CHAPTER 1

1. INTRODUCTION AND LITERATURE REVIEW

Poor nutrition is one of the major constraints of animal production in sub-Saharan Africa. This is because animals live predominantly on high fibre feeds, which are often deficient in nutrients (nitrogen, minerals etc.). Legumes have become more important for use as high quality forage for livestock, both in cultivated pastures and in naturally occurring associations. Tropical forage legumes are important in the nutrition of small ruminants (goats and sheep). Nutritionally they are 2-3 times richer in protein than cereal grains. There is an increasing interest in the use of leguminous trees as a source of high quality feed for grazing and as a supplement to improve the productivity of ruminants receiving poor quality roughages. Leguminous trees are usually long-lived and have low maintenance requirements and, therefore, enhance the sustainability of farming systems (Gutteridge and Shelton, 1994).

In semi-arid and arid environments, legumes are important because plant growth is limited by rainfall and inadequate feed supply represents the most critical constraints to animal production (Devendra, 1989). Tree and shrubs legumes have provided valuable forage for herbivores since the time of their domestication (Robinson, 1985). At least 75% of the shrubs and trees of Africa serves as browse plants and many of them are leguminous (Skerman, 1977).

The nutritional quality of tree legumes varies from excellent (*Leucaena leucocephala*) to quite poor (*Acacia* species). Poor quality can firstly be due to tannins, which reduce the digestibility of herbage and protein, and secondly due to phylloides (expanded and flattened leaf petioles) of some species, instead of pinnate or binnate leaves, which are very high in fibre and therefore of low digestibility (Gutteridge and Shelton, 1994).

Table 1.1 Characteristics of forage tree legume species (Brewbaker, 1986)

Species	Form	Preferred env.	Tolerance of					CP	IVDOM
			Drought	Water logging	Acid soils	Alkaline soils	Cold		
A. angustissima	Shrub	Humid/ tropics	Fair	Fair	Good	-	Fair	23	48
A.saligna	Shrub/ Tree	semiarid/ subtropics	Good	Fair	Good	Good	Good	12-16	40
I.species	Shrub	tropics/ subtropics	Good	Poor	Good	Good	Fair	-	-
L.leucocephala	Shrub/ tree	shrub/tree	Good	Poor	Good	Fair	Fair	15-28	55

1.1 Description of *Indigofera* species

Shrubby *Indigofera* species are up to 2m high, erect, branched:leaflets are in five to eight pairs and oblanceolate, about 1 to 1.5 cm long, smooth above and hairy beneath, while flowers are yellow in 6-12 flowered racemes. Pods are chestnut-brown when mature, 1.5 – 4 cm long, polished and six to eight seeded (Andrews, 1952). *Indigofera* species generally prefer light (sandy) and medium (loamy) soils, require well-drained soils and can grow in very alkaline soil (Liogier, 1990).

Indigofera spicata is a vigorous and potentially useful tropical legume but contains hepatotoxic amino acid (Indospicine), which interferes with the metabolism (Hutton, 1970). A number of other *Indigofera* species also contain indospicine and it is recommended that they should be fed with care and not constitutes more than 50% of the diet of cattle and should not be fed to pigs or poultry (Church, 1980). *Indigofera* species have low palatability during the rainy season, but are well browsed towards the end of the dry season when secondary shoots are also eaten readily.

Indigofera species contain the pigment indigo, which may become an important commercial crop in various tropical and sub-tropical areas, apart from its use as grazing forage and high quality supplement for ruminants (Haude, 1997). Leaves of *Indigofera* species, alone or in combination with other ingredients, are also used in herbal medicine to treat fever, headache and acute cough (Liogier, 1990).

Indigofera arrecta originated from East Africa, and it is today found throughout the world ′s tropical regions. Its dispersion is largely due to the growth of indigo production in the European colonies. It was taken to Indonesia where, during the 19th century it was widely grown. The same plant was later grown in India in comparison to indigenous indigo plants. Compared to other species, *Indigofera arrecta* contains better pigment quantities and became economically the most important indigo species in India.

1.2 Chemical composition of *Indigofera* species

An analysis of *Indigofera hirsuta* (Dougall and Bogdan, 1966) indicating a composition of 23.8% crude protein (CP), 2.0% ether extract (EE), 15.2% crude fibre (CF), 46.8% nitrogen free extract (NFE), 1.88% calcium (Ca) and 0.37% phosphorus (P), demonstrated its excellent quality. However, silage prepared of *Indigofera hirsuta* satisfied only the maintenance requirements of stock and was not well eaten by sheep (Catchpoole and Henzell, 1971). One of the valuable attributes of *Indigofera hirsuta* is that it produces prolific seed, namely 440 000 seeds/kg.

The calcium concentration of *Indigofera* species is relatively high and usually ranges from 0.5 to 2.0%, where normal ranges of 0.20 to over 0.30%, would satisfy animal requirements. The stems of leguminous plants became more fibrous with age and contain more (CF) and less (CP) than the younger stems. Little fibre has, however, been observed in the leaves of legumes and they remain nutritious and palatable at an advanced stage of growth, often throughout the dry season, when legumes are of particular value for late season grazing (Bartha, 1970).

1.3 Factors affecting mineral contents of the plants

Concentrations of mineral elements in forage are dependent upon the interaction of a number of factors, including soil pH, plant species, stage of maturity, and climatic conditions.

1.3.1 Soil pH

As the soil pH increases, the availability and the uptake of Mn, Zn, Cu by forages decrease, whereas the forage Mo and Se concentration increases (McDowell, 1985).

1.3.2 Stage of maturity

As the plants mature, mineral content declines due to a natural dilution process and the translocation of nutrients to the root system. In most circumstances P, K, Mg, Na, Cl, Cu, Co, Fe, Se, Zn and Mo decline as the plant matures (Ford *et al*., 1979).

1.3.3 Climatic conditions

The temperature and rainfall all affect the rate of growth and the rate of transpiration and the latter factor has an influence on the amount of salts in solution brought in by the roots of the plant (Dougall and Bogdan, 1958).

1.4 Environmental adaptation

Indigofera spicata is distributed in tropical Africa, South Africa, Madagascar, Sri Lanka, Southern and South-eastern Asia and tropical America. It occurs in grasslands and rocky places, but mostly on wastelands and other disturbed habitats. *Indigofera spicata* is relatively drought resistant and can grow under moderate annual rainfall and on relatively poor soils. The plants are moderately specific in their rhizobium requirements and can be inoculated by a few strains of cowpea-type rhizobium (Henzell, 1962).

Introduced into cultivation, *Indigofera spicata* has yielded well, formed balanced mixtures with grasses and was reasonably grazed. The use under cultivation is, however, restricted by its toxicity to animals expressed in liver degeneration in cows and sheep, and especially in horses, while pregnant animals can abort (Hutton, 1970).

1.5 Nutritive value

It is important to understand the term nutritive value, which is also a key in this discussion. Nutritive value is a function of the feed intake and the efficiency of extraction of nutrients from the feed during digestion. Feeds of high nutritive value promote a high level of production (Eagan *et al*., 1986). The nutritive value of feed is determined by the ability to provide the nutrients required by animals for maintenance, growth and reproduction. The nutritive value of browse legumes depends on the voluntary intake of feeds consumed and the extent to which the quantity of dry matter consumed by animals supplements dietary energy, proteins, minerals and vitamins. Much will depend on the actual quantity of feed eaten by the animal on a daily basis (Dougall *et al*., 1964).

1.5.1 Factors which influence nutritive value

Different plant species differ inherently in their rate of reproductive development. This results not only in changes in chemical and anatomical characteristics, but also in proportion of plant parts e.g. leaf, stem and petiole. Management and environment can then play a significant role in affecting nutritive value.

1.5.1.1 Plant maturity

Advancing plant maturity is associated with lowering of nutritive value by virtue of a decrease in leafiness and a decrease in the leaf: stem ratio, changes in the composition of the cell wall (Akin *et al*., 1977) and loss of cell contents during maturity (Ballard *et al*., 1990). The loss of cell contents during maturation is a major factor contributing to the decline in nutritive value.

1.5.1.2 Environment

Temperature and light are the most important environmental factors that affect nutritive value. The temperature under which plants are grown has a direct effect on the concentration of chemical constituents, with genotype then determine exactly how different species change with increasing temperature. Higher temperature usually promotes the accumulation of structural material (cell wall material) and more rapid metabolic activity, which decrease the pool size of cell contents (Ford *et al*., 1979).

1.5.1.3 Genetic variation

Plants have adapted to specific environments through evolution and those that have evolved under grazing have protective mechanisms against predatory attack (whether it be by animals or insects). Some of those mechanisms include lignification and secondary compounds, which will influence the nutritive value (Tabe *et al*., 1993).

1.5.2 Measurement of nutritive value

The direct estimation of nutritive value involves, at least, the measurement of digestibility. The availability of digested nutrients and their efficiency of use by the animal may either be measured directly or, more usually, predicted from digestibility using standard equations derived from a large number of feeding trials (NRC, 1985).

1.5.2.1 Total collection

The usual method for direct measurement of digestibility is a total collection trial, in which animals are constrained and the entire amount of feed eaten and faeces voided are weighed and analysed, the difference being assumed to be digested (NRC, 1985; SCA, 1990).

1.5.2.2 Marker technique

When digestibility estimates of diet consumed by grazing animals are desired, total collection trials are difficult, and indirect methods, such as the use of a marker, are therefore recommended. This can be done either by the dosing of animals with markers to estimate both faecal output and intake, or by using markers, which are part of the herbage.

1.5.3 Methods for predicting nutritive value

Nutritive value can be predicted or estimated in terms of digestibility or the voluntary intake. Coleman *et al*. (1990) reviewed methods for predicting nutritive value, which included bioassay, chemical and structural characteristics as well as instrument-based methods such as the near-infrared reflectance spectroscopy (NIRS). There are two steps involved in predicting nutritive value, which are as follows:

1.5.3.1 Data-base selection

Selection of an appropriate sample data-base, with high quality reference data, is the most important part of the prediction process.

1.5.3.2 Development and evaluation of prediction equation

Weis (1993) proposed the use of theoretically based, rather than empirical relationships or models, to predict nutritive value.

1.5.3.3 Biological procedure

Three bioassay methods have been developed i.e. *in vitro* digestibility using rumen microorganisms (Tilley and Terry, 1963), *in vitro* digestibility using an enzyme preparation (McLeod and Minson, 1978) and the *in situ,* or nylon bag-technique (Ørskov and McDonald, 1979).

1.5.3.4 Physical procedure

- Near-infrared reflectance spectroscopy

Noris *et al*. (1976) were the first to report the use of NIRS to estimate chemical composition and nutritive value of forages.

The nutritive value of feeds should be ranked on the basis of the following characteristics (Leng, 1986):

- voluntary consumption potential;
- potential digestibility and ability to support high rates of fermentative digestion;
- high rates of microbial protein synthesis in the rumen relative to volatile fatty acids;
- high rates of propionic synthesis relative to total volatile fatty acids synthesis; and
- ability to provide bypass nutrients for absorption from the small intestines.

Tree legumes must have both desirable agronomic characteristics and a high nutritive value to be useful as forage. The leaves and the stems may be used either as a complete feed or as a supplement to other feeds. In some species, a major limitation to the use of one or more of the above-mentioned components is the presence of toxic and/or anti-nutritive factors (Norton, 1994).

1.5.4 Anti-nutritive and toxic factors in forage tree legumes

Leguminous trees and shrubs often have thorns, fibrous foliage and growth habits that protect the crown from defoliation. Certain anti-quality factors also affect animals and the nutritive value of forages (Norton *et al.*, 1992). The anti-nutritional effects present in some tree legumes are: reduction in voluntary intake; diminished digestibility of nutrients; adverse effects upon rumen metabolism and toxicity. Non- ruminants (e.g. pigs and poultry) are usually more susceptible to toxicity, as potential toxins may be denatured in the rumen (Duke, 1977).

1.5.1.1 Strategies for managing anti-nutritive factors

a) Use supplements to overcome the anti-nutritive factor,
   - High concentrations of condensed tannins can lower the feeding value due to reduced availability of nutrients, especially proteins and lower cell wall digestion (Barry and Blaney, 1987).

b) Reduce access to the problem feed
   - By reducing the proportion of the problem legume in the diet, adverse effects can be reduced (Wildin, 1985).

1.6 Voluntary feed intake

Rumination and fermentation are relatively slow processes and fibrous feeds may have to spend a longer time in the digestive tract. If feeds and their indigestible residues are retained for longer periods in the digestive tract, the animal's daily intake will be reduced. In ruminants there is a positive relationship between digestibility of feeds and their intake i.e. there will be an increase in intake, as the energy digestibility of feeds increase (Blaxter, 1961). Actually, intake is more closely related to the rate of digestion of diets than to digestibility, although the two measures are often related to one another, i.e. feeds that digest rapidly and are of high digestibility and promote high intake (Campling and Lean, 1983).

1.6.1 Intake of legumes

Physical regulation of intake in ruminants is a major factor influencing intake of forage by its mechanism of retention time of dry matter in the rumen. Forages with a long retention time in the rumen have a lower intake than those with a shorter retention time (Thorton and Minson, 1973). The shorter retention of legume particles is related to leaf anatomy, resulting in disintegration into small round particles. This is distinct from the long needle-like particles of the vascular bundles, as generated from grass leaves, and also faster rate of digestion of legumes compared to grasses. The physical regulation of intake is expressed as a relationship between intake and digestibility but Laredo and Minson (1973) showed that forages of the same digestibility could have vastly different intakes.

The main chemical component of feeds that determines the rate of digestion is the neutral detergent fibre (NDF), which is a measure of cell wall content. There is a negative relationship between NDF content of feeds and the rate at which they are digested. One consequence of this relationship is that those feeds that are equal in digestibility, but differ in NDF (cell wall) content, have different intakes. The two families of pasture plants, grasses and legumes, provide an example. At equal digestibility, legumes contain less cell wall and are consumed in quantities about 20% greater than grasses (Forbes, 1986).

The digestibility of plant material in the rumen is related to the proportion and lignification of plant cell wall. Tree forages with a low NDF content (20-35%) usually have a higher digestibility, while species containing lignin often have a low digestibility. Stems have higher lignin content than leaves and are thus less digestible (Bamualim *et al.*, 1980).

1.6.2 Factors which influence food intake

1.6.2.1 Psychological factors

Psychological factors also play a role in determining the feeds which animals choose, and the amount which they can consume. Chesworth (1992) stated that sheep and goats kept in pens, would eat more when they can see more food that they can consume. They suggest a practical way of increasing food intake; if animals are fed in pens, the food bins should always have sufficient feed.

1.6.2.2 Physiological factors

Animals that are offered a diet that has a very low energy content will consume more in an attempt to compensate. There are areas of the brain, in and around the hypothalamus, that monitor the animal's physiological status by measuring the level of glucose, lipids and amino acids in the blood plasma. When animals eat, the level of these compounds in the blood rise and when they do, there is a growing feeling of satisfaction, such that the animal stops eating (Forbes, 1995).

1.6.2.3 Animal size

Food intake is generally determined by the metabolic size of the animal and it is proportional to the animal's metabolic body weight. A mature animal would eat a diet, which will provide only enough food to maintain body weight and condition, whereas an animal, which is growing, requires enough food to supply its needs, both for maintenance and for extra body tissues (Illius and Allen, 1994).

1.6.2.4 Physical factor

1.6.2.4.1 Plant structure

The content of fibrous cell walls is a major factor, since these structures are less soluble and take up more space than the cell contents. Forages contain a large proportion of their organic matter content (35-80%) as cell walls, which provide the structural integrity of the plant (Jung and Allen, 1995). Minson (1990) reported that legume forages have a greater DM digestibility than grasses.

1.6.2.5 Dietary factor

1.6.2.5.1 Fibrous compounds

The source of fibre has a great influence on the rate of digestion. As grasses and legume forages mature, the nitrogen content drops and digestibility of fibrous feeds decreases. The poor digestibility of fibrous feeds is reflected in very low intakes by livestock.

1.6.2.6 Environmental factor

1.6.2.6.1 Effects of heat

When ambient temperatures are high, food intake decreases dramatically. If humidity is high, food intake is also reduced. This is because of the fact that animals produce heat inside the rumen and within their bodies.

1.6.2.7 Effects of climate and season on forage quality

1.6.2.7.1 Temperature

Lower digestibility at higher temperature is the result of the combination of two main effects i.e. high environmental temperatures result in the increased lignification of plant cell wall and high temperatures also promote more rapid metabolic activity. This activity decreases protein and soluble carbohydrates and increases the structural cell wall components (Van Soest, 1994).

1.6.2.7.2 Water

Lack of water tend to retard plant development and thus to slow maturity with the result that digestibility is increased and dry matter yield is reduced. Various studies have shown that lack of water increases digestibility and irrigation tends to decrease it (Wilson, 1983; Evans and Wilson, 1984; Dias Filho *et al.*, 1991).

1.6.2.7.3 Soil

Plants grown on different soils offer a different balance of mineral elements, which influence their growth and composition. Soil effects can be viewed from two points mainly: the accumulation in the plants of minerals and the influence of minerals in the plant on its organic matter yield, composition, and digestibility (Metson, 1978).

1.6.2.7.4 Defoliation and diseases

The physical loss of leaves, stems, or both represents a major stress that puts pressure on the plants to mobilize its reserves and put forth new leaves to restore its photosynthetic capability (Parsons *et al*., 1988; Parsons and Penning, 1988).

1.6.3 Utilization and beneficial effects of forage legumes

There are a number of advantages concerning the use of leguminous forages (Devendra, 1988). These include:

- Provision of variety in the diet;
- Source of dietary nitrogen (N), energy, minerals and vitamins;
- Laxative influence on the alimentary system;
- Reduced cost of feeding.

1.7 General description of *Leucaena leucocephala*

With *Leucaena leucocephala*, for example, the forage provides a valuable source of protein, energy and sulphur for rumen bacteria. This genus includes about 50 species, which occur almost exclusively in tropical America. It originated from Mexico but spread by accidental introduction first to the Caribbean islands and then to other areas and now has a pan-tropical distribution. This plant is valued for: its ability to withstand repeated defoliation, high yields of foliage and its tolerance to low soil fertility and relatively low rainfall. Slow early growth and a risk of animal poisoning are weak points (Plucknett, 1970).

The toxic constituent in *Leucaena* is a non-protein amino acid, mimosine, which is an antimitotic and depilatory agent (Hegarty *et al*., 1964). Mimosine occurs in all parts of the *Leucaena* plant, but in high concentrations particularly in the tips of actively growing shoots (8-12%) and young leaves (4-5%) (Lowry *et al*., 1983). The effect only occurs if

Leucaena constitutes a high proportion of an animal's diet (>30%), for an extended period, and may be negated by innoculation with specific rumen bacteria.

1.7.1 Environmental adaptation

Leucaena leucocephala is tolerant of adverse moisture conditions, apparently because of its deep roots and can be grown at an annual rainfall ranging from 500 to 5000 mm. At a low rainfall range it responds well to irrigation. Well-drained soils are required for good growth and high yields and waterlogging or flooding are not tolerated. It can withstand a slight soil acidity (of up to pH=5.0) but grows much better in neutral or slightly alkaline soils. *Leucaena leucocephala* is more tolerant of a low phosphorus status of the soil than a number of other tropical legumes and this may be due to the presence of endotrophic mycorrhiza which has been found in the roots (Possingham *et al*., 1971).

Leucaena is a tropical species requiring warm temperatures (25-30°C) for optimum growth (Brewbeker *et al*., 1985). It is not tolerant of frost which causes shedding of the leaves (Isarasenee *et al*., 1984). It is well known for its high nutritional value and for the similarity of its chemical composition with that of lucerne. Tannins in the leaves, and especially in the stem of *Leucaena,* reduce the digestibility of the dry matter and protein. Digestibility and intake values for *Leucaena* range between 50-71% (Jones, 1979). The lower values were suggested by Jones (1969) to be associated with effects of Mimosine on intake when pure diets of *Leucaena* were fed.

1.7.2 Chemical composition

Crude protein, in the majority of references quoted by Hill (1971), range from 14 to 19% in dry matter for the whole herbage, but Oaks (1968) gave a wider range, 15 to 25%. The content of CF usually fluctuates from 33 to 38%, NFE from 35 to 44%, CP and CF contents in the leaves are given as 28.8 and 12.8%, respectively. CP contents vary with plant age, which in its turn depends on the frequency of utilization.

1.7.3 Herbage productivity

Dry matter productivity varies with soil fertility and rainfall, edible yields range from 3 to 30 tons dry matter/ha/year. Deep fertile soil receiving more than 1500mm of well-distributed rainfall produced the largest quantity of fodder. Yields of *Leucaena*, where the temperature limits the growth rates, may be 1,5 to 10 tons of edible fodder/ha/year (Brewbaker *et al*., 1985).

The minimum requirements of ruminants for phosphorus (P) varies from 1.2 to 2.4g/kg feed dry matter, depending on the physiological function. Forage trees generally have high P concentrations (McMeniman and Little, 1974). Calcium (Ca) is closely associated with P metabolism in the formation of bones, and a Ca: P ratio of 2:1 is usually recommended for ruminant diets. Ca is rarely limiting in forage diets and the same is true for forage trees (Norton *et al*., 1992). High concentration of oxalic acid in the leaves may, however, decrease the availability of Ca during digestion and affect Ca metabolism in sheep (Gartner and Hurwood, 1976).

1.8 Limitations and problems

1.8.1 Non-toxic secondary plants compounds

The non-toxic compounds limit the nutritive value of forages by lowering their digestibility and palatability (Van Soest, 1982). Higher concentrations (>20g/kg DM) of these compounds are required for negative effects and the primary site of activity is in the digestive tract or sensory organs associated with feeding behavior (Reed *et al*., 2000).

1.8.2. Tannins

In particular, many tree legumes contain condensed tannins (CT). Tannins may have both positive and negative effects on feed quality for ruminants. Tannins are water-soluble phenolic compounds in plants with a molecular weight of >500 and with the ability to precipitate gelatin and other proteins from aqueous solution. In high concentrations they reduce intake and digestibility of proteins and carbohydrates, which will ultimately lead to a reduced animal performance.

Tannins can also increase the flow of protein compound through the rumen to the small intestines, thereby escaping microbial fermentation (McNeill *et al.*, 1998). Forages containing tannins can also protect animals against diseases caused by parasitic worms e.g. lambs grazing legume forage that contains tannins have a lower faecal parasitic egg count and worm burdens than lambs grazing *Medicago sativa*, which does not contain tannins (Reed, 1995).

Table 1.2. Example of non-toxic plant compounds of tannins present in forage and browse legumes

Pasture/browse Legumes	**Predominant tannins**	**Animal**	**Nutritional effect**
Acacia aneura	CT*	Sheep	Reduction in N digestibility, decreased wool yield and growth (Prichard *et al.*,1988).
A. cyanophylla	CT	Sheep	Reduced feed intake, negative N digestibility, loss in weight (Reed *et al.*, 1990).
A. nilotica	CT	Sheep	low growth rate, reduced N and NDF digestibility (Tanner *et al.*, 1990).
L. leucocephala	CT	Poultry	Poor N retention, low apparent ME (D'Mello and Acamivic, 1989).

*CT means condensed tannins

1.8.3 Lignin

Plant stems contain more lignified structural tissue than leaves and as a result are much less digestible (Moore and Jung, 2001). It is known that forage lignin concentrations vary, depending on the environmental conditions, where warm temperatures tend to increase lignin concentration in tropical plants. Lignification tends to decrease under low light, because under limited light plant development is delayed (Reed, 1995). Lignin also reduces the nitrogen balance of the animals by increasing endogenous and microbial nitrogen loss in faeces (Woodward and Reed, 1995).

1.8.4 Toxic-compounds in plants

Plants contain a wide range of toxic compounds, which may affect animals. Animal species differ in their susceptibility to plant toxins. For example, browsers are less susceptible than grazers (Cheeke, 1995).

1.8.5 Mimosine

In ruminants, the deleterious effects of mimosine are diverse, including loss of hair and wool, organ damage and death in animals unadapted to *Leucaena leucocephala* forage or in those given intravenous or oral doses of the pure amino acid (Reis *et al*., 1975). A solution to the mimosine problem could be the development of low mimosine cultivars. However, low mimosine types are found to be less productive and have poor vigour. The other approach is to feed leucaena mixed with other feeds. Hiremath (1981) suggested that the use of leucaena fodder might be restricted to 30% of the forage in the case of cattle and 50% for goats.

1.8.6 Indospicine

The toxic agent is 1-2-amino-6-amidinohexanoic acid, which was named indospicine (Hutton, 1970). Its toxicity to the animals is expressed in liver degeneration in cows and sheep, and especially in horses, and pregnant animals can abort (Hegarty and Pound, 1968).

1.8.7 Saponins

These are widely distributed in the plant kingdom and have a bitter taste and foaming properties (Agarwal and Rastogi, 1974). They have several negative effects that include poor growth, ruminal bloat, reduced feed intake and palatability, enzyme inhibition reduced nutrient absorption, antifungal activity that affects ruminal microbiology, rumen metabolism and ammonia binding properties (Cheeke, 1995).

1.9 Hypothesis and objectives

The main objective of this study is to evaluate the dry matter production, intake and the nutritive value of five *Indigofera* species, which are as follows; *I. arrecta*, *I. cryptantha*, *I. costata*, *I. amorphoides* and *I. viciodes*. This objective can be achieved through the analysis of chemical composition, *in vitro* digestibility and the determination of voluntary intake. The tropical legumes appear to be a richer source of protein and most minerals than grasses, and more usually legumes supplement grasses to improve the overall nutritive value of forage. Therefore it can be hypothesized that *Indigofera* species can be utilized as a supplement to grazing livestock (CP and minerals).