FEEDING BEHAVIOUR OF SHEEP AND GOATS ON LESPEDEZA AND LEUCAENA PASTURES AND THE EFFECT OF LESPEDEZA HAY ON FEACAL EGG COUNT

By

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Declaration

I, Walter G. Ketshabile, hereby declare that the research in this thesis is the result of my own investigation, except where acknowledged, and has not, in its entirety or part been previously submitted to any university or institution for degree purposes.

Signed. ………………………………………………………

I, Prof. Nsahlai, I.V. chairperson of the supervisory committee, approve release of this thesis for examination.

Signed…………………………………………………………

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List of Figures

List of Tables

List of Abbreviations

ADF	Acid detergent fiber
AOAC	Association of Official Analytical Chemists
CP	Crude protein
CT	Condensed tannin
DM	Dry matter
DMI	Dry matter intake
FEC	Feacal egg count
GE	Gross energy
GI	Gastro-intestinal
HEM	Hemicelluloses
NDF	Neutral detergent fiber
OM	Organic Matter
QT	Quebracho tannin
SL	Sericea lespedeza
VFI	Voluntary feed intake

Contents

Chapter 2: Daily variation on Intake rate and feeding behaviour by sheep and goats on Lespedeza and Leucaena

Chapter 3: The effect of supplementation of sheep and goats grazing Kikuyu pasture with *Serecia Lespedeza* on Endoparasites.

ABSTRACT

Feeding of lespedeza to sheep and goats, besides supplying protein, could be a possible alternative remedial control measure against gastro-intestinal parasites in sheep and goats. However, the feeding behaviour of individual animals and their feed intake are likely to influence t its effect on the parasites. This study was conducted to determine the different feeding behaviour of sheep and goats on *Sericea lespedeza* and its effect on faecal egg count. The first part dealt with behaviour of animals feeding on lespedeza or leucaena within the rangeland while for parasitic response they were fed on lespedeza or veld hay.

During feeding behavior, three sheep and three goats averaged 2- 3 years of age were observed for 30 days during the months of March and April 2006. Activities such as browsing, grazing and idling were recorded after every two minutes for every animal while following animals at a distance of five meters. Feed intake was determined by recording the number of bites made by each animal for a period of ten minutes and by estimating the weight of forage eaten.

More ($P<0.001$) browsing time was observed on goats at both lespedeza and leucaena plot than on sheep, with goats consistently spending longer time browsing than sheep on both lespedeza and leucaena than sheep between 7.00 and 14.00h. More of the browsing time of goats was spent on leucaena than on lespedeza. The longest time of grazing by animals was on the lespedeza plot than on leucaena plot, with sheep grazing for a longer ($P<0.001$) time than goats. The biggest difference in grazing time for sheep at the lespedeza and leucaena occurred during morning hours. Animal type and interaction of feed animal type significantly affected idling time with goats Idling for a longer ($P<0.001$) time than sheep at both the lespedeza and leucaena plots.

Feeding rate (bite/min) for both sheep and goats were similar on both lespedeza and leucaena plots. Intake rates were higher ($P<0.01$) for both sheep and goats on leucaena than on lespedeza, with sheep having higher ($P<0.01$) intake rates than goats on both plots. Animals had the fastest bite rate and intake rate during midday (12.00h) and lowest rates at 14.00h. The highest intake rate occurred on leucaena in the morning and afternoon, but lower than lespedeza during midday.

For parasites response twelve sheep and twelve goats aged between 3 and 4 years were used in a study that lasted 60 days. Animals were naturally infested by gastro-intestinal parasites.

Egg count was done according to McMaster egg count technique (Ministry of Agriculture, Fisheries and Food, 1977) by magnifying parasitic eggs from faecal samples dissolved in saturated sodium chloride. During feacal egg count, the effect of animal on feed intake was highly significant ($P<0.001$) with sheep consuming more of each kind of feed (lespedeza or hay) than goats. Live weight of animals decreased during the early period of feeding, beyond which it remained stable. Egg count varied significantly ($P = 0.015$) among periods of sampling, a general trend indicating a decrease from day 0 to day 46 beyond which egg count tended to increase. When regression analysis was done to determine the effect of the previous week's intake, it was observed that increased intake during the previous week was associated with depression in egg count, the effect attaining significance ($P<0.05$) for both sheep and goats on hay and for sheep on lespedeza.

The results of this study are rather inconclusive about the effect of supplementing small ruminants with *Sericea lespedeza* hay on gastro-intestinal parasites, owing to variation associated with intake of lespedeza and hay, thus warranting further investigation.

Chapter 1

General Introduction and Literature Review

1.0 General introduction

Sheep and goats production within both temperate and tropical regions is constrained by heavy burden of gastro-intestinal parasites (GIP), particularly the nematodes (*Haemonchus contort*us). These parasites can lay 5,000 to 10,000 eggs in a day within the abomasum of animals. Once the eggs are passed out with faeces on to the pasture, they hatch into larvae within 4 to 6 days (Loyacano et al., 2002), then crawl to the top of grass blades where they are later picked during grazing by animals. They attach to the lining of the gut, starts to feed, molt and develop into adult worms. Animals heavily infested by these parasites will have diarrhoea, become emaciated and anemic, and show signs of edema or eventually die.

The conventional method of control is based on repeated use of synthetic anthelmentic drugs. Several problems associated with the over use/or misuse of these drugs were recently observed worldwide (Prichard, 1994). Development of resistance by the parasites to the drugs has become more pronounced, and a search for alternative control is justifiable. Consumers of animal by-products have also become cautious of possible contamination of the products as a result of drugs residual effect, while small-scale farmers are also pushed out of the industry by unaffordable cost of drugs.

Manipulation of animal nutrition can increase the ability of animals to withstand the adverse effect of parasitism. Since animals that are likely to suffer more are those on poor nutrition, Coop *et al*. (2001) noted that improvement of animal nutrition could influence the development and consequences of parasitism by increasing the ability of host animals to cope with adverse consequence of the parasites. This means that the nutrients supplied can increase the immune response against the parasites or contribute by maintaining tissues damaged by parasites. Also, supplied nutrients can improve the ability of host animals to overcome parasitism by limiting the establishment, growth rate, fecundity or persistence of parasitic population. When animals are supplemented with dietary proteins, these proteins will be degraded and used by ruminal microorganism, or pass undegraded. Both the microbial protein and by-pass protein will be available at the lower gut of the ruminant or intestines for absorption.

The effect of supplementing sheep and goats with forages containing anthelmentic properties will therefore depend on the availability of that forage plant, its acceptance or selective behavior of animals. *Sericea lespedeza* (SL), also known as Chinese bush clover is one forage plant that has shown potential in controlling gastro-intestinal parasites. Its anthelmentic property is attached to the high concentration of its tannin content. Tannin is also associated with a number of adverse conditions when fed on by livestock. It is associated with reduced voluntary intake, reduced absorption of some minerals, reduced microbial activity in the rumen, and reduced protein utilization including toxic effect that can damage the kidney and liver. As a result tannins are often thought to decrease growth rate (Ben Salem *et al*., 2002), meat (Priolo and Ben Salem, 2004) and milk (Gilboa *et al*., 2000) production of sheep and goats fed on tanniferous plants. However, low levels of tannin (3-4 % DM) can benefit ruminants by protecting protein degradation from bacterial deamination and preventing bloat (Jones *et al*., 1976). Recent studies suggested that tannins could have some effect on nematode depopulation (Athenasiadou *et al*., 2003; Min *et al*., 2003; Waghorn and McNabb, 2003).

Sheep and goats differ in their feed selection (Lu, 1988). Goats appear to have capacity in selecting more nutritious parts of the forage offered than sheep and can adapt to seasonal variations in forage availability. This variation is more evident when goats are offered shrubs and trees on rangeland, but less evident when the feed is given in a trough (Morand-Fehr *et al*., 1991). When allowed free choice of a large variety of herbage, goats try to balance variations in fiber content in available pasture vegetation, both at high and at low fiber content, and also to maintain a protein content in the ingested herbage within a limited range (Fedele *et al*., 1993). This may indicates that within a short range of grazing, goats are more likely to select high quality forage than the rest of the available plants in order to maintain their nutritional requirement.

Different animals prefer different plant species, or proportion of plants in their diet. Since tannins are toxic, the amount of forage that can be eaten by animals in a day will depend on the animal's bite size and bite rate at which they will eat and on the postingestive effects of tannins. It is hypothesized that when there is plenty of good quality forage, animals are more likely to make more bite rates of larger sizes than when it is in short supply. When the forage is plenty, animals will select the highest quality forage present. Cooper and Owen-Smith (1986) suggested that lower browse availability limits the bite size of browse plants by goats. However, previous studies by Dziba *et al*. (2003) suggested that goats obtained higher bite rates when food availability was low in winter as compensation for the lower bite size.

This study will first focus on investigating the difference in feeding behaviour of sheep and goats, and their intake rate within the rangeland when feeding on lespedeza and leucaena. Different behavioral activities displayed by animals when feeding will be determined on individual animal. Although different methods in determining feeding behaviour and forage intake rate of animals can be used, in this study, short-term intake rate will be used. With this method the ingestive behavioural components of individual animal intake and influential interacting components of the pasture can be determined (Burns and Sollenberger, 2002). This method is equally used for wild and domesticated animals, and does not require any sophisticated equipments.

Most studies on the use of SL in controlling gastro- intestinal parasites were done using either goats or sheep separately, but not in comparison. In this study the two species of animals will be used together. It is hypothesized that the effect of lespedeza on reducing parasitic infestation will be more pronounced on goats because of their higher tolerance of forages with tannins than sheep. By preferring browse to sheep, goats are expected to take more of lespedeza, which will reduce the parasite and improve their live weight through improvement of protein supply, which is to be absorbed in the lower gut.

Literature Review

1.1 Background Information

In the last decade, the use of anthelmentic drugs in controlling gastro-intestinal (GI) parasites of ruminants has brought fear to livestock farmers and consumers due to an increasing resistance of parasites, residual effects in animal products and pasture, such that there was an increasing demand in developing alternative non-drug GI parasite control strategies (Butter *et al*., 2001).

These parasites reduce the efficiency of production of small ruminants (especially sheep and goats) and have adverse effects on their welfare resulting in depressed weight gain when feed intake is reduced (Butter *et al*., 2000) loss of endogenous protein and anorexia. The most highly pathogenic species of these GI parasites is *Haemonchous contortus*, which is widely distributed in the tropics.

Several alternative control strategies have been under investigation in order to minimize the loss caused by these parasites. These include breeding of genetically resistant animals (Gray, 1997) vaccination (Emery, 1996), biological control (Gronvold *et al*., 1996), nutrient supplementation (Coop & Holmes, 1996) and the use of forage plants with anthelmentic properties. The use of forage plants could be the best alternative since these can be readily available in the rangelands to most farmers, cost less and are of high nutritional value to grazing animals with less contamination of the pasture. Several studies suggested that the chemical composition of some plants could affect the number of different worm species depending on the concentration of condensed tannins (Niezen *et al*., 1998 and 2002b), while other studies have shown that the phenolic compound from these forages can also protect plant proteins from degradation in the rumen and could increase the supply and absorption of amino acids from the small intestines (Waghorn *et al*., 1987).

Small ruminant animals primarily depend on natural forages, which fluctuate in quantity and quality between seasons as well as years. Within the rangelands, there are those forage plants which will be selected by small ruminants, not because they meet their nutritional requirement, but because of the physiological and morphological orientation of the animal. Domestic sheep and goats and wild species under the same environmental conditions have foraging strategy defined as that of mixed/ intermediate feeders, feeding on a mixture of plant types including grass, forbs and browse (Hoffman, 1989). To understand how forage plants can be used in controlling GI parasites of sheep and goats, there is need to know whether these different feeding strategies can be exploited such that the animals can be able to take enough of the phenolic compounds.

1.2 Feeding behaviour of Sheep and goats

The response of grazing livestock to their environment strongly influence dietary selection, energy expenditure and forge intake, as some vegetation sites are preferred to others for grazing (Pfister *et al*., 1988). Sheep (*Ovis aries L.*) and goats (*Capra hircus L.*) are similar in body size and thus alleged to be more selective and have greater relationship in dietary selection than ungulates (Underwood, 1985; Van soest, 1982). Previous researchers reported that goats are more selective than sheep due to their intrusive behaviour within the rangeland. They appear to be able to tolerate a wide range of tastes than other types of domestic animals. Devendra & Burns (1983) also observed that goats could select relatively high quality diet from a variety of feeds. Goats prefer diet with high protein content but lower fiber content than other animals. When goats and sheep were fed three forages with different levels of crude protein, Huston *et al*. (1988) found that goats respond with an increased intake of higher levels of supplemented protein compared to sheep.

Some studies have revealed seasonal variation in feed selection between sheep and goats. For example, Pfister *et al.* (1988) reported that during the wet season, goats selected several browse and forbs species while sheep selected grass. However, they also observed that at times, sheep also selected forbs and substantial quantities of browse. When the ingested materials were evaluated for crude protein and cell wall content (CWC), goats were seen to select higher ($P<0.05$) crude protein than sheep (16.3 and 15.5%), respectively), but they did not differ in the selection of CWC, although sheep selected lower ($P<0.05$) lignin than goats because of wet season difference. A study by Nortorn *et al*. (1990) also showed that goats preferred legume leaves (34-75% of diet) than cattle (12-45%), while sheep selected against legumes (5-19%) in preference of grass (58-74% of diet) in all seasons. They suggested that sheep preferred grazing from the lower level where they are able to select grass leaves, while goats preferred grazing from the top where they can pick leguminous leaves.

In the Sahelian zone of Burkina Faso, Sanon *et al*. (2005) reported that sheep and goats reached peak browsing activity in the dry season, 28 and 58%, respectively. They also observed that during the rainy season when herbaceous plants are abundant, cattle and sheep were similar in foraging, and when forage resources declined sheep shifted to browsing, while most of the time goats preferred browsing. Gordon & Illius (1988) made similar observation that goats are more conservative in their feeding habits and tended to consume grass and forbs species more than sheep during the dry season or winter when grass and forbs are limited. They also noted that the difference in their foraging strategy is associated with difference in their physiology and anatomy. The selective feeding habits of goats is associated with narrow and more pointed mouth parts, which enable them to select good quality food from surrounding materials of lower quality. Gordon & Illius (1988) associated ruminants, which feed predominantly on grasses with broader, more flattened incisor arcade when comparing them with animals that browse on woody dicotyledonous plants. Other special characteristics such as long pendulous ears; drooping ears and shorter upper jaws were suggested by Rout et al. (2002) as characteristics enabling them to browse rather to graze like other ruminants, since the lower lip touches the ground first. A study by Pfister *et a*l. (1988) showed that goats adopt a bipedal stance, which enables them to forage at higher levels than sheep. They also reported that goats stand on their hind legs foraging on a vertical dimension. Even though this behaviour does give them some foraging and thus nutritional advantage, it could increase the energy cost of foraging.

Concerning digestive efficiency, available evidence suggests that with good quality forage with organic matter digestibility values of about 60% and above (Schmid *et al*., 1983; Doyle *et al*., 1984) observed that there was no difference between sheep and goats. With poor quality forages and roughages, goats appear to digest fiber more efficiently than sheep. A study by Gordon & Illius (1992) indicated that goats appear to digest forages higher in tannin than sheep. The difference in utilization of tannin rich forages may be a function of differential ruminal metabolism of toxins (Kronberg and Walker, 1993). Furthermore goats are known to be more tolerant to tannin than sheep, because goats have salivary secretion containing praline-rich protein, which bind tannins alleviating their aversive effects (Hoffman, 1987).

1.3 Forage Plants for Small Ruminants

Sheep and goats feed on a wide spectrum of feeds and can select those that meet their nutritional needs and avoid those that can cause toxicocis. In arid and semi arid regions, particularly during the dry seasons when roughage quality and crop residues prevail, browse species play a major role in providing feed for ruminants (Kibon & Orskov, 1993; Ahn *et al.*, 1989). Several studies done on some of these browse plants reported high content of crude protein and suggested them as suitable supplements

One of the browse plants, which had undergone extensive study, is *Acacia saligna*, a native plant of western Australia, with ranges of crude protein content of 105 to 132g/kg and condensed tannin content of 83 (mature trees) to 156g/kg (young trees) (Ben Salem *et al*., 1999). In Australia it is most commonly planted as ornamental, but in recent times it is increasingly planted for fodder production and for soil conservation. Due to its high content of tannin, a report by Degen *et al*. (2000) showed that drying the foliage does not improve its dry matter intake (DMI) when fed to sheep and goats, contrary to what was reported by Ben Salem *et al.* (2005) who suggested that air drying can reduce its astringency. Although the feeding value of the phyllodes of *Acacia saligna* may be reduced by the presence of condensed tannin, Howard *et al*. (2000) reported that they have low or moderate digestibility. Trials by Vercoe (1989) showed that its phyllodes have high levels of crude protein (18.3%) but low digestibility 36.5%). However, Woodwards & Reed (1989) suggested that the phyllodes are not good for ruminants.

Another browse plant that has gained recognition as a potential forage plant for ruminants within the arid and semi arid regions is *Leucaena Leucocephala*. However, its full utilization as forage plant has being minimized by a toxic compound called Memosine (Sethi & Kulkarni, 1995), contained mainly in the seeds and leaves. A report of contrasting results has been reported by Jones & Megaritty (1983), when they compared goats feeding on *leucaena L*. in Australia and Hawaii. They found that goats in Hawaii did not exhibit any signs of toxicity with less than 1% excretion of memosine in their urine, while those in Australia had hypothyroid in 3 weeks time. Another reason for less usage of *leucaena L.* by ruminant livestock farmers is its slow early growth. Garcia *et al*. (1996) suggested that if leucaena can be planted in research farms, seedlings could be made available to farmers at an affordable price as a solution to curb its slow growth.

Comparative to Leucaena in nutritive value, but without memosine is another forage plant called *Sericea Lespedeza* (SL). It is a useful low-input forage plant (Puchala *et al*., 2005), which can adapt to acid soils that are shallow and low in fertility. However, when compared with crabgrass/tall fescue the digestibility of its neutral detergent fiber was observed to be lower (40.1

v 55.7%). In the United States, it is often grown as an alternative to Alfalfa (Turner *et al*., 2005), because of its comparable protein content, but its usage by animals can be limited by tannin. Terrill *et al*. (1992) reported that the concentration of tannin in Lespedeza could be more than 200g/kg DM depending on the species. Ruminant livestock such as sheep, goats and cattle can readily consume lespedeza when mixed with other feeds of low crude protein or when it is dried as hay, however, sheep and goats are more likely to select it than cattle. Terrill *et al.* (1989) reported reduced dry matter intake, fiber disappearance, and nitrogen digestibility as condensed tannin concentration increased in *Sericea lespedeza* offered to sheep.

1.4 Tannins in Forage plants

Tannins are polyphenolic compounds and are the most common compounds found in most African forage plants. Approximately 80% of woody plants and 15% of herbaceous dicotyledonous species contain tannin (Bryant *et al.,* 1992). Tannins can be beneficial or detrimental to ruminants depending on the type and concentration. For example, 2-4% in diet of small ruminants protect protein from degradation and increases the absorption of essential amino acids, whereas 4-10% depress voluntary feed intake (VFI) (Terrill *et al*., 1992; Barry and McNabb, 1999). Other reported benefits include an increase in wool production, milk protein secretion, ovulation rate, development of more nutritionally based and ecologically sustainable systems for disease control in grazing animals. Tannin levels in excess of 50g/kg dry matter on the other hand can lead to low palatability, reduced digestibility, lower intake, inhibit digestive enzymes and may be toxic to rumen micro-organisms (Kumar & Vaithiyanathan, 1990.

Hydrolysable tannin and Condensed tannin are two different groups of tannins found in plants (Kumar, 1983), and generally trees and shrubs contain both. The two tannin compounds differ in nutritional and toxic effect. Hydrolysable tannins are polymer of gallic acid and ellagic acid esters and have core molecules that consist of polyols such as sugars and phenolics such as catechin (Clifford, 2001). They can also be cleaved by hot water and tannases, and consist of carbohydrates core with phenolic carboxylic acid bound by ester linkages (Van Soest, 1995). The digestibility inhibiting effects are reduced, but toxicity increases if Hydrolysable tannins are degraded by hydrolysis and then absorbed. Hydrolysable tannins elicit hyper secretion of gastric mucus and histo-pathological lesions of the gastrointestinal tract (Mitjavila *et al.,* 1977). They are able to pass from the intestine into the blood, and then be carried to the liver, where they block the action of the detoxifying enzymes. They are potentially toxic to ruminants and may even cause death (Reed, 1995).

Condensed tannins (CT) are also known as pro-anthocyanidins. They are the most widespread and typical of plant tannins. Mangan (1988) observed that when they are degraded with hot mineral acid, they produce anthocyanidins (e.g. cyaniding and pelargonidin). Some studies have indicated that tropical plants tend to contain higher amount of CT than temperate species (Pell *et a*l., 2001) in various concentrations in different species. Majority of these condensed tannins occur in vacuoles of plant cells, and a number of browse species contain 70-95% (Jackson *et al*., 1976) in the form of soluble condensed tannins. They are also found in a number of important forage genera within the family *Fabaceae*, which include Lespedeza, Onobrychis, Hydysarum, Coronilla, Trifolium and Lotus (Bate- Smith, 1973; Jones *et al*., 1976).

Condensed tannins are considered to be non- toxic because they are not easily absorbed, but they are associated with lesions of the gut mucosa. When present in high concentration, they become antinutritive by binding to cell wall polymers, rendering the walls undegradable, as well as by binding digestive enzymes secreted by rumen micro-organisms, rendering the enzymes inactive (Gary *et al*., 1996). In ruminants, it has been reported that high levels of CT might decrease voluntary feed intake, rumen digestibility of fiber, and animal growth. However, concentration up to 60 g/kg DM could have beneficial effects on rumen escape protein and reduce the incidence of bloat (Barry & Manley, 1986; Wang *et al*., 1996). In non- ruminants, a diet content of less than 60 g/ kg DM CT can cause adverse effects including decreased feed intake and growth, reduced utilization of intestinal epithelial layer and in severe cases cause death (Trevino *et al*., 1992).

1.5 Metabolism of Condensed tannin in the digestive tract

Tannins are said to bind with at least four groups of proteins in ruminant animals such as, dietary proteins, salivary proteins, endogenous enzymes and gut microbes including microbial enzymes, and the strength of these complexes depend on characteristics of both the tannin and protein (Haslem, 1989). The effects of CT, such as inhibition of feed intake and digestion by ruminants are usually ascribed to their ability to bind proteins (D’Mello, 1992).

Protein complexes with condensed tannin may pass through the digestive tract unchanged. Condensed tannins containing diets may increase the flow of nitrogen to the small intestines because the pH in the rumen and mouth favour the formation of tannin-protein complexes, while the pH in the stomach favors dissociation of tannin-protein complexes resulting in an improved nitrogen absorption and retention. However, where the complex is only partially dissociated, the increased flow may pass undigested through the lower tract and get completely lost as excretion in feaces (Nastis & Malechek, 1981; Nunez-Hernandez *et al*., 1989). Studies of condensed tannin from sorghum hay, leucaena and *Acacia aneura* (Mulga) in the gastro intestinal tract of sheep suggested substantial losses of CT (89, 92 and 88% for sorghum, leucaena and mulga, respectively) of which 75-80% occurred in the post rumen tract (Goodchild, 1990).

Condensed tannin may also form complex with carbohydrates such as glycoproteins, but usually with lower affinity than proteins (Barry, 1989). Feeding high tannin forages to ruminants can induce a deficiency of rumen- degradable nitrogen, thus indirectly impairing the fermentation of structural carbohydrates (D'Mello, 1992). Condensed tannin that is not bound to protein can also inhibit the fermentation of structural carbohydrates in the rumen by forming indigestible complex with cell wall carbohydrates, rendering them undegradable. CT also forms complexes with microbial enzymes, rendering them inactive (Gamble *et al.,* 1996). Digestion of carbohydrates dependend on the characteristics of the feeds, including both the intrinsic degradability and rate of fermentation, and the rate of feed intake and passage (Pitt *et al*., 1999). If protein resists degradation or diets are deficient in protein, microbial growth in the rumen is sub-optimal, which can in-turn retard carbohydrate breakdown (McDonald *et al*., 1995).

1.6 Methods of dampening the effect or inactivating tannins

Since plant tannins hinder utilization of fodder for livestock, it is desirable to reduce the level of tannins. Several methods have been tried to overcome problems associated with high tannin ruminant feeds. Field drying of tanniferous forages is one method that had been considered by some researchers as a method of detannification of forages with high concentration of tannin. Terrill *et al* (1989) observed that field drying of high tannin- *Lespedeza Cuneata* decreased its tannin concentration, resulting in improved intake and increased nitrogen and fiber digestibility.

Wood ash and charcoal can also decrease total extractable phenols and total extractable tannins (Struhsaker *et al*., 1997; Banner *et al*., 2000; Poage *et al*., 2000; Ben Salem *et a*l., 2005). Lambs fed bitterweed (*Hymenoxys Odorata DC*) alone consumed less than lambs that received bitterweed with activated charcoal (Poage *et al*., 2000), while soaking acacia in acacia wood-ash solution (Ben Salem *et al*., 2005) decreased total extractable phenols, total extractable tannins, but also reduced OM and CP content.

Simple soaking, washing and boiling with water have been shown to remove 80% of tannin from sal seed meal (Singh and Arora, 1978b, Panda *et a*l., 1979) but the dry matter loss of 18-23% could carry away the soluble nutrients. When whole sorghum was emerged in water (Reichet *et al*., 1980) for 90 days, tannin content reduced from 3.63 to 0.3%. Furthermore, it was observed that the nutritional quality of high-tannin sorghum (Price *et al*., 1980 does not improve when boiled in water. Although some alkali such as NaOH and Ca $(OH)_2$ were reported to remove tannins maximally up to 74 and 100%, respectively, some studies (Wah *et al*., 1977; Singh & Arora, 1978b) reported loss of dry matter from 20-70%, which could lead to the leaching out of the soluble nutrients in the ruminants feed.

Nozaki and Tanford (1963) suggested that urea supplementation with tannin-rich feeds can improve the feed quality by providing the extra N source when the hydrogen bonds are destabilized, resulting in the hydrophobic interaction, which may participate in the formation of the protein- tannin complex. Certain absorbents such as Polyvinylpyrolidone (PVP) and Polyethylene glycol (PEG) are known to bind more strongly than proteins. A review done by Kumar & Singh (1984) indicated that the binding property of tannins was operative *in vivo* because PVP markedly reduced the growth depressing effect of tannin acid in chicks. Although all these methods were considered practical, they were dismissed as uneconomical when done under field conditions. However, several researchers suggested that supplemental PEG could cause increased intake of tannin containing plants by animals (Kumar & Vaithiyanathan, 1990; Silanikove *et al*., 1994; Landau *et al*., 2000). It is also speculated that animals might self regulate their intake of PEG when fed on foods rich in tannins because animals can learn to consume foods and solutions that attenuate aversive effects of food ingestion (Phy & Provenza, 1998)

1.7 Voluntary feed intake

Tannin tends to affect the nutritive value of ruminants feeds by reducing voluntary feed intake. Forbes (1995) suggested that if voluntary intake were too low, rate of production would be depressed, resulting in requirements for maintenance becoming a very large proportion of the metabolizable energy consumed and so giving a poor efficiency of food conversion.

In ruminants, voluntary feed intake (VFI) is regulated by both short and long term mechanisms (Dulphy & Dermarquilly, 1994). Long-term mechanisms adjust supply to animal requirements in order to maintain body weight, while for short-term mechanism; feed intake is regulated fairly accurately within a day and within a meal by physical mechanism. Once, the rumen has filled to a particular level Dulphy & Dermarquilly (1994) suggested that ingestion will stop and the daily intake will then be determined by rate of digestion of digestible material and the transit rate of indigestible (i.e. the rate of clearance of ingested material from the rumen) materials, thus when the quality of feed in the rumen decreases the animal may resume consumption (Balch & Campling, 1962).

1.7.1 Animal factors affecting voluntary feed intake

When feed is consumed, voluntary feed (VFI) in ruminants is controlled by centers in the Hypothalamus, situated beneath the cerebrum in the brain (McDonald *et al.*, 1981; Ramalho Ribeiro, 1989), which receives signal from the body. However, McDonald *et al.* (1981) also observed that theories of Chemostatic, lipostatic and thermostatic regulation also regulate VFI. These theories of regulation are said to come into play only when physical limitations of intake do not intervene (Broster *et al.*, 1981) as is likely to be the case with diets containing large amounts of fiber, and they are thought to be long-term regulation of feed intake related to the animal's energy balance (Ramalho Ribeiro, 1989).

Chemostatic regulation of intake is said to occur when animals feed on diets high in concentrates, while lipostatic regulation occurs when an animal consume as much energy as it can utilize, not only for growth, maintenance and milk production, but for the deposition of fat. Animals that feed on high concentrate feeds are said to have large parotid glands, small rumen with high rate of passage (Hofmann, 1989). Their parotid glands are specialized in secreting compound that can enable the animals to select plants high in secondary compound such as tannin (Fisher, 2002) but cannot be selected by grazers.

Broster *et al.* (1981) and McDonald *et al*. (1981) suggested that VFI is also directly related to the animal size, abdominal capacity and gut capacity, and would increase with increasing animal size. When growing animals feed *ad-libitum*, Sanz Sampelayo *et al*. (1998) observed that kids had lower requirement of metabolic energy than lambs, but had higher efficiency in utilizing dietary protein than lambs. Santra *et al*. (1998) also found that goats significantly digest OM, NDF and ADF more than sheep because of the total protozoa in the rumen of goats, although the total gut length in goats is lower than in sheep. The ability of goats to consume large amounts of tannin- rich forages than sheep is suggested by Mehansho *et al*. (1987a) to be due to the relatively rich proline (6.5%) glutamine (16.5%) and glycine (6.1%), found in their parotid saliva.

1.7.2 Feed factors affecting voluntary feed intake

Madsen *et al.* (1997) suggested that the most important factor limiting feed intake by animals fed diets containing large amounts of roughage is the physical fill of undigested feed residues in the rumen. The rate at which previously ingested feed is removed from the rumen (Beever, 1993) during completion of the processes of degradation and feed passage also influences VFI of ruminants. The clearance of DM present in ingested feed particles from the rumen may occur as a result of solubilisation, microbial digestion or propulsion on digester from the reticulo-rumen into the omasum following communition (Kennedy & Doyle, 1993). Wilson & Kennedy (1996) suggested that any feed factor that increases the inherent rate breakdown of large particles would result in an increase in the rate of passage of small particles from the rumen. Certain aspects of forages are directly attributed to the rate of breakdown of feed particles in the rumen. Plant material comprises cell walls and cell constituents (Kennedy & Doyle, 1993) which contribute to difference in structural cells of low digestibility and highly digestible photosynthesizing cells. The content of non- cellulosic polysaccharides relative to cellulose is generally higher in grasses than in legumes and in stem tissue than leaf tissues (Kennedy & Doyle, 1993). Stage of maturity will also affect the amount of non-cellulose polysaccharides present in plant tissues (Kennedy & Doyle, 1993).

The physical processing of ruminant diet containing large amounts of cellulose has shown to influence daily feed intake (Walker, 1984; Lu *et al*, 2005). The method of processing feeds, such as chopping, grinding, milling or pelleting affects feed intake (Walker, 1984). For example, when feed is chopped into short pieces, the length of the fibers is decreased and the animals have less opportunity to select between different parts of feed. This lead to an increase in feed intake and reduced time of eating. However, when grass or hay is offered in long, unchopped form, the animals have more opportunity to select between stem and leaf. Omokanye *et al*. (2001) observed that chopping of browse species before feeding livestock enhanced intake by around 60%. In forage legumes such as *Lotus sp*., condensed tannins can be detrimental to ruminant livestock production (Waghorn *et al*., 1999). If they occur at concentrations above 60 g kg^{-1} DM, condensed tannins reduce voluntary feed intake and depress digestion efficiency (Barry and Duncan 1984; Barry and Manley, 1986). At moderate concentrations, however, condensed tannins can be beneficial to ruminant livestock production. (Barry & Duncan, 1984) also observed that high-condensed tannin in *lotus pedunculatus* (63 and 106g /kg DM) substantially depressed Voluntary Feed Intake in sheep (-27%), while (Waghorn *et al.* 1994) reported smaller depression of voluntary feed intake (-12%) when 55g CT/kg DM in *lotus pedunculatus* was fed. Medium CT concentration in Sulla (45g/ kg) and in *Lotus corniculatus* (34 and 44g/ kg DM) had no effect upon VFI (Terrill *et al* 1992b; Wang *et al* 1996a). Pritchard *et al.* 1988, reported that the CT in *Acacia aneura* (Mulga) (2 - 11% DM) depressed intake by 40 –50%, to sub-maintenance levels, compared with sheep given Mula with 24g PEG /Day. These findings indicate that forages with high concentration of tannin can elicit a reduced feed intake, but when PEG is added, the intake rate can be improved

1.8 Tannin effect on protein degradation

Tannins are well known for their ability to protect proteins from degradation in the rumen either by forming complex with dietary proteins or by reducing the activities of microbial proteases. Bonsi *et al.* (1996) observed that high concentration of tannin in Leucaena forage and higher amount of essential and non-essential amino acids could be responsible for its slow degradation as compared to that of Sesbania forage. They suggested that faster degradation of Sesbania enabled greater quantities of rumen metabolites to enhance rumen microbial function and proliferation. Similar observations were made by Kaitho *et al*., (1998) when supplementing sheep on two forages of low tannin concentration (*Sesbania sesban* and *Chamaecytisus palmensis*) and two leucaena forages species *Leucaena leucocephala* and *Leucaena pallid*a). They observed that faster degradation of low tannin forages resulted in increased population of cellulolytic microbes, which rapidly reduced the quantity of digestible browse in the rumen, thereby allowing more microbes to colonize and degrade the basal diet. This suggested that protected proteins from ruminal degradation of forages high in tannin would then increase supply of amino acid to the abomasums and intestine (Min & Hart, 2003), thus improving animal nutritional status. A study by Mbugua et al. (2005) revealed that with low tannin concentration, there is modification of the tertiary structure of proteins, which becomes unstable and easily degradable, while with high tannin concentration the tannin-protein complex becomes less soluble resulting in lower microbial population, the consequences they suggest could be direct toxic effect of tannin on the microbial population.

1.9 Effect of tannin on carbohydrates/ fiber degradation

Micro- organisms in the rumen are essential for digestion (Aerts *et al*., 1999) since they are able to degrade structural components of plant cells such as cellulose and hemicellulose. These microorganisms need ammonia and some amino acids to synthesize their cellular proteins, of which intake of forages high in tannin may impair their role in the rumen. Several studies reported direct inhibition of fiber degradation in the presence of tannins (Barry & Duncan, 1984; Barahona *et al*., 1997 and Waghorn *et al*., 1987). The presence of condensed tannins in forages was reported by Barry and Manley (1984) to depress ruminal digestion of readily available carbohydrates and hemicellulose, while at the same time it increased post ruminal non- ammonia nitrogen absorption relative to non tannin containing forages.

1.10 Tannin effect on endo- parasites

Plants, which contain condensed tannin, have nematocidal effects against free- living nematodes (Taylor and Murant, 1966; Chandel and Mehta, 1990) and in areas where farmers heavily depend on anthelmentic drugs, the use of plants with anthelmentic properties has been considered as an alternative. Several studies (Niezen *et al*., 1998; Athenasiadou *et al*., 2000; Min *et al*., 2003; Paolini *et al*., 2003; Min *et al.,* 2005) have shown that when ruminants graze tannin-rich forages or are fed purified condensed tannins to the diet, there is a reduction in parasite eggs, larval development and worm burden.

Butter *et al*. (2000) reported that the inclusion of *Quebracho tannin* (QT) in low protein diets reduced feacal egg count (FEC) at a similar level as animals fed on high protein diet, but when QT was in high protein diet egg count did not reduce further. When animals were dosed with high concentration of QT (2% (w/v), all worms were reported to have died within 2h, and at 1% (w/v) QT only 75% died, while at low concentration of 0.05% (w/v) less mortality was observed. In a similar study by Athanasiadou *et al*. (2000), feacal egg count reduced by 50% in animals drenched with QT at 8% of their food intake, relative to the control, while the worm burden reduced by 30%, but no further reduction noted with continued drenching. Furthermore, Paolini *et al*. (2003a) reported an overall reduction of 64% in egg count in feaces of goats administered with tannin extract, but without any difference in worm population. Further studies by Paolini *et al*. (2003c) reported varied results of the effect of QT on different gastrointestinal parasites of infected goats. The variation was suggested to be attributable to the stage of the parasites exposed to animals.

Neizen *et al*. (1998) reported a decrease in FEC and worm burden when sheep were fed on fresh forages of sulla (*Hydysarum Coronarium* L) and big trefoil (*Lotus pedunculatus*). FEC reduced by 25% in lambs grazing sulla starting from day 14, while worm burden was reported to have reduced by 58% relative to animals on Lucerne. Min & Hart (2003) also reported a decrease in faecal egg count on goats grazing *Sericea lespedeza* (SL) compared with those on non-CT forages. Although all of the above studies had suggested that reduction in feacal egg count, larval population and worm burden can be due to the effect of condensed tannin, there is contradiction on how this chemical compound affects the parasite population (Butter *et al.,* 2000; Min *et al*., 2005; Shaik et al., 2006; Lange, 2006). Some studies suggest that direct effect of condensed tannin on adult worms and larvae could be responsible for the reduction, while others suggest indirect effect through protein supplementation.

Terrill (1994), suggest that since CT is not absorbed in the digestive tract of the animal, it becomes concentrated in feaces, where it may be chemically active. In faeceal pellets CT may react directly with parasites by binding to the cuticle of larvae, which is rich in the glycoprotein (Thompson & Geary, 1995) and as such could inhibit larval development. This therefore suggest that nutrient availability to the parasite will be obstructed and thus retarding larval growth as there will be reduction in the parasite metabolism, and the parasite may die (Athanasiadau *et al*., 2000). However, other studies suggested that the direct effect of CT is on established worms due to the change in the abomasal environment. Shaik *et al.* (2004, 2006) and Lange *et al.* (2006) explained that the greatest reduction of the mature worms as compared to the immature worms could be due to the sudden change of environment, which the already established worms experience as opposed to those who are newly introduced.

Some of the studies suggest that an increase in supply of dietary protein (Butter *et al*., 2000; Min *et al*., 2000) to the host animal has an indirect effect on resistance to GI parasites by enhancing immune response through improved protein. Paolini *et al*. (2003a) suggested reduction in fecundity of female worms as the main effect of CT in reducing egg secretion. Min *et al.* (2005) suggested that CT in forages may have direct effect on parasites themselves or indirect effects by increasing resistance of ruminants to infection through improved protein nutrition.

Tannin is also known to reduce the amount of *Coccidian oocysts* in small ruminants. Dung et al. (2003) reported a decrease in number of *Coccidian oocysts* when replacing supplementation of commercial concentrate with cassava hay. The effect of cassava was observed after 30 days of replacement, but was highly significant after 90 days. Their report showed an increase from 990 to 3,930 after 90 days, while 100% replacement with cassava hay oocysts reduced from 1,012 to 254. Similar study by Nguyen *et al*. (2005) on leucaena, jackfruit and cassava foliage, guinea grass and ruzi grass observed reduction of *Coccidia oocysts* in goats offered leucaena, cassava, and jackfruit than those offered grass.

1.10.1 Weight gain due to tannin

There are contradictory reports on weight gain of animals feeding on forages containing CT. Athanasiadou *et al*. (2000) reported that although all treatments elicited feed intake animals receiving CT failed to gain weight relative to ones on the control feed that had increased weight. Butter *et al*. (2000) suggested that parasitized animals fed high protein diet did not have greater weight gain partly because of reduced feed intake following worm establishment in the small intestines. Secondly, the loss of endogenous protein was elevated in infected lambs through an increase in mucoprotein secretion and gut tissue turnover to repair damaged gastro- intestine. The performance of beef cattle was inferior on SL pasture relative to Lucerne pasture (Schmidt *et al*., 1987).

Some studies by Barry & Duncan 1984, Barry *et al*. (1986) and Waghorn *et al*. (1987) suggested that forages containing condensed tannin in the range of 6 – 10% DM can improve growth rate. Min *et al*. (2005) reported higher average daily gain of goats grazing on SL than those on control forages, however, lack of weight gain was observed with kids, which they ascribed to the possibility of their gastrointestinal tract not coping with high tannin levels. Coop & Kyriazakis (1999) argued that any response to dietary protein supplementation by young growing animals, which are infected, would be very small, because animals might succumb to the adverse consequences of parasitism before reaching reproductive stage.

A study by Bengaly *et al.* (2007) showed that as the level of tannin supplement increases there is also a tendency for live weight gain to decrease. Breed difference seemed to have a major role in tolerance of tannin as the decrease in live weight gain was more pronounced in Nguni goats compared to Boer goats despite their similar initial weight. Bengaly *et al*. (2007) reported Boer goats with higher feed conversion efficiency than Nguni goats (0.21 vs. 0.17 g gain/ g feed).

Condensed tannin is suggested to partially protect dietary protein against rumen degradation and as such increase flow of amino acids into small intestine and increase absorption (Waghorn *et al.,* 1994). This increase is suggested to counteract losses of protein attributed to gastrointestinal nematode infection (Sykes, 1994) and as a result increases the growth rate of parasitized animals (Niezen *et a*l., 1995). Fraser *et al*. (1988) and Clark *et al*. (1990) suggested that improvement on growth rate is due to an increase in animal protein supply.

1.11 Discussion and conclusion

Productivity of small ruminants in arid and semi-arid regions has been highlighted as dependent on forage plants, most of which produce secondary chemical compounds, which do not offer any nutritional value to the animals. However, the review has shown that some of these forages such as *Sericea Lespedeza* can be of potential benefit to the ruminants when supplementing low quality forages.

Of the different methods, that can inactivate tannins, field drying was observed to be more economical and can improve feed intake, increase nitrogen retention and fiber digestibility. Other methods are uneconomical and are difficult to apply under field conditions. The review has shown that gastrointestinal parasites in the abomasum and small intestine cause extensive losses of protein in sheep and goats by re-directing protein synthesis away from skeletal muscle development to the repair of gut tissues. By increasing dietary protein intake abomasal infusion of protein may result with animals being able to tolerate this infection and improves nitrogen retention, which subsequently increases animal immunity to the parasites. Several studies conducted on forages containing tannin have shown that they can potentially supply supplementary protein to small ruminants and reduce the high infestation of the gastrointestinal parasites. Some of these forages, especially *Sericea lespedeza*, once established can be less costly to maintain, thus is economically sustainable and in addition does not have residual effect on the rangeland and animal products, thus allowing a reduced use of anthelmentic drugs.

Although there are some contradictory results on how CT exactly reduces these parasites, there are promising results that when used with feed of low concentration of crude protein, feacal egg count is reduced from animals that had natural infection.

Chapter 2

Daily Variation of feed intake rate and feeding behaviour by sheep and goats on Lespedeza and Leucaena.

Abstract

The study investigated the extent to which sheep and goats differ in their feeding behaviour and feeding rate in leucaena and lespedeza pastures. Three sheep and three goats were observed during the months of March and April 2006. For Feeding rate, each animal was observed for 10 minutes at 10.00h, 12.00h and 14.00h for 6 days. Feeding behaviour lasted three consecutive days from 7.00h to 16.00h during which individual animal's activity was recorded every 2 minutes. Bite count and bite weight were used to determine intake rate while browsing. Sheep had larger ($P<0.01$) bite rate than goats, while lespedeza elicited lower bite rates than leucaena. The fastest feeding rate and bite rates occurred during midday (12.00h) and lowest at 14.00h. Goats spent 3.24 and 3.93 times longer than sheep browsing, while sheep spent 2.75 and 2.27 times longer grazing than goats on lespedeza and Leucaena, respectively. Goats idled for a longer duration than sheep at both plots. These results indicate that sheep differ in their feeding behaviour, however the inclination to idle and play for long may energetically be costly to goats.

***Key words*:** Sheep, goats, intake rate, feeding behavior, *Sericea lespedeza*, leucaena

2.1 Introduction

Feeding behaviour of ruminants can be influenced by many factors such as the forage quantity and quality, availability of water, topography, climatic condition and some other social factors. Although sheep and goats vary in their physical appearance and production levels, they can be reared over a wide range of environments. Their production levels can only be achieved under optimum management conditions, especially those that allow them to meet their nutritional requirements.

Sheep and goats are important because of their ability to convert forages and crop residues into meat, fiber, skin and milk (Gutierrez, 1985), an indication of their capability in converting unused natural resource into proteins of high biological value. Sheep can differ from goats in their feeding behaviour and diet selection. Goats can select their diets from a range of feeds extending from high quality grasses to bitter and tanniferous browse (Sidahmed, 1986). They are natural browsers preferring to eat leaves, twigs and shrubs, while sheep prefer to eat short, tender grass and clover. Goats are very agile and will stand on their hind legs to eat vegetation, while sheep can graze very close to the soil surface (Pfister *et al,* 1988). Among domesticated ruminant livestock, goats are the most selective and cattle are the least selective animals. The fractions which goats select most are buds, leaves, fruits and flowers, containing less fiber and more protein, and are the most nutritious parts of plants (Lu, 1988). A study by Gong *et al.* (1996), suggested that sheep can show a greater tendency of penetrating into the canopy to take deep bites on grass, whereas goats showed a tendency of being shallow grazers, grazing from the top downwards. Feeding behaviour of similar body sized animals can also be differentiated by their mouth morphology and gut size. Body size, digestive system, gut volume and mouth size were used by Van Soest (1982) in classifying herbivores according to their feeding habits.

According to Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA) staff (2004), ruminants generally graze seven to eighteen hours a day, and within livestock class this stays the same day to day. The peak periods of grazing are after daybreak, in the late afternoon and around midnight. The amount they eat a day depends on their bite size and the rate at which they eat. Goats prefer to browse a wide range of browse species in different seasons, while sheep selectively browse few species during the dry season, but the time devoted by cattle to browsing is almost stable throughout different seasons (Sanon, 2007).

In order to develop a meaningful strategy in grazing sheep and goats within the same environment one need to have an understanding of their difference in feeding behaviour and whether there can be any nutritional advantage derived from such difference. The objective of the present study was to investigate feeding behaviour and intake rate of sheep and goats given *Sericea lespedeza* and leucaena.

2.2 Materials and Method

Experimental animals: Three female Nguni cross Boer goats aged 2 years (30.3 ± 2.25kg mean SD) and three Damara female sheep aged 3 years (32.5 ± 10.5kg mean SD) were used at the Lespedeza and Leucaena plots. These animals were obtained from the livestock section of the

University of KwaZulu-Natal Research Farm at Ukulinga, Pietermaritzburg, where the experiments were done.

Experimental sites: The lespedeza plot, measuring 80m x 60m, is located on the southeastern side of the Livestock section at Ukulinga Research farm. Within the plot are grasses such as, *Eragrostis Plana (60%)* which is an unpalatable grass of low grazing value, *Cynodon dactylon (30%)* a relatively good pasture grass of average grazing value and *Eragrostis Curvula (10%),* another economically important pasture grass of average grazing value. The Lespedeza used was a re-growth, which was nearing the flowering stage and was planted in rows, which were equally spaced by 1 meter.

The Leucaena pasture is on the eastern side of the Livestock buildings, at the far end of the farm. The land was 66 meters by 80 meters. It was sub divided into six smaller plots of 22 x 40 meters. There were no interior gates although animals were able to move from one plot to another without any obstruction. The rows of leucaena were 3 meters apart and had already reached the flowering stage. On average the plants were about 1.5 meters in height. The lower layer was covered by *Panicum Maximum* grass, most of which was over grown. Water was provided in plastic troughs at both the Lespedeza and the Leucaena plots.

Lespedeza is perennial upright semi- woody forbs, with one to many slender stems, which have numerous branches. McGraw *et al*. (1989) observed that, it is relatively slow to establish, having weak, vulnerable seedling stage, but with good seed production it will persist for years without reseeding, and is recognized for its tolerance to drought, acidity and shallow soils of low fertility. The leaves are thin, trifoliate and are attached by short petioles. They are wedge – shaped, wider at the tip than at the base. The lower leaf surface has silky hairs, while stems have scale like stipules. Flowers of lespedeza are small and whitish –yellow with purple to pink markings, and occur in clusters of 1-3 in the upper leaf axils, fused at the base. Seeds are long, tan or greenish in colour. Lespedeza has high tannin concentration, which decreases its palatability and digestibility, and is relatively unaffected by insect pests and diseases (McGraw *et al*., 1989).

Leucaena is a thornless shrub or tree that may grow to heights of 7-20 m. The plant can also be bushy with several stems, and is known for its drought resistance (Aganga and Tshwenyane, 2003). It has bipinnate leaves with 6- 8 pinnate bearing 11-23 pairs of leaflets 8-16 mm long. The inflorescence is a cream coloured globular shape, which produces flat brown pods 13-18mm long containing 15-30 seeds. Jones (1979) suggested that the digestibility and intake values of leucaena range from 50-71% and from 58 to 85 g/kg, respectively. Its leaves and stems contain tannin that reduce digestibility of dry matter and protein, while mimosine from its foliage and pods is associated with a reduction in intake. Leucaena is said to have few pests because of the insecticidal properties of mimosine (Aganga and Tshwenyane, 2003). Mild infestation of small aphids like insects called *Psyllids* or jumping lice cause distortions of leaves and attack by secondary moulds, which feed on the sticky exudates of *Psyllids*.

Experimental procedure: The experiments were done during the months of March and April 2006. The daily temperature during the experimental period ranged from 13.2^0C to 24.2^0C with a mean of 18.7^0C, and rainfall of 1mm to 22mm with a mean of 11.5 mm. Intake rate in each plot was determined for six days. Temporary holding pens were erected at both the lespedeza plot and the Leucaena plot with gates to keep animals closer. Also six cages (2.4 x 2.4meters per cage), which were moved daily, were erected along the experimental plants. One animal was transferred at a time for observation into the experimental cage, where a tally counter (ENM Company-England) was used for recording the number of bites. After 10 minutes of observation, bite size was measured with the aid of a Vernier Caliper (Mitutoyo Corporation- Japan). The diameters of the cut plant branches were measured and branches with corresponding diameters were then cut to estimate the weight of the eaten branches. Fresh samples were weighed, oven dried at 60ºC to constant weight, and then pooled pending laboratory analysis.

Feeding behaviour was determined for three days in each plot. Recordings started at 7.00am and ended at 16.00h. Animals were followed at a distance of about 5 meters in the Leucaena plot. The animals' activities were recorded every 2 minutes. Feeding activities included browsing, grazing, and idling.

Chemical Analysis: Analysis of the chemical composition of Lespedeza, Leucaena and grass was done in the laboratory of the University of KwaZulu – Natal, Pietermaritzburg. Dry Matter (DM), ash, crude protein (CP) was determined by proximate analysis using the method of

Association of Official Analytical Chemists (AOAC, 1990). The neutral detergent fibre (NDF) and acid detergent fibre (ADF) were determined by the method of Van Soest *et al*. (1991), while hemicellulose was calculated as the difference between NDF and ADF. Analysis of condensed tannin in feeds was conducted using colorimetric determination of condensed tannin (Makkar and Goodchild 1996), based on butanol-HCl reagents, and results expressed as Leucocyanidin equivalent (Porter *et al*., 1986). Gross energy was determined using bomb calorimeter (dds CP500, Automatic Colorific Processor) supplied by Coalab Supplies.

Statistical Analysis: Data on time spent by both sheep and goats feeding on lespedeza and leucaena were subjected to analysis of variance using GLM procedure of SAS, according to the following model:

$$Y_{ijkl} = \mu + F_i + A_j + D_k + T_l + (FA)_{ij} + (AT)_{il} + (FAT)_{ijl}\ e_{ijk;}$$

Where: Y_{ijkl} = Individual hourly observation; μ = Overall mean; F_i = effect of feeds; A_j = effect of animal type; $D(F)_k$ = effect of day within feed; T_l = effect of time of observation; $(FA)_{ij}$ = interaction between feeds and animal types; $(AT)_{jl}$ = Interaction between animal type and time of observation; $(FAT)_{ijl}$ = interaction between feeds; animal types and time of observation; and e_{ijkl} = unexplained variation assumed to be randomly and independently distributed

Lespedeza had slightly higher content of crude protein, neutral detergent fiber, acid detergent fiber and energy content than Leucaena. *Panicum maximum* had much lower crude protein and higher gross energy, neutral detergent fiber and acid detergent fiber. Lespedeza had higher content of tannin than leucaena, while *Panicum maximun* did not contain tannin.

2.3 Results

Table 2.1 Chemical composition (g/kgDM) of lespedeza, leucaena and grass found in the experimental plots

Feed	DM	OM	CP	NDF	ADF	HEM	GE)(MJ/kg	Tannin (%DM)
Lespedeza	914	905	226	345	278	67	19.175	9.42
Leucaena	930	873	217	331	226	105	19.318	5.8
780	712	898	59	780	521	259	21.742	0

DM =dry matter; OM = organic matter; CP = crude protein; NDF = neutral detergent fiber; ADF = acid detergent fiber; HEM = hemicellulose; GE = gross energy; Pan Max = *Panicum Maximum*

Feeding behaviour: Variation in feeding behaviour of sheep and goats on lespedeza and leucaena plots is shown in Table 2.2. Goats spent more (P<0.001) time browsing than sheep. The feed type or interaction of feed and animal type did not affect the browsing time. Goats spent more time browsing on leucaena than on lespedeza. Animals grazed for a longer (P<0.01) time on lespedeza than on the leucaena plot. The difference in grazing time between sheep and goats was higher (P<0.01) for the lespedeza than for the leucaena plot. Sheep grazed (P<0.001) 2.75 and 2.27 times more than goats at the lespedeza and leucaena plots, respectively. Goats idled (P<0.01) 2.25 and 1.8 times longer than sheep at the lespedeza and leucaena plots, respectively. The effect of animal type and interaction of feed and animal type significantly affected idling time while feed type differed significantly (P<0.001) from each other.

Table 2.2 Variation on feeding activities of sheep and goats on lespedeza and leucaena

		Browsing time (min)	Grazing time (min)	Idling time (min)
Sheep(n=3)	Lespedeza	33	341	81
	Leucaena	31	230	29
Goats(n=3)	Lespedeza	107	124	205
	Leucaena	122	101	52
	RMSE	19.088	26.175	21.248
	F. Effect	Ns	0.001	0.001
	A. Effect	0.001	0.001	0.01
	FxA Effect	Ns	0.1	0.01

Lesp = lespedeza; Leuc. = Leucaena; RMSE = Root mean sum of standard error; F = Feed; A = Animal species; FxA = interaction of feed and species; ns = not significant

Variation of feeding behaviour over time: Figure 2.1a shows the proportion of time spent by sheep and goats browsing on lespedeza and leucaena. Between 7.00 and 14.00h goats consistently spent a longer time browsing on lespedeza and leucaena than sheep, with more time being used to browse leucaena.

Sheep consistently grazed for a longer duration than goats (Figure 2.1b), the biggest difference occurred during the morning hours in both plots, beyond which the difference reduced slightly in the leucaena plot, but drastically to a minimum by late afternoon in the lespedeza plot.

From the early morning till 14.00h goats in the lespedeza plot spent more time idling, with peak idling occurring at 10.00h and 13.00h, while during the same time at the leucaena their idling peaked at 10.00h and 15.00h (Figure 2.1c). Throughout the day sheep spent a lower proportion of time idling in both the lespedeza and leucaena plots.

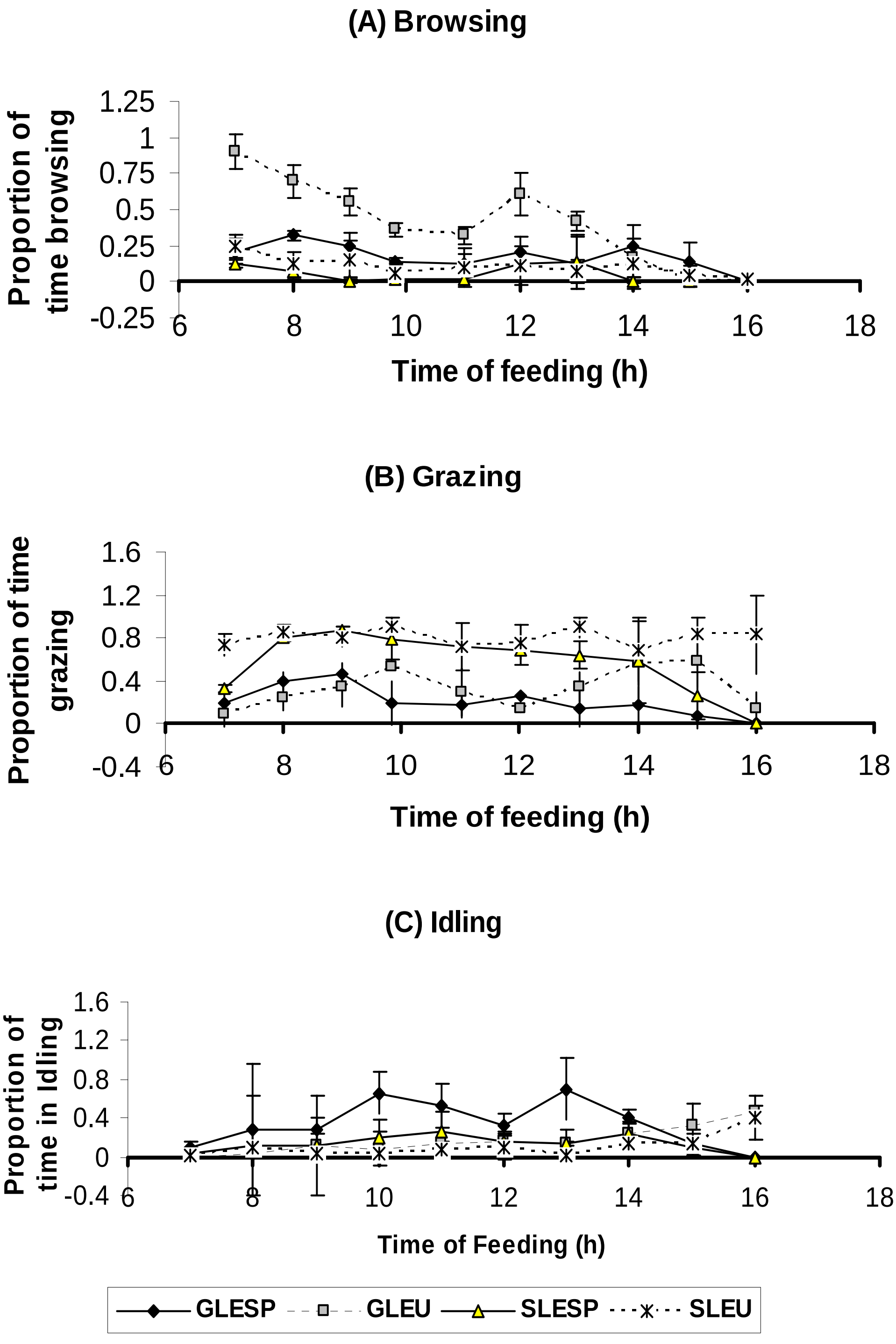

Figure 2.1 Proportion of time spent browsing, grazing and idling by sheep (SLESP or SLEU) and goats (GLESP or GLEU) on lespedeza or leucaena

Feeding and Intake rate:. Feeding rate (bite/min) of sheep and goats were similar on both plots of lespedeza and leucaena, and were not affected by any factor. Intake rates were higher (P<0.01) on leucaena than on lespedeza for both sheep and goats, with sheep having higher (P<0.01) intake rates than goats on both plots.

Table 2.3 Feeding rate (bite/min) and intake rate (g FW/min) or (g DM/min) of sheep and goats on lespedeza and leucaena.

		Feeding rate (bite/min)	Intake rate (g FW/min)	Intake rate (g DM/min)
Sheep (n=3)	Lespedeza	8.59	13.16	5.35
	Leucaena	8.3	15.44	6.28
Goats (n=3)	Lespedeza	8.66	11.01	4.48
	Leucaena	7.66	13.59	5.53
	RMSE	3.378	5.62	2.285
	F. Effect	Ns	0.01	0.01
	A. Effect	Ns	0.01	0.01
	FxA Effect	Ns	Ns	Ns

RMSE = Root mean sum of standard error; F = Feed; A = Animal species; FxA = interaction of feed and species; ns = not significant

The effect of time was highly significant (P<0.001) for both bite rate and intake rate, with the fastest bite rate and intake rate occurring during mid-day (12.00h) and the lowest rates at 14.00h. Leucaena had a higher intake rate than Lespedeza in the morning and afternoon, but a lower intake rate than Lespedeza during the mid-day period. The effect of feed type x time interaction was significant (P<0.001) for both the intake rate and bite rate.

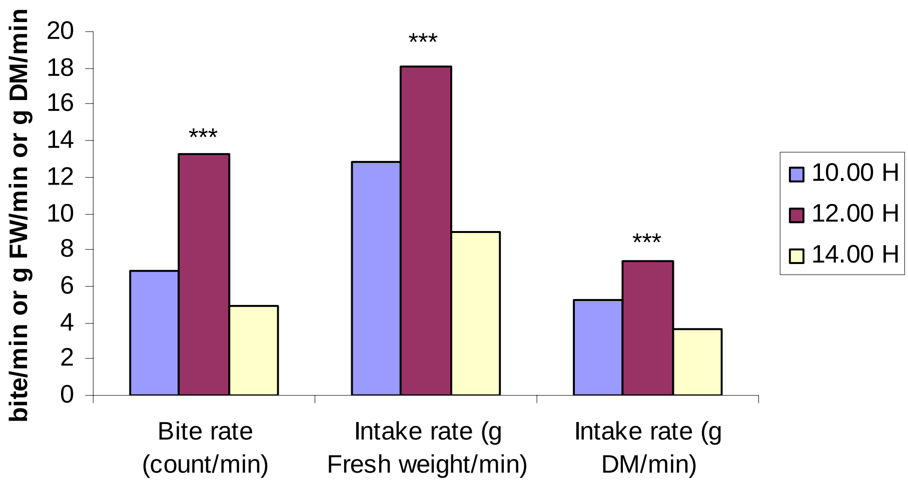

Figure 2.2 Overall Least Square means for bite rate (bite/min) and intake rate (g FW/min or g DM/min) by sheep and goats over three different periods of time

2.4 Discussion

Feed attributes: Lespedeza had higher crude protein (CP) content than was reported by Min *et al*. (2005), (24.73% v 15.9 %), while the CP and GE for leucaena were comparable to those reported by Mtenga *et al*. (1991), (23.33 v 24 %) and NAS (1971), (19.32 v 20.1 Mj/kg), respectively. Lespedeza NDF, but not ADF, was similar to that reported by Min *et al*. (2005). This disparity could be due to the re-growth stage of the forages (Mtenga *et al*., 1991). Secondly, variation in the chemical composition of the present feeds as compared to those found by other researchers could be due to the specific parts of plants picked for analysis, since the present study analysed the whole plant (stems, seeds and flowers) unlike other studies where only leaves were analysed.

Although the crude protein and energy content of the two forage plants (lespedeza and leucaena) used during the present study were similar, lespedeza had higher content of NDF, ADF and tannin concentration. This suggests that due to the higher content of NDF in lespedeza its intake by animals is likely to be lower than that of leucaena, and its ADF will also in turn reduce its digestibility. Similarly, the higher concentration of tannin in lespedeza is likely to reduce the degradation of dietary proteins in the rumen and increase the supply of amino acids to the abomasums and small intestines, resulting in the nutritional improvement of the animals. As suggested by Kaitho *et al*. (1998), plants with moderate tannin content are more effective as protein supplement as they can provide both degradable and non-degradable protein. Although, concentration of tannin for the present study was seen to be higher (9.4% for lespedeza and 5.8% for leucaena) than that reported by Barry and McNabb (1999) (3 to 4 % DM) it was observed not to widely vary feeds palatability.

Feeding behaviour: The results of the present study have shown that goats preferred browsing for a longer period of time than sheep on lespedeza and leucaena. When browsing, goats preferred different parts of the vegetation relative to sheep. This present study was done towards the end of the rainy season when most of the forage plants were almost mature. Plant maturity is associated with decreased protein content but increased fiber content. In this situation, it was observed that goats preferred to select parts which were still juicy, tender and nutritious like young leaves, buds and flowers which were not found at the lower part of the plants, preferring high protein containing parts. These findings are similar to those made by Qinisa & Boomker (1998) and

Lunginbul *et al*. (2002) when goats selected high protein diets than sheep. In another study, Sanon *et al*. (2007) observed sheep spending 4.8%, 3.28% and 28% of their feeding time while goats spent 43%, 44.6% and 52% of their feeding time browsing in the rainy season, post rainy season and dry season, respectively. This may suggest that when both sheep and goats are exposed to the same rangeland, goats can survive better since they will apprehend forage not accessible to sheep, which probably will be of higher nutritional value.

The longer time spent by goats browsing on lespedeza and leucaena than sheep can also be attributed to the difference in their morphological and physiological traits (Malechek & Provenza, 1983). During the present study, sheep appeared to selectively graze leafy components at lower level of plants rejecting other components such as seedheads and stalks, while goats were able to browse reproductive tillers, flowers and green leaves which appeared at higher level, and at times pulled branches that can bend, held them between their forelegs and plugged off buds and inflorescence. This different feeding behaviour shown by the two species of animals may suggest that sheep were more selective for high quality leafy components while the unselective behaviour of goats could be associated with their physiological trait of being able to digest feed higher in fiber content (Gong *et al*., 1996). Within the leucaena plot, goats repeatedly used their morphological trait of` bipedals stand to forage at various heights than sheep (Pfister *et al*., 1988). Although leucaena, as a result of its mimosine content, can cause loss of appetite, excessive salvation, depilation and in-coordination of gait and enlarged thyroid gland (Garcia *et al*., 1996), these effects were not noticed in this study, perhaps owing to the presence of dihydroxy pyridine (DHIP) degrading bacteria (*Synergistes jonesii*) in the rumen and to the short length of the study.

Although the two forage plants did not differ much in their nutritional quality, lespedeza had higher content of tannin (Table 2.3), which statistically did not influence the browsing time of goats. Although goats can secrete proline-rich proteins to neutralize the negative effect of tannins, this did not confer any intake advantage. However, tannin in forage plants can even cause ruminants to limit intake of even the most nutritive feed. Ngwa *et al*. (2002) claimed that animals will seldom exceed their capacity of detoxifying tannins because they quickly experience internal malaise and limit their intake, then turn to ingest a diverse array of plants to minimize toxicosis. In this study goats turned, although for a limited time, to graze some patches of grasses like *Cynodon dactylon* and *Eragrostis,* perhaps in order to minimize toxicity. The goats' inclination to idle for a longer period than sheep may be a strategy to limit the effect of offending factors. While at the leucaena plot, their idling was reduced since they prefer to browse young leaves and flowers from leucaena shrubs, which were lower in tannin. Other characteristics such as plant leaf size could have contributed to the longer period of time spent by goats browsing on leucaena than on lespedeza. By nibbling on small, thin, short leaves of lespedeza goats could have been discouraged, but preferred those of leucaena which were much larger and more conspicuous. The high seed rate of lespedeza could have been another factor that contributed to the longer idling time of goats as compared to leucaena, which had few seeds. Within the two experimental plots, it is possible that diffences in the percentage of time spent feeding on leucaena and lespedeza could be confounded by the quality and availability of grass species in each of these pastures

As expected, goats grazed less than sheep at both the lespedeza and leucaena plots owing to their preference for browsing. Similar to the present study, Pfister *et al*. (1988) found that sheep spent 36% and goats 18% of their foraging time grazing at or near ground level. This behaviour may result with sheep being at greater risk of ingesting contaminated material that may add to their parasites burden.

Intake rate: Sheep and goats can display marked contrasts in ingestive behaviour when grazing different maturity stage of grasses and legumes (Gong *et al*., 1996). Despite similar bite rate by sheep and goats during the present study, sheep had higher intake rate than goats. The difference in intake rate could be attributable to ages of the two animal species. Goats used during the study were younger than sheep, and as such their forage intake (g FW/min or g DM/min) is more likely to be less than that of older animals (sheep). Their feed intake can then be expected to be proportional to their body weight, hence lower intake rate than for sheep. The feeding rate (bite/min) of goats in this study therefore matches that of sheep, probably because of the nutrients demand for their growing bodies (Animut *et al*., 2005). This resulted with goats making more bites per minute to match those of sheep but less intake rate while bites of sheep resulted with larger amount of feed per minute. This may suggest that during period of animal growth, young animals need feeds of high nutritional value in order to meet their body requirement.

The higher intake rate by both animals on leucaena than on lespedeza is seen to be attributable to the difference in the structural characteristics of the two forage plants and the difference in the chemical composition of plants. Although the leaf ratio per branch for lespedeza could have been higher than for leucaena, branches of leucaena were open with larger leaves and flowers that enabled animas to apprehend them easily and make more bites per minute for lespedeza than for leucaena. Similar to the observation by Dziba *et al*. (2003), leaves on unbrowseable short shoots limited bite size, while those on browseable long shoots did not restrict bite sizes, but resulted with higher intake rates. Lespedeza had short shoots compared to those of leucaena, resulting in lower intake rate, while leucaena with long shoots enabled higher intake rate by animals.

Another factor of higher neutral detergent fiber and acid detergent fiber of lespedeza contributed to lower intake rate as animals had to take some time chewing and ruminating in order to reduce the particle size for swallowing. Reduction of particle size is suggested to be an essential part of foraging by goats (Lu *et al*., 2005) as it increases surface area for digestive rumen microbes and enzymes, and increases digesta passage. However, during the present study, it was observed that sheep had higher intake rate than goats. This is attributable to the amount of forage they consumed per bite and their reduced idling behaviour. At the Leucaena plot, sheep did not idle as much as goats, and were able to spend more time at a particular feeding station. Peacock (1996) suggested low intake rate by goats than by sheep when feeding on low quality forage to be attributable to their selective behaviour of highly nutritious materials. It could be that at the leucaena plot goats had low intake rate because they had to select young leaves and flowers that were more nutritious while sheep took more fibrous feed.

Time and feed type influenced Intake rate. The high intake rate that occurred during the mid-day (12.00h) could have been due to warm temperatures which averaged between 24.2^0 C and 23.3^0 C during the months of March and April, respectively. Grazing animals tend to change their foraging strategy throughout the season due to difference in climatic conditions (Reppert (1957). When the temperature is cool, animals will take more time foraging but less feed, but when it becomes hot more feed will be taken during the morning hours and afternoon while during mid-day they will be under shades in order to stay cool.

2.5 Conclusion

The result from this study shows that there is contrast in feeding behaviour of sheep and goats. When exposed to the same rangeland, goats will spend most of their feeding time browsing and selecting the most nutritive parts of the plant, which are rich in protein and less fibrous. Goats will pick smaller amount of feed several times while sheep will pick larger amount of feed within a shorter period of time. Since goats graze at a higher canopy than sheep, they are less likely to suffer to the same degree from endo- parasitic infection.

Chapter 3

The effect of supplementation of sheep and goats grazing kikuyu pasture with lespedeza on endo-parasites burden

Abstract

Endo-parasite infection is the major cause of economic loss in small ruminants production. This study investigated the potential of *Sericea lespedeza* (*Lespedeza cuneata*) hay on controlling nematodes infection in sheep and goats, which were naturally infected from the pasture. Twelve sheep and twelve goats (both males and females) aged 3 to 4 years grazing from kikuyu pasture were, within animal type blocked by weight into six groups, and within a group randomly allocated to two feeding treatments (*Sericea lespedeza* and veld hay) for 13 weeks during the months of March and May 2006. Animals were fed in pens individually at 16.00h when they return from grazing kikuyu pasture. Animals were weighed weekly while rectal feacal sampling was done on days 0, 18, 46 and 83 for egg count. Sheep showed a greater ($P<0.001$) appetite than goats. Egg count was not affected by either feed, animal type or their interaction. Owing to the variable intake, regression analysis was used to explore the relationship between the previous week's intakes on the egg count. The previous week's intake of lespedeza was negatively ($P<0.05$) related to faecal egg count for sheep but not for goats that had low intakes. The interpretation of this resulted was confounded by the fact that veld hay intake was also negatively ($P<0.01$, $P<0.05$) associated to egg count for goats and sheep. Owing to the variable intake and non-conclusive nature of these results, the negative effect of *Sericea lespedeza* on endo-parasites burden deserves further investigation.

Key words: Endo-parasites, sheep and goats, *Sericea lespedeza*, protein

3.1 Introduction

The problem of endo-parasites in small ruminants, particularly sheep and goats, has for several years caused concern to livestock farmers' worldwide. They are the major cause of economic loss to production of small ruminants (Miller and Horohov, 2006). In tropical and subtropical regions, where marginal levels of nutrition lead to high incidences of infection, animal death due to nematodes infections is widely apparent (Waller, 1997). In areas where farmers solely depend on synthetic anthelmintics for their control, such as in Australia and New Zealand (Pritchard, 1994; Waller, 1997) and in the US (Miller and Barras, 1994; Zajac and Gipson, 2000; Terril *et al*., 2001) rapid increase in resistance has been observed and chemical residues in animal product and on pasture have also increasingly brought some fears to both consumers and farmers (McKellar, 1997; Hordegen *et al*., 2003). This has brought about the quest for alternative worm control methods that are practical and realistic for implementation into the farm production system (Butter *et al*., 2000). The nematodes can cause severe blood loss resulting in anemia, anorexia, depression, loss of condition, and eventual death (Miller and Horohov, 2006). Other sub-clinical signs include reduced feed intake, depressed live weight gain, milk and wool production and impaired soft tissue deposition and skeletal growth (Butter *et al*., 2000).

The use of browse plants containing phenolic compounds (condensed tannin) had been suggested (Niezen *et al*., 1998; Athanasidau *et al*., 2000; Butter *et al.,* 2000; Min and Hart, 2003; Paolini *et al*., 2003a; Shaik *et al.,* 2004) as alternative method to control endo-parasites in small ruminants. When grazed as fresh forage *Sericea lespedeza* (SL) was reported to reduce feacal egg count (FEC) of infected goats and to inhibit larvae development of *Haemonchus contortus* (Min and Hart, 2003; Shaik *et al.,* 2004). Furthermore, when fed dried and ground lespedeza, Shaik et al. (2004) observed a significant reduction of feacal egg count from goats that had natural and experimental infection of *H. contortus*. However, since there are limited studies on the use of lespedeza as hay, more studies are necessary to confirm its potential use in endo-parasite control and as a supplement.

The objective of the present study was to investigate the effect of supplementing *Serecia lespedeza* hay on fecal egg count in the faeces of sheep and goats, which were naturally infected by nematodes from the pasture.

3.2 Materials and Method

Animals and housing: The experiment was run for 13 weeks during the months of March to May using twelve goats of 3 to 4 years of age, comprising of two breeds i.e. Nguni and Boer goats, and twelve Damara sheep. The initial goats weight ranged from 26 to 45kg (mean ± SD 35.67 ±

9.11 kg), while sheep' weight ranged from 25 to 47 kg (mean ± SD 34.92 ± 7.29 kg)). Four goats and four sheep were randomly selected to monitor the passage rates. Initial weights of selected goats ranged from 28.5 to 44.0 kg (mean ± SD 36.25 ± 8.81 kg) while sheep weights ranged from 31.0 to 47.0 kg (mean ± SD 39.0 ± 7.71kg). Each of the two feeding treatments (lespedeza and veld hay), were represented by two sheep and two goats, making a total of four animals per treatment.

These animals were neither drenched before the experiment nor inoculated with parasites larvae, but had acquired natural worm burden from the previous pastures. All these animals were kept at the Ukulinga Research Farm of the University of KwaZulu-Natal (30^0 24`S, $29^0$ 24` E at an altitude of 700m). Animals were kept inside a raised house with slatted floor during the night, while during the day they were out on the pasture. They were kept in individual pens (70cm wide, 50cm long and 90 cm high) fitted with feeding troughs and automatic drinkers. The pens, feeding troughs and drinkers were thoroughly cleaned every morning after animals had gone out for grazing.

Experimental feed: A re-growth of a 4-year old lespedeza stand was cut when it was at a vegetative stage, air-dried before milling and bagging for later use, while the baled grass hay cut from the outskirts of Ukulinga Farm was bought from the Range Management center (grass had 32g/kg crude protein, 690g/kg neutral detergent fiber, 453g/kg acid detergent fiber and 16.4 mj/kg gross energy). Both feeds were chopped to an average length of about 10cm before feeding to animals in order to reduce stem length and wastage. Plots planted with kikuyu grass were used for grazing the animals during the day. Voermol phosphate block consisting of Calcium (120g/kg), Phosphate (60 g/kg) and Sulphur (35g/kg) obtained from National Cooperative Dairies, Pietermaritzburg, was provided during grazing and animals had access to water ad-libitum.

Experimental Design: Animals within a small ruminant type electronic scale (sheep or goats) were weighed, block by weight into six weight categories, within each of which animals were randomly assigned to the two feed categories (Veld hay and SL hay). Consequently, there were six goats and six sheep in each of the dietary treatments constituting a 2 x 2 factorial design (2 hay x 2 animal type). Individual animals were each offered 300g dry matter feed in the afternoon when returning from the pasture. Feed refusals were weighed the following morning before weighing the feed allocation for the next feeding. Water troughs and floors were cleaned on daily basis to avoid contamination. Animals' weights were monitored every week using an electronic scale.

Rectal feacal sampling: Rectal feacal sampling was done on day 0, 18, 46 and 83. Individual animal's feacal sample was placed in a plastic bag and stored in ice cubes for transportation to the laboratory for egg count. Dissolving 400 grams of *sodium chloride* into 1000ml water made a saturated solution of NaCl. Two grams of faeces was added into 58ml of saturated NaCl solution in a 100ml beaker. The mixture was crushed to pass through a tea strainer into another beaker. Using a Pasteur pipette a sub sample was drawn from the filtrate while stirring and filled into the McMaster slide chambers. The slide was allowed to stand for 5 minutes for the eggs to float to the surface and debris to settle to the bottom of the chambers before counting. Eggs were magnified using a 10-x10-magnification lens and counted according to McMaster egg counting technique (Ministry of Agriculture, Fisheries and Food, 1977).

Preparation of markers: The solid phase was marked with Cr- hay and liquid phase with Co-EDTA. To determine the passage rate, veld hay was mordanted with chromium by following the procedure described by Uden *et al*. (1980). Two kilogram of sun dried veld grass hay was weighed, soaked for 2 hours and washed thoroughly in tap water to remove dirt and solubles. *Potassium dichromate* ($K_2 Cr_2O_7$), representing 33% of the dried veld hay to be mordanted was spread on the dried hay and water was added to completely cover the material mordanted. The container was tightly covered with the lid and tied with a string before baking in an oven at 100^0C for 24 hours. After baking, the mordanted hay was thoroughly washed with tap water until the water was faintly coloured. The mordanted material was then suspended in tap water and ascorbic acid, equivalent to one half of the original dried hay material added. The mordanted material in the ascorbic acid was left for 1 hour. Finally, the mordanted material was washed several times in tap water and dried in an oven at 65^0C for 24 hours, after which it was stored in a plastic bag for later use.

To prepare *Cobalt ethylenediaminetetraacetic* acid (Co-EDTA), 297.2 g Na-EDTA, 190.4 g $CoCl_2.6H_2O$ and 32.0g NaOH were dissolved in 1600 ml of distilled water in a 5-liter beaker and gently heated (Uden *et al*., 1980). The solution was left to cool to room temperature before adding 160 ml hydrogen peroxide. After leaving the mixture for 4hours at room temperature, 2400ml of 95 % (v/v) ethanol was added. The mixture was then refrigerated overnight. Finally, The resulting crystals were filtered and washed with 80% (v/v) ethanol and dried overnight at 100^0 C.

Administration of Marker and sampling: After four weeks of feeding on experimental diets, each selected animal was fed 15 g of mordanted hay before being allowed on pasture for grazing. The mordanted material was mixed with a small amount of molasses in order to encourage consumption. Animals were allowed 30 minutes to consume as much as they can of the mordanted material before dosing with 30ml of liquid marker (10g of Co-EDTA dissolved into 300ml of water). Rectal faecal samples were then collected at 0, 3, 5, 7, 9, 11, 13, 24,27, 31, 33, 35, 48, 55, 72, 80, 96, 104, 120, 128, 144, 142, and 168 hours after dosing. Sampled faeces were dried at 60^0 c for 48 hours, then ground using a laboratory mill (IKA cutting mill) and stored at room temperature in small plastic containers pending laboratory analysis of chromium and cobalt. Concentrations of chromium and cobalt in feaces samples were determined using an atomic absorption spectrophotometer.

Chemical analysis: Feed samples were analyzed for dry matter (DM), gross energy (GE) was determined using bomb calorimeter (dds CP500, Automatic Processor, by Coalab Supplies) and crude protein (CP) according to AOAC (1990), and for neutral detergent fiber (NDF) and acid detergent fiber (ADF) according to Van Soest (1992). Hemicellulose was determined by subtracting acid detergent fiber from neutral detergent fiber. Condensed tannin was analyzed using the Butanol- HCl method (Makkar and Goodchild, 1996) and results were expressed as Leucocyanidin equivalent (Porter *et al*. 1986).

Data analysis: Analysis of data was conducted using the general linear model procedure of the Statistical Analysis system (SAS version 6, 1989), according to model:

$$Y_{ijkl} = \mu + A_i + F_j + (A*F)_{ij} + T_k + W_l + e_{ijkl}$$

Where Y_{ijkl} = individual observation, μ = Overall mean, A_i = effect of animal type, F_j = effect of feed type, $(A*F)_{ij}$ = effect of animal interaction feed type, T_k = co-variate effect of initial egg count, W_l = co-variate effect of initial live weight, and the error term e_{ijkl} as an unexplained variation assumed to be randomly and independently distribute.

Weekly intake of feeds and animal weight changes were also analysed according to model:

$$Y_{ijk} = \mu + A_i + F_j + W_k + (A* F*W)_{ijk} + e_{ijk},$$

Where Y_{ijk} = individual observation, μ = overall mean, A_i = effect of animal type, F_j = effect of feed type, W_k = effect of week, $(A* F* W)_{ijk}$ = effect of animal, feed and week interaction while the error term e_{ijk} is an unexplained variation assumed to be independently distributed.

Given the variation in intake, regression analysis was employed to explore the effect of the previous week's intake on the current week's egg count. Other variables introduced into the regression were the initial egg count and the initial live weight.

Passage rates were estimated following the method proposed by Grovum and Williams (1973). Data for chromium concentration and cobalt were used to determine the fractional rates of passage of particle and liquid, respectively. Difference between animal type and feed type were analyzed using the GLM procedure (SAS, 1987) according to the model:

$$Y_{ij} = \mu + A_i + F_j + e_{ij}$$

Where Y_{ij} is the individual observation, μ is the over all mean, A_i is the average effect of the animal type and F_j is the average effect of the feed type. The error term e_{ij}, is assumed to be independently and normally distributed.

3.3 Results

Lespedeza has higher contents of crude protein and energy and lower fiber content relative to veld hay, while crude protein and energy contents of kikuyu grass is in between that of the other forages. Tannins were analyzed only for lespedeza, which is reasonable endowed.

Table 3.1 Chemical composition (g/kg) of lespedeza hay, veld hay and Kikuyu grass

Feed	DM	OM	CP	NDF	ADF	HEM	GE (mj/kg)	Tannin (%DM)
SL	910	823	227	346	279	67	19.72	9.45
Veld hay	960	869	32	690	453	237	16.4	0
Kikuyu	245	234	98	133	60	73	17.84	0

DM= Dry matter; OM= Organic matter; CP= Crude protein; NDF= Neutral detergent fibre; ADF= Acid detergent fibre; HEM= Hemicellulose; GE= Gross Energy. SL= Serecia Lespedeza

The feed type tended to affect the final weight while animal type and interaction of feed and animal type had no effect. Animal effect was highly significant (P<0.001) on feed intake with sheep consuming more (P<0.001) of each kind of feed (lespedeza and veld) than goats. Feed effect and the interaction of feed and animal type were not significant.

Table 3.2 Variations of mean initial weight, final weight and feed intake for the entire feeding period

		Initial weight (kg)	Final weight (kg)	Feed intake (g/d)
Goats (n = 6)	Veld hay	34.92	29.2	164.59
(n = 6)	Lespedeza	36.42	34.29	225.08
Sheep (n = 6)	Veld hay	36.83	31.08	166.03
(n = 6)	Lespedeza	39.75	33.63	245.89
	RMSE	6.821	5.056	47.072
	F. Effect	ns	0.1	ns
	A. Effect	ns	ns	0.001
	FxA effect	ns	ns	ns

RMSE = Root mean sum of standard error; F. = feed type; A. = animal type; F* A = interaction of feed and animal; ns= not significant.

Variation of feed intake and initial weight: Throughout the feeding period, sheep consistently had higher intake of lespedeza and veld hay than goats, with greater intake of lespedeza during weeks 3 to period 8. Similar intake is observed between period 8 and 10, beyond which more veld hay was taken than lespedeza. The figure shows a decreasing trend in the intake of lespedeza by goats from feeding period 5 to the last week, while veld hay intake tended to increase during this period.

The live weight of sheep and goats decreased during feeding period 3 to period 5, beyond which it remained stable for goats on grass hay or increased slightly before stabilizing for the other treatments. Sheep on lespedeza experience the least changes in live weight.

Table 3.3 Logarithmic egg count from day zero to day 83 for sheep and goats fed on lespedeza and veld hay

	Animals				
	Goats		Sheep		
Days	Veld hay	Lespedeza	Veld hay	Lespedeza	SED
0	7.47	7.89	6.23	7.20	-
18	7.22	7.27	6.79	6.95	0.757
46	6.74	7.03	6.28	7.13	1.426
83	7.15	8.0	6.97	7.20	1.276

SED = Standard error deviation

Faecal egg count was not affected by animal type, diet or interaction. Although, the spacing between sampling and periods was not even, repeated measure analysis was applied to diagnose the effect of period of sampling. Egg count varied significantly ($P = 0.015$) among period of sampling, a general trend indicating a decrease from day 0 to day 46 beyond which egg count tended to increase. In view of the extremely varied intake, egg count was then regressed on the previous week's intake to determine if periods of high intake of lespedeza were followed by depressed egg count. The relationships derived using regression analyses are presented in Table 3.3.

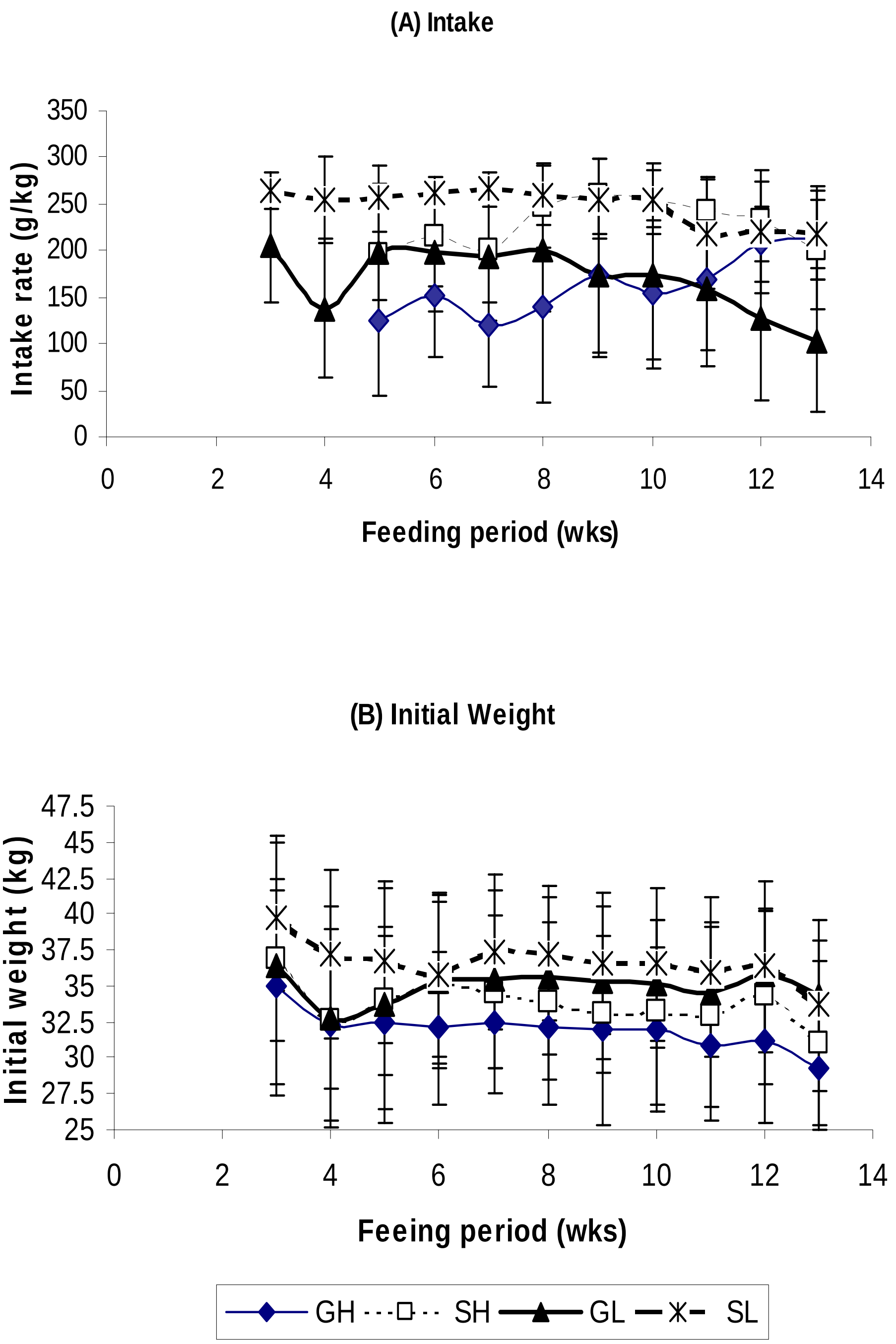

Figure 3.1 Weekly variations of feed intake (g/kg) and live weight for sheep fed on veld hay (SH) or lespedeza (SL) and goats on veld hay (GH or lespedeza (GL)

The effect of the initial weight was highly significant (P<0. 001) for goats on lespedeza and for sheep on hay. The effect of the initial egg count was significant (P<0. 05) for sheep on lespedeza alone. Increased intake during the previous week was associated with a depression in egg count, the effect attaining significance (P<0.05) for both goats and sheep on hay and for sheep on lespedeza (P<0.05). The initial weight had a positive relationship with egg count but the effect was significant for goats on lespedeza and for sheep on hay.

Table 3.4 The relationship between the current weeks eggs count and the previous week's intake, initial Weight and initial egg count.

	Animals			
	Goats		Sheep	
	Veld hay	Lespedeza	Veld hay	Lespedeza
Intercept	5.62^{NS}	1.39^{NS}	6.62***	-3.49^{NS}
Intake	-0.002*	-0.00003^{NS}	-0.0007*	-0.002*
Initial wt.	0.634^{+}	0.874***	0.731***	0.147^{NS}
Initial egg	0.139^{NS}	0.370^{NS}	-0.0006^{NS}	1.1775*
P value	0.14	0.0001	0.01	0.05
R^2	0.285	0.374	0.0582	0.322

Initial wt. = Initial weight; Initial egg = initial egg count; P value = Overall effect; R^{2} = Square root, NS = P>0.05; * = P< 0.05; *** = P<0. 001; + = P<0.1

Goats and sheep had similar fractional rate of passage of particles through the rumen (2 .0 % v 2.5 %), and through the hindgut (8.6 % v 7.7 %). The fractional rate of passage of the liquid phase through the rumen tended to be lower (P = 0.0648) for goats than for sheep (4.7 v 6.1%, however, the liquid passage rates through the hind gut were similar between the two species (12.3 v 16.2 %).

The type of feed and animal did not affect any of the kinetic parameters. The fractional rates of passage of particles through the rumen were 2.1 v 2.3%, and through the hindgut were 7.7 v 8.5

% for hay and lespedeza, respectively. Meanwhile, the liquid passage rates via the rumen were 5.4 v 5.4% and through the hindgut 16.3 v 12.1% for hay and lespedeza, respectively.

3.4 Discussion

Certain anti-nutritive and toxic factors such as condensed tannin in forage plants affect the nutritive value of forages and animal performance (Norton, 1994). Reduction in voluntary intake, diminished digestibility of nutrients, adverse effects upon rumen metabolism and toxicity are some of the anti-nutritional effects that occur when ruminants feed on these forages (Clausen, *et al*., 1990; Garg, *et al*., 1992; Murdiati, *et al*., 1992). *Sericea lespedeza* (SL), a forage plant that has high concentration of tannin is also among forages that can exhibit these effects. In the current study, when compared with veld hay, its intake rate was higher than that of veld hay. Although feed effect and interaction of feed and animal type did not significantly affect intake, it is suggested that high intake of lespedeza by animals was due to the drying effect that reduced tannin toxicity and improved its palatability. By continuously having greater intake of lespedeza may also suggest that the ruminal microorganisms might have adapted to the presence of tannin and as such were able to degrade it. Shaik *et al*. (2006) noted similar improvement in intake of SL hay when fed to goats. Although based on fiber and protein content, lespedeza appears to have higher nutritive values than veld hay that had higher fiber content and low crude protein. The high intake of lespedeza also suggests that fiber digestion was possible.

The study has also shown sheep with larger intake of lespedeza during the early feeding period compared to goats. Before sheep can adjust to the taste of their diet they seem to prefer satisfying their nutritional needs first, while goats start by sampling their diet before they can adjust to their need. This behaviour is more likely to promote high intakes by sheep relative to goats during the early phase of the feeding period. .

A decrease in live weight for all treatment groups during the early feeding period is seen to be associated with a decrease in feed intake which is a reflection that both types of animals were unable to meet their requirements. All groups experienced average reduction in live weight of 10%. Weight of goats on veld hay then tended to stay lower throughout the feeding period while that of sheep increased slightly before stabilizing. The ability of animals on lespedeza unlike on veld hay to recover some of the live weight lost during the initial phase of the study may be attributable to the tannin-protein complex that escaped degradation in the rumen but dissociated in the abomasums. This process is suggested to improve the absorption of amino acid in the small intestine (Waghorn *et al.* 1994; Ben Salem *et al.*, 2005). It is possible that the released tannin may complex with other proteins in the lower gastrointestinal tract. As observed by Butter *et al.* (2000), when the available protein in feed is not sufficient to meet the penalty of infection associated with nutritional loss and tissue damage, the energy and protein of feed taken is diverted away from growth.

Interpreting Table 3.3 and Figure 3.1 together, it appears when the intake of sheep fed on lespedeza was high (day 0 to day 46) a more pronounced depression in feacal egg count occurred relative to those on veld hay, beyond day 46 lespedeza intake experienced a slight depression which was associated with a rise in egg count by day 83. This is confirmed by the significant negative effect of the previous week's intake on the egg count for sheep on Lespedeza presented in Table 3.4. The effect was not significant for goats perhaps because goats tended to have a lower lespedeza intake than sheep, which is surprising given goats' ability to secrete proline-rich proteins in their saliva (Austin *et al.*, 1987) which reduces astringency. This depression could be associated with (I) the change in the abomasal environment (Lange *et al.*, 2006) of adult parasites, rendering them less active in reproduction due to the introduction of tannin, (ii) increased digested true protein at the small intestines which stimulate the immune system and improved performance (Norton, 1999). This may suggest that tannin directly affect adult worms whose egg-laying ability is depressed or the parasites are expelled from the gastrointestinal tract. This interpretation is confounded by the observation that the intake of veld hay was also negatively associated, though to a less magnitude, to egg count in sheep and in goats (Table 3.4). Generally it is recognized that animals on diet high in protein content have low feacal egg count than those on low protein diet due to increased nitrogen retention (Butter *et al.,* 2000; Chartier *et al.*, 2000). However, some reports have shown animals on diets of low protein content with depressed feacal egg count (Blackburn *et al.*, 1991).

The present study shows no difference in the fractional rate of passage of digesta between goats and sheep. This observation was unexpected because of the different feeding behavior of the two species of animals. The fractional rate of passage of digesta for goats was expected to be faster than that for sheep because of the tendency of goats to been more selective in feeding and to be more efficient in digestion of fiber-rich feed than sheep. However, result of the present study agrees with previous studies of fractional passage rate for sheep and goats supplemented in stalls (Molina *et al*., 2000; Isac *et a*l., 1994) where similar outflow rate was observed. In contrast to the present results, Garcia *et al*. (1995) noted faster fractional rate of passage of digesta for goats on pasture in comparison to sheep, indicating that goats could have been more selective of nutritious forages and more efficient in digesting fiber –rich feeds than sheep.

However, the two feeds (Lespedeza and Veld hay) supplemented to the animals did not show any effect on the fractional passage of particles through the rumen and through the hindgut. Since diarrhea was not observed within any treatment group, it suggested that animals were not at high risk of parasites.

3.5 **Conclusion**

Although feeding lespedeza hay to sheep and goats has shown potential in reducing internal parasites burden, the results are not conclusive owing to the variation associated with the intake of both hay and lespedeza. These animals were perhaps no hungry given that they grazed good quality kikuyu pasture. Retrospectively, the addition of molasses to both hays might have ensured stable intake. The investigation on passage rate shows that sheep and goats have similar rate of passage when other parameters that can influence their selection behaviour are eliminated.

Chapter 4

General Summary and Conclusion

Currently, production of sheep and goats is becoming more difficult to handle due to the problem of gastro-intestinal parasites, which have evolved resistance to synthetic anthelmentic drugs. The high cost of synthetic drugs, their possible residual effect on animal by-products and adverse effects of the parasites seem to be pushing small scale farmers out of the industry. Treatment by supplementing sheep and goats with forages containing anthelmentic properties could be an alternative strategy that is affordable by all farmers. This study was based on supplementing sheep and goats with *Sericea Lespedeza* (SL), a highly nutritious forage plant that contains tannin, and adapt well to different climatic conditions. Besides being highly nutritious, lespedeza with high concentration of tannin is said to have some negative effect on animals by reducing their voluntary intake due to the toxic effect of tannin and depression of microbial digestion in the rumen. For lespedeza to effectively control animal parasite, animals should be able to select it during grazing.

In the first part of the study, lespedeza was used together with leucaena, because of their comparable nutritional quality, but low concentration of tannin in leucaena, to investigate whether sheep and goats will respond indifferently to lespedeza. Leucaena has undergone extensive research as a fodder crop, and is well accepted by farmers (Garcia *et al.*, 1996), while the interest on lespedeza is fairly new in the research field and not known to farmers. Besides being slow in establishing, lespedeza is seen to be a good alternative forage plant to leucaena, suitable for use by small farmers who do not have enough resources in terms of finance for buying expensive synthetic drugs for internal parasites. When intercropped within the pasture with other forages of low quality, lespedeza can contribute as a source of protein supplement to small ruminants and a therapy for internal parasites. Although lespedeza has higher content of tannin than leucaena, it does not have the mimosine found in the leucaena. However, during the study, it was observed that animals preferred browsing for a longer period of time on leucaena, because of the difference in structural characteristic of the plants and physiological difference of the two species of animals. Goats were seen to browse leucaena longer than lespedeza while sheep browsed it less than lespedeza (Chapter 2). Goats browse leucaena more than sheep because they were able to reach parts not accessible to sheep.

When browsing on lespedeza, the length of time taken by goats was seen not to be due to anatomical feature of goats but rather physiological feature. The behaviour shown by the two species of animals on lespedeza could also be seen to be due to their intuition as their intake was high during their early feeding period. This was seen to result with animals spending more of their feeding time grazing on vegetation that does not contain tannin. Sheep's inclination in spending less time in browsing and more time grazing than goats increases their chance of being infested by parasites. However, this disadvantage that sheep have is counteracted by having higher intake rate (Table 2.3) of feed than goats, which can equate to the faster feeding rate of goats. From the study, it is suggested that supplementation of animals could be done during mid-day (12.00h) when their intake rate is highest.

The latter part of the study had to investigate lespedeza's effect on *endo- parasite*. When feeding of lespedeza hay was compared with veld hay, sheep and goats seemed to cherish lespedeza better than veld hay. Several reasons were suggested. When dried, the toxic effect of lespedeza seemed to have diminished and its palatability improved. It could have resulted with animals not feeling much of astringency in the mouth. Another reason could be due to the low neutral detergent fiber and acid detergent fiber contents of lespedeza and high crude protein compared to the veld hay. This could be that the degradation of veld hay within the digestive system of animals took more time than that of lespedeza. Although sheep has higher intake than goats during this period, their intake diminished with time when that of goats increased slightly, which is an indication that goats are able to withstand the toxic effect of tannin better than sheep.

Feeding of lespedeza hay is associated with improvement in live weight of animals (Min *et al.,* 2005). During this study, neither of the feeds seemed to improve live weight probably due to insufficient supply of protein for absorption in the lower gut. Thus, when there is insufficient intake of energy and protein, the small amount available can be diverted from growth and be used for repair of tissues damaged by parasite. However, the slight improvement in live weight of animals on lespedeza during the middle period of feeding was an indication that dietary protein could have escaped degradation from the rumen and dissociated in the lower gut for digestion and improvement of amino acid absorption.

Despite the short period of observation during this study, lespedeza could have depressed egg-laying ability and/or improved the immune system of host animals. This is supported by the decreased in feacal egg count of sheep on lespedeza following period of high feed intake and the increase in feacal eggs count when feed intake decreased. Depression in egg laying ability of adult worms could have occurred in conjunction with improvement of the immune system as both reduced egg count and increase in weight gain were observed during the same period after high feed intake. Goats, however, did not have any significant decrease in egg count because of lower intake of lespedeza. The depression in egg count of animals on veld hay is unexplainable, as even weight improvement was not observed.

From this study, it can be concluded that although sheep and goats differ in selecting their feed, none had advantage over the other in terms of nutritional intake. Lespedeza could have potential of controlling gastro-intestinal parasites and could be used as a source of protein supplement to animals due to its high protein content. Small-scale farmers can incorporate lespedeza into the management of their small stock as it can adapt well to different environmental conditions. Further investigation on the effect of Lespedeza per se on gastro-intestinal parasites is suggested.

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