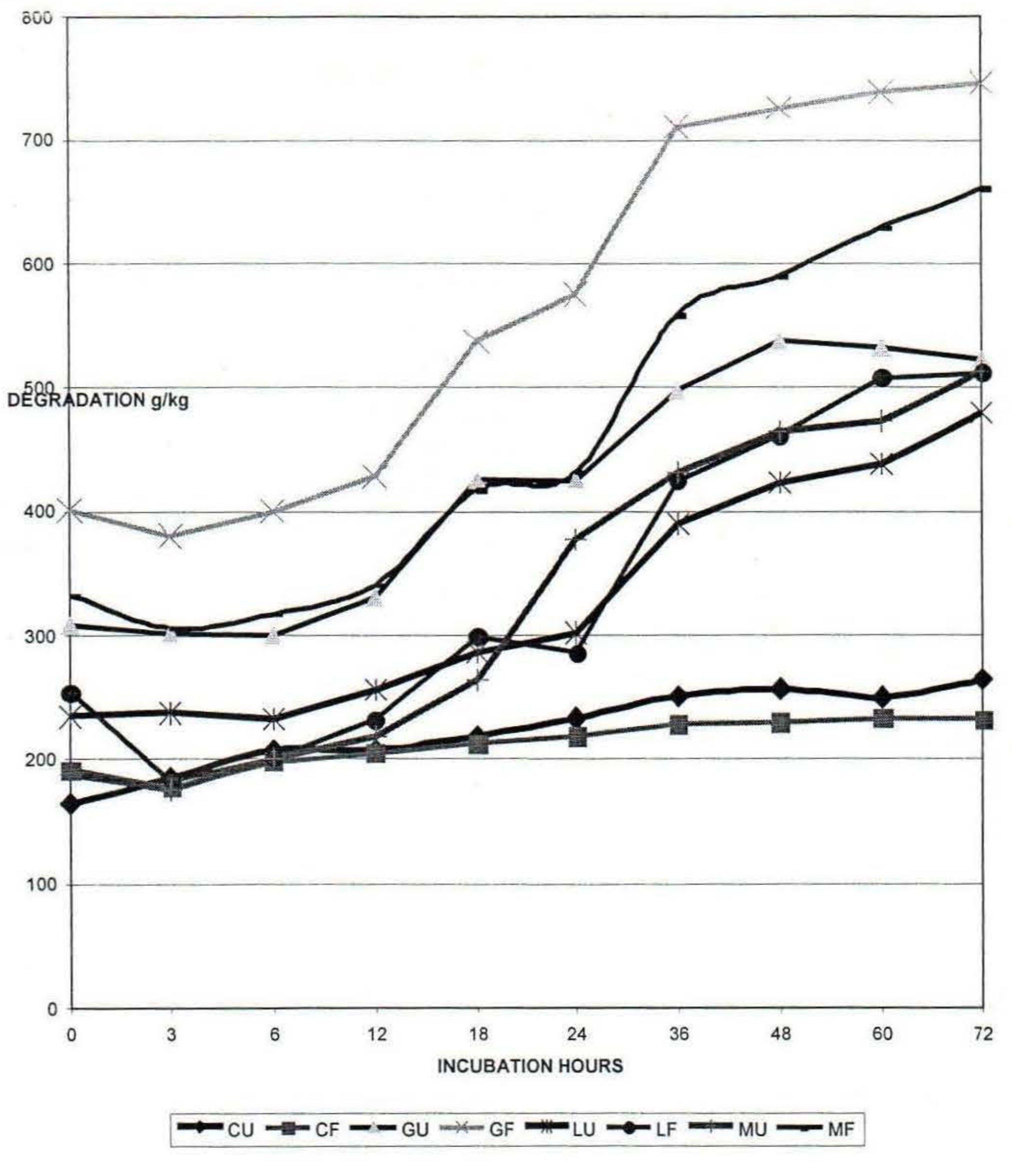
	Maize		Calliandra		Gliricidia		Leucaena		SE
	U	F	U	F	U	F	U	F	
Organic Matter	93.68^{b}	93.58^{b}	94.54^{a}	94.73^{a}	91.68^{c}	91.67^{c}	94.03^{b}	93.16^{d}	0.21
Crude Protein	7.56^{c}	7.03^{e}	18.18^{d}	19.18^{d}	20.68^{c}	23.38^{b}	25.89^{a}	25.29^{a}	0.31
NPN(%Total N)	27.25^{c}	37.96^{a}	10.36^{e}	11.15^{e}	12.18^{e}	31.97^{b}	15.87^{d}	15.24^{d}	2.51
C:N Ratio	37.54^{a}	35.09^{a}	14.65^{b}	14.62^{b}	13.93^{b}	11.76^{c}	10.14^{c}	10.41^{c}	2.45
Calcium	0.15^{e}	0.20^{e}	0.94^{c}	0.91^{c}	1.31^{a}	1.16^{d}	0.60^{d}	0.61^{d}	0.02
Phosphorus	0.24	0.23	0.14	0.14	0.20	0.22	0.24	0.23	0.01
NDF	71.44^{b}	70.51^{b}	70.63^{b}	77.00^{a}	58.13^{d}	55.70^{d}	62.40^{c}	75.55^{a}	0.94
ADF	37.56^{cd}	32.95^{e}	58.67^{b}	66.08^{a}	38.22^{cd}	32.74^{d}	41.63^{c}	45.01^{c}	1.99
NDFN(% Total N)	64.95^{d}	42.47^{e}	90.27^{a}	78.16^{bc}	86.92^{ab}	59.74^{d}	80.97^{b}	79.92^{b}	2.63
ADFN(% Total N)	37.75^{c}	14.24^{d}	60.15^{a}	68.08^{a}	40.22^{c}	13.47^{d}	44.29^{c}	42.59^{c}	1.45
ADL	9.06^{g}	4.40^{h}	29.74^{b}	34.46^{a}	19.18^{c}	12.15^{f}	23.83^{d}	27.06^{c}	0.75

^{abcdefgh} Values having different superscripts in a row are significantly different ($P \leq 0.05$), U = Unfermented, F = Fermented

Fermentation raised ($P\leq0.05$) NPN content of maize and *Gliricidia* silages and had no effect on NPN content of *Calliandra* and *Leucaena* silages. Fermentation raised ($P\leq0.05$) NDF, ADF, ADFN and ADL content in *Calliandra* and that of NDF and ADL in *Leucaena.* It lowered ($P\leq0.05$) ADF and ADL content in maize and *Gliricidia* and NDFN content in *Calliandra, Gliricidia* and maize. It increased ($P\leq0.05$) ADFN content in *Calliandra,* but lowered it in *Gliricidia* and maize and did not affect both NDFN and ADFN content in *Leucaena.*

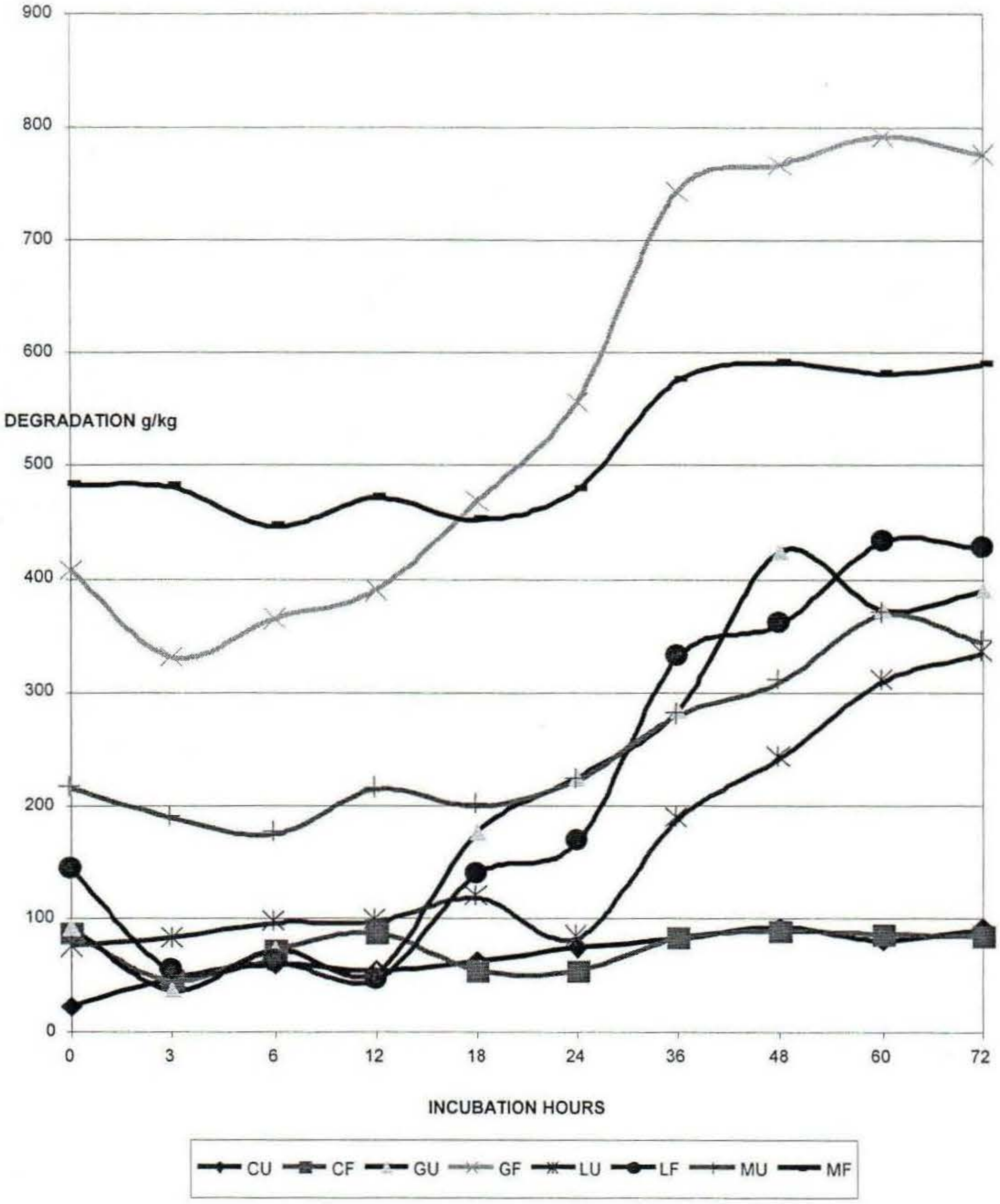
3.1.3.3 Degradation of fermented and unfermented browses and maize forage

Degradation curves for the browses and maize forage in their fermented and unfermented forms for DM, OM and N are given in Figs. 1, 2 and 3 respectively. The washable fraction of DM, at time 0 hours of incubation was bigger than the degradation fractions in the rumen up to 6 hours of incubation (Fig. 1). This was the same with all the browses and maize in their fermented or unfermented forms. Degradation rose after 6 hours of incubation. Degradation at 72 hours appeared not to be the peak degradation in all cases. Degradation was highest for *Gliricidia,* followed by maize, while *Leucaena* and *Calliandra* were the least degraded. Degradation of the fermented forage was greater than of the unfermented forages except in the case of *Calliandra* where the unfermented form appears to have degraded to a greater extent than the fermented form. Degradation of OM of all the browses and maize in their fermented and unfermented forms (Fig. 2) followed the same trend as for DM (Fig. 1). Similarly degradation of N in all the browses and maize forage (Fig. 3) in their fermented and unfermented forms followed the same trend as for DM and OM.



CU – Unfermented *Calliandra,* CF – Fermented *Calliandra*, GU – Unfermented *Gliricidia,* GF Fermented *Gliricidia,* LU – Unfermented *Leuceana*, LF – Fermented *Leuceana*, MU – Unfermented Maize, MF – Fermented Maize.

FIG.1 DRY MATTER DEGRADATION OF FERMENTED AND UNFERMENTED BROWSES



CU – Unfermented *Calliandra,* CF – Fermented *Calliandra*, GU – Unfermented *Gliricidia,* GF - Fermented *Gliricidia,* LU – Unfermented *Leuceana*, LF – Fermented *Leuceana*, MU – Unfermented Maize, MF – Fermented Maize.

FIG. 3 NITROGEN DEGRADATION OF FERMENTED AND UNFERMENTED BROWSES

3.1.3.4 Degradation constants for fermented and unfermented browses and maize forage

Results for degradation constants for DM, OM and N of the forages are given in Table 3, 4, 5 respectively. The results (Table 3) for treatment effect show that **w, a, b, pd, ED** and **c** for DM were higher ($P \leq 0.05$) for the fermented forms of the browses and maize forage except **tl** which was higher ($P \leq 0.05$) for the unfermented forms. However **a, b, pd, tl** and **ED** were relatively higher and **c** relatively lower for unfermented *Calliandra* and *Leucaena.*However **ED** was relatively lower for unfermented *Leucaena.* The value of **a** was higher for the fermented forms in all the browses and maize forage.

The results (Table 3) for forage effect show that *Calliandra* had the lowest ($P \leq 0.05$) values for all the degradation constants, except **c** indicating poor degradation of *Calliandra*. *Leucaena* had the highest ($P \leq 0.05$) **b** and **tl** values and the lowest ($P \leq 0.05$) values for **c**. Degradation of DM was relatively greater for the unfermented *Calliandra* and *Leucaena* than for their fermented forms. Forage effect showed that maize forage had the highest ($P \leq 0.05$) **pd** followed by *Leucaena, Gliricidia* and lastly *Calliandra.* However, *Gliricidia* DM degradation had the highest ($P \leq 0.05$) **ed** followed by maize, *Leucaena* and lastly *Calliandra.*

3.1.3.4 Degradation constants for fermented and unfermented browses and maize forage

Results for degradation constants for DM, OM and N of the forages are given in Table 3, 4, 5 respectively. The results (Table 3) for treatment effect show that **w, a, b, pd, ED** and **c** for DM were higher (P≤0.05) for the fermented forms of the browses and maize forage except **tl** which was higher (P≤0.05) for the unfermented forms. However **a, b, pd, tl** and **ED** were relatively higher and **c** relatively lower for unfermented *Calliandra* and *Leucaena.*However **ED** was relatively lower for unfermented *Leucaena.* The value of **a** was higher for the fermented forms in all the browses and maize forage.

The results (Table 3) for forage effect show that *Calliandra* had the lowest (P≤0.05) values for all the degradation constants, except **c** indicating poor degradation of *Calliandra*. *Leucaena* had the highest (P≤0.05) **b** and **tl** values and the lowest (P≤0.05) values for **c**. Degradation of DM was relatively greater for the unfermented *Calliandra* and *Leucaena* than for their fermented forms. Forage effect showed that maize forage had the highest (P≤0.05) **pd** followed by *Leucaena, Gliricidia* and lastly *Calliandra.* However, *Gliricidia* DM degradation had the highest (P≤0.05) **ed** followed by maize, *Leucaena* and lastly *Calliandra.*

Table 3: Degradation constants (g/kg DM) for DM of fermented (F) and Unfermented (U) *Calliandra* (Call.), *Gliricidia* (Glir.), *Leucaena* (Leuc.) and maize

	Calliandra		Gliricidia		Leucaena		Maize		Treatment effect		Forage effect			
Parameter	U	F	U	F	U	F	U	F	U	F	Call.	Glir.	Leuc.	Maize
w	164.11	191.75	308.28	380.17	234.39	253.96	188.29	332.18	223.77	289.52	177.9^{d}	344.2^{a}	244.2^{c}	260.2^{b}
a	187.46	175.86	282.96	333.37	220.94	213.76	202.37	276.61	223.4^{b}	249.90^{a}	181.7^{d}	308.2^{a}	217.3^{c}	239.5^{b}
b	74.86	56.50	278.49	487.87	526.69	467.70	355.20	635.19	308.80^{b}	411.80^{a}	65.7^{d}	383.2^{c}	497.2^{a}	495.2^{b}
PD	262.32	232.36	561.44	821.24	747.63	681.45	557.57	911.80	532.2^{b}	661.70^{a}	247.3^{d}	691.3^{c}	714.5^{b}	734.7^{a}
tl	2.42	1.32	3.34	1.69	3.00	8.00	6.00	2.00	3.69^{a}	3.25^{b}	1.87^{d}	2.51^{c}	5.50^{a}	4.00^{b}
c	0.042	0.068	0.040	0.018	0.010	0.018	0.030	0.013	0.030^{b}	0.033^{a}	0.055^{a}	0.036^{b}	0.014^{d}	0.022^{c}
ED	222.3	215.2	456.2	613.7	354.1	402.6	376.1	517.6	352.2^{b}	437.3^{a}	218.7^{d}	534.9^{a}	378.3^{c}	446.8^{b}

[ab] Treatment effect: F, U; Values with different superscripts in a row are significantly different (Critical t value = 1.968 at $P \leq 0.05$).

[abcd] Browse effect : Call., Glir., Leuc., Maize;., Values with different superscripts in a row are significantly (Critical t value = 1.968 at $P \leq 0.05$)
w - washable fraction, a - rapidly soluble fraction, b - slowly degradable fraction, PD - potential degradability (a+b), tl - lag time in hours, c - rate of degradation at fraction b (per hour), ED - effective degradability.

Treatment effect values for **w**, **a**, **b**, **PD** and **ED** for OM were higher ($P \leq 0.05$) for the fermented forms of the browses and maize forage (Table 4). The unfermented forms of the browses and maize forage had higher ($P \leq 0.05$) values for **tl** and **c**. The **c** value was relatively higher for the unfermented forms of *Gliricidia* and maize than their fermented forms. Unfermented *Calliandra* had higher ($P \leq 0.05$) **b**, **PD** and **tl** values than the fermented form. Results for the forage effect show that *Calliandra* was least degraded as it had the lowest ($P \leq 0.05$) degradation constants although it had the highest ($P \leq 0.05$) **c** value (Table 4). *Gliricidia* had the highest ($P \leq 0.05$) **ED** followed by maize, *Leucaena* and lastly, *Calliandra.* The results for treatment effect for **w** and **a** for N were higher ($P \leq 0.05$) for the fermented forms of the browses and maize forage (Table 5). The values of **b**, **PD**, and **tl**, were higher ($P \leq 0.05$) for the unfermented forms. The fermented form of the browses and maize forage had a higher ($P \leq 0.05$) **ED** value. The forage effect results in Table5 show that N in *Calliandra* was least degraded as it had the lowest ($P \leq 0.05$) degradation constants except for **c**, which were highest ($P \leq 0.05$). *Gliricidia* had the highest ($P \leq 0.05$) **ED** followed by maize, *Leucaena* and lastly, *Calliandra.*

3.1.3.5 Rumen microbial protein yield with fermented and unfermented browses and maize forage

Estimated total rumen microbial protein yield (TRMP) was relatively higher for the fermented forms of the browses and maize forage except for *Calliandra* (Table 4). Forage effect results show that TRMP was highest for *Gliricidia* and lowest for *Calliandra.*

Table 4: Degradation constants (g/kg OM) for OM and microbial protein yield (MP) of fermented (F) and unfermented (U), *Calliandra* (Call.), *Gliricidia* (Glir.), *Leucaena* (Leuc.) and maize forage

	Calliandra		Gliricidia		Leucaena		Maize		Treatment effect		Forage effect			
	U	F	U	F	U	F	U	F	U	F	Call.	Glir.	Leuc.	Maize
w	133.52	181.10	274.48	372.04	201.41	221.97	167.49	314.13	194.2^{b}	272.3^{a}	157.3^{d}	323.3^{a}	211.7^{c}	240.8^{b}
a	168.86	169.00	257.58	298.08	193.91	176.95	159.67	267.44	195.0^{b}	227.9^{a}	168.9^{d}	277.8^{a}	185.4^{c}	213.6^{b}
b	81.10	64.76	296.55	512.16	379.28	510.81	406.97	576.48	291.0^{b}	416.1^{a}	72.9^{d}	404.4^{c}	445.0^{b}	491.7^{a}
PD	249.96	233.75	554.14	810.25	573.18	687.76	566.65	843.92	486.0^{b}	643^{a}	241.9^{d}	682.2^{b}	630.5^{c}	705.3^{a}
tl	3.16	2.58	4.60	1.54	4.00	8.00	5.00	3.00	4.19^{a}	3.78^{b}	2.87^{d}	3.07^{c}	6.00^{a}	4.00^{b}
c	0.049	0.048	0.037	0.032	0.017	0.016	0.031	0.017	0.033^{a}	0.028^{b}	0.048^{a}	0.034^{c}	0.017^{d}	0.024^{c}
ED	206.49	207.60	432.60	594.95	331.82	373.98	371.06	507.69	335.5^{b}	421.1^{a}	207.0^{d}	513.8^{a}	352.9^{c}	439.4^{b}
MP	29.28	29.50	59.49	81.81	46.80	52.26	52.14	71.27	47.04	58.91	29.39	70.65	49.55	61.71

^{ab} Treatment effect: F, U; Values with different superscripts in a row are significantly different (Critical t value = 1.968 at $P \leq 0.05$).

^{abcd} Browse effect: Call., Glir., Leuc., Maize; Values with different superscripts in a row are significantly different (Critical t value = 1.968 at $P < 0.05$).

w – washable fraction a – rapidly soluble fraction, b – slowly degradable fraction, PD – potential degradability (a+b), tl – lag time in hours, c – rate of degradation at fraction b (per hour), ED – effective degradability. MP – microbial protein

Table 5: Degradation constants (g/kgN) for N of fermented (F) and unfermented (U) *Calliandra*, *Gliricidia*, *Leucaena* and maize

	Calliandra		Gliricidia		Leucaena		Maize		Treatment effect		Forage effect			
	U	F	U	F	U	F	U	F	U	F	Call	Glir	Leuc.	Maize
w	23.36	87.40	86.76	407.65	76.1	143.10	215.12	482.27	100.34^{b}	280.11^{a}	55.38^{d}	247.2^{b}	109.6^{c}	348.7^{a}
a	58.68	63.66	96.57	279.33	95.21	85.13	181.80	397.86	108.10^{b}	206,50^{a}	61.20^{d}	187.9^{b}	90.20^{c}	289.8^{a}
b	35.31	39.09	389.93	617.19	5100.11	653.70	303.35	381.53	1457.0^{a}	423.00^{b}	37.00^{d}	504.0^{b}	2877^{a}	342.0^{c}
PD	93.99	102.75	486.50	896.52	5195.32	738.83	485.15	779.39	1565.0^{a}	625.00^{b}	98.00^{d}	692.0^{b}	2967.^{a}	632.0^{c}
tl	10.00	10.00	10.00	1.00	10.00	10.00	4.00	1.00	8.50^{a}	5.50^{b}	10.00^{a}	5.50^{b}	10.00^{a}	2.50^{c}
c	0.034	0.016	0.028	0.029	0.001	0.014	0.010	0.013	0.018^{a}	0.018^{a}	0.025^{b}	0.028^{a}	0.007^{d}	0.01^{c}
ED	61.97	84.28	284.73	640.79	174.69	324.62	283.77	565.10	201.29^{b}	403.70^{a}	73.13^{d}	462.8^{a}	249.7^{c}	424.4^{b}

^{ab} Trearment effect: F.U; Values with different superscripts in a row are significantly different (Critical t value = 1.968 at $P \leq 0.05$). ^{abcd} Browse effect: Call., Glir., Leuc., Maize: Values with different superscripts in a row are significantly different (Critical t value = 1.968 at $P \leq 0.05$).

w – washable fraction a – rapidly soluble fraction, b – slowly degradable fraction, PD – potential degradability (a+b), tl – lag time in hours, c – rate of degradation at fraction b (per hour), ED – effective degradability.

3.1.4.0 Discussion

3.1.4.1 Fermentation characteristics of the browse and maize forage silages

Maize forage fermented better than the browses. A high content of lactic acid and a low pH are indications of the desirable lactic acid fermentation in silages (Mahanna, 1998; Vetter and Kendall, 1978). A lactic acid level of 3 to 13% DM and pH level of 4.2 or less is desirable for good silage (Bareeba, 1977; Mahanna, 1998). The fermentation results for maize forage in this study compare very well with these levels. The higher pH values in the browse silages can be attributed to the low levels of lactic acid and high protein levels. The level of lactic acid was lower ($P \leq 0.05$) in the browse silages, which indicated poor fermentation. A higher ($P \leq 0.05$) level of NH_3-N in maize silage than in the browse silages indicated more protein degradation in maize silage. Crude protein in the browses, especially in *Calliandra* was not readily fermented or broken down. The low level of lactic acid and high pH in *Calliandra* silage indicated that *Calliandra* silage did not ferment well. Visual observation indicated that *Calliandra* silage had greater mould damage than either *Gliricidia* or *Leucaena* silages. The poor fermentation of *Calliandra* can be attributed to its high content of tannins and lignin. Tannins and lignin in fodder are capable of adsorbing or binding microbial enzymes, nitrogen and carbohydrates (Zahedifar, 1977; Fahey *et al.,* 1980; Hill *et al.*, 1987; Navas-Camancho *et al.*, 1993; Moya-Rodriguez *et al.,* 2002).

However, all the silages had similar low levels of butyric acid indicating minimum undesirable butyric acid fermentation, which occurs in spoiled silages. A butyric acid concentration of more than 0.2% DM would be undesirable (Vetter and Kendall, 1978; Edwards and McDonald, 1978; Mahanna, 1998). Of the browse silages, *Gliricidia* fermented best as it had higher (P>0.05) than either *Calliandra* or *Leucaena* silages. However, all the browse silages could not keep well for long on account of their low lactic acid.

3.1.4.2 Chemical composition of the fermented and unfermented browses and maize

The CP content was higher (P>0.05) in fermented *Gliricidia compared* to the unfermented form. This was possible as the C : N ratio narrowed from 13.93 to 11.76 in unfermented and fermented *Gliricidia* respectively indicating changes in the DM of the fermented materials. Mahana (1997) also recorded increased CP content from 17.9% in fresh grass-legume to 19.6% in grass-legume silage. The values obtained for CP content in the browses are comparable with those reported elsewhere for leaves and edible stem (Topps, 1992; Flores *et al.,* 1979; Jones *et al.,* 1992; Kaitho, 1997). The increase in NPN in the fermented materials can be accounted for from the fermentation pattern of the silages (Table 5). Increase in NPN due to fermentation in silage occurs particularly in low DM silages (Mahana, 1997; Weiss *et al.,* 1986; Charmley and Veira, 1990). Increase in NPN however, as a source of readily available N, could augument ruminal degradation of fibre by the rumen bacteria and increase the amount of energy derivable from the diet by ruminants (Preston and Leng, 1987). High levels of NPN in silages is an indication of extensive proteolysis (Bareeba, 1979; Weiss *et al.,* 1986; Cushnahan and Gordon,1995). Fermentation increased (P≤0.05) NDF levels in *Calliandra* and *Leucaena* silages but it did not affect the NDF levels for maize and *Gliricidia* silages. The levels of ADF were reduced ($P>0.05$) by fermentation in maize and were not affected in *Leucaena.* Weiss *et al.* (1986), observed that fibre constituents are not affected by normal fermentation with the exception of losses in hemicellulose. NDF and cellulose remain fairly constant among silages and fresh herbage although ADF and lignin may be elevated. The results in this study show that there were increases ($P\leq0.05$) of both NDF and ADF levels in fermented *Calliandra,* but reduced ($P\leq0.05$) ADF levels in maize and *Gliricidia.* The content of ADL was higher ($P\leq0.05$) in fermented *Calliandra* and *Leucaena.* It was lower ($P\leq0.05$) in fermented maize and *Gliricidia.* Fibre fractions, ADF and NDF indicate how much substrate will be available for fermentation. Abnormally high values indicate that less free sugars are available. The results of the fibre constituents therefore, indicate that fermented *Gliricidia* would be a more utilizable silage than either *Calliandra* or *Leucaena* and comparable to maize silage.

Fermentation lowered ($P\leq0.05$) NDFN and increased ($P\leq0.05$) ADFN in *Calliandra,* which would lower degradation of *Calliandra* silage in the rumen. Although fermentation lowered ($P\leq0.05$) NDFN content in *Gliricidia* and maize, it also lowered their ADFN content, which would improve their utilization. The NDFN and ADFN content in *Leucaena* were not affected by fermentation. Nitrogen associated with NDF as NDFN is normally cell wall-bound protein, which also includes the indigestible N found in the ADF residue. The NDFN is digestible, but slowly degradable (Weiss *et al.,* 1986). A high level of ADFN is suggested as a sensitive assay for nonenzymic browning or Maillard reaction due to overheating of feeds. Proteins get bound to the carbohydrate fraction of the feed and the resulting nutrient complex is indigestible (Weiss *et al.,* 1986). Silages that experience temperatures in excess of 49°C are heat-damaged or caramelized usually caused by excess oxygen trapped in the silage mass (Mahana, 1997).

3.1.4.3 Degradation of fermented and unfermented browses and maize forage

The degradation curves for DM, OM, and N in Figure 1, 2 and 3 respectively show that the soluble fractions at time 0 hours of incubation were bigger than the degradation fractions in the rumen up to 6 hours of incubation. This is as a result of the lag phase when the rumen microbes get attached to the material before degradation begins (Orskov and Shand, 1997; Jones *et al.,* 1992). According to Orskov and Shand (1997), during this time there is no net disappearance of substrate and there may even be an increase in weight during the first 2-4 hours such that they recommended withdrawal of the first bag after 8 hours when the lag phase is completed. Jones *et al.* (1992) found a highly significant species x time interaction between *Leucaena* and *C. calothyrsus* and *C. surinamensis* for rumen digestion of dry matter. They found that even after 48 hours in the rumen, 91% of the initial N remained in *C. calothyrsus*. They also found that *Leucaena, C. calothyrsus* and *C. surinamensis* gained NDF during the first 12 hours in the rumen with *Leucaena* gaining most and C. calothyrsus least. *C. calothyrsus* did not lose NDF even after 48 hours. Both species of *Calliandra* gained ADF and ADL during the first 12 hours. The low degradation of *Leucaena* and *Calliandra* observed in this study was possible due to their high content of lignin, tannins and phenolics, which adsorb and bind carbohydrates, nitrogen and even microbial enzymes (Zahedifar,1977; Fahey *et.al.,* 1980; Navas-Camacho *et al*., 1993).

Degradation constants of DM for treatment effect (Table 3) show that fermentation increased ($P \leq 0.05$) all the fermentation parameters and correspondingly reduced **tl**. However, in the case of *Calliandra* and *Leucaena,* fermentation reduced the **a**, **b** and **PD** fractions as well as **ED.** The poor degradation of *Calliandra* and *Leucaena* exhibited by their low **PD** and **ED** values could have been due to their higher fibrous composition of particularly ADF compared to *Gliricidia* and maize (Table 2). Therefore, DM was more soluble and degradable in fermented *Gliricidia* and maize, which is in agreement with the results obtained by Cushnahan and Gordon (1995) who reported increased **a**, reduced **b** fractions but increased effective degradation for DM of ensiled grass. However, the results indicate that DM was less soluble and less degradable in fermented *Calliandra* and *Leucaena.* Fermentation elevated ADFN in *Calliandra,* an indication that fermented *Calliandra* could have undergone the browning effect and therefore, would be less degradable (Weiss, *et al.,* 1986). The nutrient composition results (Table 2) show that fermented maize and *Gliricidia* had higher ($P \leq 0.05$) CP and NPN content. The NH_3-N in the silage mass as a result of proteolysis and deamination could have been retained in the ammonium form (Cushnahan and Gordon, 1995) while OM was lost as carbon as evidenced by the reduced C : N ratio in fermented maize and *Gliricidia*(Table 2). The higher levels of N, particularly soluble N in the form of NPN could have contributed to the greater degradation of fermented *Gliricidia* and maize (Sutton *et al.,* 1994; Koster *et al.,* 1996). The content of NPN in *Calliandra* and *Leucaena* was not affected ($P \leq 0.05$) by fermentation (Table 2) and fermentation did not improve their DM degradation (Table 3). *Calliandra* was least degraded. Similarly, Kamatali *et al.* (1992), Jones *et al.* (1992) and Nsahlai *et al.* (1995) reported poor degradation of *Calliandra*. The high levels of ADL

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Degradation constants for OM for treatment effect (Table 4) show that degradation was higher ($P \leq 0.05$) for the fermented forms of the browses and maize. However, in the case of *Calliandra* the unfermented form had higher ($P \leq 0.05$) degradation (**b** and **PD**). The higher degradation of OM of fermented *Gliricidia* and maize (Table 4) is in line with their higher DM degradation of their fermented forms (Table 3). Of the three browses, fermentation occurred most extensively in *Gliricidia* and therefore, the effect of fermentation could have been most profound in it. This was further evidenced by the lower ($P \leq 0.05$) C:N ratio in its' fermented form. Effects of fermentation include proteolysis, deamination, solubilization of proteins and loss of soluble carbohydrates and the more soluble cell wall constituents that are utilised for energy by the micro-organisms in the course of fermentation. These factors could have given rise to the increase in NPN (Bareeba, 1979;Weiss *et al.,* 1986) in fermented *Gliricidia* and maize, which could have facilitated their degradation. *Calliandra* OM was least degraded, which was in agreement with other reports where *Gliricidia* and *Leucaena* have been reported to be readily degradable and *Calliandra* poorly degraded (Kamatali *et al*., 1992; Jones *et al*., 1992; Nsahlai *et al.,* 1995).

Values for N degradation were higher for **w** and **a** for the fermented browses and maize except *Leucaena* (Table 5) and were in agreement with other reports where ensiling has been reported to increase the **w** and **a** fractions (Cushnahan *et al.*, 1995). This could have occurred as a result of proteolysis and deamination that solubilises the protein N. The fermented forms of maize and *Gliricidia* had lower (P ≤0.05) content of fibre-bound N in the form of ADFN and higher (P ≤0.05) NPN than their unfermented forms (Table 2). Unfermented *Leucaena* had higher degradation (**b** and **pd**) than the fermented form. This could have been as a result of *Leucaena* silage having fermented only moderately without it's NPN content and C : N ratio being affected.

Values for N degradation (**b** and **PD**) for *Calliandra* and *Gliricidia* were higher for their fermented forms (Table 5). Fermentation was more extensive in *Gliricidia* than in *Calliandra* (Table 1). However, fermented *Gliricidia* and *Calliandra* had higher (P ≤0.05) levels of NPN resulting into higher values of **w** and **a** for N. Both fermented and unfermented *Calliandra* had relatively similar levels of NPN and appear to have had relatively similar **w** and **a** values for N while fermented *Gliricidia* had much higher **w** and **a** values for N corresponding to the much higher level of NPN.

3.1.4.4 Rumen microbial protein synthesis with fermented and unfermented browses and maize forage

Intestinal protein supply is from two sources microbial protein synthesized in the rumen and feed protein escaping degradation in the rumen. Therefore, a means of increasing efficiency of rumen microbial protein (RPM) synthesis or feeding protein sources resistant to rumenal degradation would be beneficial to the animal. Fermentation solubilises protein N and makes it available for rumen microbial metabolism (Bareeba, 1979). Hence in this study, fermentation tended to increase RMP synthesis with *Gliricidia, Leucaena* and maize forage except with *Calliandra* where it had no effect (Table 4). The results for browse effect (Table 4) showed that RMP synthesis was highest with *Gliricidia and* least with *Calliandra.* Microbial protein synthesis is dependent upon an adequate supply of fermentable N required by the micro-organisms (Preston and Leng, 1987). Fermented *Calliandra* had the least ($P \leq 0.05$) NPN content (Table 2) as well as the highest ($P \leq 0.05$) content of unavailable N (ADFN), which could have resulted in the low, RMP synthesis.

3.1.5 Conclusion

Of the browses, *Gliricidia* fermented best and *Calliandra* had poor fermentation with low lactic acid levels. The content of NPN was high in fermented *Gliricidia* but was not affected in *Calliandra* or *Leucaena,* while the content of NDF and ADF tended to increase in *Calliandra* and *Leucaena.* Fermentation increased degradation of DM, OM, N and RMP synthesis in *Gliricidia* and *Leucaena* but not in *Calliandra.* Therefore, *Gliricidia* would be a better browse than either *Calliandra* or *Leucaena*.for inclusion in maize silages.

3.2.0 EXPERIMENT 2: Fermentation characteristics, nutrient composition and degradation of browse/maize forage mixture silages.

3.3.1.0 Introduction

Leguminous tree foliages can provide high quality fodder with high CP ranging between 120 to 298 g/kg^{-1} DM (Topps, 1992; Sabiiti and Cobbina, 1992; Sabiiti, 2001). Nevertheless, they contain anti-nutritional factors, which affect their adequate utilization by livestock. The most prevalent of these factors are tannins and other phenolics (Lowry, 1990; Flores *e, al.*, 1979; Bareeba and Aluma, 2000). Ensiling could be used as one of the methods for alleviating the effects of anti-nutritional factors in tree foliages since the silo environment of temperature, moisture and acidity changes the chemical composition of ensiled materials (Weiss *et al.,* 1986; Charmley and Veira, 1990; Tamminga *et al.,* 1991; Cushnahan and Gordon, 1995; Cushnahan *et al.*, 1995).

However, some of the effects of anti-nutritional factors could have nutritional advantage in livestock. The binding effect of proteins by tannins could protect dietary proteins from rumen degradation and make it available in the lower gut (Fahey *et al.,* 1980; Zahedifar 1997). The tannins release the protein in the higher acidity environment of the lower gut (Zahedifar, 1997). In Experiment 1 the browses produced poor silage when ensiled alone. In this experiment *Calliandra, Gliricidia* and *Leucaena* foliages were ensiled with maize in varying proportions. The objective of this experiment was to determine the fermentation characteristics, nutrient composition and rumen degradation of maize.silage containing browses.

3.2.2.0 Materials and methods

3.2.2.1 Ensiling

Chopped *Calliandra, Gliricidia* and *Leucaena* forages were mixed separately with chopped maize forage in the proportions of 0, 10, 20, 30, 40 or 50% DM basis. The mixtures were then ensiled in triplicate 2kg lots in polythene bags, which acted as silos. The materials were tightly packed and the bags tightly tied. The experiment was set up in a completely randomized design in the laboratory. The DM of the materials at ensiling was 30, 24, 29 and 25% for *Calliandra, Gliricidia, Leucaena* and maize respectively. The materials were allowed to ferment for 30 days.

3.2.2.2 Data collection and chemical analyses

Data collection and chemical analysis regarding the silages was done as in Experiment 1 (Section 3.1.2.2).

3.2.2.3 Degradation of the browse/maize silages and rumen microbial protein synthesis

Rumen degradation and rumen microbial protein synthesis were determined using the same procedures as described in Experiment 1. (Section 3.1.2.3 and 3.1.2.4 respectively).

3.2.2.4 Statistical analysis

The data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (1999). Where significant differences were obtained, means were compared using standard error (SE) at probability level of 5%.

3.2.3.0 Results

3.2.3.1 Fermentation characterisrics of the browse/maize silages

The effect of level of *Calliandra* addition on the fermentation characteristics of the silages is shown in Table 6. The results show that *Calliandra* addition tended to increase ($P \leq 0.05$) DM content of the silages. Acetic acid content was lowered ($P \leq 0.05$) as the level of browse increased. Butyric acid content did not change with browse addition. Lactic acid content was low and decreased ($P \leq 0.05$) with the 40% and 50% levels of browse addition. The pH levels were low and similar at all levels of browse addition. The concentration of NH_3–N was lowered ($P \leq 0.05$) by addition of 20% or more browse. Addition of 20% or higher browse decreased ($P \leq 0.05$) DM losses.

Table 6: Fermentation characteristics (% DM) of browse/maize silages containing different levels of *Calliandra* browse

	Browse level (%)						
	0	10	20	30	40	50	SE
DM	30.03^{e}	31.35^{ed}	34.53^{b}	32.73^{bc}	36.27^{a}	36.73^{a}	0.51
Acetic acid	1.59^{a}	1.33^{b}	1.23^{b}	1.22^{b}	1.24^{b}	1.01^{c}	0.31
Butyric acid	0.16	0.10	0.05	0.13	0.12	0.07	0.09
Lactic acid	3.03^{a}	3.16^{a}	2.85^{a}	2.51^{ab}	2.28^{b}	2.01^{bc}	0.21
pH	3.97	3.94	3.99	3.85	4.02	3.97	0.08
NH_3-N (% Total N)	3.73^{a}	3.24^{ab}	2.38^{b}	1.68^{c}	1.61^{c}	1.52^{d}	0.003
DM Losses	19.90^{a}	17.70^{a}	9.87^{b}	10.87^{b}	9.30^{b}	8.73^{b}	1.01

^{abcde} Values with different superscripts in the same row are significantly different ($P < 0.05$)

The effect of level of *Gliricidia* addition on the fermentation characteristics of the silages is shown in Table 7. Acetic acid content of the silages was lowered ($P \leq 0.05$) by the 50% level of browse addition. Butyric acid, lactic acid and pH levels were low and did not change with browse addition. The levels of NH_3–N was lowest ($P \leq 0.05$) with the 40 and 50% browse addition. Dry matter losses were lowest ($P \leq 0.05$) at 50% browse addition.

Table 7: Fermentation characteristics (%DM) of browse/maize silages containing different levels of *Gliricidia* browse

	Browse level (%)						
	0	10	20	30	40	50	SE
DM	30.03	29.00	29.53	29.83	29.30	29.80	0.51
Acetic acid	1.59^{a}	1.38^{ab}	1.78^{a}	1.42^{ab}	1.41^{ab}	1.16^{b}	0.13
Butyric acid	0.17	0.10	0.04	0.05	0.07	0.11	0.09
Lactic acid	3.03	2.77	3.13	3.15	3.30	3.57	0.21
pH	3.97	3.98	4.00	4.05	4.07	4.15	0.08
NH_3-N(% Total N)	3.73^{a}	2.87^{bc}	3.00^{b}	2.84^{bc}	2.61^{c}	2.72^{c}	0.003
DM Losses	19.90^{a}	22.60^{ab}	18.97^{ab}	17.37^{ab}	17.53^{ab}	15.67^{bc}	1.01

^{abc} Values with different superscripts in the same row are significantly different ($P < 0.05$)

The effect of level of *Leucaena* addition on the fermentation characteristics of the silages is shown in Table 8. Acetic acid content of the silages was lowest ($P \leq 0.05$) with the 50% level of browse addition. Butyric acid levels were lowest ($P \leq 0.05$) with the 30-50% levels of browse addition. However, lactic acid and pH levels were also low and did not change with browse addition. The level of NH_3 –N were lowest ($P \leq 0.05$) with the 40 and 50% levels of browse addition. Dry matter losses were lowest ($P \leq 0.05$) at 50% browse addition.

Table 8: Fermentation characteristics (%DM) of browse/maize silages containing different levels of *Leucaena* browse

	Browses level (%)						
	0	10	20	30	40	50	SE
DM	30.03	30.60	30.70	30.30	30.87	31.37	0.51
Acetic acid	1.59^a	1.29^a	1.31^a	1.34^a	1.29^a	1.18^b	0.13
Butyric acid	0.39^a	0.14^a	0.14^a	0.07^b	0.09^b	0.02^b	0.09
Lactic acid	3.03	2.98	3.10	3.08	3.02	3.89	0.21
pH	3.97	3.73	4.06	4.06	4.11	4.25	0.08
NH_3-N(% Total N)	3.73^a	2.89^b	2.79^{bc}	2.46^{cd}	$2\ .67^c$	2.32^c	0.003
DM Losses	19.90^a	17.03^b	16.33^b	17.37^{ab}	12.70^{bcd}	12.17^{bcd}	1.01

^{abcd} Values with different superscripts in the same row are significantly different ($P < 0.05$)

The effect of browse on fermentation characteristics is shown in Table 9.

Table 9: Browse effect on fermentation characteristics (% DM) of the browse/maize silages

	Browse/maize silages			
	Calliandra	*Gliricidia*	*Leucaena*	*SE*
DM	33.64^{a}	29.58^{c}	30.6^{b}	0.21
Acetic acid	1.25^{b}	1.46^{a}	1.33^{ab}	0.05
Butyric acid	0.11	0.09	0.14	0.04
Lactic acid	2.64^{b}	3.16^{a}	3.02^{a}	0.08
pH	3.98	4.04	4.03	0.03
NH_3-N(% Total N)	2.36^{b}	2.97^{a}	2.81^{a}	0.001
DM losses	12.73^{c}	18.67^{a}	15.92^{b}	0.41

^{abc} Values with different superscripts in the same row are significantly different ($P > 0.05$).

Calliandra/maize silages had higher ($P \leq 0.05$) DM content than either *Leucaena*/maize or *Gliricidia*/maize silages. *Gliricidia*/maize silages had higher ($P \leq 0.05$) levels of acetic acid than *Calliandra*/maize but similar levels with *Leucaena*/maize silages. Butyric acid contet content was similar in all the silages. *Calliandra*/maize silages had lower ($P \leq 0.05$) levels of lactic acid compared to *Gliricidia*/maize and *Leucaena*/maize silages. Also, *Calliandra*/maize silages had lower ($P \leq 0.05$) levels of NH_3 –N and lowest ($P \leq 0.05$) DM losses. Dry matter losses were highest ($P \leq 0.05$) in *Gliricidia*/maize silages

The effect of level of browse addition on the fermentation characteristics of the silages is shown in Table 10.

Table 10: Browse level effect on fermentation characteristics (% DM) of browse/maize silages containing different levels of browse

	Browse level (%)						
	0	10	20	30	40	50	SE
DM	30.03^{e}	30.38^{de}	31.59^{bc}	30.96^{cd}	32.14^{ab}	32.63^{a}	0.29
Acetic acid	1.59^{a}	1.33^{b}	1.44^{ab}	1.29^{bc}	1.31^{bc}	1.12^{c}	0.07
Butyric acid	0.24^{a}	0.11^{ab}	0.08^{b}	0.08^{b}	0.09^{b}	0.07^{b}	0.05
Lactic acid	3.03	2.97	3.03	2.91	2.87	2.82	0.12
pH	3.97^{bc}	3.88^{c}	4.02^{bc}	3.99^{bc}	4.07^{ab}	4.18^{a}	0.05
NH_3-N(%Total N)	3.73^{a}	3.00^{ba}	2.72^{bc}	2.33^{c}	2.31^{c}	2.19^{d}	0.001
DM Losses	19.90^{a}	19.11^{a}	15.06^{b}	15.20^{b}	13.18^{c}	12.19^{c}	0.58

^{abcde}Values with different superscripts in the same row are significantly different ($P < 0.05$)

Addition of browse tended to increase ($P \leq 0.05$) DM content of the silages. Acetic acid and butyric acid levels decreased ($P \leq 0.05$) with the 10%-50% levels of browse addition. Lactic acid content was low and was not affected by level of browse addition. The pH increased ($P \leq 0.05$) with the 40% - 50% level of browse addition. The content of NH_3–N decreased ($P \leq 0.05$) with 20 – 50% levels of browse addition. Dry matter losses were decreased ($P \leq 0.05$) with 20 – 50% levels of browse addition.

3.2.3.2 Chemical composition of the browse/maize silages

The effect of level of *Calliandra* browse addition on the chemical composition of the silages is given in Table 11.

Table 11: Chemical composition (%DM) of maize silages containing different levels of *Calliandra* browse

	Browse Level (%)						
	0	10	20	30	40	50	SE
Organic Matter	93.04	94.00	91.70	91.87	92.26	93.09	0.48
Crude Protein	6.25^{d}	7.68^{d}	9.35^{c}	12.52^{b}	12.84^{b}	14.10^{a}	0.55
NPN(%) Total N)	38.19^{a}	25.74^{b}	20.89^{b}	17.42^{bc}	16.87^{bc}	14.49^{c}	3.53
Calcium	0.19^{b}	0.19^{b}	0.19^{b}	0.19^{b}	0.20^{a}	0.21^{a}	0.004
Phosphorus	0.19	0.14	0.16	0.15	0.16	0.17	0.03
NDF	64.86	61.46	62.71	61.73	61.53	63.23	1.38
ADF	41.41^{d}	38.55^{d}	44.66^{cd}	49.81^{b}	50.76^{b}	57.51^{a}	1.49
NDFN(% Total N)	44.14^{a}	29.81^{c}	38.88^{ab}	41.71^{a}	47.43^{a}	47.03^{a}	2.31
ADFN(% Total N)	25.00^{b}	28.13^{b}	35.15^{a}	42.51^{a}	38.35^{a}	41.40^{a}	2.98
ADL	3.52^{b}	4.49^{b}	6.92^{b}	13.90^{a}	14.57^{a}	16.69^{a}	1.23

^{abcde}Values with different superscripts in the same row are significantly different ($P \leq 0.05$)

Organic matter content was not affected by addition of *Calliandra* browse addition. The content of CP of the silages increased ($P \leq 0.05$) with each level of browse addition while NPN content tended to decrease. The content of NDF in *Calliandra*/maize silages was not affected by additions of browse. However, the content of ADF increased ($P \leq 0.05$) with browse addition of over 20%. The content of NDFN, ADFN and ADL were higher ($P \leq 0.05$) with the 30% level of browse addition.

The effect of level of *Gliricidia* browse addition on the chemical composition of the silages is given in Table 12.

Table 12: Chemical composition (% DM) of browse/maize silages containing different levels of *Gliricidia* browse

	Browse level (%)						
	0	10	20	30	40	50	SE
Organic Matter	93.04	93.52	92.39	92.47	92.35	93.15	0.48
Crude Protein	6.25^{d}	8.82^{bc}	9.96^{b}	11.37^{b}	13.86^{a}	14.97^{a}	0.55
NPN(%) Total N)	38.19	37.12	40.53	42.82	44.96	42.69	3.53
Calcium	0.19	0.20	0.20	0.20	0.19	0.12	0.004
Phosphorus	0.21^{a}	0.10^{b}	0.17^{b}	0.13^{b}	0.10^{b}	0.15^{b}	0.03
NDF	64.86^{a}	58.58^{b}	56.96^{b}	54.22^{bc}	54.10^{bc}	53.01^{cd}	1.38
ADF	41.41	39.06	39.74	40.58	39.07	41.37	1.49
NDFN(% Total N)	44.14^{a}	25.02^{b}	26.72^{b}	21.50^{b}	24.97^{b}	25.09^{b}	2.31
ADFN(% Total N)	25.00^{a}	18.13^{a}	20.81^{a}	11.94^{b}	12.18^{b}	13.06^{b}	2.98
ADL	3.52^{c}	3.45^{c}	4.18^{b}	4.99^{b}	5.46^{ab}	6.34^{a}	1.23

^{abcd} Values with different superscripts in the same row are significantly different ($P\leq 0.05$).

Organic matter content was not affected by addition of browse. Crude protein content increased ($P\leq 0.05$) with browse addition, but the content of NPN was not affected. While Ca content was not affected, P conent was decreased by addition of browse.The content of NDF and NDFN were lower ($P\leq 0.05$) in silages with browse, while that of ADF was not affected by browse addition. The content of ADFN was lowest ($P\leq 0.05$)

with the 30-50% level of browse addition. The content of ADL increased ($P \leq 0.05$) with 20% level of browse addition.

The effect of level of *Leucaena* browse addition on the chemical composition of the silages is given in Table 13.

Table13: Chemical composition (%DM) of browse/maize silages containing different levels of *Leucaena* browse

	Browse level (%)						
	0	10	20	30	40	50	SE
Organic Matter	93.04	93.09	93.11	93.13	93.85	93.96	0.48
Crude Protein	6.25^{e}	8.77^{d}	9.97^{d}	11.89^{c}	13.66^{b}	15.80^{a}	0.55
NPN (% Total N)	38.19^{a}	30.10^{a}	28.30^{b}	22.07^{b}	26.60^{b}	29.21^{b}	3.53
Calcium	0.19	0.19	0.19	0.19	0.19	0.20	0.004
Phosphorus	0.21^{a}	0.18^{b}	0.17^{b}	0.16^{b}	0.15^{b}	0.15^{b}	0.03
NDF	64.86^{a}	62.05^{a}	61.95^{a}	62.89^{a}	57.59^{b}	59.60^{b}	1.38
ADF	41.41	42.22	42.28	44.77	45.84	45.02	1.49
NDFN(% Total N)	44.14^{b}	38.47^{bc}	41.53^{b}	52.78^{a}	53.67^{a}	52.65^{a}	2.31
ADFN(% Total N)	25.0^{a}	10.69^{b}	12.37^{b}	24.95^{a}	27.95^{a}	22.20^{a}	2.98
ADL	3.52^{c}	4.96^{b}	5.52^{b}	8.36^{ab}	9.99^{a}	11.10^{a}	1.23

^{abcde} Values with different superscripts in a row are significantly different ($P \leq 0.05$).

Organic mater was not affected by level of browse addition. Content of CP tended to increase($P \leq 0.05$) with browse addition. The content of NPN decreased ($P \leq 0.05$) with 20% level of browse addition. The content of Ca was not affected, while that of P was decreased by browse browse addition. The content of NDF was lower ($P \leq 0.05$) with 40% levels of browse addition, while the levels of ADF were not affected by browse addition. Levels of NDFN, ADFN and ADL were higher ($P \leq 0.05$) with 30% browse addition.

The effect of browse on chemical composition of the silages irrespective of level of browse addition are given in Table 14.

Table 14: Browse effect on chemical composition (% DM) of the browse/maize silages

	Browse /maize silages			
	Calliandra	Gliricidia	Leuceana	SE
Organic Matter	92.66^{a}	92.65^{b}	93.36^{a}	0.18
Crude Protein	10.42^{b}	10.87^{a}	11.06^{a}	0.21
NPN(% Total N)	21.43^{c}	41.05^{a}	29.08^{b}	1.33
Calcium	0.20^{b}	0.18^{b}	0.19^{a}	0.002
Phosphorus	0.16^{b}	0.14^{b}	0.18^{a}	0.01
NDF	62.59^{a}	56.96^{c}	61.49^{b}	0.52
ADF	47.12^{a}	40.21^{c}	43.59^{b}	0.56
NDFN	41.56^{a}	27.91^{c}	47.21^{b}	0.87
ADFN	35.09^{a}	16.69^{b}	20.53^{b}	1.13
ADL	10.02^{a}	4.66^{c}	7.24^{b}	0.46

^{abc} Values with different superscripts in the same row are significantly different ($P < 0.05$).

Gliricidia/maize silage had lower ($P \leq 0.05$) levels of OM than either *Calliandra*/maize or *Leucaena*/maize silages. *Gliricidia*/maize and *Leucaena*/maize silages had similar CP content, but it was lower ($P \leq 0.05$) in *Calliandra*/maize silage. The content of NPN was highest ($P \leq 0.05$) in *Gliricidia*/maize silage. The content of Ca and P was higher ($P \leq 0.05$) in *Leucaena*/maize silages. *Calliandra*/maize silage had highest ($P \leq 0.05$) levels of NDF, ADF, NDFN, ADFN and ADL. *Leucaena*/maize silages had higher ($P \leq 0.05$) levels of NDF, ADF, NDFN, ADFN and ADL than *Gliricidia*/maize silages.

The effect of level of browse addition on the chemical composition of the silages is shown in Table 15.

Table 15: Browse level effect on chemical composition of the browse/maize silages

	Broswe level (%)						
	0	10	20	30	40	50	SE
Organic Matter	93.04^{abc}	93.21^{a}	92.40^{a}	92.49^{a}	92.82^{abc}	93.40^{a}	0.28
Crude Protein	6.25^{f}	8.42^{e}	9.76^{d}	12.03^{c}	13.29^{b}	14.96^{a}	0.32
NPN(%Total N)	38.19^{a}	30.99^{b}	28.24^{b}	27.44^{b}	29.48^{b}	28.79^{b}	2.04
Calcium	0.19^{b}	0.19^{b}	0.19^{b}	0.19^{b}	0.19^{b}	0.20^{a}	0.003
Phosphorus	0.2^{a}	0.18^{ab}	0.17^{ab}	0.15^{bc}	0.15^{bc}	0.14^{bc}	0.02
NDF	64.86^{a}	60.70^{b}	60.54^{b}	59.62^{bc}	57.74^{c}	58.61^{bc}	0.80
ADF	41.41^{c}	39.94^{c}	42.23^{c}	45.05^{b}	45.23^{b}	47.97^{a}	0.86
NDFN(% Total N)	44.14^{a}	19.54^{d}	24.02^{c}	25.87^{bc}	29.18^{b}	27.43^{b}	1.33
ADFN(% Total N)	25.00	22.32	22.78	26.13	26.16	25.55	1.72
ADL	3.52^{c}	4.45^{c}	5.54^{c}	9.08^{b}	10.01^{ab}	11.38^{a}	0.71

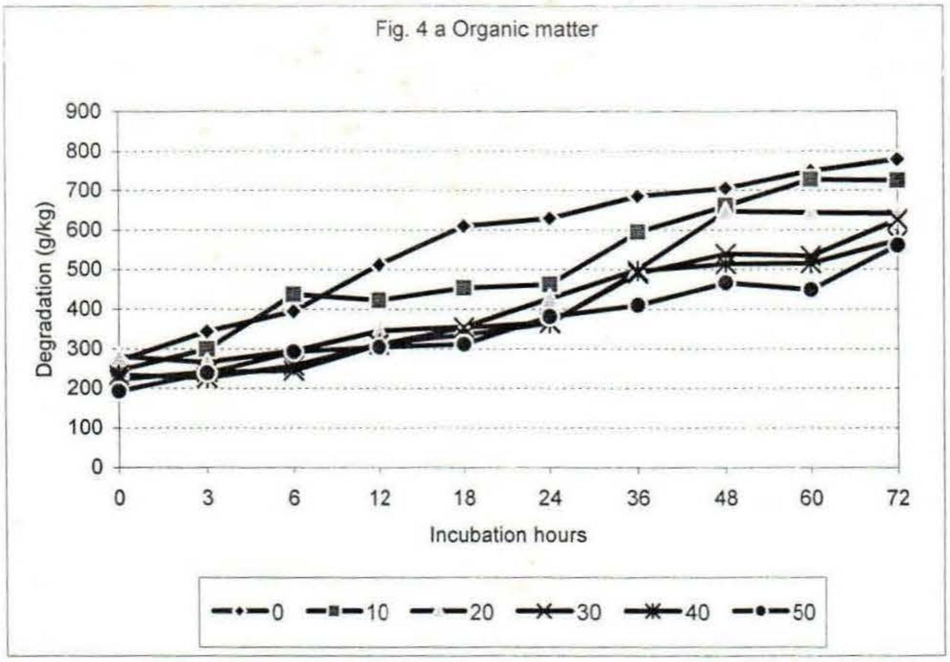
^{abcdef} Values with different superscripts in the same row are significantly different ($P < 0.05$)

While addition of browse increased ($P \leq 0.05$) CP content in the silages, that of NPN was decreased ($P \leq 0.05$). While Ca content of the silages was highest ($P \leq 0.05$) with the 50% browse addition that of P tended to decrease with browse addition. Browse addition decreased ($P \leq 0.05$) NDF and increased ($P \leq 0.05$) ADF content with the 30% level of browse addition but it lowered ($P \leq 0.05$) NDFN, and did not affect ADFN content. The content of ADL was higher ($P \leq 0.05$) with 40 and 50% browse additions.

3.2.3.3: Degradation curves of the browse/maize silages

Calliandra/maize silages degradation curves for OM and N are presented in Figs. 4 a and 4 b respectively. Maize silage was most degraded and each level of *Calliandra* browse addition reduced OM and N degradation. Degradation of the 20 and 30% *Calliandra*/maize silages were also similar but relatively lower than that of 10% *Calliandra*/maize and maize silages. Degradation of The 40 and 50% *Calliandra*/maize silages was much lower than that of 10% *Calliandra*/maize and maize silages. The N degradation curves (Fig. 4 b) showed a similar trend as for OM. Nitrogen in the 20 and 30% *Calliandra*/maize silages was degraded to a similar extent. Degradation of N in the 40 and 50% *Calliandra*/maize silages was similar degraded to a but lower.

Organic matter and N degradation in *Gliricidia*/maize silages is given in Fig 5 (a) and 5 (b) respectively. In all the silages OM and N appear to have degraded to a similar extent irrespective of level of browse addition.



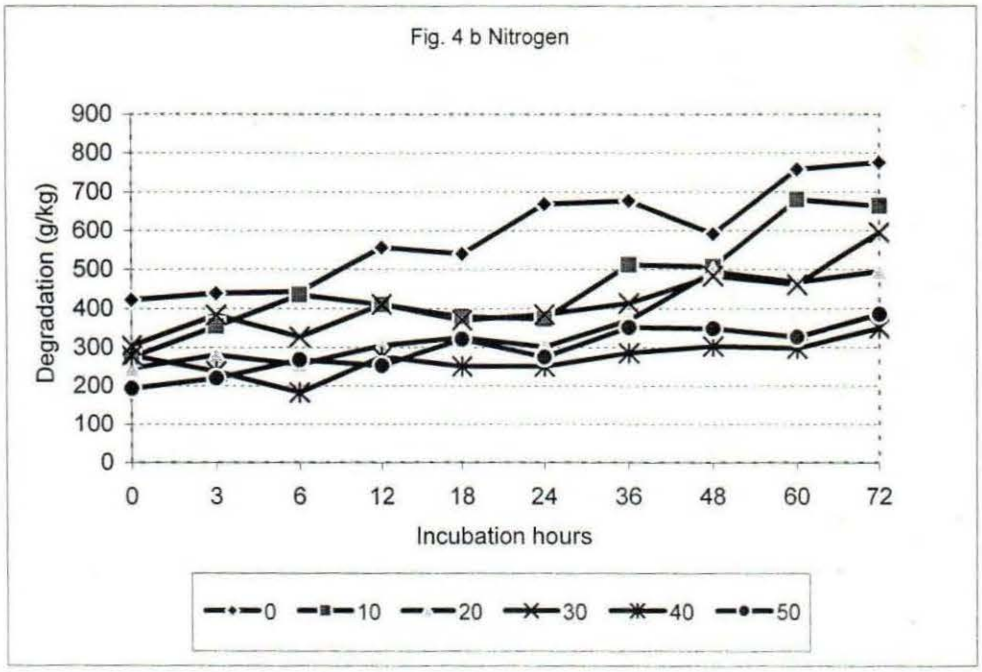
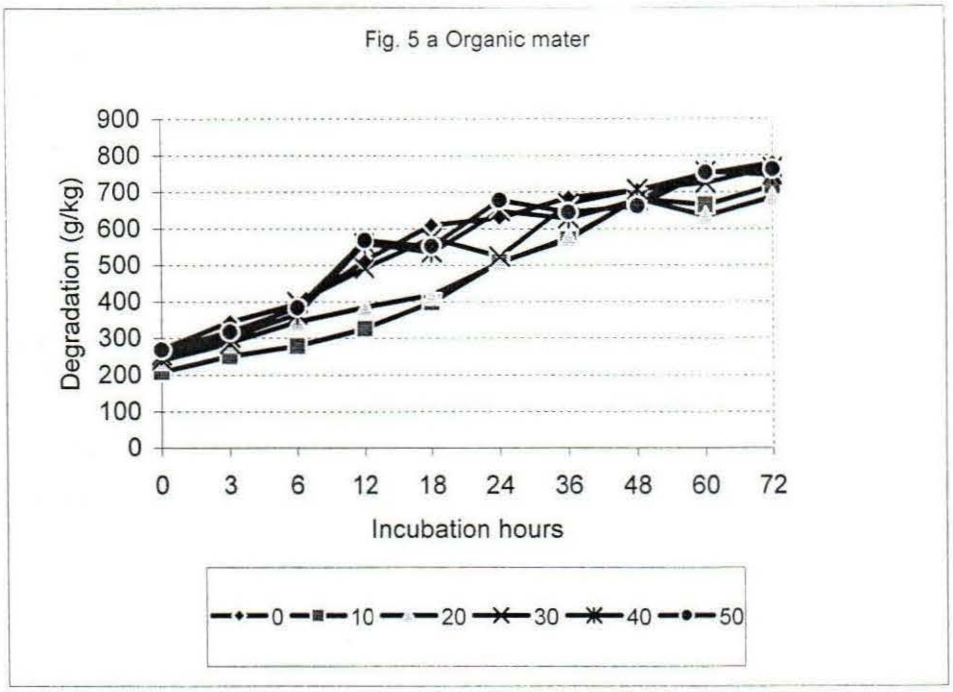


Fig. 4: Degradation curves for OM and N in Calliandra/maize silages (0–50% browse-Fig. 4a and b respectively.



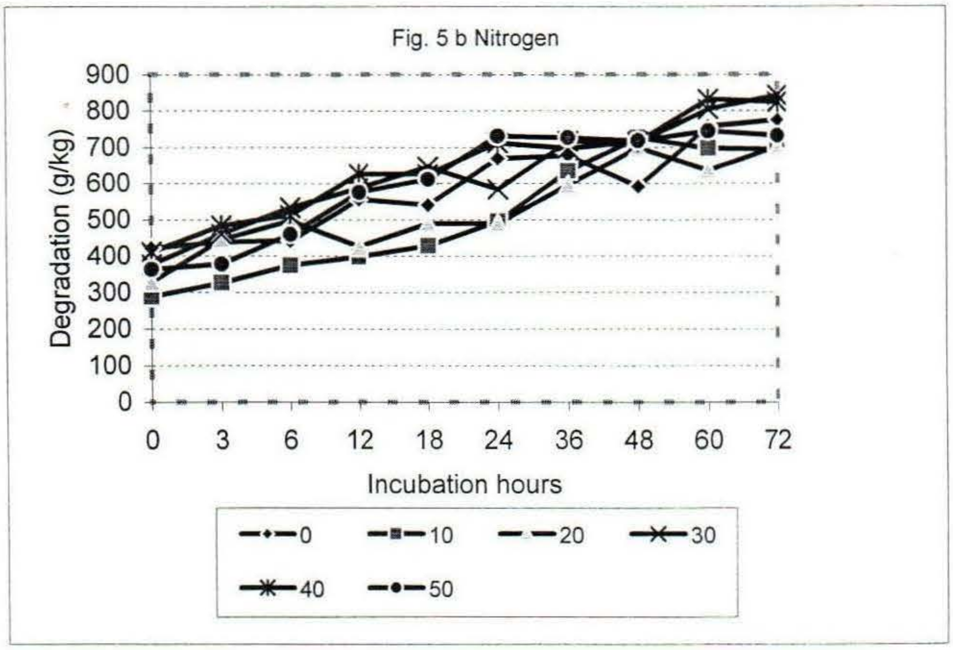
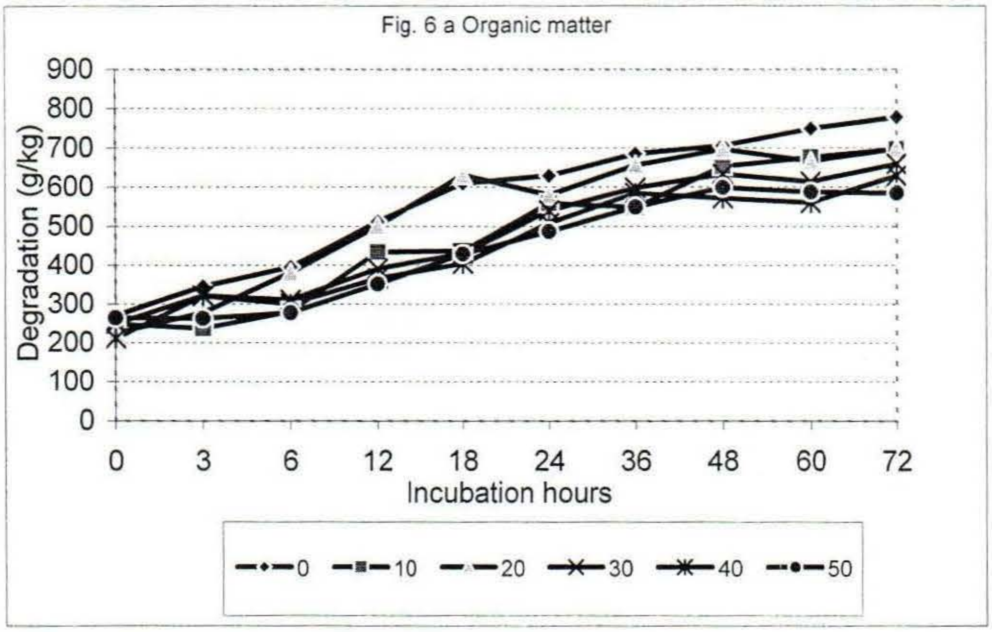


Fig. 5: Degradation curves for OM and N in Gliricidia/maize silages (0-50% browse)-Fig 5a and b respectively

Degradation curves for OM and N for *Leucaena*/maize silages are shown in Figs. 6 (a) and 6(b) respectively.



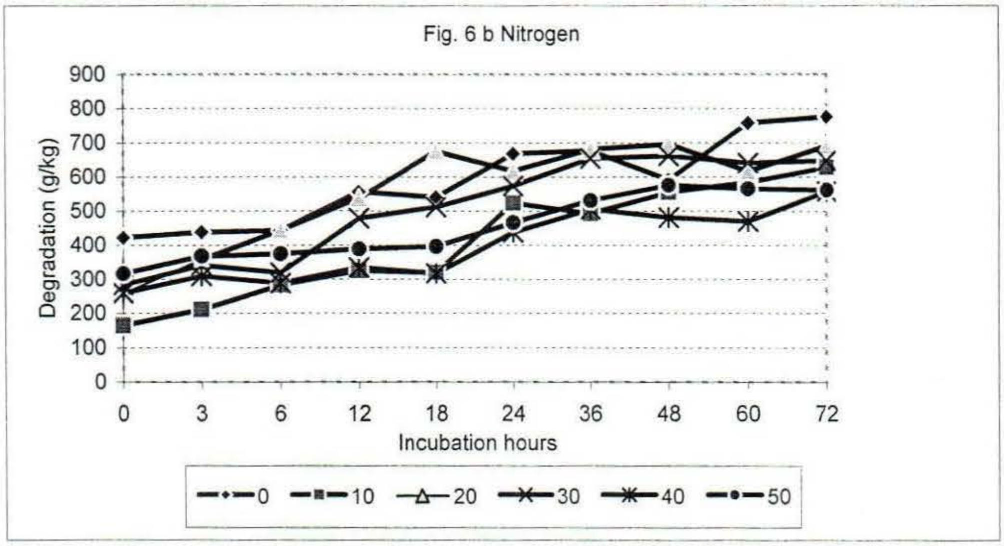


Fig. 6: Degradation curves for OM and N in Leucaena/maize silages (0-50% browe)- Fig. 6a and b respectively

Maize silage OM was most degraded followed by the 10 and 20% *Leucaena*/maize silages, which degraded to a similar extent. The 30% and 40% *Leucaena*/maize silages were also degraded to a similar extent, while the 50% *Leucaena*/maize silage was least degraded. Nitrogen was most degraded in maize silage and it was least degraded in the 40 and 50% *Leucaena*/maize silages.

3.2.3.4: Degradation constants for the browse/maize silages

Organic matter degradation constants are given in Table 16. The mean values indicate browse level effect on degradation. Mean values for **w** and **a** for OM were lower ($P \leq 0.05$) with the browse/maize silage and they showed no consistent trend with levels of browse addition. Mean values for **b** for OM up to 30% level of browse addition were higher ($P \leq 0.05$) than for maize silage alone. However, the 40 and 50% levels of browse addition reduced the values. The 10% browse/maize silage had the highest ($P \leq 0.05$) mean **b** values. The **b** values for *Gliricidia*/maize silages were similar to those for maize silage alone. The **PD** values were higher ($P \leq 0.05$) with the browse/maize silages than with maize silage alone. However, the values, declined with higher levels of browse addition.

Table 16: Organic matter degradation constants (g/kg DM) for the browse/maize silages

Browse	Constants	Browse Level (%)					
		0	10	20	30	40	50
Calliandra	w	270.56	245.97	280.51	222.73	234.00	192.59
	a	285.92	294.79	256.88	220.45	221.30	219.98
	b	480.00	586.78	710.98	627.79	471.36	313.97
	pd	765.92	881.57	967.87	848.24	692.66	533.94
	c	0.055	0.020	0.013	0.014	0.019	0.028
	tl	0.646	1.000	1.000	1.000	1.000	1.000
Gliricidia	w	270.56	208.43	239.62	240.93	254.25	269.10
	a	285.92	210.71	257.37	286.18	257.93	276.61
	b	480.00	618.40	493.89	480.00	480.00	460.00
	pd	765.92	829.11	751.26	766.18	737.93	736.61
	c	0.055	0.025	0.030	0.046	0.059	0.064
	tl	0.646	1.000	1.000	1.718	0.506	0.719
Leucaena	w	270.56	248.89	225.38	249.44	251.91	264.67
	a	285.92	234.42	230.54	268.75	234.72	256.36
	b	480.00	503.89	460.00	420.15	400.00	379.73
	pd	765.92	738.31	690.54	688.90	634.72	636.09
	c	0.055	0.035	0.079	0.038	0.040	0.038
	tl	0.646	1.000	0.695	1.418	0.253	1.931
	w	270.56^{a}	234.43^{b}	248.50^{b}	237.70^{c}	246.72^{b}	242.12^{b}
Means	a	285.9^{a}	246.6^{e}	248.3^{d}	258.5^{b}	238.0^{f}	251.0^{c}
	b	480.0^{d}	570.0^{a}	555.0^{b}	509.0^{c}	450.0^{e}	385.0^{e}
	pd	766.0^{d}	816.0^{a}	803.0^{cb}	768.0^{c}	688.0^{e}	636.0^{f}
	c	0.055^{a}	0.027^{f}	0.040^{c}	0.032^{e}	0.039^{d}	0.043^{b}
	tl	0.664^{e}	1.000^{e}	0.898^{d}	1.379^{a}	0.586^{f}	1.217^{b}

^{abcdefg} Means with different superscripts in the same row are significantly different (P≤0.05), t = 1.964.w - washable fraction, a - rapidly soluble fraction, b - slowly degradable fraction, PD - potential degradability (a+b), tl - lag time in hours, c - rate of degradation at fraction b (per hour).

The 10% browse/maize silage had the highest ($P \leq 0.05$) mean **PD** value. The **PD** values for *Gliricidia*/maize silages were similar to those of maize silage. The mean values for **c** were lower ($P \leq 0.05$) with the browse/maize silages than with maize silage alone but increased with higher levels of browse addition. The values of **tl** were also lower ($P \leq 0.05$) with the browse/maize silages than with maize silage alone, but decreased with higher levels of browse addition. Similar trends of **c** and **tl** values were observed for the browse/maize silages of each of the three browses studied.

Nitrogen degradation constants are given in Table 17. A similar trend as for OM with higher levels of browse addition to the silages was observed. Mean values for **w** and **a** for N were lower ($P \leq 0.05$) with the browse/maize silages with a gradual decrease for *Calliandra*/maize silages and a gradual increase with *Gliricidia*/maize silages with higher levels of browse addition. Mean values for **b** for N were higher ($P \leq 0.05$) for the browse/maize silages, but declined with higher levels of browse addition. However, 10 – 40% *Calliandra*/maize silages had **b** values in excess of 1000g/kg. This affected the mean value of **b** accordingly. The potential degradability (**PD**) of N was higher ($P \leq 0.05$) with the browse/maize silages than with maize silage alone, but declined with higher levels of browse addition. However, 10–40% *Calliandra*/maize silages had values of **PD** in excess of 1000g/kg. This also affected the mean values of **PD** accordingly. Mean values of **c** and **tl** did not show a consistent trend with higher levels of browse addition. However, with *Calliandra*/maize silages **c** and **tl** values were similar for the 10–40% levels of browse addition and they were higher for 50% browse level.

Table 17: Nitrogen degradation constants (g/kg N) for the browse/maize silages

		Browse level (%)					
Browse	Constants	0	10	20	30	40	50
Calliandra	w	421.91	274.48	246.07	305.07	278.88	193.53
	a	424.40	328.94	249.75	328.95	240.66	211.16
	b	373.03	5084.45	4897.69	3320.92	1493.65	157.83
	pd	797.43	5413..39	5147.44	3649.51	1734.31	368.99
	c	0.029	0.001	0.001	0.001	0.001	0.043
	tl	1.000	1.000	1.000	1.000	1.000	1.115
Gliricidia	w	421.91	288.37	328.38	377.06	411.54	363.95
	a	424.40	292.65	389.99	435.51	444.13	348.38
	b	373.03	533.85	455.60	439.94	380.00	400.00
	pd	797.43	826.50	845.60	875.46	824.13	748.38
	c	0.029	0.025	0.016	0.028	0.042	0.072
	tl	1.000	1.000	1.000	1.000	0.899	0.580
Leucaena	w	421.91	164.87	257.58	282.39	295.06	316.31
	a	424.40	184.98	295.25	293.94	266.75	317.97
	b	373.03	478.31	380.00	380.00	333.42	300.21
	pd	797.43	663.29	675.25	673.94	600.17	618.18
	c	0.029	0.033	0.109	0.056	0.023	0.030
	tl	1.000	1.000	1.084	1.439	1.000	1.000
Means	w	421.91^{a}	242.57^{e}	277.34^{d}	321.51^{b}	328.49^{b}	291.26^{c}
	a	424.4^{a}	268.9^{f}	311.7^{d}	352.7^{b}	317.2^{c}	292.5^{e}
	b	373.0^{e}	2032.0^{a}	1578.0^{d}	1380^{b}	736.0^{c}	286.0^{g}
	pd	797.0^{e}	2301.0^{a}	1889.7^{b}	17330^{c}	1053.0^{d}	579.0^{f}
	c	0.029^{c}	0.019^{e}	0.043^{b}	0.028^{c}	0.022^{d}	0.048^{a}
	tl	1.000^{c}	1.000^{c}	1.028^{b}	1.146^{a}	0.966^{d}	0.898^{e}

^{abcdefg} Means with different superscripts in the same row are significantly different (P≤0.05), t = 1.964. w - washable fraction, a - rapidly soluble fraction, b - slowly degradable fraction, PD - potential degradability (a+b), tl - lag time in hours, c - rate of degradation at fraction b (per hour).

Effective degradation (**ED**) for OM (Table 18) were higher ($P \leq 0.05$) for maize silage and were progressively lowered ($P \leq 0.05$) by higher levels of browse addition to the silages. This observation was true for *Calliandra/*maize and *Leucaena/*maize silages with peak **ED** values at 20% level of browse addition for *Leucaena/*maize silages. The **ED** values increased with higher levels of browse addition with *Gliricidia/*maize silages (Table 18).

Table 18: Effective degradation, ED, (g/kg) of OM and N of the maize silages containing different levels of browse

Browse	Browse level(%)						
	0	10	20	30	40	50	Mean
			Organic matter				
Calliandra	591.09	500.21	488.31	421.76	411.85	357.38	461.77^c
Gliricidia	591.09	490.56	495.44	558.84	576.86	587.40	550.03^a
Leucaena	591.09	512.42	562.51	495.02	470.48	472.23	517.29^b
Mean	591.09^a	501.06^c	515.42^b	491.87^c	480.74^d	472.34^d	
			Nitrogen				
Calliandra	606.49	440.25	404.18	412.97	325.83	296.88	414.43^c
Gliricidia	606.49	810.83	830.53	860.93	810.81	729.47	774.84^a
Leucaena	606.49	425.95	585.11	495.96	443.09	467.25	503.98^b
Mean	606.49^a	559.01^b	606.61^a	603.73^a	514.58^c	497.87^c	

^{abcd}values with different superscripts in the same row or column are significantly different (($P \leq 0.05$), t=1.964.

Effective degradation (**ED**) for N in *Calliandra*/maize and *Leucaena*/maize silages (Table, 18) showed similar trends as for OM. However, **ED** values for *Leucaena*/maize silages showed peak degradation at 20% level of browse addition. The **ED** values for *Gliricidia*/maize silages increased to peak value at 30% level of browse addition and declined thereafter.

3.2.3.5 Browse effect on degradation constants for the browse/maize silages

Browse effect on OM degradation parameters (Table 19) showe that *Gliricidia*/maize silages had higher ($P \leq 0.05$) **w**, **a** and **c** values and lower ($P \leq 0.05$) **tl** values.

Table 19: Browse effect on OM degradation (g/kg)constants for the browse/maize silages

Constants	Browse/maize silages		
g/kg OM	*Calliandra*	*Gliricidia*	*Leucaena*
w	241.06^{b}	247.15^{a}	251.81^{a}
a	249.89^{b}	262.45^{a}	251.79^{b}
b	531.81^{a}	502.05^{b}	440.63^{c}
pd	781.70^{a}	764.50^{b}	692.41^{c}
c	0.025^{b}	0.047^{a}	0.048^{a}
tl	0.941^{b}	0.932^{c}	0.991^{a}
ed	461.77^{c}	550.03^{a}	517.29^{b}

^{abc} Values with different superscripts in the same row are significantly different ($P \leq 0.05$), t = 1.964w - washable fraction, a - rapidly soluble fraction, b - slowly degradable fraction, PD - potential degradability (a+b), tl - lag time in hours, c - rate of degradation at fraction b (per hour), ED - effective degradability

Calliandra/maize silages had higher ($P \leq 0.05$) **b** and **PD** values, but lower ($P \leq 0.05$) **tl** values than *Leucaena*/maize silages. Values of **ED** were higher ($P \leq 0.05$) for *Gliricidia*/maize silages than for *Leucaena*/maize and *Calliandra*/maize silages.

Browse effect on N degradation constants (Table 20) showed that *Gliricidia*/maize silages had higher ($P \leq 0.05$) values for **w** and **a** values than *Leucaena*/maize and *Calliandra*/maize silages.

Table 20: Browse effect on N degradation (g/kg)constants for the browse/maize silages

Constants	*Browse/maize silages*		
g/kg N	*Calliandra*	*Gliricidia*	*Leucaena*
w	286.66^{b}	365.20^{a}	289.69^{b}
a	297.31^{b}	389.18^{a}	297.22^{b}
b	2554.60^{a}	430.40^{b}	374.16^{c}
pd	2851.91^{a}	819.58^{b}	671.38^{c}
c	0.013^{c}	0.035^{b}	0.047^{a}
tl	1.019^{b}	0.913^{c}	1.087^{a}
ed	414.43^{c}	774.84^{a}	503.98^{b}

^{abc} Values with different superscripts in the same row are significantly different ($P \leq 0.05$), $t = 1.964$

w - washable fraction, a - rapidly soluble fraction, b - slowly degradable fraction, PD - potential degradability (a+b), tl - lag time in hours, c - rate of degradation at fraction b (per hour), ED - effective degradability

Calliandra/maize silages had higher ($P \leq 0.05$) values of **b** and **PD** values, but lower ($P \leq 0.05$) values for **c** and **tl** for N degradation while *Leucaena*/maize silages had lower ($P \leq 0.05$) values for **b** and **PD** but, higher ($P \leq 0.05$) values for **c** and **tl**. Values for **PD** for N degradation were higher ($P \leq 0.05$) for *Gliricidia*/maize silages than for *Leucaena*/maize and *Calliandra*/maize silages.

3.2.3.6 Rumen microbial protein (RMP) synthesis

The mean values show that RMP synthesis decreased ($P \leq 0.05$) with higher levels of browse addition (Table 21). Browse effect results show that RMP synthesis was higher ($P \leq 0.05$) for *Gliricidia*/maize silages than for *Leucaena*/maize and *Calliandra*/maize silages. However, RMP synthesis with *Gliricidia*/maize silages increased with addition of 20% or more browse. Rumen microbial protein synthesis with *Leucaena*/maize silages showed a peak at 20% level of browse addition and thereafter declined. It decreased steadily with *Calliandra*/maize silages.

Table 21: Rumen microbial protein (RMP) synthesis (g/kg DM) for the maize silages containing different levels of browse

Browse	Browse level (%)						
	0	10	20	30	40	50	Mean
Calliandra	82.50	70.53	67.17	58.13	57.00	49.91	64.21^c
Gliricidia	82.50	68.09	68.66	77.51	79.92	82.07	76.46^a
Leucaena	82.50	71.55	78.56	69.15	63.84	66.56	72.03^b
Mean	82.50^a	70.06^b	71.46^b	68.26^c	66.92^c	66.18^c	

^{abc} values with different superscripts in the same row or column are signifantly different ($P \leq 0.05$), t = 1.964

3.2.4.0 Discussion

3.2.4.1 Fermentation characteristics of the browse/maize silages

Butyric acid content was lower in all the browse/maize silages compared to the maize silage (Table 10). Addition of browse could have therefore, minimised undesirable butyric acid fermentation as it increased DM content, particularly in *Calliandra*/maize silage (Table 6). Butyric acid fermentation is more prevalent in low DM silages even when the pH of the silage is low (Vetter and Kendall, 1978; Mahana, 1997). While lactic acid content in *Gliricidia*/maize (Table 7) and *Leucaena*/maize (Table 8) silages was similar to that of maize silage, it was lower for *Calliandra*/maize silage (Table 6) with 30% or more level of browse addition. Lactic acid is the stronger and preserving acid in silage (Vetter and Kendall, 1978; Mahana, 1997). Therefore, the lower levels of lactic acid observed in *Calliandra*/maize silages (Table 9) with more than 30% browse addition (Table 6) indicate that the silages would not keep as well as *Gliricidia*/maize and *Leucaena*/maize silages even though the pH levels were low. Addition of more than 20% browse in all the silages lowered ($P \leq 0.05$) the concentration of NH_3 –N. This indicated decreased proteolysis and deamination of protein in the browse/maize silages as well as limited fermentation (Bareeba, 1979; Cushnahan and Gordon, 1995; Cushnahan and Mayne, 1995). The limited fermentation and proteolysis in *Calliandra*/maize silages could be attributed to the high DM content of *Calliandra* (Bareeba, 1979) and the fact that *Calliandra* has high content of tannins and lignin (Bareeba and Aluma, 2000),which are capable of adsorbing and binding nitrogen, carbohydrates, fibre and microbial enzymes (Zahedifar, 1977; Fahey, *et al*., 1980; Hill, *et. al*., 1987; Navas-Camancho *et al.*, 1993; Moya-Rodriguez *et al.*, 2002). Also, addition of more than 20% browse in all the silages decreased ($P \leq 0.05$) DM losses. The results of this study indicated that addition of *Gliricidia* to the silage did not affect the quality of the silage. However, there would be limited fermentation in silages having more than 30% browse addition.

3.2.4.2 Chemical composition of the browse/maize silages

Addition of browse in all the silages (Table 11, 12, 13 and 15) increased ($P \leq 0.05$) CP content with a decreasing trend of NPN content. However, browse addition of 30% or more resulted in increased NDF, ADF, NDFN, ADFN and ADL indicating diminishing nutritional value of additional browse. The combined effect of higher levels of fibre-bound N and lower levels of CP could have contributed to *Calliandra*/maize silages having lower ($P \leq 0.05$) levels of NPN (Table 14). The fibre fractions, ADF and ADL, which are resistant to fermentation and the less soluble fibre-bound N, were higher ($P \leq 0.05$) in *Leucaena*/maize silages than in *Gliricidia*/maize silages. Hence, *Leucaena*/maize silages had lower ($P \leq 0.05$) levels of NPN than *Gliricidia*/maize silages although the two silages had similar levels of CP indicating greater solubilization of N to have occurred in *Gliricidia*/maize silages than in *Leucaena*/maize silages. These results therefore, indicate that silages of 20% browse/maize mixture (DM basis) would ferment well and would have 9-12% CP and fibre-bound N and ADL content would be lower than in the browses alone.

3.2.4.3 Degradation of the browse/maize silages

Each level of browse addition reduced OM and N degradation particularly in *Calliandra*/maize silage. (Fig. 4, 5 and 6) although each level of browse addition increased ($P \leq 0.05$) CP content of the silages, which should have enhanced degradation of the silages with higher levels of browse addition (Sutton *et al.*, 1994; Koster *et al.*, 1996). Reduced degradation of OM and N in *Calliandra*/maize silages with higher levels of browse addition could have been as a result of the silages having less ($P \leq 0.05$) NPN content (Table 11) to enhance degradation. Also, *Calliandra*/maize silages had higher ($P \leq 0.05$) levels of lignin (Table 14), and *Calliandra* contains tannins, which are known to affect enzyme activity of rumen bacteria (Molina, *et al.,* 1999; El hassan, *et al.,* 2000). Degradation in *Leucaena*/maize silages declined with increasing levels of browse addition (Fig.6), but not to the same extent as in *Calliandra*/maize silages. *Leucaena* also contains tannins, but not as much as in *Calliandra* (Bareeba and Aluma, 2000). Therefore increasing concentration of tannins with higher levels of browse additon could have caused the decline in degradation of silages with higher levels of *Leucaena* browse.

Organic matter and N in all *Gliricidia/maize* silages were degraded to a similar extent as the maize silage (Fig. 5). This could have been possible as addition of *Gliricidia* to the silages increased ($P \leq 0.05$) CP content without affecting the level of NPN content (Table 12). Besides, *Gliricidia* has very low tannin content (Bareeba and Aluma, 2000), which would otherwise affect degradation at higher levels of browse inclusion in the silages (Hill, *et al.*, 1987; Navas-Camancho *et al.,* 1993; Moya-Rodriguez *et al.,* 2002). Browse/maize silages containing less than 20% browse had higher ($P \leq 0.05$) **PD** for OM and N than maize silage alone (Table 16 and 17). Kabatange and Shayo (1991) also reported improved degradation of maize stover when supplemented with *Leucaena* hay. Addition of up to 20% browse improved mean **PD** values, however additional browse resulted in declining degradation with the 40% and 50% browse addition having lower degradation than maize silage. The higher degradation of the silages with 20% browse addition could have been as a result of higher ($P \leq 0.05$) CP content of the browse/maize silages (Table 11, 12, 13 and 15). Various reports have indicated increased silage or low quality roughage intake and digestibility as a result of protein supplementation (Sutton *et al.,* 1994; Aston *et al.,* 1994). Muinga *et al.*, (1995) observed increased rumen NH_3-N and rate of rumen degradation of Napier grass when steers were fed the Napier grass supplemented with *Leucaena.* The declining degradability of silages containing more than 30% browse inspite of higher CP content could have been due to increasing levels of ADL and much of the N being fibre-bound, particularly as ADFN (Table 11,12 and 13) resulting in less N being available to enhance degradation.

The mean **c** values for OM (Table 16) had a decreasing trend ($P \leq 0.05$) with browse addition to the silage, while **tl** values had an increasing trend. These trends of decreasing **c** values and increasing **tl** values with increasing levels of browse addition conform to the trend of decreasing degradation with browse additon already observed, particularly in *Calliandra*/maize silages (Fig. 4). The decrease in degradation of the silages with browse addition is much more evident with **PD** values for *Calliandra*/maize and *Leucaena*/maize silages (Table 18). *Calliandra*/maize silage has the least **ED** value for OM and N (Table 18). The decrease in degradation occurred inspite of increasing CP content with browse addition to the silage. These results indicate that *Calliandra*/maize silages were poorly degraded as it has been reported before (Kamatali *et al.,* 1992; Jones *et al.*, 1992). *Gliricidia*/maize silages had increasing **c** and decreased **tl** values for OM particularly for the 40% and 50% browse levels. Also, *Gliricidia*/maize silages had the highest **ED** value (Table 18), highest **c** and least **tl** values for OM (Table 19). These results indicate that *Gliricidia*/maize silages were most degraded compared to the other silages. Fermentation was greater in *Gliricidia*/maize silages with higher acetic acid, lactic acid and NH_3-N levels (Table 9). Also, *Gliricidia*/maize silages had higher ($P \leq 0.05$) soluble N as NPN, least fibre bound N and ADL (Table 14). These, factors could have been responsible for the higher degradation of *Gliricidia*/maize silages.

Similarly, **PD** values for N for *Calliandra*/maize and *Leucaena*/maize silages indicate declining degradation with higher levels of browse addition (Table 17). This is more apparent with **ed** values (Table 18). Also, *Calliandra*/maize silage had the lowest **c** and **ed** values compared to the other silages (Table 20). The mean **PD** values for N in *Calliandra*/maize silage were higher than 1000g/kg (Table 17 and 20) as a result of the high content of tannins in *Calliandra* (Bareeba and Aluma, 2000), which adsorb and bind fibre and protein material (Fahey, *et. al.,* 1980; Jones *et. al.,* (1992). *Gliricidia*/maize silage had an increasing trend of **c** values for N with browse addition and its **tl** values were lowest for the 40% and 50% browse levels (Table 17). Besides, *Gliricidia*/maize silages had the highest ($P \leq 0.05$) **ED** value for N compared to the other silages (Table 20). These results indicate that degradation of N was greater in *Gliricidia*/maize silages than in either *Calliandra*/mize or *Leucaena*/maize silages. *Gliricidia* does not contain substancial levels of tannins (Bareeba and Aluma, 2000), and *Gliricidia*/maize silages contained less fibre bound N and more soluble NPN than the other silages (Table 12). These factors could have enhenced degradation of *Gliricidia*/maize silages.

3.2.4.4 Rumen microbial protein (RMP) synthesis

Maize silage is a high-energy feed and would therefore have the energy that is essential for RMP synthesis (Bareeba, 1979). Rumen microbial protein synthesis decreased with higher levels of browse addition to the silage (Table 21). Browse addition could have therefore, decreased available energy in the browse/maize silages. The trend was particularly apparent with *Calliandra*/maize and *Leucaena*/maize silages, although there was peak RMP synthesis with 20% *Leucaena*/maize silage. Besides available energy, adequate available N in the form of NH_3-N is critical for RMP synthesis (Bareeba, 1979; Rowe, *et. al.,* 1980; Preston and Leng, 1987). *Calliandra*/maize and *Leucaena*/maize silages had increasing levels of ADFN (Table 11 and 13) and therefore, less available N for rumen microbial metabolism with higher levels of *Calliandra* or *Leucaena* browse addition. Rumen microbial protein synthesis declined in the 30% and higher levels of *Leucaena* browse additon. The ADFN content was higher ($P \leq 0.05$) with 30% or more levels of *Leucaena* browse addition (Table 13). On the other hand, RMP synthesis tended to increase with browse addition of over 20% in *Gliricidia*/maize silages (Table 21). In *Gliricidia*/maize silages, soluble N (NPN) content was not affected by browse addition while ADFN content decreased, which could have made more N available for rumen microbial metabolism than with *Calliandra*/maize or *Leucaena*/maize silages.

3.2.5 Conclusion

The results from this study indicate that *Gliricidia* is more beneficial as a browse than either *Calliandra* or *Leucaena* for inclusion in browse/maize silage mixtures. Browse/maize silage mixtures of 20–30% DM basis would be most beneficial in terms of fermentation, nutrient composition, rumen degradation and supporting RMP synthesis.

3.3.0 EXPERIMENT 3: Effect of ensiled browse/maize fodder mixtures of *Calliandra calothyrsus*, *Gliricidia sepium* or *Leucaena leucocephala* on intake, digestibility and weight gain of dairy calves

3.3.1.0 Introduction

Inadequate nutrition of livestock is a major constraint to livestock production in the tropics (ILCA, 1989; Mugerwa, 2001). When malnutrition occurs in the young stock, it results into reduced growth rate and longer time to first calving and reduced lifetime milk production. In Uganda, it was observed that maximum lifetime milk yield would be obtained if heifers calved at about 24 months of age and in order to have heifers large enough to calve at 24 months of age, they would need to gain about 600g per day from birth to calving supported by good feeding and management (Christensen and Mugerwa, 1973). Most calves in developing countries however, are expected to obtain most of their nutrients from the cheapest and most available feed resources such as pasture and crop residues, which are low in N (Preston and Leng, 1987). This arises because there is minimal application of fertilizers on the pastures. Calves offered such forages are therefore unlikely to consume adequate nitrogen for efficient rumen digestion (Hoover, 1986; Sabiiti, 2001).

Legume fodder trees have been advocated for because of their protein-rich foliage, and can improve production of animals fed on low quality grass pastures (Sabiiti and Cobbina, 1992; Sabiiti, 2001). Some of the most widely used tree legumes in the humid tropics are *Gliricidia, Leucaena, Calliandra* and *Sesbania* (Topps, 1992; Sabiiti and

Cobbina, 1992). *Gliricidia sepium and Leucaena leucocephala* have been found to improve intake of dry matter, rumen degradation and live-weight gain (Abdulrazak *et al.*, 1996). There are still conflicting reports on the utilization of *Calliandra calothyrsus.* Maasdorp *et al.*(1999) fed lactating cows with air-dried *A.boliviana*, *C calothyrsus* and *L. leucocephala* and found no beneficial effect with *C.calothyrsus*. However, Ebong *et al.* (1999) found leaf meal of *Calliandra calothyrsus* a potentially valuable substitute for soy bean meal.

Results from Experiment 2 showed that addition of browses to maize up to 30% resulted in good silage with high CP content (11.4-12.8%). In the present study, *Calliandra calothyrsus, Gliricidia sepium* and *Leucaena leucocephala* were ensiled with maize fodder at 30% (DM basis) and were fed to dairy calves. The objective of this study was to determine the intake and digestibility of the browse/maize silages and daily weight gain of the calves fed the silages.

3.3.2.0 Materials and methods

3.3.2.1 Ensiling

The silages were made in four trench silos capable of holding 2.5 tons of ensiled material each. One week prior to ensiling, the DM of the maize forage and the browses was determined by drying samples to constant weight in a forced air oven. The DM was found to be 23, 41, 25 and 30% for maize forage, *Calliandra, Gliricidia* and *Leucaena* browses respectively, which DM values were used to determine the proportions of the browses in the browse/maize silage mixtures. *Calliandra, Gliricidia* and *Leucaena* browses were ensiled with maize in the proportions of 240, 470 and 329kg of browse per ton of maize respectively so that browses made 30% (DM basis) of the mixtures. The control silage was maize ensiled alone. The materials were mixed as they were being put in the silos and compacted by trampling. The silages were allowed to ferment for 60 days before commencement of the feeding trial. The "buried bag" technique of Alfred *e, al.*, (1955) was used to determine dry matter fermentation losses. Bags of hesian material were used. The bags containing 5kg of the same maize/browses mixtures were buried at different levels in the silos. The bags were removed in the course of feeding.

3.3.2.2 Feeding trial

A Randomized Complete Block Design was used. Sixteen weaned Friesian calves, half of which were female and the other half males, were used and were blocked according to body weight (BW); Block I, 140 kg and over; Block II, 100-139 kg; Block III, 80-99 kg and Block IV, 70-79 kg. Each treatment was randomly assigned to one animal in each block. The experiment ran for eight weeks. The calves were weighed with an electronic weighbridge for three consecutive days in the mornings at the beginning of the experiment. Thereafter, the calves were weighed at weekly intervals in the course of the experiment. The animals were confined and fed individually at 8.00 hrs and 16 hrs and water was given *ad libitum*. Daily consumption (kg) of the silages per animal was determined as the difference between the silage (kg) offered and the refusals. Three methods, total collection, chromic oxide and acid insoluble ash indicator were used to determine the digestibility of the silages. Dosing the animals with chromic oxide (20g/day; 10g at the morning and evening feeding) was commenced in the fifth week and continued through the sixth week, which was the collection week. Samples of feed and faecal grab samples were collected daily in the morning and afternoon during the collection week and composited for each animal. For the total collection procedure, collection of the faeces for each animal was done daily in the morning at 8 hrs and 17hrs during the collection week. The faeces were weighed and samples taken to determine faecal DM and then faecal DM output. The animal pens were scrubbed clean daily after the 17 hrs. collection of faeces.

3.3.2.3 Chemical analyses

Analysis for DM losses, pH, VFA and NH_3-N of the buried bag silages was done as in Experiment 1 (Section 3.2.2). The DM of the silages and faeces was determined by drying silage samples in a forced air oven at 60°C for 48 hours. They were then ground to pass through a 2 mm sieve in a laboratory mill. Chemical analysis was done for OM, CP, NPN, Ca, P, NDF, ADF, NDFN, ADFN and ADL as with the laboratory silo silages in experiment 1 (Section 3.2.2). Chromic oxide was analysed according to AOAC (1990) procedures and acid insoluble ash according to Van Keulen and Young (1977).

3.3.2.4 Statistical analysis

The data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (1999). Where significant differences were obtained, means were separated using SE at probability level of 5%.

3.3.3.0 Results

3.3.3.1 Fermentation characteristics and chemical composition of the silages

The fermentation characteristics of the silages are given in Table 22. *Calliandra*/maize silage had higher ($P \leq 0.05$) DM content than the other silages. Maize silage alone had higher ($P \leq 0.05$) acetic acid content while *Gliricidia*/maize silage had higher ($P \leq 0.05$) lactic acid content than the others.

Table 22: Fermentation characteristics (% DM) of the maize silages containing 30% browse (DM basis) fed to weaned calves

	Browse/maize silage				
	Calliandra	Gliricidia	Leucaena	Maize	SE
DM(%)	32.33^{a}	27.03^{b}	28.70^{b}	28.77^{b}	0.65
Acetic Acid	1.23^{b}	0.87^{b}	0.89^{b}	2.42^{a}	0.24
Butyric Acid	0.11	0.48	0.10	0.12	0.08
Lactic Acid	3.83^{b}	5.28^{a}	3.64^{b}	3.52^{b}	0.13
pH	3.87^{b}	3.90^{b}	4.20^{a}	3.86^{b}	0.35
NH_3-N (% Total N)	5.08^{c}	5.47^{b}	4.93^{d}	5.86^{a}	0.24
DM Losses	3.15^{b}	7.81^{a}	3.17^{b}	6.19^{a}	0.73

^{ab} Values with different superscripts in the same row are significantly different ($P \leq 0.05$).

Leucaena/maize silage had higher ($P \leq 0.05$) pH, compared to other silages. Maize silage had higher ($P \leq 0.05$) NH_3-N content than the browse/maize silages. Ammonia nitrogen content differed ($P \leq 0.05$) among the browse/maize silages with *Calliandra*/maize silage having the highest. Dry matter losses were higher ($P \leq 0.05$) in *Gliricidia*/maize and maize silages compared to the other silages. The chemical composition of the silages is summarized in Table 23. Browse/maize silages had higher levels of crude protein than maize silage. Most of the N in *Calliandra*/maize silage was fibre-bound as NDFN or ADFN. Also ADL tended to be high in *Calliandra*/maize and *Leucaena*/maize silage. Calcium content tended to be low in maize and *Leucaena*/maize silages.

Table 23: Nutrient composition (% DM) of the maize silages containing 30% browse (DM basis) fed to weaned calves.

	Browse/maize silage			
	Calliandra	Gliricidia	Leuceana	Maize
OM	93.09	92.70	92.56	90.97
Crude Protein	15.18	13.63	10.09	8.11
NPN (% Total N)	23.33	38.99	26.09	29.23
Calcium	0.63	0.55	0.28	0.19
Phosphorus	0.14	0.17	0.18	0.20
NDF	73.03	61.84	68.42	69.19
ADF	44.69	37.15	39.50	40.38
NDFN	85.34	42.04	50.99	47.80
ADFN	97.53	59.01	40.40	44.02
ADL	13.00	4.56	7.87	3.80

3.3.3.2 Feed intake, digestibility and weight gain

The DMI of the dairy calves (kg/day and g/kg$W^{3/4}$) of the silages is given in Table 24.

Table 24: Dry matter intake and digestibility of the maize silages containing 30% browse (DM basis) fed to weaned calves

	Browse/maize silages					
	Calliandra	Gliricidia	Leucaena	Maize		SE
Dry matter intake						
Kg/day	2.69	2.80	2.81	2.55		0.21
%BW	2.68	2.34	2.70	2.31 0.		0.9
g/kg$W^{3/4}$	84.70^{a}	77.35^{ab}	84.92^{a}	73.44^{b}		2.82
DM digestibility (%) by methods					**Mean**	
Total Collection	59.62	65.02	62.88	68.40	63.99^{a}	1.09
Chromic Oxide	62.70	69.05	62.59	62.12	64.11^{a}	1.09
Acid Insoluble Ash	64.22	58.91	58.55	56.80	59.62^{b}	1.09
Mean	62.18	64.33	61.34	62.45		1.09
Weight gain (kg/day)	-0.06^{c}	0.14^{a}	0.07^{b}	0.07^{b}		0.03

^{ab} Values with different superscripts in the same row or column are significantly different ($P \leq 0.05$).

Silage DMI (kg/day and %BW) were similar ($P>0.05$) among the silages. However, DMI as g/kg$W^{3/4}$ was lower ($P>0.05$) for maize compared to *Calliandra*/maize and *Leucaena*/maize silages. The browse/maize silages had similar DMI (g/kg$W^{3/4}$). The acid insoluble ash indicator method gave lower ($P \leq 0.05$) estimates of digestibility compared to the other methods. However, there were no significant ($P>0.05$) differences in DM digestibility between the silages. Calves fed *Calliandra*/maize silages had the least ($P \leq 0.05$) weght gains and their mean weight gain was negative (Table 24). Mean weight gain was higher ($P \leq 0.05$) with calves fed *Gliricidia*/maize silages compared to those fed either maize or *Leucaena*/maize silage. Nutrient digestibility values (Table 25) were calculated according to the chromic oxide indicator method.

Table 25: Apparent digestibility coefficients of nutrients of the maize silages containing 30% browse (DM basis) fed to weaned calves using chromic oxide method.

	Browse/maize silages				
Nutrient	Calliandra	Gliricidia	Leuceana	Maize	SE
OM	65.19^b	71.01^a	65.56^b	65.77^b	1.18
CP	56.27^b	62.88^a	19.76^c	46.29^b	4.54
NDF	58.49	61.30	56.49	58.42	1.60
ADF	52.91^a	46.65^a	38.03^b	45.30^a	2.03

abc Values with different superscripts in the same row are significantly different ($P < 0.05$)

Gliricidia/maize silages had higher ($P \leq 0.05$) OM digestibility than the others, which contained similar OM digestibilities. Also *Gliricidia*/maize silage had higher ($P \leq 0.05$) CP digestibility compared to the rest of the silages. *Leucaena*/maize silage had least ($P \leq 0.05$) CP digestibility. While NDF digestibility was similar among silages, ADF digestibility was lower ($P \leq 0.05$) in *Leucaena*/maize silage compared to the others.

3.3.4.0 Discussion

3.3.4.1 Silages

Fermentation characteristics of the silages fed (Table 22) show that *Gliricidia*/maize silage had higher ($P \leq 0.05$) lactic acid content and would therefore preserve better than the other silages because lactic acid is a stronger acid (Mahana, 1998). These results are similar to the results obtained with the laboratory silos in Experiment 2. Although *Leucaena*/maize silage had higher ($P \leq 0.05$) pH, all the silages had low pH levels of less than 4.2 indicating good silage fermentation (Mahana, 1997). Also, all the silages had comparable NH_3-N levels indicating similar degree of proteolysis and deamination to have occurred in the silages (Cushnahan and Gordon, 1995). Browse/maize silages had higher crude protein content (Table 23) indicating enrichment of the silages by addition of the browses. Most of the N in *Calliandra*/maize silage however, was fibre-bound as NDFN or ADFN, which could have been as a result of overheating (Weiss *et al.,* 1986). *Gliricidia*/maize silage had elevated levels of NPN, which could enhance its degradation and utilization in the rumen.

3.3.4.2 Feed intake

The higher levels of CP and lower ($P > 0.05$) levels of NH_3-N in browse/maize silages than in the maize silage (Table 22) could have contributed to the higher DMI of the browse/maize silages (Cushnahan and Gordon, 1995). Studies have indicated that the higher CP content of browses increase CP content of diets of grazing animals and subsequently increase their DMI (Jones, 1982; Reynolds and Adeoye, 1986; Ivory, 1990; Topps, 1992).

3.3.4.3 Digestibility of the silages

Dry matter digestibility values did not differ between total collection and chromic oxide indicator methods (Table 24), but were lower ($P \leq 0.05$) for acid insoluble ash indicator method. The mean DM digestibility from the three methods did not differ between the silages. *Gliricidia*/maize silage had higher ($P \leq 0.05$) OM digestibility than the other silages, whose OM digestibility values were similar (Table 25). In previous studies, *Gliricidia* has shown higher DM digestibilities or degradation in the rumen (Topps, 1992; Dzowela, *et al.,* 1995; Maasdorp *et al.,* 1999). *Gliricidia*/maize silage had relatively higher content of soluble N (NPN), less fibre and less fibre-bound N, which factors could have contributed to its higher OM digestibility. The lower DM or OM digestibility of *Leucaena* and *Calliandra* diets could be attributed to the high levels of tannins in the browses (Bareeba and Aluma, 2000).

Soluble N becomes available to the rumen microbes and auguments their activity and therefore, digestibility of diet material (Preston and Leng, 1987). However, while CP digestibility was higher ($P> 0.05$) in *Gliricidia*/maize silages, it was least ($P> 0.05$) in *Leaucaena*/maize silage. There are consistent reports that fibre bound protein in browses particularly *Calliandra* becomes available in the lower gut and it is valuable as bypass protein in ruminants (Kaitho, 1997; Mpairwe, 1998; Fahey *et al.* 1980; Hill *et al.*, 1987; Navas-Comacho *et al.* 1993; Zahedifar, 1997 and Moya-Rodriguez *et al.,* 2002). The protein adsorbed by lignin and tannins at higher pH in the rumen can be relased at low pH in the lower gut (Zahedifar 1997). These reports would lend credence to the observed high levels of CP digestibility in *Calliandra*/maize and *Gliricidia*/maize silages in this study.

Although there are reports of comparable CP digestibility or degradability for *Leucaena* and other browse diets (Topps, 1992; Jones *et al.*, 1992 Nguyen, 1998; Maasdorp *et al.*, 1999; Bareeba and Aluma, 2000), there are also reports of peculiar unavailability of CP in *Leucaena*. Flores *et al.*, (1979) reported that although the N content of *Leucaena* herbage was higher than that of grass (Rhodes grass), solubility *of Leucaena* N in a buffered (pH, 6.5) mineral solution was significantly ($P< 0.001$) lower than that of Rhodes grass. Yet, feeding *Leucaena* increased milk production when the cows were selecting a Rhodes-grass diet containing 18.2% CP. Flores *et al.*, (1979) anticipated that while the protective mechanism over N in *Leucaena* was unknown, the mimosine amino acid contained in *Leucaena* and converted to 3 hydroxy -4-(H)-pyridone (DHP), a potent goitrogen, in the rumen could stimulate the cow's metabolism and lead to increased milk production. El-Harith *et al.*, (1979) observed considerably higher mean faecal weight of rats receiving *Leucaena* meal plus ferrous sulphate treatment than that of the control animals. The mean feacal weight of animals offerred heat-treated *Leucaena* meal on the other hand was noticeably lower than that of the control animals. Tsumbira (2002) observed highest feacal N with goats receiving *Leucaena* supplemented diets, which was also reflected in poor N retained and N utilized while highest N absorbed was obtained with *Gliricidia* supplementation.

3.3.4.4 Weight gain of the calves

The mean, weight gains were low over 8 weeks of the experiment with all the silages. Weight gain was lowest with calves fed *Calliandra* /maize silages and their overall mean weight gain was negative. Comparatively *Calliandra* could be an inferior browse to *Leucaena* or *Gliricidia* in supporting weight gain and other productivity (Dzowela *et al.*, 1995; Massdorp *et al.,* 1999). Results in experiment 2 showed that degradation of *Calliandra*/maize silages is severely affected after 30% level of browse addition, which may have resulted in poor performance of calves fed the 30% *Calliandra*/maize silage. The presence of phenolics, have been implicated for the inadequate response of livestock to *Calliandra* or *Leucaena* feeding (Jones *et al.,* 1992; Kaitho, 1997; *Massdorp et al.,* 1999, Bareeba and Aluma, 2000). However, Ebong *et al.*, (1999) reported highest growth rate and most efficient feed utilization in goat kids fed a ration mixture of equal quantities of soybean meal and *Calliandra* leaf meal.

3.3.5 Conclusion

Inclusion of *Calliandra, Gliricidia* or *Leucaena* browses in browse/maize silage mixtures at 30% DM basis increased CP content and did not affect fermentation of the silages. *Calliandra* particularly increased DM content of the silages, which resulted in higher DMI. *Gliricidia*/maize silage had higher OM and CP digestibility than *Calliandra*/maize silage or maize silage alone while CP digestibility in *Leucaena*/maize silage was very low. Browse/maize silages alone, particularly *Calliandra*/maize silage did not adequately support weight gain of weaned calves.

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3.4.0 EXPERIMENT 4: Effect of feeding ensiled *Calliandra calothyrsus*, *Gliricidia* sepium and *Leucaena leucocephala* browse/maize mixtures supplemented with dairy meal on milk yield and composition

3.4.1 Introduction

Herbage quality, digestible energy and protein intake are among the most important factors limiting production by grazing cattle, particularly in areas with long dry spells of weather when green feed is limited (Mugerwa *et al.,* 1973; Jones, 1982; Kabirizi, *et al.,* 2000; Mugerwa, 2001). Therefore, there has been growing interest in legume tree fodders particularly because of their high CP content in their foliage and edible soft stems and their ability to remain green throughout the year (Topps 1992; Sabiiti and Cobina, 1992; Sabiiti, 2001). Supplementing grass fodder with legume tree fodders improves the overall N content of the diet, DMI and utilization resulting in higher livestock production (Muinga, 1993; Nguyen, 1998; Nguluve and Muiv, 1999; Maarsdorp *et al.,* 1999). Utilization of the tree forages can be improved by processing, such as wilting, drying or feeding them together with other feeds or forages inspite of the anti-nutritional factors they contain (Lowry, 1990; Topps, 1992). The most prevalent anti-nutritional factors found in legume tree forages are phenolics, tannins and lignin. Results of Experiment 2 showed that the 20% level of browse inclusion in the silages was optimal in terms of level of CP content, degradation of OM and N as well as RMP synthesis. In this experiment, *C. calorthyrsus, G. sepium* and *L. leucocephala* forages were ensiled with maize at 20% (DM basis) and fed to lactating dairy cattle. The objective of the experiment was to determine the milk producing ability of the browses when ensiled with maize.

3.4.2.0 Materials and methods

3.4.2.1 Ensiling

The silages were made at Makerere University Agricultural Research Institute, Kabanyolo. *Calliandra, Gliricidia* and *Leucaena* foliage (leaf and petiole, and edible soft stems) were harvested three months after pruning. The maize used (milk stage) was variety Longe 1, grown at the University farm. The silages were made in four trench silos with a capacity of 3 tons of ensiled material each. One week prior to ensiling, the DM of the maize crop and the browses was determined by drying samples to constant weight in a forced air oven. The DM values obtained were used to determine the proportions of browse and maize that would give mixtures of 20% browse (DM basis). The DM was found to be 39, 24, 24 and 25% for *Calliandra, Gliricidia, Leucena* and maize respectively. At these levels of DM, the browses were ensiled with maize in the proportions of 160 kg of *Calliandra* and 250 kg of *Gliricidia* and *Leucaena* each per ton of maize. The control treatment was maize silage alone.

The materials were mixed as they were put in the silos and compacted by trampling. The sides and the top of the silos were covered with polythene sheeting and then covered with soil. The silages were allowed to ferment for 60 days before commencement of the experiment. The "buried bag" technique of Alfred *et al.* (1955) was used to determine dry matter fermentation losses. Bags of hesian material were used. The bags containing 5 kg of the same browse/maize mixtures were buried at different levels in the silos and removed at the time of feeding.

3.4.2.2 Feeding and sample collection

A 4x4 Latin square design was used for the experiment with four lactating Friesian dairy cows in early lactation. There were four feeding periods of 28 days each in which the adjustment period was two weeks and data were collected for two weeks. The animals were confined in stalls and fed from troughs. The stalls were cleaned daily in the mornings and afternoons. At the commencement of the experiment, the animals were weighed for three consecutive days and were allowed one week to adjust to the stalls. Thereafter the animals were weighed at the end of each feeding period using a portable electronic weighbridge. Fresh silages were offered in troughs each day in two equal meals at 8 hrs and 14 hrs and the day's silage offer (kg) was recorded during the last 2 weeks of each period. During the collection period samples of the silages and refusals for DM determination were taken daily and stored in a cold room and silage samples were then bulked. Water was available to the animals all the time.

Total digestible nutrients (TDN) was used as the basis for determining the supplementation level required by the animals. Feeding standards obtained from Etgen and Reaves (1978) were used. The average body weight of 400 kg and milk yield of 10 kg per day were used to estimate the cow's maintenance and milk production requirements for TDN. The corresponding requirements were 3.1kg of TDN for maintenance and 0.33 kg of TDN per kg of 4.0% fat corrected milk yield per day. Silage intake was estimated at 10 kg DM per day and to be containing 65% TDN. The level of daily supplementation determined per animal was therefore 4 kg of dairy meal containing

75% TDN. The concentrate was offered in two equal halves during milking at 8 hrs and 14 hrs.

The chromic oxide indicator method was used for determination of digestibility. The animals were dosed with 20g of chromic oxide daily in two equal halves of 10g for the a.m. and p.m. feeding. Dosing with chromic oxide commenced in the second week and continued through the third week during which collection of grab feacal samples was done. Grab feacal samples were taken daily in the morning and afternoon and composited for the one week of collection.

Milk yield was recorded daily for the morning and afternoon milking during the last two weeks of each period. The am and pm milk samples were obtained after the milk was thoroughly mixed. The samples were strained through a clean piece of cloth and preserved with 3 to 4 drops of 10% potassium dichromate. The am and pm samples were composited and mixed thoroughly to make a day's sample. The samples were kept in a cold room until analysed for protein, butter fat, and total solids.

3.4.2.3 Chemical analyses

Dry matter losses, pH, VFAs and NH_3-N of the silages from the bags were determined as described in Experiment 2. The dry samples of the silages collected during the 14 days of data collection were composited, dried and ground in a laboratory mill to pass through a 1mm sieve and stored in air tight sample bottles until analysed. The composited feacal samples were air dried, and ground to pass through a 1mm sieve in a laboratory mill and stored for chemical analysis. Chemical analyses were done on feed and feacal samples as described in experiment 3. Milk samples were analysed for total protein by the Kjeldah method; butter fat by the Gerber method, total solids by evaporation and total-solids-not fat by difference between butter fat from total solids.

3.4.2.4 Estimation of energy content of rations

MAFF (1987) guidelines were used for determining energy and protein requirements for the cows. The equivalents used for the thermochemical calorie and 1Mcal. were 4.184J and 4.184MJ respectively. The feed energy value used was 18.1MJ/kg DM, which is the mean energy value of the majority of feeds fed to cattle (MAFF 1987). The equation used for determining feed metabolisable energy (MEF) according to MAFF (1987) guide lines was:

$$\mathrm{MEF} = 0.15\mathrm{DOMD\%}\ \mathrm{MJ/kgDM}$$

where, DOMD is digestible organic matter in dry mater. The expression used for determining DOMD% was according to MAFF (1987) guide lines as follows:

$$\%\mathrm{DOMD} = \frac{\underline{(\mathrm{Feed\ OM} - \mathrm{Faeces\ OM})} \times 100}{\mathrm{Feed\ DM}}$$

3.4.2 5 Statistical analysis

The data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (1999). Where significant differences were obtained, means were compared using SE at probability level of 5%.

3.4.3.0 Results

3.4.3.1 Fermentation characteristics and chemical composition of the silages

The fermentation characteristics of the silages fed are given in Table 26.

Table 26: Fermentation characteristics (%DM) of the maize silages containing 20% browse (DM basis) fed to lactating cows

	Browse/maize silages				
Characteristic	Calliandra	Gliricidia	Leucaena	Maize	SE
DM%	31.77^{a}	28.50^{b}	26.13^{b}	23.28^{bc}	1.05
Acetic Acid	2.11	1.95	2.16	2.16	0.13
Butyric acid	0.12^{b}	0.79^{a}	0.65^{a}	0.29^{b}	0.09
Lactic acid	4.75^{b}	3.26^{c}	3.73^{bc}	6.20^{a}	0.40
pH	4.33	4.18	3.81	3.67	0.29
NH_3-N(% Total N)	5.49	5.97	6.24	5.73	0.28
DM Losses %	5.01^{b}	0.28^{c}	7.41^{b}	13.50^{a}	1.83

^{abc} Values with different superscripts in the same row are significantly different ($P \leq 0.05$).

Calliandra/maize silage had higher ($P \leq 0.05$) DM content than the rest of the silages while maize silage had the least. Butyric acid content was higher ($P \leq 0.05$) in *Gliricidia*/maize and *Leucaena*/maize silages compared to *Calliandra*/maize and maize silages ehile acetic acid was similar among silages. Lactic acid content was higher ($P \leq 0.05$) in maize silage compared to the browse/maize silages. However, pH was not different among silages. Levels of NH_3-N were similar in all the silages. Dry matter losses were higher ($P \leq 0.05$) in maize silage compared to the browse/maize silages. The chemical composition of the silages and dairy meal fed is given in Table 27.

Table 27: Chemical composition (%DM) of dairy meal and maize silages containing 20% browse (DM basis) fed to lactating cows

		Browse/maize silages			
	Dairy meal	Calliandra	Gliricidia	Leucaena	Maize
OM	89.63	92.94	92.45	91.63	92.63
CP	16.67	10.65	11.88	11.66	7.99
NPN (%Total N)	12.35	21.95	34.71	27.02	41.28
Ca	0.52	0.13	0.18	0.13	0.08
P	1.31	0.40	0.65	0.51	0.48
NDF	48.07	67.07	61.70	64.90	70.60
ADF	24.03	42.40	37.33	35.58	38.27
NDFN (%Total N)	13.86	34.49	25.40	31.72	21.52
ADFN (%Total N)	6.37	24.82	11.58	14.42	16.14
ADL	8.92	19.58	11.85	13.75	6.40

Maize silage had lower CP content, but higher NPN content compared to the browse/maize silages. Also, maize silage had higher NDF content, but its ADF content was comparable to that of the browse/maize silages. *Calliandra*/maize silage had higher fibre-bound N as NDFN or ADFN compared to the other silages. The content of ADL was higher in *Calliandra*/maize silage.

3.4.3.2 Silage dry matter consumption and digestibility

Silage DMI as well as total DMI were higher ($P \leq 0.05$) for *Calliandra*/maize and *Gliricidia*/maize silages than for *Leucaena*/maize or maize silage (Table 28). Total DMI (%BW and g/kg$W^{3/4}$) were similarly higher ($P \leq 0.05$) for *Calliandra*/maize and *Gliricidia*/maize silages than for either *Leucaena*/maize or maize silage.

Table 28: Dry matter intake of maize silages containing 20% browse (DM basis) fed to lactating cows supplemented with dairy meal

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
DM Intake (kg/day)					
Silage	10.50^{a}	9.68^{ab}	9.04^{b}	9.23^{b}	0.40
Supplement	3.66	3.66	3.66	3.66	-
Total	14.16^{a}	13.34^{ab}	12.70^{b}	12.89^{b}	0.40
Silage (g/kgW$^{3/4}$)	120.85^{a}	112.07^{ab}	103.70^{b}	106.39^{b}	3.84
Total DMI					
%Body weight	3.63^{a}	3.50^{a}	3.29^{b}	3.36^{b}	0.08
g/kgW$^{3/4}$	163.33^{a}	154.74^{ab}	145.85^{b}	148.61^{b}	3.65

^{ab} Values with different superscripts in the same row are significantly different ($P \leq 0.05$).

The digestibility coefficients of the silages are shown in Table 29. Dry matter, OM and NDF digestibilities and DOMD were higher ($P \leq 0.05$) with *Leucaena*/maize and maize silages compared to the other silages. However, intake of digestible DM and OM were similar for all the silages. Digestibility coefficient for CP was least ($P \leq 0.05$) for *Calliandra*/maize silage while that of NDF was higher ($P \leq 0.05$) for *Leucaena*/maize and maize silages. Digestibility for ADF was similar for all the silages. There was higher ($P \leq 0.05$) intake of digestible CP from *Gliricidia*/maize and *Leucaena*/maize silages compared to maize silage.

Table 29: Apparent digestibility coefficients and digestible nutrient intake of maize silages containing 20% browse (DM basis) and body weight gain of lactating cows fed the silages supplemented with dairy meal

	Browse/maize silage				
Nutrient	Calliandra	Gliricidia	Leucaena	Maize	SE
Apparent digestibility coefficient %					
DM	65.76^{b}	67.13^{b}	73.52^{a}	70.59^{a}	1.21
OM	68.58^{b}	71.02^{b}	76.30^{a}	73.68^{ab}	1.10
DOMD	63.15^{b}	65.12^{b}	69.44^{a}	67.65^{ab}	0.97
CP	61.88^{b}	68.07^{a}	71.30^{a}	67.20^{a}	1.51
NDF	63.22^{b}	61.50^{b}	73.25^{a}	70.77^{a}	1.75
ADF	57.54	55.01	55.93	56.17	1.73
Digestible nutrient intake					
DM (kg/ day)	9.31	8.96	9.34	9.10	0.16
OM (kg/day)	8.94	8.69	8.82	8.72	0.25
CP (kg/day)	1.07^{ab}	1.20^{a}	1.18^{a}	0.91^{b}	0.06
ADF (kg/day)	3.07^{a}	2.47^{b}	2.29^{b}	2.48^{b}	0.18
ME (MJ/day)	134.10	130.33	132.33	130.83	
CP intake/NRC Reqmt %	89.17	109.09	100.85	79.82	
ME intake/NRC Reqmt %	134.92	131.06	135.76	137.22	
Average BW gain (kg/day)	0.52^{a}	0.28^{ab}	0.12^{b}	0.23^{ab}	0.16

^{ab} Values with different superscripts in the same row are significantly different($P \leq 0.05$).

The browse/maize silages resulted into similar CP intake. There was higher ($P \leq 0.05$) intake of digestible ADF associated with *Calliandra*/maize silage compared to the other silages. Intake of digestible CP with *Gliricidia*/maize and *Leucaena*/maize silages could meet the animals' requirements but, not with *Calliandra*/maize and maize silages. Intake of ME with all the silages could meet the animals' requirements. Average body weight gain of the animals was higher ($P \leq 0.05$) with *Calliandra*/maize silage and least ($P \leq 0.05$) with *Leucaena*/maize silage.

3.4.3.3 Milk yield and composition

Milk yield and fat-corrected milk yield (FCM) were higher ($P \leq 0.05$) with *Calliandra*/maize and *Gliricidia*/maize silages than with *Leucaena*/maize or maize silage (Table 30).

Table 30: Effect of silage type on milk yield and composition by cows fed maize silages containing 20% browse (DM basis) supplemented with dairy meal

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
Milk yield (kg/day)	9.72^{a}	9.86^{a}	9.46^{b}	9.04^{c}	0.07
BF, %	3.86	3.81	3.81	3.81	0.04
4% FCM (kg/day)	9.56^{a}	9.57^{a}	9.19^{b}	8.78^{c}	0.09
Protein, %	2.62^{b}	2.65^{ab}	2.62^{b}	2.69^{a}	0.02
Solids-not-fat, %	8.09^{b}	7.92^{b}	8.13^{ab}	8.26^{a}	0.11
Total Solids, %	11.95^{ab}	11.73^{b}	11.94^{ab}	12.07^{a}	0.09
BF yield kg/day	0.38^{a}	0.37^{ab}	0.36^{ab}	0.35^{b}	0.01
Protein yield kg/day	0.25	0.25	0.25	0.24	0.01

^{abc} Values with different superscripts in the same row are significantly different ($P \leq 0.05$).

Feeding maize silage resulted into the lowest ($P \leq 0.05$) milk yield. Milk CP (%) was higher ($P \leq 0.05$) with maize silage than *Calliandra*/maize and *Leucaena*/maize silages. Butter fat % was similar among the silages, but % TS and % SNF were lower ($P \leq 0.05$) with *Gliricidia*/maize silage compared to maize silage. Butterfat yield was lower ($P \leq 0.05$) with maize silage compared to *Calliandra*/maize silage. Protein yield was not affected by type of silage.

3.4.4.0 Discussion

3.4.4.1 Fermentation characteristics and chemical composition of the silages

The higher ($P \leq 0.05$) butyric acid concentration in *Gliricidia*/maize and *Leucaena*/maize silages (Table 26) would ultimately reduce their DMI (Cushnahan and Gordon, 1995). The higher ($P \leq 0.05$) lactic acid content in maize silage indicated better fermentation in maize silage than in browse/maize silages (Mahana 1997). The similar levels of pH of all the silages indicate that addition of 20% browse did not affect silage acidity substantially, as in Experiment 2. Ammonia N levels were also similar in all the silages (Table 26) although maize silage had relatively lower CP content (Table 21). Ammonia N has been used as an index of proteolysis particularly in grass silages (Bareeba 1979). There was more NH_3-N produced in maize silage as the results of Experiment 2 indicate but it could have combined with the silage organic acids and formed ammonium salts (Bareeba, 1979) resulting in the higher NPN content of maize silage (Table 15 and 31). The ammonium salts would be an added advantage resulting in better utilization of the silages and N retention (Bareeba, 1979).

The browse/maize silages had higher CP with less soluble N (NPN) indicating less protein breakdown during fermentation than in maize silage. This would make them less degradable in the rumen as found in Experiment 2. indicated. The higher content of fibre-bound N (NDFN and ADFN) and lignin in *Calliandra*/maize silage could render the silage less degradable than the other silages as was the case in Experiment 2. Soluble N and readily available N would be readily converted to NH_3-N, which is required for rumen microbial metabolism (Preston and Leng, 1987). Lignin content, which was high in *Calliandra*/maize silage could impede digestion of fibre in the silage (Moya-Rodriguez *et al.*, 2002).

3.4.4.2 Silage dry matter consumption and digestibility

Calliandra/maize silage had higher ($P \leq 0.05$) DMI as a result of its higher initial DM content. Also butyric acid, which is one of the factors that reduces silage DMI (Cushnahan and Gordon, 1995), was low in *Calliandra*/maize silage (Table 26). Of the browse silages, *Leucaena*/maize silage had lower ($P \leq 0.05$) silage DMI than the rest (Table 32). *Leucaena*/maize silage could have undergone a more extensive fermentation as indicated by its higher ($P \leq 0.05$) levels of DM losses and relatively higher NH_3-N (Table 26), which could have reduced its DMI (Cushnahan and Gordon, 1995). The lower DM content, low CP content and higher soluble N (NPN) content of maize silage (Table 27) could have contributed to its low DMI (Cushnahan and Gordon, 1995; Koster, *et al.*, 1996). It was not clear why *Leucaena*/maize silage had higher ($P \leq 0.05$) disgestibility for DM, OM and NDF compared to the other silages (Table 29) since all the silages fermented equally well (Table 26) and their chemical composition were comparable (Table 27). Abdulrazak *et al.*, (1996) supplemented steers on napier grass with increasing levels of dried *G.sepium* or *L.leucocephala.* Both browses increased total DMI linearly, but neither *Gliricidia* nor *Leucaena* supplementation affected the apparent digestibility of the diet.

All the silages resulted into similar intake of digestible DM, OM DOMD and ME (Table 29). Intake of digestible CP was relatively lower with *Calliandra*/maize and maize silages. *Calliandra*/maize silage had relatively lower CP digestibility although it had higher (P≤0.05) DMI. Maize silage had both lower DM intake and CP content. As a result, CP intake with *Calliandra*/maize and maize silages were lower and could not meet the cows' digestible CP requirements for maintenance and milk yield (Table 29). However, ME intake was adequate for all the diets.

None of the silages consistently caused weight loss in the animals (Table 30). Body weight gains were higher (P≤0.05) with *Calliandra*/maize silage compared to *Leucaena*/maize silage. It is possible that at 20% browse/maize silage mixture used in the experiment, the dilution ameliorated the adverse effects of tannins and lignin on the utilization of the silage. Body weight gain was least with *Leucaena*/maize silage and milk yield was also lower (P≤0.05) with *Leucaena*/maize silage than with *Calliandra*/maize or *Gliricidia*/maize silages, which would be in agreement with reported deteriorating performance of animals fed *Leucaena* diets (Quirk, *et al*., 1988; Hammond, 1995).

3.4.4.3 Effect of silage type on milk yield and composition

Milk yield and 4%FCM were higher (P≤0.05) with the browse/maize silages than with maize silage alone (Tabe 30). Muinga *et. al.,* (1995) working with *Bos indicus* x *Bos taurus* dairy cows obtained higher milk yield with increasing levels of *Leucaena* supplementation of napier grass. This was attributed to increased DMI caused by increased rumen NH_3-N concentration and rate of rumen degradation of Napier grass when *Leucaena* was offered. Results of Experiment 2 showed that browse/maize silages had higher degradation than maize silage alone. Abdulrazak *et al*., (1996) obtained higher total DMI, rumen NH_3-N and liveweight gain with increasing levels of G.*sepium* or L.*leucocephala* supplementation of *Bos Taurus* X *Bos indicus* steers. These studies indicate that increased DMI is associated with higher levels of CP in the diet as a result of supplementation with the legume browses. According to Muinga *et al*., (1995) increased supply of N to the rumen microbes increases the rate of degradation of diet material and clearance of DM from the rumen, which increases DMI. Hence, the higher performance of animals on browse/maize silages compared to maize silage alone in this experiment.

Milk yield and 4%FCM were higher ($P \leq 0.05$) for *Calliandra*/maize and *Gliricidia*/maize silages than for *Leucaena*/maize silage. Results of Experiment 2 showed that browse/maize silages (20%) had similar degradability of DM, OM and N. Cows on *Leucaena*/maize silage had lower DMI than those on the other browse/maize silages. This could explain the higher ($P \leq 0.05$) milk yields associated with *Calliadra*/maize and *Gliricidia*/maize silages compared to *Leucaena*/maize silage. However, all the browse silages had comparable digestible DM, OM and CP intake. Maasdorp *et al*. (1999) reported higher milk yield from cows receiving air-dried *L. leucocephala* compared to those receiving *C.calothyrsus.* Ensiled materials have higher digestibility as proteolysis and deamination during the ensiling process results in greater proportions of NPN and solubility of silage N that increase degradability of the silage in the rumen (Tamminga *et al*., 1991; Cushnahan and Gordon, 1995). These reports suggest that ensiled *Calliandra* and *Gliricidia* could be better utilized than in their dried form. Although *Calliandra* has high content of tannins and lignin that bind protein and make it unavailable in the rumen (Zahedifar, 1977; Fahey *et al*., 1980; Hill *et al.,* 1987; Navas-Camancho *et al.,* 1993;

Moya-Rodriguez *et. al.*, 2002) these could have been diluted adequately in the 20% *Calliandra*/maize silage. Butter fat % was not affected by type of silage since ADF intake and digestibility were similar (Sutton *et al.*, 1986). However, milk %CP, %TS or SNF (%) were higher ($P \leq 0.05$) with maize silage compared to other silages (Table 30). Feeding high levels of rumen undegradable protein (RUP) reduces milk protein concentration (Sanz Sampelayo *et al.*, 1999; Kalscheur *et al.*, 1999). The maize silage in this experiment had lower CP content and lower RUP compared to the browse/maize silages, which could have resulted in the higher milk protein content when cows were fed maize silage.

3.4.5 Conclusion

Browses ensiled with mize at 20% (DM basis) produced good quality silage. *Calliandra*/maize silage had higher DM content than either *Gliricidia*/maize, *Leucaena*/maize silages or maize silage alone. However, maize silage had higher lactic acid content although it had higher DM losses. The DMI was higher with *Calliandra*/maize silage than with either, *Leucaena*/maize silage or maize silage. However, CP digestibility was lowest for *Calliandra*/maize silage, which reduced its' DCPI compared to *Gliricidia*/maize, *Leucaena*/maize or maize silage. Browse/maize silages supported higher milk yields than maize silage alone.

3.5.0 EXPERIMENT 5: **Milk producing capacity of ensiled browse/maize fodder mixtures of *Calliandra calothyrsus, Gliricidia sepium* and *Leucaena leucocephala* supplemented with maize bran**

3.5.1.0 Introduction

To optimize the utilization of low quality forages, and maintain adequate animal production, it is necessary to enhance feed intake and digestion through the provisions of supplemental nutrients (Mugerwa, 2001). Generally, providing supplements with adequate CP to ruminants has promoted DMI, rumen degradation, and nutrient flow to the small intestine and culminated in higher animal performance (Muinga, *et.l.,* 1995; Mpairwe, *et.al.,* 2003). Besides, improvements in voluntary intake of low quality forages as a result of supplementation are frequently associated with increases in the rate of passage and forage digestion (Köster *et al.,* 1996). Crude protein content of 7% in the basal forage is considered as the threshold for adequate utilisation of forage (Hoover, 1986; Sabiiti, 2001) and according to Mathis *et al.* (2000) when CP content is greater than 7%, protein supplementation could have little benefit. Greenfield, *et al.* (2000) found that increasing dietary protein from 12 to 16% in transition dairy cattle did not improve productive performance in the subsequent lactation. Instead, it was benefitial to maintain dietary protein at 12% CP in late gestation. Other reports have indicated increases in overall milk production when dietary CP concentration is increased from 9 to 14% (DM basis) and that further increases in dietary CP concentrations often resulted in diminishing returns (Roffler, *et al.,* 1978; Kalscheur, *et al.*, 1999). Kalscheur, *et al.*, (1999) obtained increased milk, milk fat and milk protein yields with cows on high protein (17.4% CP) diets versus low protein (15.2% CP) diets in early lactation (4-14 weeks post partum). They concluded that because there was no effect of diet on milk production, decreasing CP in diets fed to cows in mid or late lactation can reduce the cost of the diet and waste N excreted from the cows. Devant, *et al.*, (2000) observed increased ($P< 0.001$) urinary N excretion at 17% CP diet with rapidly growing heifers fed high concentrate diets from 100 to 230 kg body weight suggesting CP intake in excess of requirement.

In Experiment 4, *Calliandra, Gliricidia* and *Leucaena* forages ensiled with maize at 20% (DM basis) and fed to lactating dairy cows supported higher milk yields than maize silage alone. In this experiment, *Calliandra, Gliricidia and Leucaena* forages were ensiled with maize at 20% (DM basis) and molasses was added to improve fermentation. Urea was added to the maize silage in order to increase its CP to comparable levels with those of the browse/maize silages. The silages were fed to dairy lactating cows supplemented with maize bran. The objective was to compare the effect of the browse/maize silages and maize silage with urea addition on the DMI, digestibility, and milk yield and composition.

3.5.2.0 Materials and methods

3.5.2.1 Ensiling

The silages were made as in Experiment 4. However, urea was added to the maize silage at ensiling at 0.5% of fresh weight of ensiled material. Addition of urea was expected to raise the CP content in the maize silage to a comparable level as that in the browse/maize silages. Molasses were added to all the silages at the rate of 5% of fresh weight of ensiled material to aid fermentation. Five tons of each type of silage was made. The DM of the browses and maize determined one week prior to ensiling for the purpose of determining the 20% browse (DM basis) proportions for the browse/maize mixtures was 37, 25, 24 and 25% for *Calliandra, Gliricidia, Leucaena* browses and maize forage respectively. At these levels of DM content, the browses were ensiled with maize in the proportions of 171, 254 and 263 kgs of *Calliandra*, *Gliricidia* and *Leucaena* per ton of maize respectively. The control treatment was urea-treated maize silage alone. The "burried bag" technique of Alfred *et al.* (1995) was used for determining DM fermentation losses. The bags were removed in the course of feeding and were weighed on removal.

3.5.2.2 Feeding and sample collection

A 4x4 Latin square design was used for the experiment with four lactating cows (Friesian x and indigenous local cattle crosses) in early lactation. There were four feeding periods of 28 days each in which the adjustment period was two weeks and data were collected for two weeks. The animals were confined in stalls and fed from troughs. The stalls were cleaned daily in the mornings and afternoons. At the commencement of the experiment, the animals were weighed for three consecutive days and were allowed one week to adjust to the stalls. Thereafter, the animals were weighed at the end of each feeding period using a portable electronic weighbridge.

Fresh silages were offered in troughs each day in two equal meals at 8 hrs and 14 hrs and the day's silage offer was recorded. Samples of the silages and refusals for DM determination were taken daily and stored in a cold room and the silages were bulked together after the 14-day collection period.

Total digestible nutrients (TDN) was used as the basis for determining the supplementation required as in Experiment 4. The level of daily supplementation determined per animal was 3 kg of maize bran containing 75% TDN. The bran was offered in two equal meals during milking at 8 hrs and 14 hrs.

The chromic oxide indicator method was used for determination of digestibility. The animals were dosed with 30g of chromic oxide daily in two equal halves of 15g for the a.m. and p.m. feeding. Dosing with chromic oxide commenced in the second week and continued through the third week during which collection of grab faecal samples was done. Grab faecal samples were taken daily in the morning and afternoon and composited for the one week of collection.

Milk yield was recorded daily for the morning and afternoon milking during the last two weeks of each period. The am and pm milk samples were obtained after the milk was thoroughly mixed. The samples were strained through a clean piece of cloth and preserved with 3 to 4 drops of 10% potassium dichromate. The am and pm samples were composited and mixed thoroughly to make the day's sample. The samples were kept in a cold room until analysed for protein, butterfat, and total solids.

Rumen fluid and blood samples were obtained from the animals at the end of each experimental period. They were collected four hours after the am feeding. Rumen fluid samples were obtained by rumen intubation. Blood samples were obtained by jugular vein puncture and collected into vacutainers containing EDTA anti-coagulant. The rumen fluid and blood samples were immediately taken to the laboratory for analysis.

Rumen pH was determined by measuring the pH of the rumen fluid using a pH meter. Thereafter, the rumen fluid samples were strained through double layer of cotton cloth and 25% metaphosphoric acid was immediately added at the rate of 1 ml to 5 ml of rumen fluid to preserve it. The rumen fluid samples were then kept in a deep freezer until analysed for rumen ammonia.

3.5.2.3 Estimation of energy content of rations

MAFF (1987) guidelines were used for determining energy and protein requirements for the cows as in Experiment 4.

3.5.2.4 Chemical analyses

Dry matter losses, pH, VFAs and NH_3-N of the silages from the buried bags were determined as in Experiment 1. Silage and faecal sumples were dried at 60°C to constant weight and ground in a laboratory mill to pass through a 1mm sieve and stored in air-tight sample bottles until analysed. Chemical analyses were done on feed and faecal samples as described in experiment 3. Milk samples were analysed for total protein, BF%, total solids and SNF as in experiment 4. Rumen ammonia in the rumen fluid samples was determined by steam distillation using the Kjeltec system. The blood total protein was analysed by the Kjeldahl method. Glucose was determined by the enzymic oxidation method (Randox Laboratories Ltd., 2000). Plasma albumen was determined by the photometric colorimeter test–BCG–method (Human Gasellschaft Fur Biochemica, 1999) while plasma urea was determined by the modified urease-berthelot method (Randox laboratories Ltd., 1997).

3.5.2.5 Statistical analysis

The data were subjected to analysis of variance using the General Linear Model (GLM) procedures of SAS (1999). Where significant differences were obtained, means were compared using SE at probability level of 5%.

3.5.3.0 Results

3.5.3.1 Fermentation characteristics and chemical composition of the silages

The fermentation characteristics of the silages fed are given in Table 31. *Calliandra*/maize silage had higher ($P \leq 0.05$) DM content compared to the rest of the silages while maize silage had the least. Butyric acid content was higher ($P \leq 0.05$) in *Gliricidia*/maize and *Leucaena*/maize silages compared to *Calliandra*/maize and maize silages. There were no significant ($P > 0.05$) differences in lactic acid content among browse silages it was lower ($P \leq 0.05$) in maize silage. Levels of NH_3-N were also similar in all the silages although they were low in maize silage. Dry matter losses were lower ($P \leq 0.05$) in *Calliandra*/maize silage compared to the other silages.

Table 31: Fermentation characteristics (%DM) of the maize silages containing 20% browse (DM basis) fed to lactating cows

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
DM	32.21^{a}	23.86^{bc}	26.04^{b}	28.97^{ab}	1.19
Acetic acid	1.15^{bc}	5.87^{a}	3.04^{b}	2.31^{b}	0.57
Butyric acid	0.09^{b}	0.72^{a}	0.59^{a}	0.17^{b}	0.11
Lactic acid	5.51^{a}	5.01^{a}	4.51^{a}	3.57^{b}	0.38
pH	3.88	3.63	3.62	4.06	0.15
NH$_3$-N (% Total N)	4.04	4.73	4.07	3.46	0.52
DM Losses (%)	3.00^{c}	19.84^{a}	16.16^{ab}	10.64^{b}	2.01

^{abc}Values with defferent superscripts in a row are significantly different ($P \leq 0.05$)

The chemical composition of the silages is given in Table 32. *Calliandra*/maize and maize silages had the lowest and similar levels of CP%. *Leucaena*/maize silage had the highest level of CP. Maize silage had the highest NPN content while *Calliandra*/maize silage had the least. The content of NDF was highest in maize silage whereas ADF content was comparable in all the silages, although it tended to be high in *Leucaena*/maize silage. The content of ADL and fibre bound N were high in *Calliandra*/maize silage compared to the other silages.

Table 32: Nutrient composition (%DM) of the maize silages containing 20% browse (DM basis) fed to lactating cows

		Browse/maize silages			
Silage composition	Bran	Calliandra	Gliricidia	Leucaena	Maize
OM	96.16	92.18	91.17	91.55	91.99
CP	11.16	9.67	11.95	12.68	9.49
NPN (%Total N)	38.21	31.85	40.47	49.80	56.65
Ca	0.14	0.17	0.21	0.15	0.12
P	0.74	0.30	0.21	0.27	0.35
NDF	70.02	68.15	68.00	65.78	71.82
ADF	8.89	43.27	40.80	49.65	45.82
NDFN (%Total N)	6.74	15.17	5.47	6.15	5.66
ADFN (%Total N)	2.65	29.73	12.18	25.44	12.34
ADL	2.22	10.82	7.42	8.69	3.72

3.5.3.2 Silage dry matter consumption and digestibility

Silage DM intake and total DM intake are given in Table 33. Silage DMI, and g/kgW$^{3/4}$ were higher ($P \leq 0.05$) for *Calliandra*/maize and *Leucaena*/maize silages than for *Gliricidia*/maize or maize silage. Total DMI (% body weight and total DMI g/kgW$^{3/4}$) followed a similar trend.

Table 33 Silage dry matter intake and total dry matter intake of the maize silages containing 20% browse (DM basis) fed to lactating cows

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
DMI (kg/day)					
Silage	7.80^{a}	6.48^{b}	7.11^{ab}	6.28^{b}	0.16
Maize bran	2.69	2.69	2.69	2.69	-
Total	10.49^{a}	9.17^{b}	9.80^{ab}	8.97^{b}	0.35
Silage (g/kgW¾)	107.12^{a}	91.96^{c}	99.63^{b}	87.27^{c}	2.29
Total (% Body weight)	3.49^{a}	3.16^{b}	3.31^{ab}	3.03^{b}	0.10
Total (g/kgW$^{3/4)}$	144.85^{a}	130.47^{b}	136.86^{ab}	125.36^{bc}	3.39

^{abc} Values with different superscripts in a row are significantly different ($P \leq 0.05$)

The digestibility of the silages given in Table 34 show that digestibility of DM, OM and DOMD were higher ($P \leq 0.05$) for maize silage compared to the rest of the silages. Crude protein digestibility was lower ($P \leq 0.05$) with *Calliandra*/maize silage than the rest of the silages. Both NDF and ADF digestibility was higher ($P \leq 0.05$) with maize silage than with the other silages. Intake of digestible DM and OM were greater ($P \leq 0.05$) and that of digestible CP least ($P \leq 0.05$) with *Calliandra*/maize silage compared to the other silages.

Table 34: Apparent digestibility coefficients and digestible nutrient intake of maize silages containing 20% browse (DM basis) and body weight gain of lactating cows fed the silages

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
Apparent digestibility coefficient %					
DM	65.77^{b}	64.92^{b}	65.63^{b}	71.38^{a}	1.16
OM	60.23^{b}	61.69^{ab}	59.80^{b}	66.53^{a}	1.71
DOMD	55.48^{b}	55.73^{b}	54.97^{b}	63.21^{a}	1.99
CP	29.24^{b}	46.83^{a}	42.76^{a}	45.10^{a}	2.92
NDF	55.52^{b}	59.07^{ab}	53.42^{b}	62.59^{a}	3.78
ADF	34.94^{c}	39.07^{bc}	45.14^{ab}	51.02^{a}	3.22
Digestible Nutrient intake					
DM (kg/day)	6.90^{a}	5.95^{b}	6.43^{ab}	6.40^{ab}	0.23
OM (kg/day)	5.89^{a}	5.24^{b}	5.44^{ab}	5.57^{ab}	0.20
CP (kg/day)	0.31^{c}	0.51^{a}	0.52^{a}	0.41^{b}	0.02
ADF kg/day	1.26^{bc}	1.12^{c}	1.40^{ab}	1.59^{a}	0.09
ME MJ/day	87.28	76.66	80.85	85.04	
CP/NRC %	35.63	55.43	55.91	50.62	
ME/NRC %	110.27	92.78	97.42	112.29	
Av. BW gain kg/day	-1.41	-0.32	0.11	-0.43	3.10

^{ab} means with different superscrpts in a row are significantly different(P≤0.05)

Intake of metabolisable energy was relatively lower with *Gliricidia*/maize silage. Intake of digestible CP did not meet the cows' requirement for maitenance and milk production for all the diets and only *Calliandra*/maize and maize silage ME intake could meet the requirements. Average BW gain (Table 34) was very low with all the silages. However, negative weight gains occur in dairy animals due to the heavy nutrient demands for lactation.

3.5.3.3 Milk yield and composition

Milk yield and FCM (kg/day) was higher ($P \leq 0.05$) with *Gliricidia*/maize and *Leucaena*/maize silages compared to either *Calliandra*/maize or maize silages (Table 35).

Table 35: Effect of silage type on milk yield and compostion by cows fed maize silages containing 20% browse (DM basis)

	Browse/maize silages				
	Calliandra	Gliricidia	Leucaena	Maize	SE
Milk yield (kg/day)	5.68^{b}	6.39^{a}	6.51^{a}	5.16^{c}	0.12
BF %	3.98	3.96	3.98	4.08	0.06
4 % FCM yield (kg/day)	5.66^{b}	6.33^{a}	6.40^{a}	5.00^{c}	0.12
Milk yield kg/kg total DMI	0.54	0.70	0.66	0.58	
Protein (%)	3.05^{a}	2.99^{ab}	2.90^{b}	3.03^{a}	0.04
Solids-not-fat (%)	7.87	7.88	7.95	8.06	0.09
Total solids (%)	11.85^{b}	11.84^{b}	11.93^{ab}	12.14^{a}	0.09
BF yield (kg/day)	0.22	0.25	0.25	0.21	0.02
Protein yield (kg/day)	0.17	0.19	0.19	0.16	0.01

^{abc} means with different superscripts in a row are significantly different ($P \leq 0.05$)

However, BF% was similar for all the silages. Milk CP% was higher ($P \leq 0.05$) with *Calliandra*/maize and maize silages, but lower ($P \leq 0.05$) with *Leucaena*/maize silages. While TS% was higher ($P \leq 0.05$) with *Gliricidia*/maize silages, SNF% was similar with all the silages.

3.5.3.4 Metabolic parameters of lactating cows fed the browse/maize silages

Rumen NH_3-N and pH levels were similar with all the silages (Table 36). Levels of blood total protein were relatively higher with maize silage. The levels of blood glucose, plasma albumin and plasma urea were similar ($P > 0.05$) with all the silages.

Table 36: Metabolic parameters of lactating dairy cows fed maize silages containing 20% browse (DM basis)

	Browse/maize silages				
Metabolic parameter	Calliandra	Gliricidia	Leucaena	Maize	SE
Rumen NH_3-N (mg/dl)	3.18	3.97	3.06	3.55	0.55
Rumen pH	6.65	6.47	6.53	6.26	0.10
Blood glucose (mg/dl)	53.75	57.50	61.25	59.50	3.88
Blood total protein (g/dl)	16.23	16.53	17.81	18.33	0.93
Plasma albumin (g/dl)	4.33	4.55	3.98	3.83	0.50
Plasma urea (mg/dl)	12.88	13.60	7.90	13.93	3.49

3.5.4.0 Discussion

3.5.4.1 Fermentation characteristics and chemical composition of the silages

Calliandra/maize silage had the best fermentation on account of its higher lactic acid and lower pH levels (Table 31). However, fermentation of *Gliricidia*/maize, and *Luecaena*/maize silages was also good as all the browse silages had lactic acid content higher than 4.5% and low pH ranging between 3.62 and 3.88 (Mahana, 1997). Maize silage on the other hand, had lower lactic acid content, a higher pH and lower NH_3-N content. Therefore, while addition of molasses to the silages could have improved the fermentation of the browse/maize silages, addition of urea to the maize silage could have restricted proteolysis hence, resulting into the lower levels of NH_3-N in maize silage (Bareeba, 1979; Charmley and Veira, 1990; Mahana, 1997). The lower levels of NH_3-N could also be an indication of restricted fermentation, hence the lower lactic acid level and higher pH of the maize silage (Mahana, 1997). On the other hand addition of urea could have had a buffering action during fermentation as well as exerting a protein sparing effect on the natural protein in the maize silage (Bareeba, 1979).

The browse/maize silages had higher CP content than maize silage (Table 32) inspite of addition of urea to the maize silage. However, maize silage had higher soluble N (NPN) content, indicating that much of the NH_3-N combined with the organic acids and formed ammonium salts (Bareeba, 1979). The higher content of soluble NPN would make maize silage more degradable in the rumen as indicated by the results of Experiment 2. The higher content of fibre-bound N (NDFN and ADFN) and lignin in *Calliandra*/maize silage could render the silage less degradable than the other silages as the results of Experiment 2 indicate.

3.5.4.2 Silage dry matter consumption and digestibility

The higher ($P \leq 0.05$) DM consumption of *Calliandra*/maize silage compared to the rest of the silages (Table 33) could have been due to the initial higher DM and low butyric acid of the silage (Cushnahan and Gordon, 1995). The higher level of butyric acid and NPN in *Leucaena*/maize silage (Table 31) could have resulted into low DM intake (Cushnahan and Gordon, 1995). *Gliricidia*/maize silage had a relatively higher level of butyric acid, which together with the low DM content and higher level of NH_3-N (Table 31) could have contributed to its lower DM intake (Mahana, 1997). Maize silage had less acidity and NH_3-N levels (Table 31), which should have increased its intake. However, maize silage had a high level of NPN (Table 32) perhaps as a result of urea addition, which could have limited its DMI (Mahana, 1997).

There were no significant differences in the digestibility of DM, OM and DOMD between the silages (Table 34). The digestibility of CP was lower ($P \leq 0.05$) for *Calliandra*/maize silage. Nitrogen in *Calliandra* is poorly degraded as indicated by the degradation results of Experiment 1 and Experiment 2. While there were no significant differences in the digestibility of NDF between the silages, the digestibility of ADF was significantly higher with maize silage ($P \leq 0.05$). The low lactic acid level, higher pH and lower NH_3-N level (Table 31) inspite of urea addition, meant that fermentation in maize silage was buffered (Bareeba, 1979). This could have left part of the more soluble forms of cellulose unfermented, which was then degraded in the rumen giving rise to the higher digestibility of ADF observed with maize silage. Digestible DM and OM intake were relatively higher with *Calliandra*/maize silage (Table 34) due to its higher DM content (Table 31). However, *Calliandra*/maize silage had, relatively lower digestible CP intake as a result of a combination of low CP content (Table 32) and low digestibility (Table 34). *Gliricidia*/maize silage had relatively lower intake of ME corresponding to its relatively lower intake of DM, OM and DOMD (Table 34). Animals lost weight because they were not meeting their CP requirements although energy requirement was met (Table 34). Also due to early lactation, animals normally lose weight.

3.5.4.3 Effect of silage type on milk yield and composition

Milk yield was higher ($P \leq 0.05$) with *Gliricidia*/maize and *Leucaena*/maize silages (Table 35), which could have been as a result of the relatively higher intake of digestible CP of the two silages (Table 34). Although CP intake with all the silages could not meet the protein requirements for maintenance and milk production of the cows (Table 34), the ratio of digestible CP intake to CP requirement was higher with *Gliricidia*/maize and *Leucaena*/maize silages (Table 34), resulting in higher milk yield with the two silages. Also, *Calliandra*/maize silage supported higher ($P \leq 0.05$) milk yield than the control maize silage (Table 35). However, feed efficiency of the silages for milk production (milk kg/kg of total DM intake) was similar between *Calliandra*/maize and maize silages (Table 35). Maasdorp *et al.,* (1999) reported that *Calliandra calothyrsus* hay had no beneficial effect for milk production. The results of this study indicate that ensiling *Calliandra*, *Gliricidia* and *Leucaena* browses with maize forage improved their utilization for milk production in cows and that *Gliricidia* and *Leucaena* browses were utilized better than *Calliandra*.

Addition of urea to maize silage increased its soluble N content and could have been beneficial for increasing the milk protein content (Sanz Sampelayo *et tal*., 1999; Kalscheur *et.al.,* 1999). It is not clear why milk protein was higher with *Calliandra*/maize silage as it had higher levels of fibre-bound N (Table 32), which should have reduced the milk protein content %. Besides, *Calliandra*/maize silage also had relatively, the lowest digestible CP intake (Table 34). Milk protein content was lower ($P \leq 0.05$) with *Leucaena*/maize silage, which corresponded to the low levels of rumen NH_3-N, and plasma urea associated with the silage (Table 36). There were no significant differences in milk butterfat content with the different silages. However digestibility and intake of ADF were higher for maize silage (Table 34) and could have influenced the relatively higher butter fat content with maize silage (Table 35), as milk fat content is a reflection of dietary roughage intake (Sutton *et al.,* 1986). Solids-not-fat and total solids content followed the same trend as for milk protein content. Butterfat and milk protein yields were higher with *Gliricidia*/maize and *Leucaena*/maize silages as a result of higher milk yield with the two silages (Table 35).

3.5.4.4 Metabolic parameters of the cows fed browse/maize silages

Rumen NH_3-N levels with all the silages were similar although the levels tended to be high with *Gliricidia*/maize silage followed by maize silage (Table 36). The rumen NH_3-N levels observed ranged between 30 and 35 mg/litre whereas the generally recommended levels of rumen NH_3-N is between 20 and 50 mg/litre (Slyter *et al.,* 1979) although for optimum degradation of fibrous substrates, rumen NH_3-N levels required could be as high as 200 mg/litre (Preston and Leng, 1987). The rumen NH_3-N levels observed in this experiment were therefore, below the levels for maximum digestion of fibre, which meant that the silages could not be adequately degraded inspite of supplementation with maize bran. The observation of higher rumen NH_3-N levels for *Gliricidia*/maize and maize silages is in agreement with the higher DM, OM and N degradation in *Gliricidia* and maize silages observed in Experiment 1 and 2. However, the rumen pH levels observed were favourable for microbial growth and digestion of fibre (Preston and Leng, 1987; Mpairwe, 1998).

There were no significant differences in blood glucose levels with the different silages (Table 36) and the levels were within the normal range of 55-110 mg/dl as reported by Mpairwe, (1998) for body metabolism. However, the levels observed were the minimum expected, which could indicate that the animals' nutritional requirements for glucose or glucose precursors could not be adequately met. There is an almost three fold increase in glucose synthesis rate in lactating cows compared with dry cows and 60 to 85% of the glucose synthesized is taken up by the mammary gland for lactose synthesis (Preston and Leng, 1987). Besides, glucose, amino acids and long-chain fatty acids are limiting in order of priority for milk production in animals on diets that are likely to be unbalanced such as crop residues, mature grass and agro-industrial by products (Preston and Leng, 1987). Therefore, the low glucose levels observed could have been a limiting factor to body functions, particularly lactation. The milk yields of 5-6 kg per day obtained here were low compared to the country averages of 10-15 kg per day (Lukyamuzi, 1994).

Blood total protein was higher ($P \leq 0.05$) with maize silage (Table 36), which was consistent with the higher rumen NH_3-N (Table 40), CP digestibility (Table 34), and high NPN content (Table 32) of the maize silage. The higher NPN content with maize silage would be beneficial for RMP synthesis as observed in Experiment 2 (Table 21) that would benefit the animal. The blood protein levels observed with all the silages however, were above the normal range of 6.7-8.7 g/dl (Mpairwe 1998), which could indicate that the cows were receiving adequate CP supply from the silages. However, the CP intake/requirement ratios (Table 34), indicate that the cows were not receiving adequate CP supply from their diets.

The plasma albumin levels were similar with all the silages (Table 36) and the levels were within the normal range of 3.5-5.0 g/dl (Mpairwe 1998). Therefore, the levels of blood albumin observed indicate that the animals were receiving adequate supply of protein to meet their requirements (Mpairwe, 1998; Mubjeesh et al., 2002).

There were no significant differences in plasma urea levels with the different silages (Table 36), but the levels were much lower than the normal level of 46 mg/dl (Mpairwe, 1998). However, the low levels observed were consistent with the observed low levels of rumen NH_3-N reflecting inadequate dietary protein intake (Manston *et tal.,* 1975; Preston and Leng, 1987). Therefore, it is possible that much of the urea in circulation was being returned to the rumen through the rumeno-hepatic system to supplement the low levels of rumen NH_3-N (Preston and Leng, 1987). Although blood total protein and plasma albumin levels indicated that the cows were receiving adequate supply of protein, the low plasma urea levels coupled with the low rumen NH_3-N levels could be more indicative of the low dietary CP supply. Normal blood total protein and plasma albumin levels could be sustained by the recycled urea to the rumen in animals receiving a maintenance diet (Preston and Leng, 1987).

3.5.5 Conclusion

Addition of molasses improved the fermentation of the browse silages. Urea addition also increased CP level of maize silage. Dry matter intake was high with *Calliandra*/maize silages due to the high DM content of *Calliandra.* However, crude protein digestibility was higher with *Gliricidi*/maize and maize silages. Browse/maize silages supported higher milk yield than maize silage alone even when maize silage was enriched with urea. Ensiling the browses with maize forage at 20% (DM basis) and molasses would be appropriate but supplementation with maize bran is necessary for satisfactory lactation performance.

CHAPTER IV

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

The study evaluated the ensiling characteristics of the browses, namely *Calliandra calothyrsus, Gliricidia sepium and Leucaena leucocephala* and the effect of ensiling on their chemical composition and rumen degradation and the feeding value of browse/maize silages in terms of DMI, digestibility, weight gain in calves and milk production in lactating dairy cattle.

In Experiment 1 while maize silage fermented well with high levels of lactic acid and low pH, the browse silages had low lactic acid levels and higher pH levels. Maize silage had the highest level of NH_3-N (% Total N) indicating greater protein breakdown in the maize silage. *Calliandra* silage had lower levels of NH_3-N compared to *Gliricidia and Leucaena* indicating limited protein breakdown. The low lactic acid and low NH_3-N levels in the browse silages indicated that fermentation was limited in the browse silages, particularly in *Calliandra* compared to maize silage. The poor fermentation in *Calliandra and Leucaena* browses could be attributed to their high content of tannins and lignin, which are known to adsorb and bind N, fibre and microbial enzymes. Rumen degradation of DM, OM and N was highest with *Gliricidia* followed by maize while *Leucaena* and *Calliandra* were least degraded. Also, fermentation increased RMP synthesis with *Gliricidia, Leucaena* and maize but not with *Calliandra.*

In experiment 2, maize forage was ensiled with the browses at levels of 0, 10, 20, 30, 40, and 50 % (DM basis). Butyric acid levels were low with a decreasing trend with browse addition. Lactic acid content decreased with browse addition and the pH levels were low ranging between 3.85 and 4.02. Rumen microbial protein synthesis consistently decreased with increasing levels of *Calliandra* and *Leucaena.* Silages containing *Calliandra* browse had the highest DM content while those with *Gliricidia* browse had the lowest DM content. *Calliandra*/maize silages had the lowest lactic acid levels and would therefore not preserve for a long time. Also, the levels of NH_3-N were lowest in *Calliandra*/maize silages indicating limited proteolysis.

Dry matter content increased with each level of browse addition while acetic and butyric acid content decreased with the 10% level of browse addition (Experiment 2). Lactic acid levels were not affected by level of browse addition. However, pH was higher with the 30% level of browse addition. The levels of NH_3-N decreased with the 20% level of browse addition indicating diminishing protein breakdown with higher levels of browse addition. Silage DM losses were lower with the 20% level of browse addition.

Calliandra/maize silages had the lowest CP and NPN content, highest fibre, fibre bound N and lignin, which factors would make *Calliandra*/maize silages less utilizable than the other silages. On the other hand, *Gliricidia* /maize silages had high levels of CP and NPN and lowest levels of fibre and fibre bound N making it a better feed than either *Calliandra*/maize or *Leucaena*/maize silages. Organic matter content was similar, but CP content increased with each level of browse addition. Browse/maize silages had lower

NPN content than maize silage, however the levels of NPN were not affected by levels of browse addition. The content of NDF decreased and that of ADF, fibre bound N and ADL increased with each level of browse addition.

Dry matter, OM and N degradation indicated that *Calliandra*/maize silages had the lowest **w** and **a** fractions, but had the highest **b** fraction. However, *Calliandra*/maize silages had the lowest rate of degradation, **c**, and the highest time lag, **tl**, which depicted *Calliandra*/maize silages as having poor degradation. *Gliricidia*/maize silages had the highest **w** and **a** fractions, **pd**, **ed** and **c** as well as the lowest **tl** values. Estimated RMP synthesis was highest with *Gliricidia*/maize silages and least with *Calliandra*/maize silages.

Maize silages containing 0 or 30% browse, (DM basis) were fed to weaned calves (experiment 3). Dry matter intake as $g/kgW^{3/4}$ was higher for browse/maize silages than for maize silage alone. Among the browses, DMI was higher for *Calliandra*/maize and *Leucaena*/maize silages compared to *Gliricidia*/maize silage. The higher DMI of the browse/maize silages was attributed to their higher DM and CP content and lower levels of NH_3-N and acetic acid. Digestibility of DM was similar among the silages. Digestibility of CP was highest with *Gliricidia*/maize and lowest with *Leucaena*/maize silages. The rates of weight gain per day were very low for all the silages indicating the need for supplementation when browse/maize silages are fed inspite of the increased CP content.

In experiment 4, maize silages containing 0 or 20% browse, (DM basis) were fed to lactating dairy Friesian cows supplemented with a dairy meal. Silage DMI (g/kg$W^{3/4}$) was highest for *Calliandra*/maize silage. *Leucaena*/maize silage had low DMI due to the high level of NH_3-N. Digestibility of CP was similar for all the silages, however digestibility of DM, OM and NDF were highest with *Leucaena*/maize silage. Milk yield was highest with cows fed *Calliandra*/maize and *Gliricidia*/maize silages and lowest with animals fed maize silage. All the diets met the animal's ME requirements for maintenance and milk yield. However, CP intake was deficient on *Calliandra*/maize and maize silages. Milk protein and total solids contents were highest for cows fed maize silage. Milk butterfat content was not affected by type of silage.

In experiment 5, maize forage was ensiled with 0 or 20% browse (DM basis). Molasses (5%) was added to all the silages to aid their fermentation and urea (0.5%) was added to maize silage to raise its CP content to comparable levels with that of the browse/maize silages. Silage DMI (g/kg$W^{3/4}$) by lactating Friesian x local cattle crosses was highest with *Calliandra*/maize silage due to the initial high DM content. *Gliricidia*/maize silage DMI was the lowest as a result of its low DM and high NH_3-N content. Digestibility of DM and OM were similar with all the silages. Digestibility of CP was lower with *Calliandra*/maize silage corresponding to the high proportion of fibre bound N in *Calliandra*/maize silage. Milk yield was highest with animals fed either *Gliricidia*/maize or *Leucaena*/maize silages. It was lowest with animals fed the control maize silage indicating that the browse/maize silages were better than the control maize silage in supporting milk yield. The levels of rumen NH_3-N were similar with all the silages and were within the expected range, but were below the levels required for optimum rate of degradation of fibrous diets. Blood urea N followed a similar trend. Blood glucose levels were similar with all the silages and were within the normal range. The levels of blood total protein and plasma albumin with all the silages were above the normal range indicating that the cows were receiving an adequate supply of protein from the diets. The low plasma urea levels together with the low rumen NH_3-N levels however, indicated inadequate dietary protein supply and the rumeno-hepatic cycle could have come into play to maintain the levels of blood total protein and plasma albumen.

Based on the results, the following conclusions can be made:

1. The limited proteolysis and fermentation in *Calliandra* and *Leucaena* browse silages could be attributed to the high tannin and lignin content of the browses.
2. Browse/maize silage mixtures of 20 –30% DM basis would be most beneficial in terms of fermentation, nutrient composition, rumen degradation and optimum RMP synthesis. Fermentation enhanced RMP synthesis with *Gliricidia* and *Leucaena* and not *Calliandra.*
3. Inclusion of *Calliandra, Gliricidia* or *Leucaena* browses in browse/maize silage mixtures at 30% DM basis would increase CP content and digestibility of OM and CP in the case of *Gliricidia* but would not support adequately weight gain of weaned calves.

4. Browse addition at 20% DM basis in browse/maize silage mixtures would not affect DMI and nutrient digestibility of the silage in mature lactating dairy cattle and would support higher milk yields than maize silage alone.
5. Addition of molasses would improve fermentation of the browse/maize silages and supplementation with a balanced concentrate is essential for maximum benefit from feeding browse/maize silage mixtures to weaned calves or lactating dairy cattle.

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