

**THE EFFECT ON INTAKE AND DIGESTION OF MAIZE STOVER WHEN
SUPPLEMENTED WITH UREA AND / OR LABLAB (*Lablab purpureus*) HAY
AND GIVEN TO NATIVE CATTLE IN SOUTHERN MALI**

by

Konimba Bengaly

Eng. Animal Husb. (IPR / Katibougou-Mali)

A thesis presented for the Degree of Master of Science
at the University of Aberdeen

August 1996

DECLARATION

This is to declare that this thesis has been composed by myself, and has not been presented in any previous application for a degree. All sources of information are shown in the text and listed in reference and all help by others have been duly acknowledged.

Konimba Bengaly

ABBREVIATIONS

ADF	Acid detergent fibre
AOAC	Association of Official Agricultural Chemists
ARC	Agricultural Research Council
CP	Crude protein
DM	Dry matter
DMD	Dry matter digestibility
DMI	Dry matter intake
DML	Dry matter loss
DOM	Digestible organic matter
ESPGRN Naturelles'	'Equipe System de Production et Gestion des Ressources Naturelles'
ME	Metabolizable energy
N	Nitrogen
NDF	Neutral detergent fibre
NPN	Non protein nitrogen
OM	Organic matter
PEG	Polyethylene glycol
$W^{0.75}$	Metabolic body weight

ACKNOWLEDGEMENTS

I wish to express my sincere and profound gratitude to the KIT / Amsterdam who accepted to sponsor my studies through the Farming System Research Project, Equipe System de Production et Gestion des Ressources Naturelles of the Malian Research Institute (IER / Bamako).

I am very grateful to my supervisors, Drs. E. R. Ørskov (Rowett Research Institute), H. Galbraith and J. R. Scaife (University of Aberdeen) for their constructive criticism, advice and encouragement.

I deeply thank Dr. R. Kay for his review of the manuscript and helpful suggestions.

Dr. M. F. Franklin and Mrs K. Robertson carried out the statistical analysis of my data. Their collaboration is acknowledged.

I strongly appreciate the effort made by Mrs M. Davidson for typing the manuscript; and also the moral support and guidance from the International Feed Resource Unit personnel, and my friends.

All the staff members of Sotuba Research Station, I say thank you, particularly to Dr. B. Ouologuem who made the necessary arrangements for the success of the field work. A note of thanks are also extended to Mr. S. Bengaly and T. Traoré for their support during the field work.

I am also thankful to Mrs S. Todd and L. Dillon for the support provided during my English training in Aberdeen Centre for English.

The collaboration, help and encouragement from a group of individuals, namely, Mr B. Sanogo, Drs A. Diarra, A. Berthé and S. O. Bah, are acknowledged.

I dedicate this work to my lovely wife Ramata Traoré for her patience and long suffering during these past two years of absence. I owe her a great debt.

TABLE OF CONTENTS

Declaration	ii
Abbreviations.....	iii
Acknowledgments	iv
Table of Contents	v
Summary	vi
Chapter 1 - Introduction	1
1.1 Introduction.....	1
1.2 Literature review.....	5
1.2.1 The Rumen Ecosystem.....	5
1.2.2 Optimizing rumen environment for roughage diet utilization.....	7
Effect of legume forage supplementation on voluntary food consumption	8
Effect of legume forage supplementation on the digestibility of roughages	13
Effect of legume forage supplementation on nutrient utilization.....	18
Effect of legume forage supplementation on animal performance.....	20
Antinutritional factors in legume forages	21
Other nutritional characteristics of legume forages	24
Chapter 2 - The effect on intake and digestion maize stover when supplemented with urea and different levels of lablab (<i>lablab purpureus</i>) forage	27
2.1 Objective	27
2.2 Materials and Methods.....	27
2.3 Results.....	36
2.4 Discussion	40
2.5 Conclusion.....	42
References	44

SUMMARY

Sixteen young bulls, local Zebu and N'Dama averaging 194 kg, were used in a 2 x 4 factorial design to measure voluntary dry matter intake (DMI) digestibility (DMD) and organic matter digestibility (DOMD) of maize stover supplemented with urea and / or lablab (*Lablab purpureus*) hay to provide either 0, 30, 60 or 90 g / kg of the stover (DM basis). Chemical composition and degradability characteristics were measured using fistulated sheep.

With stover alone the daily intakes of stover were 39.6, 44.8, 42.9, and 39.6 g DM / kg $W^{0.75}$ and with urea-supplemented stover the intakes were 43.0, 40.0, 41.5 and 43.2 g DM / kg $W^{0.75}$ for the four levels of lablab supplementation respectively. Supplementation of stover with urea and / or lablab hay had no significant effect on the digestibility of the diet. The lack of significant response could be attributed to the relatively higher digestibility of the control diet. It is suggested that the optimum level of lablab hay inclusion in the diet should be more than proportionally 0.09 (i.e. 90 g / kg diet) (eg. 0.2) in order to provide both adequate fermentable nitrogen as well as fermentable fibre, and under these circumstances supplementation with urea may not be necessary.

CHAPTER 1

1.1 INTRODUCTION

The problems of cattle feeding have received considerable attention in the tropics and sub-tropics. Most of the works have focused on dietary supplementation in the late dry season when the quality and quantity of the food supply from natural pastures is severely reduced. Security of food is exacerbated in Southern Mali after bush fires have devastated the natural fodder resources.

In Southern Mali, livestock play an important role in farming systems due to manure production and draft power. The integration of livestock and agriculture has led to an increase of crop production while animal productivity is in general low. Many factors explain the low animal productivity among which feeding is reported to be the limiting one. Yet, the quality and even the quantity of natural forage, the main source of animal food, are prone to seasonal fluctuations. Therefore, it is essential to match the purpose and level of animal production to the seasonal availability of these resources.

Southern Mali covers 10% (122,000 km²) of Mali's territory and accommodates 30% (2,500,000) of the human population (Berthé et al., 1991). The climate, soils and vegetation gradually change from North to South. Rainfall increases from an annual average of 500 mm in the northern part (semi-arid) to 1300 mm in the south (humid) and falls mainly in a distinct period between May and September. Lowest mean daily temperatures occur during the early dry season (22° C to 25° C) between November and January and highest during the late dry season (31° C to 35° C) between March and May.

The soils, *lixisols* (FAO, 1991 quoted by Leloup, 1994), originate from differential erosion of the Precambrian shelf, show varying depths and textures and are classified

as infertile. The landscape undulates slightly and is at an altitude of 300 to 400 m above sea level. The Sudan savanna vegetation changes from grass-shrublands in the northern parts to woodland savannas in the south.

The agro-pastoral systems range from transhumant pastoralism to sedentary agriculture. The latter is the most important in the region. Many mixed variants of both systems exist. The transhumant pastoralists are represented by the Peulh people whereas the agriculturalists comprise several ethnic groups. A large proportion of the cattle population is local Zebu and cross bred (Zebu x N'Dama). The free grazing system, which is common in the region, exposes the animals to vector borne diseases like trypanosomiasis and other infectious diseases.

Since the early 1970's, the government of Mali actively promoted the growing of cash crops- mainly cotton (almost all of which is produced in Southern Mali) and to a lesser extent also groundnut- and the use of animal traction. This resulted in a relatively rapid increase of the cultivated area at the expense of the natural rangelands. The number of livestock present in the region was estimated at 1,992,000 in 1977 and at 3,359,000 in 1986 (Berthé et al., 1991). This increase in livestock numbers is generally attributed to the introduction of animal traction, investment of income from cash crops in animals, and immigration of transhumant pastoralists coming from the north in search of fodder and water because of recent droughts.

Ruminant animals can maintain themselves and be productive on cellulosic crop residues. Many techniques are on hand to improve the nutritive value of cereal straws. In poor quality roughages the cellulose is associated with lignin and other compounds which make it more or less unavailable for the microbes of the rumen. It has been

known for many years that the digestibility and intake of highly lignified materials may be improved by physical (chopping, grinding, etc.) and chemical treatment. By using an alkali such as sodium hydroxide, calcium hydroxide, ammonia, etc. the bonds between the digestible hemicellulose and cellulose and indigestible lignin and silica are broken, so the physical barrier is removed. According to Davis et al. (1983), of all the alkalis tested, ammonia is preferred because it provides both the alkali effect and a source of nitrogen. However, alkali treatments are generally expensive and the chemicals are not readily available in many parts of developing countries. Consequently, urea has been studied as a source of ammonia for treatment of straw by the wet - ensiling process (Dolberg et al., 1981), which may be more convenient for small farmers (Preston and Leng, 1987). Considerable skill may be required to achieve a better ensiling process, however, and a decrease in digestibility as a result of moulding has been reported (Van Soest, 1987). For practical purposes, it may be more realistic to spray urea solution onto the straw just before feeding. With the decline of soil fertility, particularly its organic matter content, the need for an exogenous source of organic matter is increasing, however, and farmers are advised to produce this from cereal straw (from sorghum, millet, and maize) used as bedding in the cattle pens. Thus, there appears to be competition in the utilization of crop residues between feeding animals and producing organic matter. It has been suggested that this problem may be overcome by the fractionation of the straw, the lower stem being used for fertiliser, and the upper part (more digestible) as animal feed (Preston and Leng, 1987). However, such technique may be time and labour consuming at small farm level. The use of agro-industrial byproducts such as cottonseed cake and molasses is recommended, although such feeds are usually in limited supply and are costly. With the increase in human and animal population, and a subsequent reduction in land available for cropping and grazing, there is no doubt that such a feeding strategy will

be attractive to many farmers in the future. However, unless adequate feed resources are made available, grazing animals will continue to be undernourished with consequent low productivity. Though proper storage of maize stover is lacking, it may be the largest animal feed resource in Southern Mali because attempts are being made to integrate forage legumes such as lablab (*Lablab purpureus*) in maize crops. Lablab has a longer growth cycle than cowpea (*Vigna unguiculata*), and does not interfere with the harvesting of other crops (cereals, cotton).

This experiment was conducted at the Agricultural Research Station of Sotuba/Bamako in order to find simple methods of processing and/or supplementing maize stover to optimize its utilization by stall fed cattle. Urea was chosen as a supplement because, apart from being a ready source of nitrogen (N), it is widely promoted as fertiliser, and hence is readily available in the country, and farmers can handle it safely. For grazing animals it is common to include urea in blocks which the animals can lick (Ørskov, 1995), provided the dry pasture is abundant. According to Dixon (1986), forages of high N content are other slow-release forms of N, sulphur (S) and other microbial substrates into the rumen fluid to synchronize with the rate at which they are required by fibre-digesting microbes. The use of small supplement meals twice daily is probably frequent but feeding supplements as single meal probably leads to transient rise of NH₃, sulphide, etc. and so only benefits slower digestion of basic ration for part of day. The specific objectives were to find out whether it is beneficial to supplement maize stover with: 1) small amounts of lablab hay as single meal (available in limited quantity), 2) urea, or 3) a combination of lablab forage and urea.

1.2 LITERATURE REVIEW

1.2.1 The Rumen Ecosystem

Ruminants offer an advantage over monogastric animals in that the rumen or forestomach is well equipped with a wide range of symbiotic organisms which, under favourable conditions, break down an otherwise indigestible roughage. The microbes require a receptive environment for desirable fermentation patterns. The following section reviews the type of microbes found in the rumen and the factors which affect the rumen environment for efficient microbial growth.

Rumen microbial populations consist of three main groups- bacteria, protozoa and fungi. Although the type of substrate entering the ecosystem will mainly determine the population (Orpin, 1981), several of the bacteria, protozoa, and fungi species have been described in detail (Hungate, 1966). Microbial population and fermentation patterns vary with changing rumen environment. A continual supply of substrate, and salivary buffering salts and the removal of end products and residues will result in a relatively stable rumen environment, thus promoting high microbial populations and increased biomass.

Rumen bacteria

Several hundred species of bacteria have been found in the rumen and about 10^9 - 10^{10} bacteria per ml of rumen fluid have been estimated (Hungate, 1966). Among the different functional groups - cellulolytic, amylolytic, and proteolytic bacteria -, those which ferment cellulose are the most important. Cellulolytic and amylolytic bacteria both require ammonia (NH₃) and branched - chain fatty acids as growth factors. Dietary urea can provide NH₃ and so promote efficient utilization of fibrous

roughage, if the rumen pH does not fall below about 6.0 (Ørskov and Ryle, 1990). Microbial efficiency is also associated with the availability of carbohydrates contained in the fibre. For instance, it has been shown that tropical legumes are higher in protein and lower in fibre than their grass counterparts, and thus can serve as valuable supplements to straw or stover-based rations (Van Soest, 1987).

Rumen protozoa

Rumen fluid contains up to 10^6 /ml protozoa. The cilia of these organisms are restricted to tufts located mainly near the oesophagus; their function is the propulsing of food particles into the oesophagus. Two major groups of ciliate protozoa have been isolated, Holotrichs and Entidiniomorphs (Hungate, 1966). The main substrate for the Holotrichs are sugars and other soluble components, while the Entidiniomorphs survive on fibrous food particles or bacteria. The positive effect of rumen defaunation on the digestibility of fibrous feeds and the live weight gain in sheep offered straw diets has been reported (Soetanto, 1986; Bird and Leng, 1989).

Rumen fungi

It was only when Orpin (1975) discovered rumen fungi that they were considered as a functional group of microorganisms. Most of the fungal biomass is present as rhizoids infiltrating fibrous plant tissue. Ørskov and Ryle (1990) reported that this group of microorganisms may be particularly important for the degradation of the plant structural materials which predominate in coarse roughage, although lignin does not appear to be susceptible to attack by rumen fungi.

1.2.2 Optimizing rumen environment for roughage diet utilization

The feeding value of roughages, especially crop residues, is limited because they are low in nitrogen, are high in ligno-cellulosic compounds and, therefore, low in fermentable carbohydrates (Smith, 1992; Mosi and Butterworth, 1985; Preston and Leng, 1987). Moreover, the poor quality of these residues, such as maize stover, is exacerbated by their post-harvest management (prolonged exposure to residual humidity and sun in late wet season in the field). Such residues generate a low level of ammonia (NH₃) in the rumen from degraded protein to ensure an efficient digestion process (Ørskov, 1995) and a subsequent microbial protein supply to the host animal. It has been suggested that protein and non-protein nitrogen (NPN) supplements may be used to correct the N deficiency of low quality roughages (Topps, 1972; Siebert and Hunter, 1982). Forage legumes are rich in protein, both fermentable and undegradable protein (UDP), depending upon the tannin content (Said and Tolera, 1993). Since most tropical legumes have generally a high level of tannin and therefore are better sources of UDP, other sources of fermentable nitrogen such as urea may be required (Preston and Leng, 1987).

Strategies for the utilization of crop residues should aim at establishing an efficient rumen ecosystem in order to maximize fibre digestion and optimize microbial protein synthesis. An efficient rumen ecosystem requires fermentable nitrogen, energy and minerals sufficient to support the rumen microbial population. For the purpose of this review, these factors are considered through the use of urea and / or forage legumes as supplements to a basal poor quality roughage.

Effect of legume forage supplementation on voluntary food consumption

Voluntary food intake (VFI) is the amount of food eaten by an animal during a given period of time when an excess of the food is available. Food intake is important in defining Food Conversion Efficiency (FCE). Efficient food conversion, however, will be achieved only if the animal is able to obtain from the food a substantial margin of nutrients over maintenance requirements. In many animal production systems, maximum intake may not be sufficient to ensure maximum production, or may be critical to the system.

With ruminants, diet "dilution" by undegradable fibre is an important reason for intake being depressed below the animal's potential. Berthé (1991) reviewed the literature on the relationship between intake and the concentration of neutral detergent fibre (NDF) in the rumen. It was shown that the pool sizes of dry matter (DM) and NDF increased with increasing levels of intake, but the percentage increases were less than the percentage increase in intake. It seems that the animal is compensating to some extent for the increase in intake by increasing the rate of passage of material out of the rumen. While it is generally considered that for intake to be restricted, maximum degree of gastrointestinal fill must be reached, what constitutes the maximum degree of fill is uncertain (Donald et al., 1995). There will be a graded decrease in intake with fall in food quality associated with a graded increase in fill, and anatomical adaptation occurs, given time, to introduction of poor diets (Kay, 1993). The maximum degree of fill varies with the animal size and physiological state. It is also known that with a high fibre feed imbalanced in nutrients (i.e. protein, minerals, branched chain fatty acids), the degree of fill attainable will be less than with a balanced feed. Egan (1970) showed that protein infused into the duodenum could increase the degree of gut fill in sheep offered low-N hay, supporting this theory. However, the fact that amino acid supplementation in the lower tract increases intake does not provide clear-cut evidence

for distinguishing the role of bacterial fermentation from that of the animal's amino acid requirement, since such supplementation could add to the supply of nitrogen recycled to the rumen (Van Soest, 1995). Thomas et al. (1980) reported a high correlation between intake of branched chain amino acids (BCAA) and other amino acids and their passage to the duodenum in sheep fed silage. An increase in voluntary intake due to supplementation of low-N hay may be due both to increased rate of fibre digestion which decreases gut fill and to increased protein flow to the duodenum which has been shown to increase the degree of gut fill.

Early work on the use of forage supplements was mainly concerned with the need to improve the nitrogen content of diets based on poor quality roughages in order to overcome a deficiency of nitrogenous substrates for the rumen microorganisms. More recent evidence indicates that other changes occur with this supplementation which enhance the intake and digestibility of the diet (Topps, 1995). These changes seem to be related to the level of supplementation, the quality of the basal diet, and the quality of the forage supplement.

Level of supplementation

One of the biggest challenges when feeding low quality forages to ruminants is to increase their intake (Ndlovu, 1992). Chemical treatments, while successful, present several practical problems for smallholder agriculture. Addition of higher quality feeds such as legume forages to a poor-quality basal diet is more practicable. It is known that the extent of substitution of the basal diet by the forage legume, resulting in reduced intake of the basal diet, depends upon the level of inclusion of the supplement. Since high quality feeds are available in small quantities, it is better to use them as

supplements rather than as substitutes. This recognizes that the growing of the legume on a small farm may be limited by the land and labour available.

The effects of incremental levels of forage legumes as supplements to a poor- quality basal diet has been investigated (Minson and Milford, 1967 ; Siebert and Kennedy, 1972 ; Mosi and Butterworth, 1985 ; Smith et al., 1989 ; Kitalji and Owen, 1993). In these experiments, the forage legumes were fed in discrete amounts and separately from the poor quality basal diets, which were given *ad libitum*. The legume supplements were consumed without any refusals, so the differences in total dietary intake were due to differences in the intake of the basal diet. In all experiments, the legume supplements increased total food intake but the response varied widely between experiments. In general, if the amount of supplement consumed was less than 30 to 40 per cent of total intake there was an increase in the intake of the basal diet, but in some experiments the intake was unchanged or slightly reduced. A very large increase in intake of mature pangola grass (*Digitaria decumbens*) supplemented either with a field cured lucerne (*Medicago sativa* L.) or a labino clover (*Trifolium repens* L.) was found in the study by Minson and Milford (1967). Above the level of 40 per cent forage legume, the intake of the basal diet fell below that seen with the un-supplemented control diet, except in the study of Siebert and Kennedy (1972) when there was no change when lucerne contributed 45 per cent of the total dry matter intake. By contrast, Mosi and Butterworth (1985) found that the intake of diets based on crop residues (tef, wheat and oat straws, maize stover) supplemented with Ethiopian local clover (*Trifolium tembense*) was always less than that of the un-supplemented control diet. Similar results were obtained by Pathirana and Ørskov (1995). They fed un-supplemented or urea supplemented rice straw to sheep and supplemented with different increments of Glyricidia, a leguminous tree containing

about 20 per cent crude protein. The urea was sprayed in a water solution on the straw at the rate of 20 g urea / kg of straw. Although there were large increases (48%) in intake of rice straw and of the total diet as the amount of glyricidia was raised to 15 per cent of diet, both in presence and absence of urea, the degree of increase was slightly less when urea was added. In the latter experiment referred to, the authors concluded that in the absence of urea the response would be mediated both by relieving a nitrogen deficiency and by providing a source of easily fermentable fibre while in the presence of urea the response would be mediated only by the source of fermentable fibre. The reasons for such differences appear to be related to differences in the quality of the forage legume and of the basal diet and other factors.

Quality of the basal diet

If the basal diet has such a low nitrogen content as to constrain rumen microbial activity, the addition of a forage legume will increase the nitrogen content of the total diet which is likely to increase the rate of degradation of the basal diet in the rumen and so increase food intake. Such positive associative effects are well known and were originally thought to be either the main or only effect of a protein-rich supplement. A number of recent reports have shown that responses to forage supplements are not entirely due to an increase in dietary nitrogen (Smith et al., 1989; Getachew et al., 1994; Manyuchi, 1994). However, when different diets are compared, the difference in quality due to nitrogen content has been shown to be reflected in the magnitude of the effect of the legume supplement on intake. In a study by Mosi and Butterworth (1985), *Trifolium tembense* hay was used as a supplement to four different cereal straws, maize, oat, tef (*Eragrostis*), and wheat. The straws differed markedly in crude

protein content (23 to 62 g /kg) and in acid detergent fibre (710 to 780 g/kg). It was found that the extent of substitution of the basal diet tended to be greater with the apparently better quality straws (oat and maize). Part of this difference was probably due to overcoming a deficiency of nitrogen in the straws. According to Blaxter (1962), if the animal's body temperature rises, metabolic rate increases through the oxidation of protein, which may have implications for protein requirements of ruminants under hot conditions, supporting this hypothesis.

Quality of the forage supplement

The comparison between forage legumes that differ in their nutritional characteristics has received considerable attention in recent years. Early work on the need for nitrogen supplementation (Elliot and Topps, 1963) showed that forages with a high content of rumen degradable nitrogen (RDN) elicited greater responses in food intake than those with a low content. The results of a study by Smith et al.(1989) support this idea. Three forage legume hays, pigeon pea (*Cajanus cajan*), cowpea (*Vigna unguiculata*) and lablab (*Lablab purpureus*), which differed in nitrogen content, 17.4, 23.7, and 13.4 g N/kg, respectively, and *in sacco* DM degradability were compared as supplements to maize stover (nitrogen content: 3.8 g N/kg) fed to lambs. Cowpea, which had the highest nitrogen content, promoted the greatest intake of maize stover. But the extent of substitution was inversely related to the 48 hour degradability of the legumes measured *in sacco*. Similarly, Getachew et al., (1994) compared three other legumes (*Desmodium intortum*, *Macrotyloma axillare* and *Stylosanthes guianensis*) as supplements again to maize stover. *S. guianensis* which had the highest nitrogen content, promoted the greatest intake of maize stover. In addition to the nitrogen content, another important feature of legumes as valuable

supplements to straws or stover-based rations, is their lower content in fibre (Van Soest, 1987) and the total organic matter may be more easily fermented.

Effect of legume forage supplementation on the digestibility of roughages

For appreciable microbial digestion of plant materials to occur in the rumen, a close physical association is essential between the plant tissue and the microbes responsible for the digestion (Cheng et al., 1983/84; Orpin, 1983/84). It is known that enzymic activity is likely to be proportional to the mass of cellulolytic microorganisms. Yates (1984) has shown for cotton thread, that the rate of cellulose digestion is correlated with the mass of attached colonizing microbes, supporting this theory.

Leng (1990) pointed out that farmers in developing countries have generally recognized the benefits to cattle of adding a small amount of fresh green herbage to straw-based diets. These practices may have a number of beneficial effects, which include the supply of vitamin A and essential minerals and of ammonia and peptides/amino acids.

Recently the role of supplements on the digestibility of a poor-quality basal diet has been investigated (Ndlovu and Buchanan-Smith, 1985; Silva and Ørskov, 1988). These studies showed that where the supplemental forage in a straw-based diet given to sheep was of high digestibility, a boost to digestibility of the basal diet occurred even at relatively small levels of supplementation. The rate of digestibility of straw depends on the rate and extent of colonization of fibre and the biomass of adherent organisms (Cheng et al., 1990). It has always been assumed that colonization of fibre entering the rumen is from the free-floating pool of bacteria in the rumen. Krebs et al. (1989) suggested that colonization of bacteria occurs from fibre to fibre without

passing through the free-floating pool, however. An explanation given by Leng (1990) to this suggestion was that the beneficial effects of the incorporation of high-digestibility forage in an otherwise low-digestibility forage diet could be that this exerts a large effect on digestibility by providing a highly colonized fibre source to 'seed' bacteria onto the less-digestible fibre. Supplementation with legume crop residues contributes fermentable energy to the rumen in the form of available cellulose and hemicellulose which stimulate fibre digestion (Silva and Ørskov, 1985). According to Bauchop (1981), it is possible that offering such material prior to the daily feeding of straw may induce a greater degree of colonization of straw by rumen bacteria and by rumen fungi, which have been implicated in the breakdown of fibre. Other factors may be involved. For instance, Ørskov and Dolberg (1984) stated that if animals fed on untreated straws or poor quality roughages are supplemented with substrates which increase the fermentation rate of cellulose, the rumen environment becomes similar to that of animals receiving ammonia-treated straws.

Topps (1995) in his review stated that the positive effect of forage legume supplements on the activity of the rumen microorganisms and a concomitant increase in degradation of fibre has been recorded. However, such an effect was not seen with some poor quality roughages. In a study by McMeniman et al. (1988), five legumes were used as supplements to rice straw. The degradation of the straw was increased by each legume. Similarly, Ndlovu and Buchanan-Smith (1985), found that lucerne increased the rate of degradation of barley straw, brome grass and maize cobs. In contrast, Manyuchi (1994) reported that groundnut hay did not alter the *in sacco* degradation of poor quality grass hay. According to Akin (1989), it is likely that any change in the degradation of the basal diet as a result of an increase in microbial activity may depend on the number of available sites for microbial attachment. With

some roughages the cuticle layer and extent of lignification are barriers to microbial colonization, so that an increase in rumen microbial population may not be reflected in an increase in rate of degradation.

Very few studies have been carried out in which changes in the rumen environment have been measured when forage legumes are fed with poor quality basal diets (Topps, 1995). It is well known that poor quality forages provide insufficient degradable nitrogen and fermentable energy to sustain optimum digestion of fibre. Furthermore, rumen microbes require a source of fermentable nitrogen, usually as ammonia although some microbial species require preformed amino acids and peptides (Russell and Baldwin, 1978). The ideal N concentration in the rumen for efficient digestion has been variously estimated at 50-70 mg/litre (Satter and Slyter, 1974) and at 150-200 mg/litre (Krebs and Leng, 1984). However, Ndlovu (1991), reported that these levels are not easy to maintain in stall-fed animals over 24- hour, particularly if the feed is mature grass and it is fed in insufficient quantities. Forage legumes are relatively good sources of degradable nitrogen and fermentable energy so their inclusion in the diet is likely to increase the rumen population of cellulolytic microbes (Topps, 1995). Concentrations of rumen ammonia have been increased following supplementation with forage legumes (Getachew et al., 1994; Manyuchi, 1994; Kimambo et al., 1991), the increase being a function of the degradability of the nitrogen in the forage legume. In a study by Said and Tolera (1993), the legume with the lower nitrogen content (*Macrotyloma. axillare*) gave higher rumen ammonia levels than *Desmodium intortum* which had more crude protein but with a lower degradability. For certain forage legumes, especially certain species of shrubs, the availability of the nitrogen compounds would be limited by tannins (Mangan, 1988). Topps (1995), stated that forage legumes increase the total concentration of volatile fatty acids without affecting

the relative proportions and the rumen pH, indicating that forage legumes are likely to maintain a stable fermentation pattern. Ndlovu and Buchanan-Smith (1985) found that the feeding of a lucerne supplement increased the proportion of branched chain volatile fatty acids and suggested that this increase may stimulate the growth of cellulolytic microorganisms.

Recently the effect of forage legume supplementation on rate of passage of digesta has been studied. A potential increase in digestibility when these materials are added to poor quality basal diets may be impaired by a reduction of retention time of digesta, though FCE may be enhanced by the rise in VFI. Such an effect was observed by Ndlovu and Buchanan-Smith (1985) when lucerne was fed with maize cobs, and by Vanzants and Cochran (1993) when lucerne was fed at different levels with low quality prairie forage. Similarly, Manyuchi (1994) found that groundnut hay increased the fractional outflow rate of rumen solids without altering the pool size of the rumen digesta. He concluded that the increase in food intake following supplementation with a forage legume was largely facilitated by an increase in rate of passage of digesta. The mechanism by which this occurs is not fully understood. The implication of climate may probably play a part. Leng (1990), compiled a series of data in sheep and cattle fed on low-quality forage and supplemented with urea and / or bypass protein under different climatic conditions. Under tropical conditions, he reported that supplements which improve the protein : energy (P : E) ratio in nutrients absorbed by cattle fed on low-quality forage reduce metabolic heat production. Where metabolic heat production would increase body temperature then the animal reduces its feed intake. This reduction in VFI is ameliorated by the supplement which allows the acetogenic substrate which would otherwise have to be oxidized, to be partitioned into synthetic reactions with a resultant decrease in heat production (Leng, 1989). Said and Tolera

(1993) fed lambs on maize stover as a basal diet, and three forage legumes, *Desmodium intortum*, *Macrotyloma axillare* and *Stylosanthes guianensis*, used as supplements at three different levels (250, 350 and 450 g /hea /day). They recorded a high concentration of acetic acid relative to propionic and butyric acids in all treatment groups. The decrease in heat production with subsequent reduced body temperature often increases VFI and rumen turnover rate.

Effect of legume forage supplementation on nutrient utilization

The efficiency with which absorbed nutrients are converted to animal products (live weight, milk, etc.), is dependent on precisely meeting the animal's requirements for the individual nutrients required for the particular function (Preston and Leng, 1987). The P : E ratio is an important factor that is associated with the efficiency of feed utilization (Devendra, 1995). Since anaerobic fermentation in the rumen provides the microbial cells which supply the protein to the animal, the efficiency of microbial growth therefore influences the P : E ratio. Poor microbial growth due to inadequate dietary N, for example, will result in a low P : E ratio and, conversely, adequate supplementation and good rumen function enable a good balance in the nutrients available to the animal (Leng, 1982). Intake has been shown to be more sensitive to P : E ratio rather than VFA proportions, and legumes have the greatest potential to alter the former due to higher crude protein (CP) contents and often lower protein degradation rates caused by tannins (Poppi et al., 1990). In the study by Smith et al. (1989) referred to earlier, all the three legumes (pigeonpea, cowpea, and lablab) raised ME intake and increased the intake and retention of N, especially cowpea ($p < 0.001$) which had the highest nitrogen content, supporting this theory.

The patterns of feeding of supplements is important for optimizing total nutrient supply. The availability of N, S or other microbial substrates for maximal rate of fermentation and microbial growth will depend on the energy substrates being utilized. Where fibrous crop residues are fed and where the energy is derived from slowly fermented hemicellulose and cellulose, N, S and other substrates will be needed continuously over the 24 hour feeding cycle (Dixon, 1986). This author reviewed the literature on the effect of different methods of administering urea and the use of slow-release NPN compounds. In all the experiments reviewed, the differences in intake of organic matter (OM) in animals receiving no urea supplement as compared to those receiving urea once each second day was much greater than the differences among the methods of urea administration. He concluded that the decision to provide a urea supplement was far more important than the method of urea administration. In one study by Egan et al. (1986), mature sheep were fed *ad libitum* stemmy ryegrass hay (N content 0.9%, OM digestibility 54%) supplemented with 1.5% urea (in aqueous solution sprayed over the hay). The animals were given along with the hay whole lupin grain once a day (150 g per head) or every second day (300 g per head). Lupin grain supplements increased intake and there was a tendency for hay intake to be higher (911 g / d) in sheep given lupins each second day than those given lupins each day (808 g / d). The rumen ammonia concentrations were as low as 28 mg / l for the control group but were usually higher (65-250 mg / l) except on the second day of the 2 day supplemented group when they fell to 47 mg / l. The authors indicated that there is more to manipulation than identifying individual nutrients lacking and providing these along with the roughage. The variable response in voluntary food intake to tropical legume supplementation has been attributed to many factors, among which timing of supplementation may play a part. In a study, cited by Abdulrazak (1995) *ad libitum* and intermittent feeding of gliricidia forage were compared. Animals were

offered napier grass *ad libitum* as a basal diet and supplemented with gliricidia leaves at 300 g daily, 600 g every other day, 900 g once every three days or *ad libitum* daily. Restricted feeding of gliricidia affected neither live weight gains nor feed intake, hence it was suggested that gliricidia could be offered to small ruminants either daily, every second day, or every third day depending upon the availability of gliricidia forage and upon feeding practices.

It has recently been shown that the presence of rumen protozoa reduces the P : E ratio in the nutrients absorbed (Bird, 1991). In this context, it has been demonstrated that a number of tropical browse legumes have antiprotozoal properties when supplemented at between 10 and 100 g / kg diet (Leng et al., 1992a). These include several *Acacia* spp., *L. leucocephala*, *Vigna parteri*, *Cassia rotundifolia*, *Enterolobium cyclocarpium* and *E. timboura*. In practice the use of antiprotozoal forages has been shown to increase productivity in animals independently of their antiprotozoal nature due to a greater supply of essential amino acids, and where the basal forage is high in protein, extra dietary protein becomes available for post-ruminal digestion (Devendra, 1995).

Effect of legume forage supplementation on animal performance

The poor performance of ruminants fed low-quality roughages is mainly due to a deficiency of nitrogen which results in low digestibility and low intake of dry matter (Topps, 1972). Protein and NPN may be used to correct this deficiency (Topps, 1972; Siebert and Hunter, 1982). According to Falvey (1982), one of the problems of supplementing low-quality roughages with a single daily meal of urea is that the urea is rapidly degraded into NH₃ in the rumen. This results in non-synchronized release of NH₃ and energy, leading to poor utilization of urea for microbial protein synthesis and

substrate fermentation (Satter and Slyter, 1974) and sometimes to ammonia intoxication. This problem may be overcome by using slow release forms of NPN (Ferero et al., 1980) but this is generally more expensive than urea, however. Spraying urea onto poor quality roughages just before feeding has been suggested as a way of ensuring uniform release of NH₃ to rumen microbes (Hennesy, 1984). The optimum level of urea is likely to vary with the type of roughage. Verma and Jackson (1984), proposed that adding urea at the rate of 1% is adequate for roughages containing 3-4 % crude protein.

Increases in food digestibility and in the intake of the basal diet arising from supplementation with forage legume should lead to a significant increase in animal performance. However, according to Topps (1995) very few experiments have shown a marked improvement of production when tropical legumes are fed. Muinga et al. (1992 /1993) established that considerable increases in milk yield can occur in dairy cows fed on Napier grass (bana grass) when supplemented with *Leucaena leucocephala*. In both experiments there was a small increase in total DM intake. These enhanced intakes resulted in significant increases and some reduction in the extent of weight losses.

Antinutritional factors in legume forages

Antinutritional factors in food are substances which either by themselves or through metabolic products in the system, interfere with food utilization and affect the health and production of animals (Makkar, 1991). Among the several antinutritional factors which cause losses in the livestock industry, tannins, mycotoxin, mimosine, cyanogen

and nitrates have been isolated. The effects of tannins, which are common to many tropical forage legumes, will be reviewed here.

Tannins are water soluble phenolic compounds of plants with a molecular weight equal to or greater than 500 dalton and with the ability to precipitate gelatin and other proteins in aqueous solution (Mehanso et al., 1987). Hydrolysable tannins (HTs) and condensed tannins (CTs) are the two types of these compounds which may be differentiated by their structure and reactivity towards hydrolytic reagents. The main antinutritional effects of tannins present in forage, tree and shrub legumes are: reduction in VFI, diminished digestibilities of nutrients, adverse effects upon rumen metabolism.

Effect on VFI

Van Hoven (1984) found a negative correlation between tannin level *in vitro*, especially CTs in 40 natural browse plants and their DM digestibility using kudu rumen fluid. High levels of tannins may slow down the digestion of DM in the rumen, react with the outer cellular layer of the gut, and thus diminish the permeability of the gut wall (Mitjavila et al., 1987), all of which would give signals of physical distension, an important feedback signal in the ruminant for controlling feed intake. The depression in intake could also be due to unpalatability, since the tannins in plant tissues may precipitate salivary proteins causing an astringent taste in the mouth (Kumar and Horigome, 1986).

Effect on rumen metabolism

The normal pH range in the rumen allows dietary tannins to bind to dietary protein and digestive enzymes. A reduction of VFA production and microbial protein synthesis as a result of tannin levels has been reported (Kumar and Singh, 1984). However, the

binding effect of tannins on dietary protein has some merit in that it is protected from degradation in the rumen and at the low pH condition in the abomasum, the protein is released and becomes available for digestion in the abomasum and small intestine (Broderick et al., 1991). These authors reported that the CTs offer advantages over HTs because the relationship between pH and protein binding is more favorable, and because CTs are more stable and less toxic than HTs. Generally tree leaves and browse contain both types of tannin, but HTs have not been found in any forage legume of agricultural importance (see Norton and Poppi, 1995). CTs are found in many dicotyledonous plants, and particularly in the Leguminosae.

Techniques to overcome the adverse effects of tannins

Kumar and D'Mello (1995) reviewed some of the experiments in which tannin-rich forage (*Lotus pedunculatus*) and browse (*Acacia aneura*) legumes were fed to sheep with polyethylene glycol- 4000 (PEG- 4000) supplementation. Increases in liveweight gain and wool growth were recorded. The tannins bind PEG- 4000 in preference to protein, allowing dietary protein to be free for digestion. The authors pointed out that using PEG- 4000 in practice may not be economic, however.

Drying procedures (field or oven- drying) of the forage are other means for inactivation of tannins (D'Mello, 1992). Kumar (1992b) suggested the usefulness of feeding browse legumes with non-tannin grasses and urea under farm conditions.

According to Topps (1992), the most practical alternative would be either to dilute the effect of tannins by feeding the legume at low levels in a suitable mixture or to feed two or more rather than one legume species.

Other nutritional characteristics of legume forages

Tropical legumes generally contain high concentrations of most nutritionally valuable minerals except sodium (Norton, 1982 quoted by Elliot, 1986) (see table 1.1). However, nutritional requirements may not always be met, since availability for absorption and function varies with each element (Norton and Poppi, 1995).

Table 1.1. Mineral content of tropical legumes (Norton, 1982 quoted by Elliot, 1986).

Phosphorus	0.26%	(tropical grasses contain approximately 0.22% P)
Calcium	1.21%	(mean of 154 samples)
Magnesium	0.40%	(mean of 48 samples)
Sodium	0.07%	(mean of 60 samples, however over 60% of the samples contained less than 0.05% Na, a level considered minimal for cattle)
Copper	10 ppm	(mean of 14 samples)
	16 ppm	(mean of leaf and stem fractions of <i>Lablab purpureus</i>)
Zinc	42 ppm	(mean of 7 samples)
Sulphur		“variable” content and “variable” availability in the rumen
Cobalt	0.7 ppm	(requirement 0.11 ppm)

The requirements of microorganisms for sulphur (S), phosphorus (P), and magnesium (Mg) have been reported (Durand and Komisarezuki, 1988). S is essential for the synthesis of S-amino acids and for microbial protein synthesis. Minimum recommended dietary requirements are 1.5 g S / Kg DM, which would be met from a

diet containing 150 g CP / kg DM (Norton and Poppi, 1995). The absolute requirement for S is unrelated to CP content of a diet. Lower levels of S can deplete the microbial pool size and eventually lead to a reduction in digestibility of the diet. Ørskov (1992) reported that the requirement for S by rumen microbes may be related to the requirement for N, since the S- containing amino acids comprise a constant proportion of microbial amino acids. The N: S ratios have been variously estimated. Harrison and McAllan (1980), suggested that a ratio of 20: 1 of rumen available N: available S should be satisfactory while the ARC (1980) recommended value is 14: 1. S deficiency in livestock is likely to occur in the tropics because of high rainfall and the highly soluble nature of most natural S salts in soil (Leng, 1980). Consequently, Hunter et al. (1978) observed responses to S supplementation in sheep fed on *Stylosanthes guianensis* grown on low S soils and with N: S ratios as high as 15: 1.

The availability (true absorption) of P in ruminants is estimated as 0.70 of that ingested (see Norton and Poppi, 1995). P deficiency in the rumen will reduce microbial growth efficiency and in some cases the digestibility and intake of forage (Durand et al., 1986), especially tropical forages, and it can be severe in grazing animals.

Mg deficiency has also been shown to lead to a reduction in the digestibility and intake of forage (Wilson and Minson, 1980). Since tropical forages (grasses and legumes) contain sufficient amounts of Mg, deficiencies in animal grazing tropical pastures are likely to be rare (Minson and Norton, 1984).

There is comparatively little information available on the content and availability of trace elements in tropical legume forages, and it is likely that the values reported are more indicative of the soil types (Norton and Poppi, 1995). Copper (Cu) and cobalt

(Co) are the most commonly measured trace elements reported. The latter authors indicated that insufficient data are available for manganese (Mn), zinc (Zn), selenium (Se), iron (Fe), iodine (I) and possibly molybdenum (Mo), although ruminants have demonstrable requirements for these elements. Feed Cu concentration is a poor indicator of capacity to meet nutritional needs, because the availability is affected by the presence of other elements (S, Mo, Zn, Fe) and the coefficient of absorption is low and varies with season (0.01-0.06) (Norton and Poppi, 1995). Co is required for the synthesis of vitamin B₁₂ (cyano-cobalamin) in the rumen, and tropical legumes are a poor source of Co when compared with tropical grasses. Although the data are limited for Mn and Zn, tropical legumes appear to be adequate sources of both elements, and deficiencies of these trace elements in grazing animals are rare.

CHAPTER TWO

THE EFFECT ON INTAKE AND DIGESTION OF MAIZE STOVER WHEN SUPPLEMENTED WITH UREA AND DIFFERENT LEVELS OF LABLAB (*LABLAB PURPUREUS*) HAY

2.1 Objective

The objective of this experiment was to determine whether supplementation of maize stover with small amounts of lablab hay, and / or urea, would enhance the intake of the basal diet and of the total nutrients intake, and to describe the response in voluntary food intake and diet digestibility in young bulls, offered dried maize stover *ad libitum* .

2.2 Materials and Methods

Site

The experiment was conducted at Sotuba Regional Research Station, Mali. It lies at 12° 39' N and 07° 56' W, rising to approximately 320 m above the sea level. The total rainfall during the whole experimental period (from April to June 1996) was 200 mm. The mean temperature was about 35° C.

Animals (plate 1)

Sixteen young bulls, local Zebu and N'Dama, with a mean live weight of 194 kg (sd=35.2) and aged 24-36 months, were used to measure the intake and digestibility of DM. The experimental design was eight treatments applied to the animals over two periods. The treatments set formed a 2x4 factorial arrangement with four levels of lablab and two levels of urea (none, plus urea). Each animal received a different level of urea in the second period to that it received in the first and mostly a different legume treatment. Eight sequences were applied in all, each sequence being applied to two animals. The animals were housed in individual pens in a shed covered with corrugated iron, having a concrete floor from which faeces were collected and urine washed out of the area. One side of the shed had a wall. Before the start of the

experiment, the animals were dewormed with an anthelmintic, and they were weighed and sprayed with an acaricide fortnightly. They were also vaccinated against infectious diseases (Rinderpest, Contagious bovine pleuropneumonia, Anthrax and Blackleg). However, by the end of the first period of the experiment, one animal which had a non-identified health problem was discarded and an appropriate replacement was made.

Feeds (plates 2 and 3)

Maize stover

Maize (var. Sotubaka) was planted on a 5 ha plot on the station for producing grain, and the stover was used in the trial. The land was ploughed before planting at the onset of the rainy season in July 1995. Twenty days after planting, urea and ammonium phosphate were each applied at the rate of 100 kg/ha. The maize cobs were harvested in October, and the stover was left on the field until January/February when it was transported and stored in a shed.

Lablab

Lablab purpureus (var. Highworth) was grown separately from the maize to allow control of the legume : stover ratio in the diet. It was sown in August 1995 and cut and field dried in November.

Maize stover and lablab hay were chopped using a manual forage harvester into pieces up to 10 cm lengths for the stover and to 2-3 cm for the hay. The urea was sprayed in a water solution on the stover at the rate of 30 g urea / kg of stover just before feeding.

Experimental diets

Based on the above mentioned feeds, the experimental diets offered to the animals according to the metabolic body weight ($W^{0.75}$) were as follows:

- 1- Stover alone offered *ad libitum* (control) (L0)
- 2- Control plus 0.15% $W^{0.75}$ /d lablab forage (L1)
3. Control plus 0.30% $W^{0.75}$ /d lablab forage (L2)
4. Control plus 0.45 % $W^{0.75}$ /d lablab forage (L3)
5. Control plus urea plus L0
6. Control plus urea plus L1
7. Control plus urea plus L2
8. Control plus urea plus L3.

Feeding and management

The animals were fed individually, watered twice daily with buckets, and received a mineral lick. The daily stover allowance was fed in two equal meals at 08: 30 and 16 : 30 h. The basal stover was given *ad libitum* to ensure 20% refusals. The animals were offered lablab hay immediately before the basal diet was offered. The levels of lablab were equivalent to 0, 3, 6 or 9% of the dry weight of stover.

Measurements (plates 4 and 5)

Voluntary intake and digestibility

The voluntary intake of the stover and digestibility of the diet were measured during two consecutive periods. Each period consisted of a 14- day preliminary followed by a 28- day measurement period. The amounts of feed offered and refusals were recorded daily and the refusals were bulked to the end of each period, dried at 60° C for 48 h to a constant weight after successive weighings and ground through a 2 mm screen for chemical analysis. The total daily faecal output was collected into buckets. Urine was immediately washed out to avoid faeces contamination. Subsamples amounting to 20% of each 24 h collection were stored in a deep freezer. At the end of the collection period the samples were bulked, mixed and samples taken for DM and ash determination.

In sacco degradation

At the end of the experiment, the degradability of the feeds (unsupplemented stover, urea supplemented stover, lablab, stover refusals) was measured using nylon bags (Ørskov and McDonald, 1979). From each feed 3 g was incubated in the rumens of three mature fistulated sheep receiving a fixed amount of a diet composed of hay and grassnuts containing 16% crude protein (CP) at the Rowett Research Institute. Incubation periods were 4, 8, 16, 24, 48, 72 and 96 h with triplicate bags (one bag in each of the three sheep) for each period. On removal from the rumen, the bags were

washed in cold water for 20 min in a domestic washing machine (Indesit 2550). The bags were then dried for 48 h at 60° C in an oven. DM loss was calculated and expressed as percentage degradability of the original DM incubated.

Soluble DM loss plus loss of small particles was estimated by placing nylon bags in warm water (39° C) for 1 h followed by washing and drying as described above. Soluble DM was expressed as percentage solubility of the original DM in the nylon bag.

Degradability data were fitted to the non-linear model $p = a + b(1 - e^{-ct})$ (Ørskov and McDonald, 1979), where p is degradability after time t , a is the intercept of the degradation curve at time zero, b is the fraction which degrades with time at a rate constant c , and $a + b$ represents potential degradability, i.e. the fraction that will be degraded in the rumen given sufficient time (Ørskov and McDonald, 1979).

Analytical methods

The DM of the feeds and of the samples was determined by drying the sample in an oven at 105° C for 24 h and the organic matter was determined by ashing at 550° C according to the standard method of the Association of Official Analytical Chemists (AOAC, 1980). Samples were analysed for neutral detergent fibre (NDF) and acid detergent fibre (ADF) by the method of Goering and Van Soest (1970). Nitrogen was determined by the autoanalyser.

Statistical analysis

The data were subjected to analysis of variance and regression analysis when appropriate by use of the GENSTAT statistical package. Differences among means were assessed by the LSD test (Snedecor and Cochran, 1974).

2.3 Results

Chemical composition of the feeds

The chemical components of the feeds are shown in table 2.1. The mean DM content of the stover and of lablab were 934, and 917 g DM / kg respectively. The stover had the lowest mean CP content of 40 g / kg DM, being only a third that of lablab hay (122 g / kg DM). The NDF and ADF contents were lowest in lablab hay (570 and 414 g / kg DM) and highest in the stover (845 and 541 g / kg DM).

Table 2.1. Chemical composition of the feeds. Dry matter (g / kg), crude protein, ash, NDF and ADF concentrations (g / kg DM).

	Dry matter	CP	Ash	NDF	ADF
Stover	934	40	60	845	541
Lablab hay	917	122	75	570	414
Stover refusals	949	35	87	877	633

***In sacco* degradation**

The DM losses from foods in the nylon bags after incubation and the degradation constants are given in table 2.2. The stover either supplemented with urea or without urea had the lowest rates of degradation (0.025 and 0.027 per h) and lablab had the

Table 2.2. Potential degradability ($A + B$) (g / kg DM) rate constants (c) (per h) of dry-matter loss and 48 h disappearance of DM (g / Kg DM) of the feeds incubated in nylon bags in the rumens of sheep from the equation $p = a + b (1 - e^{-ct})$ in which A = washing loss and $B = (a + b) - A$ (McDonald, 1981) and L = lag phase.

Feed	<i>A</i>	<i>B</i>	<i>c</i>	<i>A+B</i>	48 h	<i>L</i> (h)	Residual s.d.
Stover							
No urea	142	449	0.025	591	433	1.9	1.49
30 g urea / kg diet	137	479	0.027	616	433	1.7	2.42
Lablab	302	317	0.089	619	619	2.5	0.82
Stover refusals							
No urea	104	296	0.024	400	318	2.3	1.23
30 g urea / kg diet	121	376	0.032	496	374	2.4	1.54

highest (0.089 per h) being almost three to four times more than that of stover. The urea-supplemented stover did not show any improvement as far as its degradation rate constant was concerned. Rates of degradation of stover and of refusals were similar. The A value ranged from 137 to 142 g / kg DM for stover supplemented with urea and non-supplemented respectively. Lablab had the highest A value (302 g /kg DM) and the refusals the lowest values ranging from 104 to 121 g / kg DM for un-supplemented and urea-supplemented stover respectively. Potential degradability ($A+B$) for stover plus urea and for lablab were similar, being 616 and 619 g / kg DM respectively. The refusals had the lowest values ranging from 400 to 496 g / kg DM for the non-supplemented and for the urea-supplemented stover, indicating that the animals were quite selective. The lag phase (L) of lablab was slightly higher than that of stover (2.5 v 1.9 h). Although lablab and the stover had similar potential degradability, lablab had the highest 48 h degradability value.

Intake and digestibility

DM intake (DMI) and DM and OM digestibility of the mixed diet are presented in table 2.3. In the absence of urea successive increments of lablab hay significantly increased ($p < 0.05$) total intake of the diet and of stover ($p > 0.05$). Adding urea to the diet had no significant effect ($p > 0.05$) on the total intake and intake of stover was slightly depressed with increasing lablab hay levels. Urea also had a slight effect (7% increase) on intake of the stover and of the total diet.

Table 2.3. Daily intake (g DM / kg^{0.75}) and diet digestibility (%) (DM, OM) in young bulls offered maize stover and supplemented with urea and / or lablab forage.

	L. purpureus, g / kg diet DM				SED	Significance
	0	30	60	90		
Total intake						
No urea	39.6	46.2	45.6	43.7	2.89	*
30 g urea / kg diet	43.0	41.4	44.3	47.4	2.89	NS
Stover intake						
No urea	39.6	44.8	42.9	39.6	2.89	NS
30 g urea / kg diet	43.0	40.0	41.5	43.2	2.89	NS
DM dig.						
No urea	55.8	53.7	54.3	56.8	2.65	NS
30 g urea / kg diet	56.7	57.3	55.7	59.8	2.65	NS
OM dig.						
No urea	60.7	60.3	59.3	61.5	2.18	NS
30 g urea / kg diet	62.5	64.0	61.9	65.8	2.18	NS

There was no significant effect ($p > 0.05$) on the digestibility of the diet both in presence and absence of urea with successive increments of lablab hay. There was a tendency for these parameters to decrease with increasing levels of lablab hay up to 90 g / kg of diet when urea was added.

2.4. DISCUSSION

In the mixed farming systems of Southern Mali, the interest in maize cropping has existed for a long time and is still increasing because maize can lead with ease to the self-sufficiency of the family and also it is an important cash crop. Where it is largely attempted to integrate forage legumes such as *L. purpureus* in maize crops, the stover is an inevitable by-product after harvesting the cobs and it is available for ruminant feeding.

The objective of this study was to describe the intake and digestibility responses when stover was offered *ad libitum* to native growing bulls supplemented with increasing levels of lablab forage and / or urea. Emphasis was made on these parameters because they are the most useful indicators of feeding value of roughage for ruminants. Depending upon the availability of roughage, the importance of intake and digestibility varies. When roughage is plentiful - this may not be always the case in Southern Mali because of the apparent competition in the utilization of crop residues (see chapter one)-, intake is by far the most important factor, while in restricted feeding it is the digestibility which is the most important factor (Ørskov, 1981). In ruminants fed on crop residues such as maize stover, intake is relatively low due to high lignocellulose and low N content, and will not provide sufficient nutrients for maintenance requirements (Leng, 1990).

The stover used in this experiment comprised the leaves, stems, blades and husks of the plant. The stover was cut when it was dry after harvesting the cobs and was then chopped into small pieces to reduce selection by the animals. Even so the cattle were clearly able to select the most digestible materials as indicated in the degradability of the feed offered and refused (Table 2.2).

The stover was similar in chemical composition to that reported by other workers (Abdulrazak, 1995; Shem et al., 1995; Mosi and Butterworth, 1985; Getachew et al., 1994; Smith et al., 1990). It was low in CP and high in fibre content. The CP content of lablab (122 g / kg DM) was intermediate between that reported by Hendricksen et al. (1981) for the stem fraction (100 g /kg DM) and for the leaf fraction (144 g / kg DM). However, it was higher than that reported by Smith et al. (1990) (84 g / kg

DM). The NDF content was higher than that reported by Hendricksen et al. (1981) for lablab stem fraction (845 v 542 g / kg DM) and ash contents were similar (75 and 76 g /kg DM).

Animals offered the control diet consumed a total DM of 39.6 g / kg $W^{0.75}$ daily and when urea was added the intake was 43 g / kg $W^{0.75}$ daily. The total DMI recorded was lower than that of Getachew et al. (1994). They recorded a total intake of between 56 and 70 g / kg $W^{0.75}$ per day in sheep offered maize stover *ad libitum* and given forage legumes which had higher CP contents than that of lablab used in the present study, in contrast to the intake levels from other workers (Smith et al., 1990). Crampton et al. (1960) suggested a standard forage intake of 80 g / kg $W^{0.75}$ daily using forages which were 70% digestible. Therefore, the low level of intake found in my experiment might be due to the low digestibility of the DM and / or the level of CP in the forage. The increase in intake caused by urea in the absence of lablab hay is in agreement with the results of Pathirana and Ørskov (1995) in sheep fed on rice straw and supplemented with urea and / or gliricidia foliage, indicating that urea per se provided fermentable N. Many studies have reported partial substitution of the basal ration by forage legume supplement (Mosi and Butterworth, 1985; Smith et al., 1990; Getachew et al., 1994; Abdulrazak, 1995). Minson and Milford (1965) reported that by including proportionally 0.10-0.20 forage legumes in the diet the intake of pangola grass by sheep was increased, owing to the elimination of CP deficiency. Topps (1995) proposed that the intake of forage legume should be maintained at a third or less of the total DM. However, the degree of the substitution effect depends upon a number of factors, the level of N in the rumen being the most important one (Getachew et al., 1994). In my study, the pattern of substitution was not clear probably due to the low level of inclusion of the forage legume. These results would suggest that supplementation of maize stover with lablab hay at a level of at least 9% (DM basis) would provide adequate fermentable N, as well as fermentable fibre, and probably above this level of lablab addition of urea may not be necessary. As far as the practice of integration of lablab in maize crops is concerned, and from the available data compiled by the Farming System Reseach Team in Southern Mali on the yields of these crops, the lablab forage : stover ratio is in the range of 0.20-0.30 (ESPGRN / Sikasso, 1994/95). Therefore, under these circumstances and the ration being fed in a mixed form, it is not necessary to

supplement with urea because lablab hay would have provided the necessary fermentable N as well as fermentable fibre in the mixed diet, keeping in mind that there is adequate processing and /or adequate storage of the feeds.

Supplementation of stover with urea and / or lablab had no significant effect on the digestibility of the diet. These results contrast those of Pathirana and Ørskov (1995), who reported an improvement in DM and OM digestibilities by urea and / or the legume forage, and the effect of the legume was greater than that of urea. Mosi and Butterworth (1985), Getachew et al. (1994) and Mbatya et al. (1983) observed no improvement in digestibility when legume forages were used as supplements to cereal crop residues, however. The latter authors concluded that the increase in DM intake might have affected DMD because of an increase in the rate of passage of digesta. The lack of significant response in these studies could be due to the relatively higher digestibility of the control diet.

Maintenance energy requirements for bullocks of breeds of small mature size weighing 200 kg are 29 MJ / d (ARC, 1980). By converting digestible organic matter (DOMD g / kg DM) to ME, as $ME (MJ / kg DM) = 0.016 \times DOMD$ (McDonald, 1995), inspection of the available data show that on average the animals received approximately 5% less than their maintenance requirement. The lack of clear response in the digestibility of the diet might be attributed to the fact that it was attempted to feed the animals at maintenance level.

2.5. CONCLUSION

A diet of maize stover supplemented with successive increments of lablab hay resulted in enhanced intake of total DM, this was achieved without any improvement of the digestibility of the diet, and it was reflected in the amount of energy supplied below maintenance requirements for all animals. Urea per se slightly improved intake of maize stover and of the total diet and the digestibility of the diet. Where the practice of integration of lablab in maize crops leads to a lablab forage : stover ratio which in the range of 0.2-0.3, it is not necessary to supplement with urea because lablab would provide the necessary fermentable N as well as fermentable fibre in the diet.

REFERENCES

Abdulrazak, S. A. 1995. The effect of supplementing roughage diets with leguminous tree forages on intake, digestion and performance of crossbred cattle in coastal lowland Kenya. *PhD thesis, University of Aberdeen.*

Agricultural Research Council. 1980. *The nutrient requirements of ruminant livestock.* Commonwealth Agricultural Bureaux, Slough.

Akin, D. E. 1989. Histological and physical factors affecting digestibility of forages. *Agronomy Journal* **81**: 17-25.

Association of Official Analytical Chemists. 1980. *Official methods of the Association of Official Analytical Chemists.* 13 th ed. Association of Official Analytical Chemists, Washington, DC.

Barry, T. N. 1984. The role of condensed tannin in the digestion of fresh *Lotus pedunculatus*. *Canadian Journal of Animal Science* **64**: 181-182.

Bauchop, T. 1981. The anaerobic fungi in rumen fibre digestion. *Agricultural Environment* **6**: 333-348.

Berthe, A. 1991. Effect of harvesting systems and wilting on Bermudagrass nutrient recovery and nutrient utilization by beef cattle. *PhD thesis, University of Florida.*

Berthe, A. L., Blockland, A., Bouare, S., Diallo, B., Diarra, M. M., Geerling, C., Mariko, F., N'Djim, H. and Sanogo, B. 1991. Profil d'environnement Mali-Sud. IER/Bamako, IRT/Amsterdam.

Bird, S. 1991. The role of protozoa in relation to the nutrition of the host animal. In *Recent Advances in the Nutrition of Herbivores* (eds. Y. W. Ho, H. K. Wong, N. Abdullah and A. Z. Tajuddin). Malaysian Society of Animal Production, Serdang, Malaysia pp. 171-180.

Bird, S. H. and Leng, R. A. 1978. The effects of defaunation of the rumen on the growth of cattle on low-protein high-energy diets. *British Journal of Nutrition* **40**: 163-167.

Blaxter, K. L. 1962. *The Energy Metabolism of Ruminants.* London: Hutchinson.

Broderick, G. A., Wallace, R. J. and Ørskov, E. R. 1991. Control of rate and extent of protein degradation. In *Physiological Aspects of Digestion and Metabolism in Ruminants* (eds. T. Tsuda, Y. Sasaki and R. Kawashima). Academic Press, San Diego, USA pp. 541-592.

Cheng, K. J., Forsberg, C. W., Minato, H. and Costerton, J. W. 1990. Microbial ecology and physiology of feed degradation within the rumen. In *Physiological Aspects of Digestion and Metabolism in Ruminants* (eds. T. Tsuda, Y. Sasaki and R. Kawashima). Academic Press, San Diego, USA pp. 594-624.

Cheng, K. J., Stewart, C. S., Dinsdale, D. and Costerton, J. W. 1983/84. Electron microscopy of bacteria involved in the digestion of plant cell walls. *Animal Feed Science and Technology* **10**: 93-120.

Crampton, E. W., Donefer, E. and Lloyd, L. E. 1960. A nutritive value index for forages. *Journal Animal Science* **19**: 538-544.

D'Mello, J. P. F. 1992. Chemical constraints to the use of tropical legumes in animal nutrition. *Animal Feed Science and Technology* **38**: 237-261.

Davis, C. H., Saadullah, M., Dolberg, F. and Haque, M. 1983. Ammonia treatment of straw for cattle production in intensive agrarian agriculture ADAB News. Bangladesh.

Devendra, C. 1995. Composition and Nutritive Value of Browse Legumes. In *Tropical Legumes in Animal Nutrition* (eds. J. P. F. D'Mello and C. Devendra) pp. 49-65.

Dixon, R., M. 1986. Maximizing the rate of fibre digestion in the rumen. In *Ruminant Feeding Systems Utilizing Fibrous Agricultural Residues* (ed. R. M. Dixon). Canberra, ACT, Australia pp. 49-67.

Dolberg, F., Saadullah, M., Haque, M. and Ahmed, R. 1981. Storage of urea-treated straw using indigenous material. *World Animal Review* **38**: 37-41.

Durand, M. and Komisarczuk, S. 1988. Influence of major minerals on rumen microbiota. *Journal of Nutrition* **118**: 249-260.

Durand, M., Beaumatin, Ph., Dumay, C., Maschy, R. and Komisarczuk, S. 1986. Influence de l'addition de phosphore sur la digestion d'une paille traitee a l'ammoniac par les microorganismes du rumen en fermenteur semi-continu (Rusitec). *Reproduction Nutrition Development*. **26**: 297-298.

Egan, A. R., Frederick, F. and Dixon, R. M. 1986. Improving efficiency of use of supplements by manipulation of management procedures. In *Ruminant Feeding Systems Utilizing Fibrous Agricultural Residues* (ed. R. M. Dixon). Canberra, ACT, Australia pp. 69-81.

Elliot, R. 1986. The use of green forage material to improve the nutritional status of animals fed low quality crop residues. In *Ruminant Feeding Systems utilizing fibrous agricultural residues* (ed. R. M. Dixon). Canberra, ACT, Australia pp. 49-67.

Elliot, R. C. and Topps, J. H. 1963. Voluntary intake of low protein diets by sheep. *Animal Production* **5**: 269-276.

ESPGRN/Sikasso. 1994/95. Rapport Commission Technique sur les Systems de Production Rurale. Campagne 1994/95.

Falvey, J. L. 1982. The effect of infrequent administration of urea on rumen ammonia and serum level of cattle consuming rice straw. *Tropical Animal Production* **7**: 209-212.

Ferero, O., Owens, F. N., and Lusby, K. S. 1980. Evaluation of slow-release urea for winter supplementation of lactating range cows. *Journal of Animal Science* **50**: 532-538.

Getachew, G., Said, A. N. and Sundstol, F. 1994. The effect of forage legume supplementation and body weight gain by sheep fed a basal diet of maize stover. *Animal Feed Science and Technology* **46**: 97-108.

Goering, H. K. and Van Soest, P. J. 1970. Forage fibre analysis (apparatus, reagents, procedures and some applications). *Agricultural handbook, US Department of Agriculture, no. 379*.

Harrison, D. G. and McAllan, A. B. 1980. Factors affecting growth yields in the reticulo-rumen. In *Digestive Physiology and Metabolism in Ruminants* (eds. Y. Ruckebusch and P. Thivend). MTP Press, Lancaster, UK pp. 205-226.

Hendricksen, R. E., Poppi, D. P. and Minson, D. J. 1981. The Voluntary Intake, Digestibility and Retention Time by Cattle and Sheep of Stem and Leaf Fractions of a Tropical Legume (*Lablab purpureus*). *Australian Journal of Agricultural Research* **32**: 389-398.

Hennesy, D. W. 1984. Response of cattle on low quality pasture to increments of urea or to a supplement of protein. *Proceedings of the Australian Society of Animal Science*. **15**: 388-391.

Hungate, R. E. 1966. The Rumen and its Microbes. Academic Press, London and New York.

Hunter, R. A., Miller, C. P. and Siebert, B. D. 1978. The effect of supplementation or fertilizer application on the utilization by sheep of *Stylosanthes guianensis* grown on sulphur deficient soils. *Australian Journal of Experimental Agriculture and Animal Husbandry* **18**: 391.

Kay, R. N. B. 1993. Digestion in Ruminants at Pasture. *World Conference on Animal Production*, Edmonton, Canada pp. 461-474.

Kimambo, A. E., Makiri, A. M. and Shem, M. N. 1991. The use of *Leuceana leucocephala* supplementation to improve the utilization of maize stover by sheep. In *Complementary of feed resources for animal production in Africa* (eds. J. E. S. Stares and A. N. Said). Proceedings of the joint Feed Resources Networks Workshop held in Botswana, 1991 pp. 430.

Kitalyi, A. and Owen, E. 1993. Sorghum stover and lablab bean haulm as food for lactating cattle in the agro-pastoral system of central Tanzania. In *Animal Production in Developing Countries* (eds. M. Gill, E. Owen, G. E. Pollott and T. L. J. Lawrence). BSAP Occasional Publication **16** BSAP (British Society of Animal Production), Edinburgh, UK pp. 170-171.

Krebs, G. and Leng, R. A. 1984. The effect of supplementation with molasses / urea blocks on ruminal digestion. *Proceedings of the Australian Society of Animal Production* **15**: 704.

Krebs, G., Leng, R. A. and Nolan, J. V. 1989. Effect on bacterial kinetics in the rumen of eliminating rumen or supplementing with soyabean meal or urea in sheep fed on low protein fibrous feed. In *The Role of Protozoa and Fungi in Ruminant Digestion* (eds. J. V. Nolan, R. A. Leng and D. I. Demeyer). Armidale, Australia: Penambul Books pp. 199-210.

Kumar, R. 1992b. Antinutritional factors, the potential risks of toxicity and methods to alleviate them. In *Legume Trees and other Fodder Trees as Protein Sources for Livestock*. (eds. A. Speedy and P. L. Pugliese). Food and Agricultural Organization of the United Nations, Rome pp. 145-160.

Kumar, R. and D'Mello, J. P. F. 1995. Antinutritional factors in forage legumes. In *Tropical Legumes in Animal Nutrition* (eds. J. P. F. D'Mello and C. Devendra) pp. 95-133.

Kumar, R. and Horigome, T. 1986. Fractionation, characterization and protein precipitation capacity of the condensed tannin from *Robinia pseudoacacia* leaves. *Journal of Agricultural Food Chemistry* **34**: 487-489.

Kumar, R. and Singh, M. 1984. Tannin, their adverse role in ruminant nutrition. *Journal of Agricultural and Food Chemistry* **32**: 447-453.

Leloup, S. J. E. 1994. Multiple use of rangelands within agropastoral systems in Southern Mali. *PhD thesis, University of Wageningen*.

Leng, R. A. 1989. Some factors influencing the efficiency of feed utilization by ruminants with special reference to the tropics. In *Recent Advances in Animal Nutrition in Australia* (ed. D. J. Farrell). University of New England, Armidale, Australia pp. 75-85.

Leng, R. A. 1990. Factors affecting the utilization of 'poor quality' forages by ruminants particularly under tropical conditions. *Nutritional Research Review* **3**: 277-303.

Leng, R. A., Bird, S. H., Klieve, A., Choo, B., Ball, F. M., Asefa, G., Brumby, P., Mudgal, V. D., Chaudhry, U. B., Haryonto, S. U. and Hendranto, N. 1992a. The potential for the forage supplements to manipulate rumen protozoa to enhance protein to energy ratios in ruminants fed poor quality grass. *Proceedings of the Food and Agriculture Organization Expert Consultation*. Animal Production and Health Paper no.102 pp.177-192.

- Magan, J. L. 1988.** Nutritional effects of tannins in animal feeds. *Nutritional Research Review* **1**: 209-232.
- Makkar, H. P. S. 1991.** Antinutritional factors in food for livestock. In *Animal Production in Developing Countries*. Proceedings of symposium BSAP occasional publication no. **16**.
- Makkar, H. P. S., Borrowy, N. K. and Becker, K. 1992.** Quantitative of polyphenolics in animal feedstuffs. *Proceedings of VXI International Conference of Groupie Polyphenol*, Lesbon, 13-17 July.
- Manyuchi, B. 1994.** High quality forages as supplements to low quality forages for ruminants: Effect on intake, digestibility and rumen digesta dynamics. *PhD thesis, University of Aberdeen*.
- Mbatya, P. B. A., Kay, M. and Smart, R. I. 1983.** Methods of improving the utilization of cereal straw by ruminants. I. Supplements of urea, molasses and dried grass and treatment with sodium hydroxide. *Animal Feed Science and Technology* **8**: 221-227.
- McDonald, I. 1981.** A review model for estimation of protein degradability in the rumen. *Journal of Agricultural Science Cambridge* **96**: 251-252.
- McDonald, P., Edwards, R. A. and Greenhalgh, J. F. D. 1995.** *Animal Nutrition*. 5th Edition.
- McLeod. 1974.** Plant tannin their role in forage quality. *Nutrition Abstract Review* **411**: 803-813.
- McMeniman, N. P., Elliot, R. and Ash, A. J. 1988.** Supplementation of rice straw with crop by-products. 1. Legume straw supplementation. *Animal Feed Science and Technology* **19**: 43-53.
- Mehanson, H., Butler, L. G. and Carlson, D. M. 1987.** Dietary tannin and salivary proline rich protein: interaction, and defense mechanisms. *Annual Review of Nutrition* **7**: 400.
- Milford, R. and Minson, D. 1968.** The effect of age and method of hay making on the digestibility and voluntary intake of the forage legumes *Dolichos lab-lab* and *Vigna sinensis*. *Australian Journal of Experimental Agriculture* **7**: 515-517.
- Minson, D. J. and Milford, R. 1967.** The voluntary intake and digestibility of diets containing different proportions of legume and mature pangola grass (*Digitaria decumbens*). *Australian Journal of Experimental Agriculture and Animal Husbandry* **7**: 545-551.
- Minson, D. J. and Norton, B. W. 1984.** The possible cause of the absence of hypomagnesemia in cattle grazing tropical pastures. A review. *Proceedings of the Australian Society of Animal Production* **14**: 357-360.

Mitjavila, S., Lacombe, C. Carreta, G. and Derache, R. 1977. Tannic acid and oxidized tannic acid on the functional state of rat intestinal epithelium. *Journal of Nutrition* **107**: 2113-2120.

Mosi, A. K. and Butterworth, M. H. 1985. The voluntary intake and digestibility of combinations cereal crop residues and legume hay by sheep. *Animal Feed Science and Technology* **12**: 241-251.

Muinga, R. W., Thorpe, W. and Topps, J. H. 1992. Voluntary food intake, live-weight change and lactation performance of crossbred dairy cows given *ad libitum* *Pennisetum purpureum* (Napier grass var. Bana) supplemented with leucaena forage in the lowland semi-humid tropics. *Animal Production* **55**: 331-337.

Muinga, R. W., Thorpe, W. and Topps, J. H. 1993. Lactational performance of Jersey cows given Napier fodder (*Pennisetum purpureum*) with and without protein concentrates in the semi-humid tropics. *Tropical Animal Health and Production* **25**: 118-128.

Ndlovu, L. R. 1991. Complementary of forages in ruminant digestion: Theoretical considerations. In *The Complementarity of Feed Resources for Animal Production in Africa* (eds. J. E. S. Stares, A. N. Said and J. A. Kategile). Proceedings of the joint Feed Resources Networks Workshop held in Gaborone, Botswana, 4-8 March 1991. ILCA, Addis Ababa, Ethiopia pp. 17-23.

Ndlovu, L. R. and Buchaman-Smith, J. G. 1985. Utilization of poor quality roughage by sheep: Effect of alfalfa supplementation on ruminal parameters, fibre digestion and rate of passage from the rumen. *Canadian Journal of Animal Science* **65**: 693-703.

Norton, B. W. and Poppi, D. P. 1995. Composition and Nutritional Attributes of Pasture Legumes. In *Tropical Legumes in Animal Nutrition* (eds. J. P. F. D'Mello and C. Devendra) pp. 23-47.

Orpin, C. G. 1975. The role of Ciliate Protozoa and Fungi in the rumen digestion of plant cell wall. *Animal Feed Science and Technology* **10**: 121-124.

Orpin, C. G. 1981. Fungi in ruminant degradation. In *Agricultural Science Seminar: Degradation of plant cell-wall material*, Agricultural Research Council, London pp. 37-46.

Orpin, C. G. 1983. The role of ciliate protozoa and fungi in the rumen digestion of plant cell walls. *Animal Feed Science and Technology* **10**: 121-143.

Ørskov, E. R. 1982. Voluntary intake of poor quality roughages by ruminants. In *Maximum Livestock Production from Minimum Land*. Proceedings of the Third Seminar held in Bangladesh, 13-18 February, 1982 pp. 72-78.

Ørskov, E. R. 1992. Protein Nutrition in Ruminants. London, UK. Academic Press.

Ørskov, E. R. 1995. Optimizing rumen environment for cellulose digestion. In *Rumen Ecology Research Planning* (eds. R. J. Wallace and A. Lahlou-Kassi). Proceedings of a Workshop held at ILRI, Addis Ababa, Ethiopia, 13-18 March 1995 pp. 177-182.

Ørskov, E. R. and Dolberg, F. 1984. Recent advances in ruminant nutrition and their relevance to milk production in developing countries. In *Milk production in developing countries*. Proceedings of a conference held in Edinburgh, Centre for Tropical Veterinary Medicine, 2-6 April 1984. Rowett Research Institute, Aberdeen, UK pp. 177-192.

Ørskov, E. R. and McDonald, I. 1979. The estimation of protein degradability in the rumen from incubation measurements weighed according to rate of passage. *Journal of Agricultural Science, Cambridge* **92**: 499-503.

Ørskov, E. R. and Ryle, M. 1990. Energy nutrition in ruminants. Elsevier, Applied Science.

Pathirana, K. K. and Ørskov, E. R. 1995. Effect of supplementing rice straw with urea and glyricidia forage on intake and digestibility by sheep. *Livestock Research for Rural Development, Vol. 7, No.2*.

Poppi, D. P., Gill, M., France, J. and Dynes, R. A. 1990. Additivity in intake models. In *Modelling Digestion and Metabolism in Farm Animals* (eds. A. B. Robson and D. P. Poppi). Proceedings of the Third International Workshop, Lincoln University, New Zealand pp. 29-46.

Preston, T. R. and Leng, R. A. 1987. Matching Ruminant Production Systems with Available Resources in the Tropics and Subtropics. Armidale, Australia: Penambul Books.

Russell, J. B. and Baldwin R. L, 1978. Substrates preferences in rumen bacteria: Evidence of catabolite regulatory mechanisms. *Applied Environmental Microbiology* **36**: 319-329.

Said, A. N. and Tolera, A. 1993. The supplementary value of forage legume hays in sheep feeding: feed intake, nitrogen retention and body weight change. *Livestock Production Science* **33**: 229-237.

Satter, L. D. and Slyter, L. L. 1974. Effect of rumen ammonia concentration on rumen microbial production *in vitro*. *British Journal of Nutrition* **34**: 199-208.

Shem, M., Ørskov, E. R. and Kimambo, A. E. 1995. Prediction of voluntary dry matter intake and growth rate of cattle from the degradation characteristics of tropical foods. *Animal Science* **60**: 65-74.

Siebert, B. D. and Hunter, R. A. 1982. Supplementary feeding of grazing animals. In *Proceedings of an International Symposium on Nutritional Limits to Animal Production from Pastures* (ed. J. B. Hacker), St Lucia, Queensland, Australia, CAB, Farnham Royal, UK, 24-28 August 19981 pp. 409-426.

Siebert, B. D. and Kennedy, P. M. 1972. The utilization of speargrass (*Heteropogon contortus*). 1. Factors limiting intake and utilization by sheep. *Australian Journal of Agricultural Research* **23**: 35-44.

Silva, A. and Ørskov, E. R. 1985. Effect of unmolassed sugarbeet pulp on the rate of straw degradation in the rumen of sheep given barley straw. *Proceedings of the Nutrition Society* **44**: 50A.

Silva, A. T. and Ørskov, E. R. 1988. The effect of five different supplements on the degradation of straw in sheep given untreated barley straw. *Animal Feed Science and Technology* **19**: 289-298.

Smith, O. B and Van Houtert, M. F. J. 1987. The feeding value of *Gliricidia sepium*. A review. *World Animal Review* **62**: 57-68.

Smith, O. B. 1992. Small ruminant feeding systems for small-scale farmers in humid west Africa. In *The Complementarity of Feed Resources for Animal Production in Africa* (eds. J. S. Stares, A. N. Said and J. A. Kategile). Proceedings of the Joint Feed Resources Networks Workshop held in Gaborone, Botswana, 4-8 March, 1991. ILCA, Addis Ababa, Ethiopia pp. 363-376.

Smith, T. Manyuchi, B. and Mikairi, S. 1989. Legume supplementation of maize stover. In *Utilization of research results on forage and agricultural by-product materials as animal feed resources in Africa* (eds. B. H. Dzowela, A. N. Said, A. Wendem-Agenehu and J. A. Kategile). ILCA, Addis Ababa, Ethiopia pp. 303-320.

Snedecor, G. W. and Cochran, W. G. 1980. Statistical Methods. 7 th ed. The Iowa State University Press. Ames, Iowa, USA.

Soetanto, H. 1986. Studies on the role of rumen anaerobic fungi and protozoa in fibre digestion. *MResc thesis, University of New England, Armidale, Australia.*

Thomas, C. Gill, M. and Austin, A. R. 1980. The effects of supplements of fish meal and lactic acid on voluntary intake of silage by calves. *Grass and Forage Science* **35**: 275.

Topps, J. H. 1972. Urea or biuret supplements to low protein grazing in Africa. *World Animal Review* **3**: 14-18.

Topps, J. H. 1992. Potential, composition and use of legume shrubs and trees for livestock in the tropics. *Journal of Agricultural Science, Cambridge* **118**: 1-8.

Topps, J. H. 1995. Forage legumes as protein supplements to poor quality diets in the semi-arid tropics. In *Rumen Ecology Research Planning* (eds. R. J. Wallace and A. Lahlou-Kassi). Proceedings of a Workshop held at ILRI, Addis Ababa, Ethiopia, 13-18 March 1995 pp. 183-190.

Van Hoven, W. 1984. Tannin and digestibility in greater kudu. *Canadian Journal of Animal Science* **64**: 177-178.

Van Soest, P. J. 1987. Effect of environment and quality of fibre on the nutritive value of crop residues. In *Plant breeding and the nutritive value of crop residues*. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 7-10 December 1987.

Van Soest, P. J. 1995. Nutritional Ecology of the Ruminant. Durhan and Downey, Oregon, USA. 2nd Edition.

Vanzant, E. S. and Cochran, R. C. 1993. Performance and forage utilization by beef cattle receiving increasing amounts of alfalfa hay as supplement to low-quality, tall grass-prairie forage. *Journal of Animal Science* **72**: 1059-1067.

Verma, M. L. and Jackson, M. G. 1984. Straw, etc, in practical rations for cattle and buffalo, with special reference to developing countries. In *Straw and other fibrous by-products as feeds* (eds. F. Sundstol and E. Owen). Elsevier, Amsterdam, The Netherlands pp. 414-430.

Wilson, J. R. and Minson, D. J. 1980. Prospects for improving the digestibility and intake of tropical grasses. *Tropical Grassland* **14**: 253-259.

Yates, N. G. 1984. Intraruminal variation in cellulose digestion in the bovine in relation to microbial colonization and activity. In *Ruminant physiology; Concepts and Consequences* (eds. S. K. Baker, J. M. Gawthorne, J. B. Mackintosh and D. B. Purser). School of Agriculture, University of Western Australia, Australia pp. 139-148.