REPLACING SUNFLOWER OILCAKE WITH UREA OR *SERICEA LESPEDEZA* AND UREA ON FEED DIGESTIBILITY AND MILK PRODUCTION OF SAANEN GOATS

By

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Submitted in partial fulfillment of the requirement for the degree

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27 February 2013

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Dear Dr Hassen

EC083-12: Effect of replacing sunflower oilcake protein with urea and fodder tree leaves on nutrient utilization, milk composition and milk yield in Saanen goats *(A Malate)*

Thank you for the response. The application for ethical approval, dated 4 September 2012 was conditionally approved by the Chairman of the Animal Ethics Committee on 27 February 2013.

Kind regards

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LIST OF ABBREVIATIONS

AA	Amino Acid
ADF	Acid detergent fibre
ADG	Average daily gain
AH	Alfalfa hay
BC	Balanced concentrate
BCS	Body condition score
BW	Body weight
$BW^{0.75}$	Metabolic body weight
Ca	Calcium
CT	Condensed tannins
CF	Crude fibre
cm	Centimetres
CP	Crude protein
CPI	Crude protein intake
CS	Cotton seed
Csb	Corn stubble
CRBD	Complete randomised block design
DM	Dry matter
DMI	Dry matter intake
GLM	General linear model
GE	Gross energy
g	Gram
HT	Hydrolysable tannins
IVOMD	*In vitro* organic matter disappearance
Kg	Kilo gram
ME	Metabolizable Energy
MP	Microbial protein
MUN	Milk urea nitrogen
NDF	Neutral detergent fibre
N	Nitrogen
NPN	Non-protein nitrogen

NRC	National Research Council
OM	Organic matter
OMI	Organic matter intake
NGOs	Non-governmental organisations
P	Phosphorus
PRP	Proline rich proteins
PEG	Polyethylene glycol
RUP	Rumen un-degradable protein
RDP	Rumen degradable protein
Rumen NH3	Rumen ammonia
SAS	Statistical analysis system
SEM	Standard error of mean
S. lespedeza (S.L)	*Sericea lespedeza*
SCC	Somatic cell count
SIUS	Slow-intake urea supplement
SOC	Sunflower oil cake
SNF	Solid non-fat
TMR	Total mixed ration
TDN	Total digestible nutrients
UDP	Un-degradable protein
UTS	Urea treated straw
UP	University of Pretoria
VFA	Volatile fatty acid

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REPLACING SUNFLOWER OILCAKE WITH UREA OR *SERICEA LESPEDEZA* AND UREA ON FEED DIGESTIBILITY AND MILK PRODUCTION OF SAANEN GOATS

by

Andries Malate

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Department: Animal and Wildlife science

ABSTRACT

In conditions where supplementation of poor quality diets is a major challenge, forage legumes such as *Sericea lespedeza* can be a good alternative supplement for protein at lower cost than most commercial concentrates. From studies done on *Sericea lespedeza* it is found plausible and valuable to supplement urea with *Sericea lespedeza* to strategically combat the deleterious effect of condensed tannins in the *Sericea lespedeza* and provide nitrogen in the rumen. This study was aimed to evaluate the effect of replacing sunflower oilcake with urea (a rumen degradable protein RDP source) or *Sericea lespedeza* (rumen undegradable protein RUP source) mixed with urea as nitrogen/protein sources on nutrient utilization, milk yield and milk composition of Saanen dairy goats. A digestibility and lactation study were conducted at the University of Pretoria Research Farm and chemical analysis performed at the University Nutrilab.

A 30 days digestibility study was conducted on male Saanen goats after the lactation study, with 23 days adaptation and 7 days data collection period. Nine male goats were randomised and allocated to the three treatments in metabolism cages. In the lactation study 36 dairy goats were blocked according to milk collected on first month of lactation into high, medium and low milk yielders, then allocated to the three treatments of total mixed rations containing sunflower oilcake (T1) at 7% main protein source, T2 (urea at 1%) and T3- *Sericea lespedeza* at 12.5% mixed with urea according to a complete randomised block design (CRBD). Milk samples were collected from individual goats monthly at two consecutive milking’s. The samples were analysed for milk fat, protein, lactose, somatic cell count and milk urea nitrogen using a Milko-Scan analyser (at Irene Lacto lab).

In the digestibility study, dry matter intake was significantly higher for goats fed on *Sericea lespedeza* with urea (T3) diet than goats fed on T1 and T2 diet. Goats on T3 diet had also significantly higher organic matter and crude protein intake than those goats fed on the other two TMR diets. The results also shows that the mean daily milk yields for the goats in the T1, T2 and T3 were 2.56, 2.46 and 2.52 kg per day respectively. T2 group had higher milk fat % (3.61) and higher milk urea nitrogen (MUN - 25.70 mg N/dl) than the other two treatments. T1 had significantly higher milk protein %. There was a great difference in milk composition of the afternoon milk as compared to the morning milk. The three TMRs had no significant difference in the nitrogen utilization and nitrogen excretion.

It is then concluded that *Sericea lespedeza* mixed with urea can be used as subsititutes for sunflower oilcake in the diets of dairy goats since no negetive effect was found. However further investigations are needed.

Key words: *Sericea lespedeza*, urea**,** digestibility, milk yield, milk composition.

CHAPTER 1

1.1 GENERAL INTRODUCTION

South Africa holds over six million goats, which represent around three per cent of Africa's goat population (National Department of Agriculture (NDA), 2009). Goats are generally acceptable owing to their distinctive traits that have made this ruminant crucial to subsistence and commercial farming in South Africa. Goats in commercial sectors are kept mainly for cash, fibre and meat production. Subsistence farmers rear goats primarily for milk and meat, since most of these farmers cannot afford to keep cattle (Casey & Van Niekerk, 1988). Currently in South Africa, goats are not a major source of milk, but are important in most of the developing countries in the continent. Milk production in commercial enterprises is usually from cattle, but it is a challenge to poor and smallholder farmers to keep dairy cows as a source of milk. Dairy cows are expensive to maintain by subsistence farmers, since they require large amounts of food, as opposed to dairy goats, which are cheap to maintain, easy to look after, can be handled by women and children, and produce enough milk for a household (Donkin, 1998). Because the population of the country is on the rise, with inequality stretching wider, poverty growing stronger in the rural areas, and malnutrition as the result of dietary disease being reported broadly across South Africa, goat milk will become more important as a source of high-quality nutrients (Donkin, 1998). Goat milk is richer than cow milk in vitamin A, niacin, inositol and choline (Haenlein & Hinckley, 1994). Goat milk is also known to help people who are allergic to cows' milk and helps patients with ulcers (Egwu *et al*., 1995). Other domestic animals and orphan foals have been raised with goats' milk. Dairy goat farming is also needed for the ever-increasing demand for dairy products, which include gourmet cheeses and yogurt (Haenlein, 2001). These are some of the reasons that have made dairy goat farming a significant form of economic, environmental and sociological elevation in many African countries.

In South Africa, most goats are kept in a natural environment, where they depend on the available vegetation as the main feed source. Goats are classified as browsers rather than grazers, and are termed 'hard', because they can adapt to and thrive under harsh conditions, but still attain adequate performance in production (Alexandre & Mandonnet, 2005). Goat overall production is limited by heavy shortages of good-quality feed, especially during the dry season (Morand-Fehr, 2005). The feed available during this dry season is high in fibre and low in protein, which results in low feed intake and low nutrient utilization from poor digestibility. Energy, protein supply and intake are limiting factors that affect milk production and milk composition. Glucose controls the movement of water into milk, and goat milk production depends on the net energy content of the forage (Greyling *et al.*, 2004). Low-quality feed results in poor nutrition, which causes slow growth and loss of body condition, and increases the chances of disease infections. Under such conditions supplementation needs to be considered and encouraged.

Supplementing poor-quality diets with forage legumes offers good-quality nutrients at low cost, unlike concentrates such as sunflower oilcake (SOC) and full-fat soya, which are expensive and not readily available in the areas in which most goats are kept (Kanani *et al.* 2006). Legumes are known to be a rich source of dietary protein and nitrogen. They improve soil structure and the quality of pastures, since they can be used as green manure crops and are effective in fixing nitrogen into the soil. Legume leaves can be harvested, sun dried and used to supplement and provide energy, protein and micronutrients. Legumes supply a variety of nutrients to goat diets at a cheaper cost than commercial concentrates. But the presence of anti-nutritional factors in legumes, such as tannins, lignin and other toxic phenolic compounds, poses a constraint to the use of legumes in animal feed (Kanani *et al.*, 2006).

Goats are browsers, nonetheless. Thus among ruminants (Min *et al.*, 2003) they are known to tolerate legumes that contain tannins. Legumes such as *Sericea lespedeza (S. lespedeza),* which contain high levels of condensed tannins (CTs), have been used in goat rations as fresh or as hay. *Sericea lespedeza* is grown easily, is cheap, and can be used as a source of good nutrients for animals by farmers. Min *et al.* (2003) found improved milk production and a higher reproductive rate when ruminants were given forage containing high CTs. *Sericea lespedeza* is also known to have the beneficial effect of controlling and reducing gastro-intestinal parasites in goats (Turner *et al.*, 2005). Legumes that contain high CTs, such as *S. lespedeza*, are noted for their positive impact in increasing bypass protein in the rumen to the small intestines although CTs have been found to have adverse effects on palatability. Condensed tannins binds to proteins in the rumen, which negatively affects microbial activity and digestibility, but increases bypass proteins to the small intestines (Min *et al.*, 2003). Under these circumstances, the use of a rumen-degradable protein (RDP) source such as urea is justified, since it will help by increasing rumen protein, enhancing microbial growth, and improving digestibility.

Strategies to provide rumen bacteria with feed include the addition of non-protein nitrogen (NPN) to maintain good levels of ammonia in the rumen and increase the RDP content (Ort´ız *et al*., 2002; Galina *et al*., 2004). Additional nitrogen to the host animal could be supplied by urea as a source of NPN, which is converted into microbial protein via ammonia. Ensuring that there are no deficiencies of nutrients in the diet for microbial growth is the key to better ruminal fermentation. The bypass ruminal protein in *S. lespedeza* would provide key amino acids to the host animal for improved performance. Ort´ız *et al*. (2002) found that carbohydrates in maize and wheat bran were valuable when used with fibrous feeds. Molasses could also be used to improve palatability, and provide a good energy source.

This study thus attempts to bring an understanding of the simultaneous effects of supplementing *S. lespedeza* (RUP source) with urea (RDP source) in total mixed rations (TMRs) for milk goats, since there is a dearth of studies about the nutritive value of *S. lespedeza* through feed digestibility and its effect on Saanen goat milk yield and composition. Moreover, with the current social and economic challenges in the rural areas of South Africa, practical solutions and strategies have to be developed to help rural people (Mmbengwa *et al*., 2008). A study that seeks to investigate and improve the production of milk in goats at cheaper cost could add value to those strategies.

1.2 General objective

This study aimed to formulate an affordable and sustainable supplementation plan by using *S. lespedeza* and urea as protein sources and replacements for SOC on feed digestibility, milk yield and milk composition in Saanen goats.

This research studied these specific objectives.

- To investigate intake, digestibility and nutrient utilization response of three total mixed ration diets formulated with various sources of nitrogen from sunflower oilcake, urea (RDP source) and *S. lespedeza* with urea to balance the rumen degradable protein and rumen undegradable protein fed to Saanen male goats

- To investigate milk yield, milk composition and body condition response of Saanen milk goats fed three total mixed diets formulated with sources of nitrogen from sunflower oilcake, urea, and *S. lespedeza* with urea

1.3 Hypothesis

- H_0: Replacing sunflower oilcake (SOC) with urea (RDP source) or *S. lespedeza* (RUP source) combined with urea has no negative effects on feed digestibility, milk composition and milk yield of Saanen goats.

1.4 Outline of the study

Sericea lespedeza as fodder for animals, as well as its CT effects, and urea as a source of NPN in milk goats, are reviewed in Chapter 2. In Chapter 3, the digestibility and voluntary intake of the three TMR treatments are evaluated with Saanen male goats. The effects and influences of TMRs containing SOC, urea, and *S. lespedeza* with urea on lactation period, milk yield, milk composition and body condition score (BCS) of Saanen goats are studied and reported in Chapter 4. The major conclusion, critical evaluation and recommendations based on data collected in this study are presented in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Goat production in South Africa

In a developing country, finding new ways to help alleviate poverty and create real economic growth is important, but if that country's huge resources are managed in a traditional way with primitive knowledge, little economic growth would be recorded. Goat production should be pictured as a potential aid to rural entrepreneurial and agricultural development. This includes studying goat feeding systems, finding local and cheap means of diet supplementation, looking at the nutritional characteristics of the feed, and researching ways of improving digestibility.

South Africa has over six million goats (Agricultural Statistics, 2003), of which 85% are owned by small-scale (non-commercialised) farmers in deep rural areas. Commercial farmers own mostly Boer and Angora goats, while farmers in the rural areas own mainly indigenous goats (National Agricultural Marketing Council (NAMC), 2005). Indigenous goats represent about 63% of goats in the country (Directorate Marketing, 2012). Eastern Cape, Limpopo, KwaZulu-Natal and North West are the largest producers of live goats. In South Africa, goats have a variety of uses, which range from meat, milk, and cheese production to mohair and cashmere. Several success stories have been reported in goat production, mostly in goat meat (chevron) and cheese in North West (NAMC, 2005). These accomplishments are evidence that with proper management, good marketing and support structures from government and non-governmental agencies, goat production offers great potential to create employment, improve food security, and increase productivity in local settings, especially for small-scale farmers in rural areas. In this country, indigenous goats are not usually used for milk production. Even though good levels of milk production (> 2 l/day) have been reported with Nguni and Boer goats (Greyling *et al*., 2004). The popular breeds of dairy goats include Saanen (white), Toggenburg (grey or brown with white stripes on the face), British Alpine, French Alpine, and Anglo-Nubian. The high-yielding Saanen is the major dairy breed in South Africa. Boer, Kalahari Red and Nguni breeds are the most common and freely available animals in rural areas (Greyling *et al.*, 2004).

In rural areas, goats are kept mostly in natural pastures, where they graze low-quality roughage, which has little beneficial effect on their growth characteristics. Most evidence from the literature suggests that the highest critical factor in goat milk production has to do with nutrition, especially for goats in harsh environments (Leng, 1990). Good nutrition can reduce the effects of harsh environments and minimize poor management. Good nutrition can also enable indigenous goats to reach their full genetic potential. However, owing to their ability to acclimatize to different environments, goats exhibit a large variation of traits as a result of natural selection under varying situations (Morand-Fehr *et al*., 2004). Goats are browsers, which also renders them valuable, because they clear weeds, reduce bush encroachment and minimize thorn bushes. Free-ranging systems are mostly followed in the country, in which goats range freely during the day and kept in kraals at night (Morand-Fehr, 2005). Some goats are kept permanently in small yards, in which huts are provided for shelter. In all of the above goats feeding systems nutrition is still not stable usually through the winter season.

Morand-Fehr (2005) reported that nutrition plays a special role in dairy farming because it has the most marked effect on production costs and is the factor that farmers can act on the most easily and rapidly to influence output. Hence there is a need to pay attention to the interaction between nutrition and milk production in rural areas where nutritional shortages are dominant. Goats adapt to different conditions in rural areas, but there is evidence that they also suffer from low nutrient supply in the dry season (Morand-Fehr *et al*., 2004). In the dry season the protein and energy content of the feed drops too low to meet the nutritional requirements for adequate milk production and sometimes cannot provide even up to maintenance level. Meanwhile, fibre contents become higher. The dry season is characterised by weak body condition, poor performance and hence reduced production efficiency (Kanani *et al.*, 2006).

Supplementing poor dry season feed is essential and viable for sustainable production in rural farming (Molina-Alcaide *et al*., 2010). However, the feeding strategy should be based on cost-effective alternatives and use local feed resources to improve the incomes of farmers. Supplementing poor-quality diets with forage legume offers an effective and cheap source of renewable nitrogen and protein compared with high-priced concentrate protein sources (Kanani *et al.*, 2006). Legumes are abundantly available in the dry season in the country, and are gaining importance as a protein supplement for ruminants (Mapiye *et al*., 2009). Mapiye *et al*. (2009) also found that legumes contain minerals and have anti-helmintic properties, but harmful plant secondary compounds in legumes restrict their utilization. Goats are known to consume legumes such as *S. lespedeza,* even though it can contain high levels of CTs. Considerable research has been done on *S. lespedeza* and goats, especially in the USA, but these researches have been limited to its effects on controlling gastro-intestinal parasites and rarely as feed for the animal to improve milk production. There is thus, a need to study the nutritional status, benefit and uses of *S. lespedeza* to improve goat milk production in South Africa, especially in rural regions. Scientific literature on the establishment and uses of *S. lespedeza* is scarce. Hence at times unpublished blogs and international community journals have been used in this study to construct evidence about its description and importance.

2.2 *Sericea lespedeza*

Sericea lespedeza is a protein-rich (RUP) flowering perennial legume when harvested early, native to Asia, and commonly known as ‘Chinese bush clover’. It can be used for grazing and as a conservation plant. It grows in a wide range of soil types and sites. It is drought resistant, with prolific seed production, and is rich in CTs, which contributes to non-bloating characteristics in animals (Vermeire *et al.*, 2007). It does not require nitrogen inorganic fertilizers. It can be grown in high acidic and infertile areas with low phosphorus soils where most legumes grow scantily. It has a deep root system, which prevents soil erosion and improves soil structure (Ball & Mosjidis, 2007). Initially, *S. lespedeza* was assumed to be unsuitable for areas that receive less than 89 cm precipitation annually. However, it has been found to adapt to averages of 76 to 100 cm rainfall annually (Wang *et al.*, 2008). *S. lespedeza* improves the OM content of the soil and its leaves are more insect and disease resistant than grasses. When properly managed, it provides good forage for livestock and wildlife (Coffey *et al.*, 2007). It can also be harvested and used as hay for ruminant feeding, provided that proper hay-making procedures are followed.

2.2.1 Sericea lespedeza *hay making*

The hay quality of *S. lespedeza* depends heavily on the harvesting stage. Harvesting around a height of 350 mm to 400 mm is considered best by the Conservation Commission of Missouri (2014). The commission also recommends that the top of the *S. lespedeza* species should bend to the ground without breaking if it is the best harvesting time. This is called the ‘stem test’ method. If the stem breaks when bent, it is a sign that it has lost some quality. The leaves shatter too quickly if left too long after cutting. Hence, cutting in the morning is recommended, and it should be baled the same afternoon. *S. lespedeza* hay should contain more than 55% leaf material when properly baled. Once *S. lespedeza* has been established in the fields, it tends to improve annually. In spring and winter, CT concentrations are least in *S. lespedeza*, but increase with rising temperatures in the summer season. Eckerle *et al.* (2010) stated that *S. lespedeza* leaves that have been harvested and sun dried are lower in CTs than fresh leaves. The hay that is gathered in summer becomes a cheap and excellent source of winter feed, if harvested correctly.

2.2.2 Use of Sericea lespedeza *as fodder for animals*

Sericea lespedeza hay used in previous studies at the University of Pretoria research farm was analysed and had the following chemical composition (Table 2.1), which was compared with *S. lespedeza* from a study by Turner *et al.* (2005).

Table 2:1 Nutritive value of *Sericea lespedeza* hay fed to goats

	UP Research Farm *Sericea lespedeza* hay	*S. lespedeza* hay from Turner *et al.* (2005)
DM	93.3	92.8
Composition (% DM base)		
CP	10.1	12.2
NDF	60.6	55.9
ADF	39.4	46.1
IVOMD	28.5	52.3

UP: University of Pretoria; DM: dry matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre; IVOMD: in vitro organic matter disappearance

Many dairy farms in the south-eastern United States use *S. lespedeza* as basic forage. Many investigations found that *S. lespedeza* was a non-palatable roughage, with low DM intake and low milk production when fed to livestock (Pitman, 2006). Conversely, other reports, several of which have been reviewed by Shaik *et al. (*2006) and Min *et al.* (2003), have suggested that *S. lespedeza* is a high-quality forage. Cattle and goat DM intake was found to increase when they were fed immature *S. lespedeza* rather than mature plants (Min *et al.*, 2003).

Sericea lespedeza is a perennial legume. Legumes have higher digestibility than grasses, thus releasing nutrients for growth and production. Garg *et al.* (2005) discovered that giving ruminants diets that contained high-quality levels of RUP, which *S. lespedeza* has, enriched the nitrogen and amino acid profiles in the small intestine. Hence, an increase in milk production and milk composition was equally realised. The high tannin content of *S. lespedeza* has a pronounced effect on its consumption, and is sometimes responsible for its apparent low palatability. Legumes such as alfalfa, hop clover and white clover, which are readily consumed by livestock, contain approximately 3-8% tannins, whereas *S. lespedeza* and other legumes that are not readily consumed by livestock average 4-15% tannins (Lange *et al.*, 2006). Tannin concentrations in plants are known to increase in early summer. The rise in CTs in *S. lespedeza* has been associated with an increase in the stage of maturity of the plants. Goats reportedly have a greater tannin tolerance level than other domestic ruminants (Robbins *et al.*, 1991). Mayo (2000) found that goats had a strong affinity with *S. lespedeza*, because they reduced *S. lespedeza* cover by 25% on farm pasture in three weeks. The significance of tannin in determining the palatability of *S. lespedeza* seems questionable. Hence, more information is needed on these plant compounds.

2.3 Tannins

Tannins are polyphenolic substances with various molecular weights and of variable complexity that bind to proteins and other molecules (Makkar, 2003; Waghorn, 2008). Tannins are divided into two types: hydrolysable tannins and CTs. For the purpose of this study, only CTs found mostly in forage legumes, including *S. lespedeza*, will be reviewed. The concentration of tannins in *S. lespedeza* is dependent on several factors, which include time of growing and season, plant age and stage of maturity, their location in the plant (stem or leaves) and whether the plant is grazed fresh or as hay. Reduced intake and reduced digestibility are negative effects associated with tannins, and were found in concentrations of above 55 g CT/kg DM forage (Min *et al.*, 2003). An increase in bypass protein is a widely found positive effect, with added advantages of reducing bloating. Moreover, a high reduction in internal parasites has been associated with CT ingestion (Coffey *et al*., 2007). CT concentration of around 20-45 g CT/kg DM was found beneficial to the animal, as it increases protein utilization efficiency and milk production (Min *et al.*, 2003).

Condensed tannins in *S. lespedeza* have been scientifically proven to reduce internal parasite loads in ruminants. In this mechanism, tannins act directly by attaching to the skin of the worms and causing the worm distress or act indirectly by improving the immune system of the animal through protein efficiency. This mechanism also reduces the hatchability of parasite eggs and the development of larvae (Coffey *et al.*, 2007). The reduction of parasites and of contamination in animals and pasture surely results in healthier and more productive animals. Another important aspect of tannins is their ‘protein-binding capacity’, which addresses the proportion of CT that precipitates proteins in the rumen. It is a complex process, which depends on the quantity, structure and molecular size of protein and CTs (Makkar, 2003). According to Hagerman *et al.* (1992), the complexes are strong and stable in the rumen, where conditions are anaerobic, but they are subject to dissociation in the abomasum, where conditions are too acidic. A decrease in the breakdown of proteins into peptides, amino acids, ammonia and volatile fatty acids (VFAs) occurs from the conditions that exist in the rumen, which would ultimately give rise to a flow of protein to the small intestine and cause an increase in amino acid absorption in the blood (Min *et al.*, 2005). Unfortunately, these conditions in the rumen are not always favourable to the animal thus, forages that contained CTs became unwelcome in most feeding systems. In a study of cows fed *S. lespedeza* hay, Eckerle (2011) reported a low level of nitrogen in the rumen, which resulted in a drastic decrease in CP digestibility. Other authors witnessed a heavy decrease in dry matter intake (DMI), negative effects on rumen bacteria, hence low rumen bacterial enzyme activity, low bacterial growth, and reduced proteolysis in the rumen when high CT forage was fed to animals (Makkar, 2004; Min *et al.*, 2003, 2004). In the past, *S. lespedeza* was declared a noxious weed in some parts of the US Mid-West for these reasons, as well as unpalatability (Shaik *et al.* 2006). But because it is a cheap source of other good micro nutrients, gives high by-pass protein benefits and added soil and agronomical gains, some strategies and supplementation measures were found to minimize the negative effects of CTs.

2.3.1 Strategies to reduce condensed tannin negative effects

There are innovative ways of converting 'disposal problem' in forage containing CTs into openings for development (Makkar, 2003). These ways are formulated from agro-industrial and forestry by-products to be used in livestock feed, thus to a limited extent are cheaper and safer. Most of the studies on inactivation or tannin exclusion (detoxification) were done on *Acacia* species and oak leaves, but the principle can be applied to any tannin-rich forage. These solutions and methods are hardly used in goat feeding, since goats have been reported to tolerate and perform well when given fodder that contains high CTs (Silanikove *et al.*, 1996). Waghorn (2008) noted that goats have larger parotid glands, which produce more saliva than most ruminants. This saliva contains high levels of proline-rich proteins which bind to CTs and leave fewer CTs for protein binding, thus goats can allow and adapt to forage that contain CTs. Some of these measures and strategies require resources and a certain level of education, the lack of which has slowed down their implementation. These methods include the use of polyethylene glycol (PEG), wood ash, drying, chemicals, corn steep liquor and urea.

2.3.1.1 Polyethylene glycol

Polyethylene glycol (PEG) is a non-ionic detergent that has high attraction for CTs. Polyethylene glycol has been used widely to reduce the effect of CTs, based on its high affinity with CTs. Mantz *et al.* (2009) explained that CTs prefer to bind to PEG, and thus it inhibits the development of complexes between the dietary protein and CTs. These authors added that pH conditions in the rumen are good for this bonding process. The presence of PEG promotes the release of nutrient from tannin-rich leaves to enhance the efficiency of microbial protein synthesis. Frutos *et al.* (2004) conducted an in vitro study and found that PEG improved fermentation and reduced gas production when used with a source of CT. Some authors found that PEG improved VFA concentration, increased the number of protozoa in ruminal fluid, and increased DMI (Animut *et al.*, 2008; Mantz *et al.*, 2009). However, Waghorn (2008) found that the addition of PEG had its limitations, because the nutrients that were realised from its addition were not utilized effectively for microbial protein formation, since leakage or disconnection of free energy occurred. Other supplementation procedures were therefore needed.

2.3.1.2 Wood ash

Wood ash contains high alkali levels that can be used in solution to reduce CTs and protein precipitation capability. Makkar (2003) stated that wood ash reduced CTs by up to 80%, and acted on the elimination of other phenols as well. Villagers and small-scale farmers have easy access to wood ash and it is free. This method was used successfully in the past with sorghum and millet, which had high levels of tannins (Makkar, 2003). Its use holds great potential in the detanninification process of *S. lespedeza* and similar forages.

2.3.1.3 Drying

The harvesting, drying and storing of forage species such as *S. lespedeza* has substantial effects on the level of CTs it contains as hay. Two important factors to consider in all of these stages are the level of moisture in the species and weather conditions during harvesting (above). Shade drying of early matured *S. lespedeza* with 65% moisture promotes greater CT reduction than sun drying. Heat treatment and lyophilisation were found to be efficient in reducing tannin levels in *Leucaena leucocephala*. These methods can be applied to *S. lespedeza* as well (Makkar, 2003; Ball & Mosjidis, 2007).

2.3.1.4 Chemicals

This involves the use of oxidising agents, aqueous organic solvents and alkali treatments to remove tannins in forages and other species. Makkar (2003) found that removal of tannins with organic solvents yielded 70% success in oak leaves. Oxidising agents such as potassium permanganate and potassium dichromate reduced tannin content by 95%. Most of these chemicals use oxygen in their process to inactivate the protein-binding capacity of tannins and are pH and temperature sensitive. Some of these agents are cheap, simple, user friendly and adaptable to small-scale industries, but training might be required.

2.3.1.5 Corn steep liquor

Corn steep liquor has been used mostly in the USA, and is regarded as safe to feed to ruminants, especially beef. It is a by-product of wet-corn milling that is cheap and palatable to ruminants. It provides a source of protein, energy, free amino acids, vitamins and minerals, with DM content of around 50% (Kalscheur *et al.*, 2008). It has also been found to increase the intake of prairie grass mixed with *S. lespedeza* in beef cattle, improve CP digestibility and heighten energy availability. Eckerle *et al.* (2007) reported an increase in ammonia, reduced pH levels and increased butyrate concentration over acetate when corn steep liquor was fed to ruminants. Corn steep liquor is good for supplementation, since it improves performance. Most of studies on this compound have been carried out in the US, where there are greater resources, but only on beef cow production. Much more information is needed about this compound in African conditions and on goats in particular.

Because these methods have advantages and disadvantages in terms of application, skill, costs and animal reaction, a more sensible and smart approach would be dietary manipulation to support the production requirements of the goats and circumvent the CT effects as they occur mostly in the rumen. Farming conditions do not necessarily require CTs to be removed in forages since they offer bypass protein benefits. The key lies in the dietary protein content, energy source and presenting adequate rumen conditions to promote high degradability and digestibility. The main aims in animal production systems is to achieve energy and protein requirements as they are the first and second limiting dietary factors of production, and boost animal performance for higher output and greater profit margins to the farmer. Studies show that when diets have surplus protein (that is, above the animal’s protein requirements), CTs affect only degradability in the rumen, but not the amino acid obtainability for absorption. Thus, the adverse effects of CTs on animal performance are found to occur when protein content in the diet is below animal needs (Waghorn, 2008). Ruminants require two types of protein in their diet for substantial production, namely RDP, which is the protein that is degraded in the rumen. This type of protein is essentially food for rumen bacteria. The second group are rumen undegradable proteins (RUP) which do not undergo rumen degradation, but pass straight to the abomasum for digestion. This group of proteins benefits the animal body directly (Garg *et al.*, 2005). Greyling *et al.* (2004) reported that the provision of energy and protein heavily influences milk yield and composition in goat milk production. Inostroza *et al.* (2010) found improved DMI, milk yield and milk composition from favourable rumen conditions from adding urea to the diet of goats. Urea can improve rumen conditions since rumen microbes prefer ammonia for nitrogen sources. Ammonia is absorbed into the animal’s system through the rumen wall or is consumed by bacteria to become microbial protein (Sherwood *et al.*, 2005). Mixing *S. lespedeza* with urea would surely provide a cost-effective and feasible method of improving the utilization of poor-quality feeds, as it is advocated by Ndemanisho *et al.* (1998) in the study with *Leucaena leucocephala* and urea-treated stover.

It is clear that nutritional benefits to the goats would be realised if CP and energy concentration were increased and microbial activity enhanced in the rumen. Urea is reviewed next, since it promotes microbial protein synthesis and improve digestibility in the rumen, while reducing the negative effect of CTs.

2.4 Urea

Urea is available to most farmers in South Africa, but comes with constraints when applying it to animal feed. This makes it less used or preferred. Excess supply of urea can lead to toxicity and death of the animals. Dry season feed is of poor quality and is low in nitrogen content. Urea has added advantages over most treatments because it increases the nitrogen content of the feed and CP content. It is the most advocated method of treatment in most developing countries and has been used on cattle in South-East Asia with success (Djibrillou *et al.*, 1998). Urea has also been found to inactivate tannins and total phenols to a greater extent (Makkar, 2003). It increases palatability, feed intake, digestibility and enhances bacterial synthesis in the rumen, which greatly supports fibre digestibility as well (Makkar, 2003; Djibrillou *et al.*, 1998). A key to suitable fermentation in the rumen lies in ensuring that microbial growth is promoted and enhanced, thus supplying urea could be the solution (Galina *et al.,* 2004).

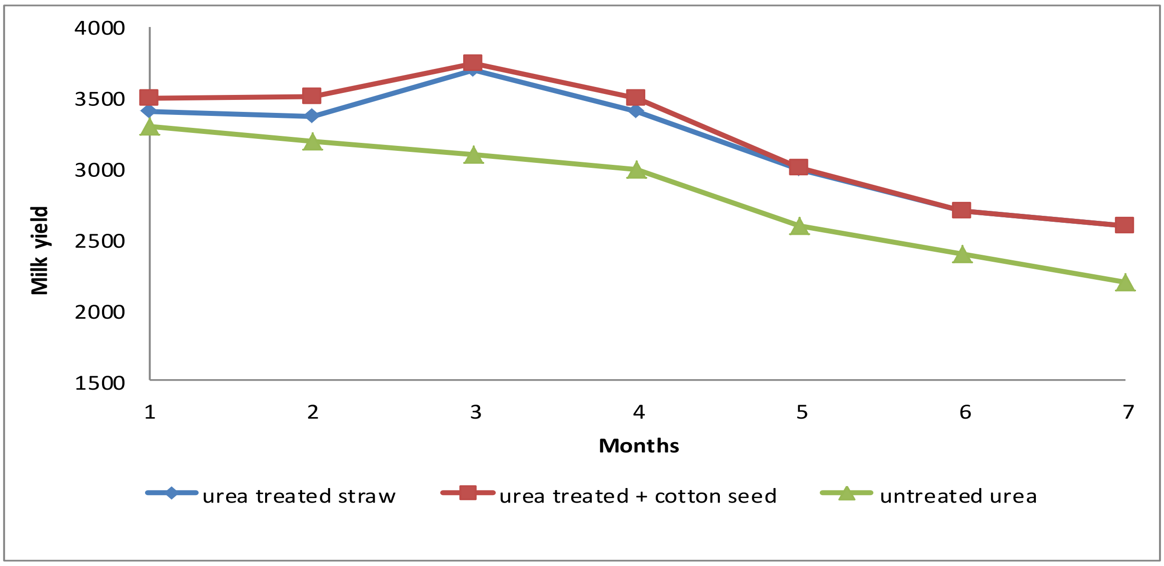
2.4.1 Description of urea

Urea is a compound that serves as a top source of nitrogen. In animal feed it is known for the pivotal role it plays in microbial protein synthesis in the rumen. It is not a natural protein hence, it is called non-protein nitrogen (NPN) which adds a large proportion of CP value of the feed. It has 46 per cent nitrogen in feed grade and makes up to 262 to 287 per cent in crude protein. The level of feeding urea is most important in animals because any value above the regulated level leads to toxicity and severe lethal consequences. Urea should also be used with a good energy source. It should not be used with feed material that contains urease, an enzyme that breaks down urea into ammonia, which can cause poor palatability of the feed. Most urea treatments are done when forages are stored as silage or during ensiling to improve the CP levels. Urea as a source of NPN is used by microorganisms in the rumen and transformed to ammonia and further into microbial protein to supply the host animal with extra nitrogen (Galina *et al*., 2004). Urea should be provided continuously to ensure that microbial ammonia requirements have been met to improve animal growth and production (Galina *et al.,* 2000). In addition, a good carbohydrate source, with a combination of low degradable protein for essential amino acids and mineral salts, is needed for proper fermentation and high production. Cell wall digestion has increased, roughage DMI and high feed conversion efficiencies have been realised as a result of supplementing non-protein nitrogen from urea (Makkar, 2003).

2.4.2 Effect of urea on milk yield

Urea-treated straw was found to increase milk yield when fed to lactating cows (Sourabie *et al.,* 1995). In the study of Djibrillou *et al*. (1998), urea-treated straw led to a 14% increase in milk yield when fed to cows, as shown in Figure 1.1. In the study the combination effect of less RUP in the rumen and a good carbohydrate source are shown through mixing urea-treated straw and cottonseed, as previously recommended. The milk yield values observed for urea-treated straw, and urea-treated straw plus cottonseed diets were higher in nitrogen content, which led to higher rumen ammonia concentration and microbial protein, creating a more encouraging environment for rumen microbial activity and higher milk production.

Figure 2.1 Milk yield from urea-treated straw, urea-treated straw plus cottonseed, and untreated straw



Source: Djibrillou *et al*. (1998)

2.4.3 Effects of urea on milk composition

The results of feeding urea-treated wheat straw on the composition of goat milk are given in Table 2.2. Group 1 animals were fed untreated straw and Group 2 were fed urea-treated straw. The percentages of water, fat, total solids, solid non-fat, casein, titrable acidity, pH and ash ($P< 0.05$) differed significantly in milk collected from Group 2 animals compared with Group 1. Urea increased the SNF and maintained the pH of milk. Such properties add to the buffering capacity and improve the keeping quality of milk (AL-Busadah, 2008). Other authors have found that urea increased milk fat and milk protein in lactating goats (Inostroza *et al.*, 2010; Greyling *et al.*, 2004).

Table 2:2 Effects of feeding urea-treated wheat straw on milk composition in goats

Parameter	Group 1 (untreated)	Group 2 (urea treated)
Fat %	2.29 ± 0.31 [a]	3.91 ± 31 [b]
Solid non-fat %	7.32 ± 0.22 [a]	8.86 ± 0.22 [b]
Ash %	0.73 ± 0.02 [a]	0.88 ± 0.02 [b]
Casein %	2.88 ± 0.13 [a]	3.52 ± 0.12
Titrable acidity (% lactic acid)	0.15 ± 0.007 [a]	0.23 ± 0.007 [b]
Total solids %	13.22 [a]	17.17 [b]
Water content %	86.78 [a]	82.83 [b]
pH	6.60 ± 0.018 [a]	6.40 ± 0.017 [b]

Means bearing different letters in a row differ significantly ($P<0.05$); Source: AL-Busadah (2008)

2.4.4 Effect of urea on intake and digestibility

Urea is known to improve DMI and digestibility. However, some results showed that urea had less effect on intake parameters. Galina *et al.* (2004) conducted a study in which he found that voluntary intake and apparent digestibility (Table 2.3) showed no differences for DM and OM for urea-treated and non-treated feed given to growing goats, which means that other confounding factors need to be secured and addressed. In many cases, urea would have an effect post ruminally if fermentation and digestion were improved. The study below shows that rumen acetate molar proportions were higher for the goats fed urea-treated straw, but were lower in propionate, while total VFAs did not differ between the two groups. These findings are supported by Bava *et al.* (2001), who suggested that a good VFA profile is needed for efficient feed utilization and production. Table 2.4 (below) shows that nitrogen intake increased significantly with the urea-treated diet at 18.60 g per day versus 14.57 with non-treated. Nitrogen digestibility was significantly higher in the urea-treated diet (76.63%), compared with the non-treated diet (54.16%). The digestibility of DM, OM, cellulose and hemicellulose was not affected by urea treatment, but NDF digestibility was significantly higher for the urea group. The study also reveals that urea has a positive effect on feed degradability, especially for cell wall and fibre components and the passage rate of ingested feed (Table 2.5). It is against this background that urea is endorsed to improve the digestibility of roughages and promote effective energy procurement and exploitation by ruminants an in particular goats.

Table 2.3: Voluntary feed intake, apparent digestibility and molar rumen volatile fatty acid proportions in urea and non-urea goat groups

	Diet	
	Non treated	Urea treated
Intake (g per day)		
DM	824 b ± 94 [a]	858 ± 118 [a]
OM	806 b ± 74 [a]	821 c ± 85 [a]
Apparent digestibility (%)		
DM	63.8 [a]	64.7 [a]
OM	48.4 [a]	54.7 [a]
Rumen NH3 (mg per 100 ml)	6.8 [a]	12.3 [b]
Rumen VFA proportions (moles per 100 moles)		
Acetate	68.8 [a]	72.2 [b]
Propionate	18.2 [a]	16.0 [b]
Butyrate	7.0 [a]	8.6 [b]
Total VFA	94.0 [a]	96.8 [a]

DM - dry matter, OM- Organic matter, NH3- ammonia, VFA – Volatile Fatty Acids

[a] Letters a–c indicate differences between diets (*P* <0.05). Source Galina *et al.* (2004)

Table 2.4: Mean dry matter intake, nitrogen metabolism and in vivo digestibility of goats

	Diet	
	Non-treated	Urea treated
N-intake (g per day)	14.57 ± 9.29 ^{a}	18.60 ± 19.08 ^{b}
Faecal-N (g per day)	1.26 ± 1.87 ^{a}	2.14 ± 3.15 ^{b}
Urinary-N (g per day)	3.17 ± 3.41 ^{a}	4.65 ± 4.5 ^{b}
N-digestibility (%)	54.16 ± 12.11 ^{a}	76.63 ± 16.14 ^{b}
DMI (g per day)	824 ± 94 ^{a}	858 ± 118 ^{a}
In vivo digestibility (%)		
DM	72.73 ± 9.2 ^{a}	79.47 ± 8.4 ^{a}
OM	65.45 ± 11.2 ^{a}	71.52 ± 13.4 ^{a}
NDF	65.11 ± 9.5 ^{a}	77.14 ± 7.5 ^{b}
Cellulose	79.16 ± 13.1 ^{a}	76.17 ± 9.0 ^{a}
Hemicellulose	77.14 ± 9.4 ^{a}	78.55 ± 5.8 ^{a}

N- Nitrogen, DMI- Dry matter intake, DM - dry matter, OM- Organic matter, NDF- Neutral detergent fibre. [a] Letters a and b indicate differences (P <0.05) between diets. Source Galina *et al.* (2004)

Table 2.5: *In situ* Neutral detergent fibre digestibility of experimental diets fed to goats

	Diets	
	Non-treated	Urea treated
Potentially degradable fibre, *A* (%)	52.41 ± 5.40 ^{a}	65.17 ± 3.6 ^{b}
Non-degradable fibre, *B* (%)	63.32 ± 3.20 ^{a}	35.18 ± 4.7 ^{b}
Passage rate, *k*p ($^{h-1}$)	0.061 ± 0.002 ^{a}	0.079 ± 0.003 ^{b}
Degradation rate, *k*d$^{(h-1)}$	0.023 ± 0.001 ^{a}	0.037 ± 0.002 ^{b}
True digestibility, *kd/(k*d+ *k*p*)* (%)	36.22 ± 2.33 ^{a}	46.24 ± 2.65 ^{b}
Half-time disappearance, *t*1/2 (h)	16.54 ± 3.14 ^{a}	19.34 ± 2.47 ^{b}

[a] Letters a and b indicate differences between diets (P <0.05) Source Galina *et al.* (2004)

2.4 Conclusion

Goats adapt well to environmental changes and different feeds, but during the dry season they suffer nutritionally from poor-quality feed. Feeding *S. lespedeza* hay to goats had both nutritional and anti-parasitic advantages, provided that the growth stage, harvest time and conditions, drying and storage were properly planned and managed. *Sericea lespedeza* as an easily established and low-input forage has huge potential for enhancing the productivity of goats and improving farmers’ livelihoods, as long as the CT effects are addressed and nutritionally manipulated to the benefit of the goats. Satisfying the nutritional requirements of high-yielding lactating goats is a demanding and complicated strategy, but supplementing tannin- rich legumes and an NPN such as urea may eliminate shortages and improve nutrition at reduced cost to the farmers. Urea is found to support a higher level of production due to its positive effect on DMI, fermentation and digestibility, but needs a good energy source for good performance. A research study with *S. lespedeza* hay and urea is warranted to determine the level of production that can be sustained and its effect on the milk quality of dairy goats. Such findings would help in the pool of scientific knowledge by assisting small-scale farmers to improve ruminant productivity, develop cheap feeding systems, and gear up for the increased demand of goat milk and its by-products.

CHAPTER 3

Effects of replacing sunflower oilcake with urea or *Sericea lespedeza* and urea on feed intake, digestibility and nutrient utilization of Saanen male goats fed total mixed rations

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3.1 Abstract

This study investigated the intake, digestibility and nutrient utilization response of three TMR diets formulated with various sources of nitrogen and fed to Saanen male goats. In the control diet (T1), SOC was used as the main source of nitrogen, while in the treatment diets SOC was replaced with a source of RDP from urea (T2) or with a combination of degradable protein (RUP) and RDN from *S. lespedeza* and urea (T3). Nine goats with average bodyweight of 21 kg were used in the digestibility trials. The goats (three per treatment) were randomly allocated to one of the three TMR diet treatments. Each goat was placed in a metabolism cage with removable feeders and water troughs. The study lasted for 30 days, consisting of 23 days of adaptation and seven days of data collection. The three diet treatments were not significantly different (P>0.0.5) in CP and most of the chemical components. However, T3 had slightly higher NDF concentration (451.5 g/kg DM) than T1 (442.4 g/kg DM). The calcium and phosphorus concentrations were similar among the three TMRs. Dry matter intake was significantly higher ($P < 0.05$) for goats fed the T3 diet (867.5 g/ kg/ day) than for those on T1 and T2 diets (648.8 and 677.7 g/ kg/day). Goats fed the T3 diet had significantly higher ($P< 0.05$) OM and CP intake than goats fed on the other two diets. The apparent digestibility of DM, OM, CP, neutral detergent fibre and acid detergent fibre did not differ significantly among the three diets ($P>0.05$). However, the T3 diet had better digestibility coefficients. The nitrogen utilization and nitrogen excretion values among the three diets did not differ significantly ($P> 0.05$). The result showed that a combination of *S. lespedeza* with urea could safely replace SOC and help reduce the cost of protein in the TMR diets without affecting negatively the digestibility of nutrients and utilization by Saanen male goats. However, further investigations are necessary to quantify the benefit of the diets in reducing the cost of nitrogen nutrition in their feeding systems.

3.2 Introduction

Sericea lespedeza has both nutritional and anti-parasitic attributes (see Chapter 2). As a low-input crop, it has potential as an inexpensive source of protein and as an environmentally friendly alternative fodder that could be used for de-worming in animals (Moore *et al.*, 2008). *Sericea lespedeza* is a perennial, warm-season legume that usually contains high levels of CTs. Condensed tannins bind to dietary protein in the rumen, thereby reducing the breakdown of protein by rumen microorganism, which in turn results in low microbial activity, low digestibility and low DMI (Min *et al.*, 2003). To overcome the negative effect of high CT concentration, it is important to include a high RDP source such as urea in the diet, so that the animals would benefit in particular from the rumen by-pass protein supply associated with feeding tannin-rich legumes such as *S. lespedeza*. Animut *et al.* (2008) found that CTs have positive and negative effects on intake, digestion, and overall performance, depending on the type and concentration of compounds that are present in the diet. Min *et al.* (2003) noted an increase in non-ammonia nitrogen flow to the small intestine and an increased essential amino acid absorption in the small intestine that supported growth and high nutrient utilization when CTs legumes were feed to sheep. Even with high inclusion levels of *S. lespedeza* in some studies (Gujja *et al.*, 2013; Moore *et al.*, 2008 and Min *et al.*, 2005), goats were able to maintain higher DMI. *Sericea lespedeza* can be used as a resourceful protein supplement because it can provide high RUPs, given that rumen microbial activity is enhanced. More detailed information is needed to identify and explain the combination effect of urea and *S. lespedeza* on intake, nutrient use and performance of goats. The present study investigated feed intake, digestibility and nutrient utilization of TMR diets that contained various sources of nitrogen, mainly from SOC or urea or a combination of *S. lespedeza* with urea as sources of protein when fed to Saanen male goats.

3.3. Materials and methods

3.3.1 Experimental diets and procedure

The digestibility trial started after the lactation study was concluded (Chapter 4). The experimental diets were fed for 30 days, which consisted of 23 days' adaptation to the TMR diets, metabolism cages, faecal bags, and the last seven days were used to collect experimental data. Three experimental diets, in the form of TMRs, were prepared as experimental treatments for this trial. The TMRs were formulated according to the milk production requirements for goats in the NRC (2007) tables, using the online Langston University goat TMR formulation model (2000). The first treatment (T1) was the control TMR, which contained SOC as the main protein source. The second (T2) had 1% urea to increase the RDP content of the TMR and replace SOC. Treatment 3 had *S. lespedeza* and urea in the TMR, in which *S. lespedeza* and urea acted as the main balanced protein sources. Saanen male animals were used to estimate digestibility and intake, as it is convenient to collect data from male animals. The experimental diets were mixed comprehensively and fed to the animals as TMRs to reduce selection and maximize intake of the roughages. The TMR ingredients were purchased in bulk from Kungwini local market. The *Eragrostis* hay and Lucerne hay were chopped with a hammer mill with a 25-mm diameter sieve, and then mixed with the concentrates. The mixing machine was cleaned carefully before and after each treatment, and the mix was weighed into separate bags for each treatment. The three diets were formulated to be *iso*-energetic, *iso*-nitrogenous and *iso*-neutral detergent fibre. Their chemical composition was analysed at the University of Pretoria Nutrition Laboratory.

The goats were weighed with an electronic balance for two consecutive days at the beginning of the trial. The results were averaged to obtain the initial bodyweight. The goats were then weighed at weekly intervals until the end of the trial. Initial and final weights were used to estimate the bodyweight gain of the animals. Feed and water were withdrawn before the morning weighing and given afterwards. Nine male goats with bodyweights of 21 ± 1.8 kg at the start of the trial were randomly allocated to nine individual metabolism cages (1 m x 75 cm x 1 m) made of welded wire-mesh with removable feeders and water troughs. The metabolism cages allowed separate collection of urine and faeces into faecal bags (Figure 3.1 and Figure 3.2). The goats had access to fresh water and the treatment diets throughout the day. Feed offered and feed refused by each goat were recorded daily and adjusted to maximize intake. The faecal bags were emptied and faeces collected, weighed, sub-sampled and bulked daily over the seven-day collection period, and then kept frozen before laboratory analysis. At the end of the collection period, the bulked faecal output from each goat was mixed thoroughly, 10% sub sampled and oven dried at 60^{o}C until a constant weight of DM. For analysis of nitrogen, another aliquot of 1/40th total faeces voided by each goat was preserved with dilute sulphuric acid in a wide-mouth airtight pre-weighed bottle separately for each animal. After the seven-day collection period, the bottles were weighed. The faecal sample collected in bottles during the trial period was mixed thoroughly and taken for nitrogen estimation. Urine excretion was collected daily per goat and measured with plastic bottles that contained 100 ml 10% sulphuric acid, then recorded, sampled and stored in the freezer for nitrogen analysis. The samples of feeds, refusal and faeces from each animal were mixed meticulously, dried and milled through a 1-mm sieve.

3.3.2 Chemical analysis

The samples of feed offered, refused and feaces were analysed for DM, ash, OM, nitrogen, NDF, ADF and nitrogen from urine samples. All the samples were analysed in duplicate to eliminate human error associated with the measurements and procedure. The error was benchmarked at less than 5%. Above 5%, the analysis was repeated. Chemical analysis was performed at the Nutrition Laboratory of University of Pretoria.

3.3.2.1 Dry matter determination

A crucible was cleaned and dried in the oven for an hour. After an hour it was removed and allowed to cool for at least half an hour in the desiccators. The crucible was then weighed to determine the dry mass. Two grams (g) of the sample was then weighed into the crucible in duplicate. The sample and the crucible were dried for 24 hours at 105 ºC. The crucible and sample were then placed in the desiccators for half an hour and left to cool for 24 hours before weighing (AOAC, 2003). The DM percentage was calculated as follows:

$$\text{DM \%} = \frac{\text{Dry mass (g)}}{\text{Sample mass (g)}} \times 100$$

3.3.2.2 Ash determination

The procedure was the same as that used for DM determination. After weighing, the samples were placed in a muffle furnace at 250 ^{o}C for 1 hour, and then at 550 ^{o}C for four hours. After the 5 hours, the furnace was switched off and the crucibles were left to cool overnight.

Thereafter the crucibles were allowed to cool down in the desiccators. The crucible and ash were then weighed. Ash % was calculated as follows:

$$\text{Ash \%} = \frac{\text{Ash mass (g)}}{\text{Sample mass (g)}} \times 100\text{: \% Ash (DM)} = \frac{\text{Ash \%}}{\text{DM\%}} \times 100$$

3.3.2.3 Organic matter

Organic matter concentration was calculated as follows:

$\text{\% OM} = \text{DM \%} - \text{ash\%}$

$\text{\%OM (DM)} = 100\%\text{: \% ash (DM)}$

3.3.2.4 Neutral detergent fibre determination

NDF determination was performed according to the procedure described by Van Soest *et al.* (1991). The samples were ground and air-dried to pass through a 1-mm screen. They were then weighed in a crucible (1 g ground sample). Then 100 ml neutral detergent solution at room temperature were added to the crucible with 0.5 g sodium sulfite and some drops of n-octanol. The mixture was heated to boiling and refluxed 60 minutes from the onset of boiling. It was then filtered and washed three times with boiling water, then twice with cold acetone. It was dried for 8 hours at 105 °C and left to cool in the desiccator.

NDF was calculated and expressed as:

$$\text{Neutral detergent fibre: NDF \%} = 100\frac{[(\text{weight of crucible} + \text{weight of residue}) - \text{weight of crucible}]}{\text{weight of sample}}$$

$$\text{NDF (DM)} = \frac{\text{\% NDF}}{\text{\% DM}} \times 100$$

3.3.2.5 Determination of acid detergent fibre

The ADF was analysed with the fibre analyser as described for the NDF, but the ADF solution was used instead of the NDF solution. It was calculated as follows

$$\text{Acid detergent fibre: ADF \%} = 100\frac{[(\text{weight of crucible} + \text{weight of residue}) - \text{weight of crucible}]}{\text{weight of sample}}$$

Safety precautions and normal laboratory practices were followed.

3.3.2.6 Nitrogen and crude protein determination

Nitrogen was determined according to the procedure described in the instructions of the LECO manual (FP-428). This is a microprocessor-based software-controlled instrument that determines nitrogen in materials (LECO Instruction Manual, 1994). Percentage CP was expressed as % N × 6.25, and corrected for moisture by dividing the % CP by % DM, as indicated above.

3.3.2.7 Digestibility determination

$$\text{Apparent digestibility g/kg} = \frac{\text{Nutrient in feed} \; - \text{Nutrient in faeces} \; \times 1000}{\text{Nutrient in feed}}$$

$$\text{Dry matter digestibility (DMD, g/kg)} = \frac{\text{DM in feed} \; - \text{DM in faeces} \; \times 1000}{\text{DM in feed}}$$

$$\text{Organic matter digestibility (OMD, g/kg} = \frac{\text{OM in feed} \; - \text{OM in faeces} \; \times 1000}{\text{OM in feed}}$$

3.3.3 Statistical analysis

The data were analysed with the general linear model (GLM) of SAS (2004) to test for statistical differences among the TMR diets. Significant differences between least squares means for the three diets were separated with Fisher's test (Samuel, 1989).

Figure 3.1 Metabolism cages/crates with separate collection of urine

Figure 3.2 Collection of faeces into faecal bags

3.4 Results

3.4.1 Chemical composition of Sericea lespedeza and the three diets

The chemical compositions of T1 (SOC, control), T2 (urea) and T3 (*S. lespedeza* with urea) diets are presented in Table 3.1. Although there were no significant differences among the three diets (P > 0.05), it appears that T3 diet had the highest NDF, ADF and calcium values, while the lowest values was recorded in the T2 diet for the same parameters. CP and phosphorus concentrations were relatively the same for all treatments. The composition of *Sericea lespedeza* hay used for the TMR diets was also analysed as previously presented in table 2.1.

Table 3.1 Chemical composition of the three total mixed rations (least squares means ± se) and *Sericea lespedeza* hay used

Parameter	Total mixed rations			
%	T1	T2	T3	±SEM
CP	12.54	12.53	12.47	0.38
NDF	44.24	40.96	45.15	2.87
ADF	22.50	21.12	23.36	1.93
Ca	0.74	0.73	0.82	0.07
P	0.33	0.32	0.33	0.03
UP Research Farm *Sericea lespedeza* hay				
DM	93.3			
Composition (% DM base)				
CP	10.1			
NDF	60.6			
ADF	39.4			
IVOMD	28.5			

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea; SEM: standard error of mean, CP: crude protein, NDF: neutral detergent fibre, ADF: acid detergent fibre, Ca: calcium; P: phosphorus. UP: University of Pretoria; DM: dry matter; IVOMD: in vitro organic matter disappearance. ^{a,b} Means with different superscripts in the same row differ significantly (P < 0.05).

3.4.2 Apparent digestibility of total mixed rations

The apparent digestibility coefficients for the three diets were not significantly different ($P>0.05$) in terms of DM, OM, CP, NDF and ADF digestibility (Table 3.2).

Table 3.2: Apparent digestibility (%) of the three total mixed rations fed to Saanen goats (least squares means)

	Total mixed rations			
Parameter	T1	T2	T3	±SEM
Apparent digestibility coefficient (%)				
DM	79.1	78.6	84.2	2.34
OM	80.3	80.1	85.0	2.15
CP	75.3	75.8	83.7	3.20
NDF	65.6	61.8	70.4	2.00
ADF	61.6	64.0	68.2	4.46

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea; SEM: standard error of mean; DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fibre, ADF: acid detergent fibre. ^{a,b} Means with different superscripts in the same row differ significantly ($P<0.05$)

3.4.3 Voluntary dry matter intake and bodyweight change

DMI was significantly higher ($P < 0.05$) in goats fed the T3 diet (867.5 g/ head/ day) than those fed T1 and T2 (648.8 and 677.7 g/ head/day). Goats fed on T3 had significantly higher ($P< 0.05$) OM and CPI than goats fed the other two diets (Table 3.3). However, the three diets did not differ ($P> 0.05$) in terms of NDF and ADF intake (g/head/day). The voluntary intake of goats (g/head/day) maintained the same pattern when they were expressed in grams per kilogram metabolic bodyweight per day (g/kg BW $^{0.75}$/day).

Table 3.3: Voluntary feed intake and bodyweight changes of the three total mixed rations fed to male Saanen goats (least square means ± SEM)

	Total mixed rations			
Parameter	T1	T2	T3	± SEM
Number of animals	3	3	3	
Initial weight (kg)	20.3	21.0	21.0	1.39
Final weight (kg)	23.0	22.7	24.7	2.15
Weight gain (kg)	2.7	1.7	3.7	1.00
Voluntary intake (g/head/day)				
DM	648.8^b	677.7^b	867.5^a	±65.31
OM	528.2^b	542.6^b	737.2^a	±65.11
CP	75.8^b	88.1^b	108.2^a	±9.61
NDF	460.6	417.5	566.8	±51.46
ADF	138.1	141.1	185.9	±17.19
Voluntary intake (g/kg $BW^{0.75}$ / day)				
DM	61^b	64^b	78.0^a	±5.4
OM	50^b	52^b	66^a	±4.9
CP	7^b	8^b	9^a	±0.7
NDF	45.3	41.8	54.9	±5.0
ADF	13.6	14.1	18.0	±1.7

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea; SEM: standard error of mean; DM: dry matter, OM: organic matter, CP: crude protein, NDF: neutral detergent fibre, ADF: acid detergent fibre· ^{a,b} Means with different superscripts in the same row differ significantly ($P < 0.05$)

3.4.4 Nitrogen balance

The results of the nitrogen balance are given in Table 3.4. The diets did not differ in nitrogen intake, excretion and retention. However, goats fed on T2 diet had higher total nitrogen excretion (3.08 g/head/day) compared with 2.86 and 2.78 g/head/day recorded for goats fed the T1 and T3 diets, respectively. Although statistically not significant (P > 0.05), the nitrogen retention for goats fed the T3 diet appeared to be highest (14.52 g/head/day), while those fed on T1 diet had the lowest (8.44 g/head/day) nitrogen retention.

Table 3.4: Nitrogen balance of the three total mixed rations diets fed to Saanen male goats (least squares means ± se)

	Total mixed rations			
Parameter	T1	T2	T3	± SEM
Nitrogen utilization				
Intake g/head/day	11.3	14.0	17.3	1.791
Nitrogen excretion g/head/ day				
Faeces	2.16	2.34	2.04	0.075
Urine	0.70	0.74	0.74	0.172
Total	2.86	3.08	2.78	0.123
Nitrogen retention	8.44	10.82	14.52	2.012

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea. SEM: standard error of mean. ^{a,b} Means with different superscripts in the same row differ significantly (P<0.05)

3.5 Discussion

Meeting the nutritional requirements of goats at various stages of production is important. Babayemi and Bamikoli (2006) indicated that 7% CP in DM is the critical minimal level of CP content required for optimal ruminal function. In this study, the CP concentration of the three diets was 12.5%, as recommended by NRC for lactating Saanen goats (NRC, 2007). The diets had a similar composition because of the inclusion of similar ingredients in more or less the same proportion. The difference was in the NDF percentage of T2 diet, which was slightly lower than the *S. lespedeza* and urea T3 diet. This could be due to the differences in roughage sources and fibre content of the ingredients used to formulate the three diets. The NDF and ADF content of the diets used in the present study ranged from 40% to 45% and 21% to 23% respectively, which is similar to the levels indicated by Animut *et al.* (2008) and Moore *et al.* (2008), who used *S. lespedeza* hay as a roughage source for goats in a growth trial. The fibre content of the feed plays a pivotal role in ruminal function. Hence a higher amount of NDF and ADF may indicate high level of cell wall content, which can affect degradability and digestibility.

The digestibility coefficients for DM, OM, CP, NDF**,** and ADF did not differ significantly among the diets, which demonstrates that replacing SOC with urea alone or with a combination of *S. lespedeza* and urea had no negative influence on the digestibility of nutrients. Similar results were reported by Lange *et al*. (2006) and Sahoo and Walli (2008) when sheep were fed *S. lespedeza* and different sources of protein with varying ratios of RDP/RUP diets to goats. In contrast to the present study, Inostroza *et al. (*2010) reported that nutrient digestibility improved when TMRs containing urea and sunflower meal were given to lactating cows. Urea with a good energy source is known to promote high digestibility, especially of fibre in feed, since the optimum rumen environment and nutrient sources exist when ruminants receive urea in ideal amounts. T3 diet with a balanced combination of RDP and RUP from *S. lespedeza* and urea seemed to have consistent higher apparent digestibility of nutrients compared with T1 and T2, although the differences among the TMR diets were found to be not significant (P>0.05).

In this study, goats on T3 diet had higher (P<0.05) voluntary intake of DM, OM and CP. However, the NDF and ADF intakes were not significantly different. The DMI of T3 goats (867.5 g/ head/ day) was higher than the DMI of T1 and T2 goats, which consumed 677.7 and 648.8 g DM/kg/day, respectively. Turner *et al*. (2005) reported a similar pattern in which goats fed a diet containing *S. lespedeza* had greater DMI, which consequently increased the OM and nutrient intakes, resulting in an increased growth rate. In this study, the OMI of T3 goats was 737.2 g/head/day compared with 528.2 for the control and 542.6 g/head/day for T2, respectively. The OMI values recorded in the study are lower than the values reported by Galina *et al.* (2004) who found 800–825 g/head/day when urea-treated corn stubble and alfalfa with a balance concentrate mix were given to growing kids. The OMI values are however higher than values reported by Pal *et al.* (2010), when an *iso*-nitrogenous leaf meal mixture of legumes replaced a concentrate mixture on goat growth and nutrient utilization.

Goats on T3 had significantly higher crude protein intake (CPI) than goats on T1 and T2 diets. According to Turner *et al.*, (2005) rumen micro-organisms respond well to the methodical addition of urea to diets, and micro-organisms also adapt to the presence of CTs in legumes with prolonged feeding by inducing enzymes capable of degrading tannins (Makkar, 2003). In this study, goats on T3 diet had a balance of RDP and RUP in the TMR to enhance the activity of rumen microflora and the study adaptation period was long enough for rumen micro-organisms to adjust to the tannins in *S. lespedeza*, hence the higher DMI, OMI and CPI. The intake of T3 goats was higher than the other two diets, which suggests that theoretically a conducive environment for high fibre digestibility exists, but the observed difference was not significant to support that theory, since NDF intake was not affected by the treatments. Min *et al.* (2005) reported that butyrate, *iso*-butyrate, *iso*-valerate, and valerate were greater in animals fed *S. lespedeza*, which leads to suitable pH levels that promote diverse populations of rumen microbes and better microbial activities, such as increased CP deamination by protozoa. Bava *et al.* (2001) found that supplementing high-fibre diets with NPN (urea) improved fermentation, digestibility, and VFA production. The daily total DMI of goats, irrespective of dietary treatment, was between 677.7 and 867.5 g/head/day, which is equivalent to 3-4% of total bodyweight. This is an indication that the three diets were edible and non-repugnant.

Sericea lespedeza contains CTs. One of the major effects of CTs appears to be on the nitrogen balance in the animal. The nitrogen balance of the present study revealed that nitrogen utilization appears to be higher in T3 goats, but the difference was not significant (P>0.05). The excretion of nitrogen (g/head/day) in faeces was greater (P>0.05) in T2 goats than the other TMR diets. The urine excretion of nitrogen was similar for goats on T2 (0.74 g/head/day) and T3 (0.74 g/head/day). *Sericea lespedeza* with urea had no effect (P>0.05) on nitrogen retention, but the values recorded appeared to be higher than those of the rest of the TMRs. In this study, all the animals, regardless of the TMR diet, had a positive nitrogen balance, showing that these diets are suitable for supporting production. The T3 findings of this study disagrees with reports that indicate greater faecal nitrogen losses in animals that are given tanniferous forages (Pal *et al.*, 2010). According to Terrill *et al.* (1995), the tannin-protein complex was detached in the acidic environment of the abomasum, and intestinal absorption of protein and overall nitrogen utilization were increased, which agrees in part with the findings of the present study. The trend for positive nitrogen retention in this study is possibly due to the stable amino acid alignment and apparent biological value of proteins in the TMR diets. Faecal nitrogen comprises of undigested dietary nitrogen and metabolic faecal nitrogen, thus it is dependent on the microbial nitrogen yield. Pal *et al.* (2010) found that apparent nitrogen digestibility may be transformed without a change in available amino acid at tissue level. The nutritional significance of *S. lespedeza* with urea in the T3 diet on nitrogen balance needs to be further investigated, since no significant difference (P>0.05) was obtained.

CHAPTER 4

Effects of replacing sunflower oilcake with urea or *Sericea lespedeza* and urea on milk yield, milk composition and body condition of Saanen goats

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4.1 Abstract

This study investigated milk yield, milk composition and body condition response of 36 Saanen milk goats fed three TMR diets formulated with various sources of nitrogen. In the control diet (T1), SOC was used as main source of nitrogen, while in the treatment diets SOC was replaced with a source of RDP from urea (T2) or with a combination of RDP and RUP from *S. lespedeza* and urea (T3). The goats were blocked into high, medium and low yielders according to first-month lactation milk yield. The animals from each category were then allocated randomly to the three TMR diets according to a complete randomised block design. Group intake was recorded for all the goats in the three treatments. The goats were milked twice a day. Milk samples were collected once a month from individual goats at two consecutive milking in the morning and afternoon. The samples were analysed for milk fat, protein, lactose, somatic cell count (SCC) and milk urea nitrogen (MUN). The results show that the daily milk yields for the goats in the T1, T2 and T3 groups were 2.56, 2.46 and 2.52 kg per day, respectively. There were significant differences ($P<0.05$) across the TMR treatments on goat BCS and bodyweight with T1 group obtaining better BCS than the other two treatments. Goats that received the T1 and T3 diets had higher intake than the T2 diet. Goats that received the T2 diet had better milk fat (3.61%) and higher MUN of 25.70 mg N/dl than the other two treatments. Goats on T1 had significantly higher milk protein percentages compared with T2 and T3. Higher milk lactose levels and higher SCC were recorded for the goats fed T3. There was a great difference in the milk composition of the afternoon milk compared with the morning milk in all the treatments. Milk composition was affected by the early, mid and late lactation stages of the goats. It is concluded that supplying RUP and RDP, as in T3, supported a similar level of milk yield to the SOC-based diet (T1). This suggests great potential for the strategic inclusion of *S. lespedeza* as source of forage and RUP in the diet of Saanen goats.

4.2 Introduction

Recently there has been an increase in demand for dairy goat cheese globally, which is spreading to Africa and other developing countries. Thus interest in commercialising goat milk production is attracting more producers. Goat's milk is also needed for the production of up-market yogurt and powdered milk (Mestawet *et al.,* 2012). The milk industry pays farmers according to milk solids especially milk fat and milk protein concentrations as these technically reflect milk value in the industry rather than just milk volume (Roger *et al.*, 2011). It is then economically viable for farmers to consider milk solids and milk yield when embarking on dairy goat farming.

Goats are commonly found in rural areas in the country, where the feeding system sometimes results in low seasonal milk yield and poor milk quality, particularly during the dry season. Low lactation yields and poor milk quality in most cases are because of poor flock administration, the fluctuating nutritive quality of forage, and limited feed availability (Mellado *et al.*, 2005). Milk production in goats depends mostly on the net energy and protein content of the forage and its essential vitamin and mineral contents. In commercial goat production systems, nutrition per se is not a problem. However, feeding costs make up more than 70% of total production costs. To reduce feeding costs, attempts are often made to use cheap locally available plant species and agricultural or industrial by-products as feed ingredients to provide high-quality nutrition for the animals and help farmers to increase profit. *Sericea lespedeza* could be used to supplement low-quality diets and meet the nutritional requirements of lactating goats (Melaku *et al.*, 2003).

The use of *S. lespedeza* in animal rations, however is limited because of the adverse effect of its tannins on palatability, fermentation and digestibility as a whole (Bhatta *et al.*, 2002). On the other hand CTs boost the absorption of essential amino acids from the small intestine by increasing bypass protein from the rumen and thus improve animal productivity (Min *et al.*, 2003). Supplementing *S. lespedeza* foliage to a basal diet would dilute the concentrations of tannins, but another nutritionally sound strategy would be to add urea with *S. lespedeza* to adequately meet the requirements of rumen microbes and the nutritional needs of the lactating goats, and diminish the negative effect of CTs on protein degradation in the rumen. *S. lespedeza* has a high level of RUP, which is driven by the CTs it contains (Garg *et al.*, 2005) and urea has a high level of RDP, which together should fulfil the protein requirements of the goats. Carbohydrates in maize and wheat bran have been shown to be valuable when used with fibrous low-protein forage diets as well (Ort´ız *et al*., 2002). It was therefore deemed useful to measure the milk yield and milk quality of Saanen goats fed *S. lespedeza* and urea to determine the commercial merit of the milk that is produced and also as a way of helping small-scale farmers to improve their feeding systems.
The objective of this study was to determine the effect of replacing SOC, a costly protein source used in commercial sectors, with urea (nitrogen and RDP source) or *S. lespedeza* (RUP source) and urea on the milk yield, milk composition and body condition of Saanen goats.

4.3 Materials and methods

4.3.1 Study area

The study was conducted at the Small Stock Research Unit, Hatfield Research Farm, University of Pretoria. The University of Pretoria's research farm is located geographically at 28.11°E, 25.44°S, and 1370 metres above sea level (masl) (Hassen *et al*., 2008; Van Niekerk *et al*., 2009). The area receives precipitation of ± 674 mm per annum (Tjelele, 2006; Hassen, 2006). The climate around Pretoria is sub-tropical with warm and wet conditions in summer and is dry, sunny and cold in winter (sometimes below zero). Soil characteristics at the research farm are classified as sandy loam with a pH of 4.2, which means it is slightly acidic. Nutrient concentration in milligrams per kilogram (mg/kg) are phosphorus (P) = 29, potassium (K) = 73, calcium (Ca) = 158, magnesium (Mg) = 38 and sodium (Na) =11 (Hassen *et al*. 2008).

4.3.2 Experimental diets and preparation

Three experimental diets, in the form of TMRs, were prepared as experimental treatments for this trial. The TMRs were formulated according to the milk production requirements for goats in the NRC (2007) tables, using the online Langston University goat TMR formulation model (2000). The first treatment (T1) was the control, which contained 7% SOC as the main protein and nitrogen source. In the second treatment (T2), SOC was replaced with 1% urea to increase the RDP content of the TMR. In the third treatment, SOC and a portion of Lucerne hay were replaced with 12.5% *S. lespedeza* (RUP and roughage source) and 1% urea in the TMR, where both *S. lespedeza* and urea acted as the main balanced protein (RDP + RUP) sources for the TMR (T3). Dry matter intake was carefully recorded twice a week for each group for the whole experimental period. Forty kg TMR were fed daily to the group of 12 goats per treatment in a shed in two portions (morning and afternoon). Intake was calculated the next morning by deducting the feed that remained in the trough and the feed spills under and around it. The three diets were formulated to be *iso*-energetic, *iso*-nitrogenous and *iso*-NDF. The chemical compositions of the diets were analysed at the University of Pretoria Nutrition Laboratory.

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Table 4.1 Ingredients and chemical composition of total mixed rations fed to Saanen goats

Ingredients (%)	T1	T2	T3
Urea, 46% N	0.0	1.0	1.0
Salt	0.5	0.5	0.5
Sodium bicarbonate	0.4	0.4	0.4
Limestone, calcium carbonate	1.2	1.2	1.2
Full fat soya roast	1.2	1.2	1.2
Molasses meal	2.0	7.9	4.9
Cottonseed	4.2	4.2	4.2
Wheat bran	5.0	5.0	4.9
Sunflower oilcake	7.0	0.0	0.0
Hominy chop SA	17.8	17.8	17.8
Maize ground	20.9	20.8	20.8
Vitamin premix 1	0.4	0.4	0.4
Eragrostis hay	19.9	19.8	19.8
Lucerne hay	19.9	19.8	10.8
Sericea lespedeza hay (matured)	0.0	0.0	12.5
Chemical composition			
CP %	14.3	14.2	14.3
Metabolizable energy (MJ/kg of DM)	11.77	11.76	11.79
CF	17.2	16.9	17.1
TDN%	60.0	61.0	60.0

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea; CP: crude protein, CF: crude fibre; TDN: total digestible nutrients. Expected analysis as feeds was formulated by Langston University Goat Research and Extension programs (2000)

Table 4.2: Chemical composition of the three total mixed rations fed to Saanen goats

Treatments	Nutrient (DM %)							
	CP	GE (MJ/kg)	Starch (g/100g)	NDF	ADF	Ash	Ca	P
T1	13.3	17.64	30.32	40.1	23.6	5.6	0.76	0.3
T2	13.4	17.41	30.32	40.1	22.8	5.9	0.84	0.3
T3	13.1	17.94	31.40	40.6	23.1	5.3	0.80	0.3

Source: University of Pretoria Nutrition Laboratory

DM: dry matter, T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea. CP: crude protein, GE: gross energy, NDF: neutral detergent fibre; ADF: acid detergent fibre; Ca: calcium; P: phosphorus

4.3.3 Experimental animals

The goats kidded in August and were fed the control diet (T1) for the first month of lactation to measure data on their milk yield. Thirty six (36) Saanen goats with mean initial bodyweights of 55.6 ± 2.5 kg were selected for the experiment. The goats were blocked according to their individual milk yield into high, medium and low yielders. From each block, four animals were allocated randomly to one of the three experimental diets, which contained SOC (T1), urea as the main source of nitrogen and RDP (T2) and *S. lespedeza* (roughage and RUP source) combined with urea (T3). The goats were fed the treatments in a group (3 x 4) from the second month through to the eighth month of lactation.

4.3.3.1 Management of animals

Before the commencement of the trial, the goats were hoof trimmed, assessed according to the FAMACHA card using the colour of the eyes and eyelids, and drenched with Tramizan solution to control internal parasites. Afterwards, the goats were weighed to obtain their initial weights and then housed in sheds, where they received their treatment in groups of 12 goats per treatment, using the feeding pens (two per shed). The goats were then fed their TMR twice a day to reduce spillage during feeding. The sheds had water troughs that allowed ad libitum water consumption and cleaned every morning. Group feed intake was measured every week by recording two consecutive days' feed intake, and an iron sheet was placed under the feeding pens to collect spillages. After an initial adaptation period of 14 days, data were collected for quantity of feeds offered and refused to determine voluntary feed intake. Goats were weighed every week and based on the bodyweight results, the quantity of feeds offered were adjusted according to the recommendations from NRC tables for small ruminants.

4.3.4 Experimental design

A complete randomised block design was used in this experiment. Three experimental treatments were allocated to goats within a block based on milk yield recorded during the first month of lactation. A total of thirty-six experimental units were used in the study.

4.3.5 Milking procedure and recording

The goats were milked twice a day from 07:30 to 09:30 in the morning and from 14:30 to 16:30 in the afternoon. The milking parlour allowed only six goats to be milked at a time. Hence the first goats to be milked in the morning were the first to be milked in the afternoon. A strip cup was used to collect foremilk from each quarter at every milking time for all goats. Milk yield was measured during milking with Waikato milk meters and recorded manually for the entire period of lactation, which lasted eight months.

4.3.6 Milk sampling and analysis

Samples from two consecutive morning and afternoon milking were collected monthly, which represented the early (September-October), mid (November-January) and late (February-March) lactation phases. The milk samples were drawn from the milk meter to small bottles (50 ml) containing preservative. The preservative was dissolved and mixed well, by carefully tilting the box containing the bottle sideways after milking. The samples were then transported to Lactolab at Irene Agriculture Research Council (ARC) after every milk sampling day and analysed for milk fat, lactose, protein, somatic cell count (SCC) and milk urea nitrogen (MUN) using a Milko-Scan-Foss electric analyser. The analyser is operated by ARC lab technicians at Irene, following the procedures detailed in the Milko-Scan^{TM} FT120 manual 491431/Rev.17.

4.3.7 Body condition score and body weight

Body condition (BSC) score was used to indicate the fat reserves during lactation. The scores used ranged from 1.0 to 5.0, and half scores were used as intermediate points. Body condition score was assessed fortnightly and bodyweight measured weekly throughout the experiment. Body condition score was recorded as monthly scores by finding the average of two fortnightly scores. Bodyweight was measured as monthly by adding all the weekly weights in a month and dividing by the number of weeks in that month (average). Body condition score was used to estimate fat cover in the lumber region and the brisket fat pad. The goats were weighed with an electronic scale.

4.3.8 Statistical analysis

Milk yield, milk quality parameters and BCSs were subjected to analysis of variance (ANOVA) in a complete randomized block design) using the general linear model (GLM) procedure of SAS (2004) to test for statistical difference between treatments. The treatment means were ranked using Fisher's test.

Figure 4.1 Goat group sheds and feeding pens

Figure 4.2 Total mixed ration mixture

Figure 4.3 Picture of the goats milking and recording routine

4.4 Results

4.4.1 Milk yield

The milk yields of goats fed TMRs containing sunflower oilcake, urea, and *S. lespedeza* with urea are presented in Table 4.3.

Table 4.3 Milk yield of Saanen fed total mixed rations with different sources of protein.

	Milk yield (l/goat/day)	Bodyweight gain (kg/goat)	Body condition score (1-5 scale)	Intake (kg/head/day)
Total mixed rations diet				
T1	2.49	5.14^a	3.34^a	3.13
T2	2.39	4.89^b	3.06^b	3.10
T3	2.45	4.95^b	3.15^b	3.11

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea. $^{a-d}$ Means in the same column with different superscript differ significantly ($p<0.05$)

The mean milk yields recorded during the eight months of lactation are depicted in Figure 4.4. The goats showed levels above 2 l/goat/day for milk production (Table 4.3). The peak milk yield was in the first month of lactation and gradually decreased, but for T2 the milk yield was lower for the first month, increased up to the fourth month (December) then started to decrease. Treatment 3 had peak milk yield in September and dropped during October, but increased slowly in November. Goats on T1 had higher milk yield in the first three months than the T2 and T3 goats, then it decreased eventually to a similar level to those recorded for the other two treatments.

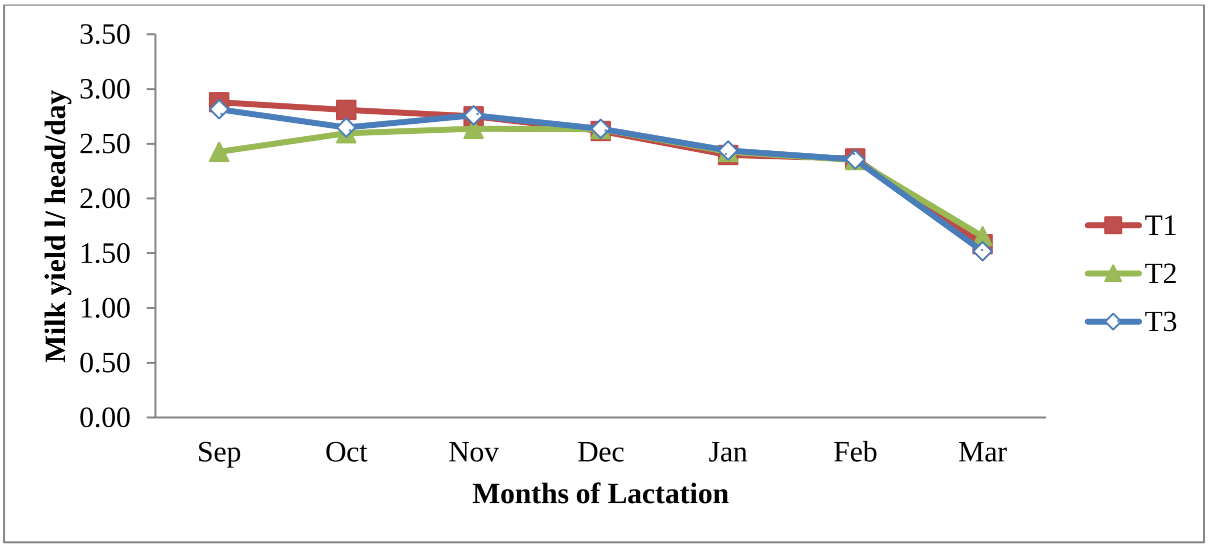

Figure 4.4 Lactation curves for Saanen milk goats fed total mixed rations with sunflower oilcake (T1), urea (T2) and *S. lespedeza* and urea (T3).

4.4.2 Body condition score and body weight gain

The results for BCS and bodyweight gain are presented in Figure 4.5 and Table 4.3. The BCS and bodyweight show significant differences ($P < 0.05$) among goats fed the three TMR diets. Figure 4.5 indicates that the BCS of the goats on all the TMRs increased linearly with months of lactation, and the correlation was positive ($r = 0.95$). The BCS of goats on T1 diet remained higher throughout lactation, except for the fifth month (January), when goats on T3 diet recorded higher BCS than T1. Goats on T2 diet had a BCS that was above that of the T3 diet on the second month (October), and then remained third for the rest of the lactation period. The mean bodyweight gain of the goats is related to BCS trends as well. Goats on control T1 diet had significantly higher ($P<0.05$) bodyweight gain than the other treatment groups (Table 4.3).

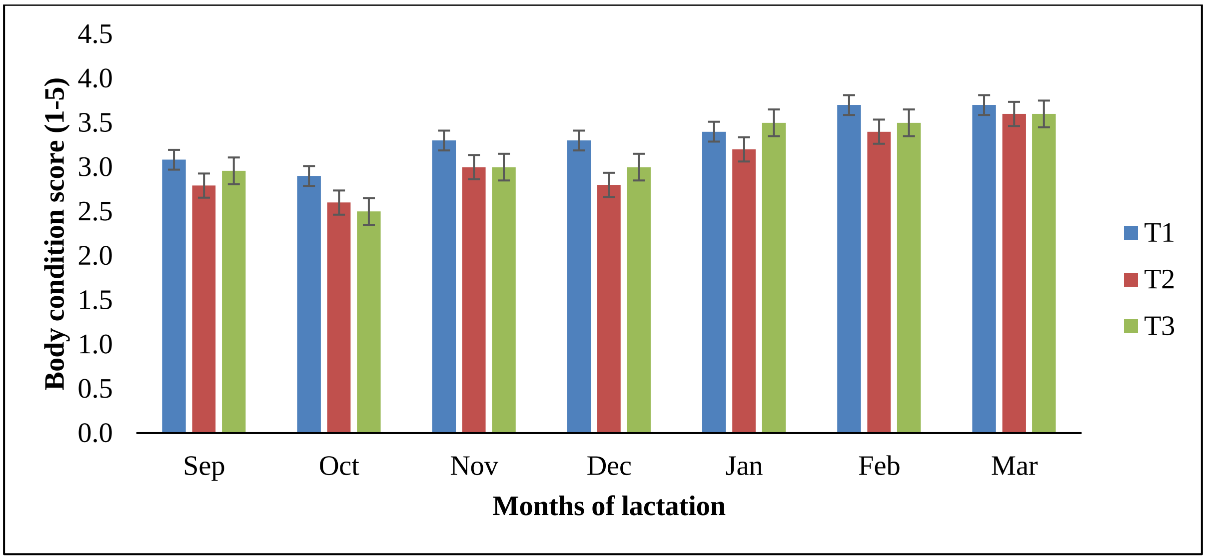

Figure 4.5 Body condition score of lactating Saanen goats fed the three total mixed rations: T1 with sunflower oilcake, T2 with urea, and T3 with *Sericea lespedeza* and urea. The score used ranged from 1.0 to 5.0. BCS: body condition score.

4.4.3 Effect of total mixed ration treatment on milk quality

Milk composition was assessed from the milk yield of the Saanen goats that were fed the three TMRs. The milk was analysed for milk fat, milk protein, lactose, milk urea nitrogen, SCC and pH, as presented in Table 4.4. Milk from goats on T2 had higher milk fat percentages (3.61) and higher milk urea nitrogen (25.70) than the control and T3 diets. Milk from goats on the T1 diet had higher milk protein percentages. The SCC of milk from goats on the T3 diet was higher than for those on the T1 or T2 diets.

Table 4.4 Milk composition of Saanen goats fed the three total mixed rations (least squares of means)

	Total mixed ration			
Parameters	1	2	3	SEM
Milk composition				
Milk fat (%)	3.47	3.61	3.59	0.18
Milk protein (%)	2.87^{a}	2.74^{b}	2.82^{b}	0.03
Milk lactose (%)	4.37	4.34	4.41	0.05
Milk urea nitrogen (mg N/dl)	24.34	25.70	24.84	0.84
Somatic cell count (cell/ml)/1000	1.41	1.34	1.78	0.18
pH	6.57	6.63	6.65	0.07

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea. [a,b] Means with different superscripts in the same row differ significantly ($P<0.05$)

4.4.4 Effect of milking time on milk quality

According to Guo *et al.*, (2001) replacing proportional bulking of individual morning and afternoon samples with a single afternoon milk sample would not compromise accuracy, provided that the appropriate corrections are made to prevent over-estimation of milk constituents, especially milk fat yields. In this experiment the effects of milking time on the milk composition of goats fed the three TMRs are shown in Table 4.5. There is a great difference in the composition of the afternoon milk compared with the morning milk for all the treatments. All treatment groups had significantly higher ($P<0.001$) milk fat, milk urea nitrogen and SCC in the afternoon milking than the morning milking. Milk protein and milk lactose were not significantly different between morning and afternoon milking times in all the treatments.

Table 4.5: Effect of milking time on the milk composition of goats fed the three total mixed rations

	Time	Fat %	Protein %	Lactose %	MUN (mgN/dl)	SCC (/1000)
T1	AM	2.7^{a}	2.9	4.4	21.8^{a}	0.83^{a}
	PM	4.2^{b}	2.9	4.3	26.9^{b}	1.98^{b}
T2	AM	2.8^{a}	2.8	4.5	23.1^{a}	0.71^{a}
	PM	4.5^{b}	2.7	4.2	28.3^{b}	1.96^{b}
T3	AM	2.7^{a}	2.8	4.4	21.3^{a}	0.87^{a}
	PM	4.5^{b}	2.9	4.4	28.3^{b}	2.68^{b}
SEM		0.1	0.03	0.05	0.68	0.14

T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea. MUN: Milk urea nitrogen, SCC: Somatic cell count. $^{a-b}$ Means in the same column with different superscript differ significantly (P<0.05)

As shown in Figure 4.6 (below), T2 had higher milk fat yield of 3.97 %, 3.70% and 3.96% in early, mid and late lactation stages, respectively, than the other treatments. Treatment 3 produced the second highest milk fat percentage, while T1 produced the least milk fat percentage. The TMRs had a significant (P<0.01) effect on milk fat. An overall correlation coefficient (r) of 0.87 was observed between milk yield and milk fat

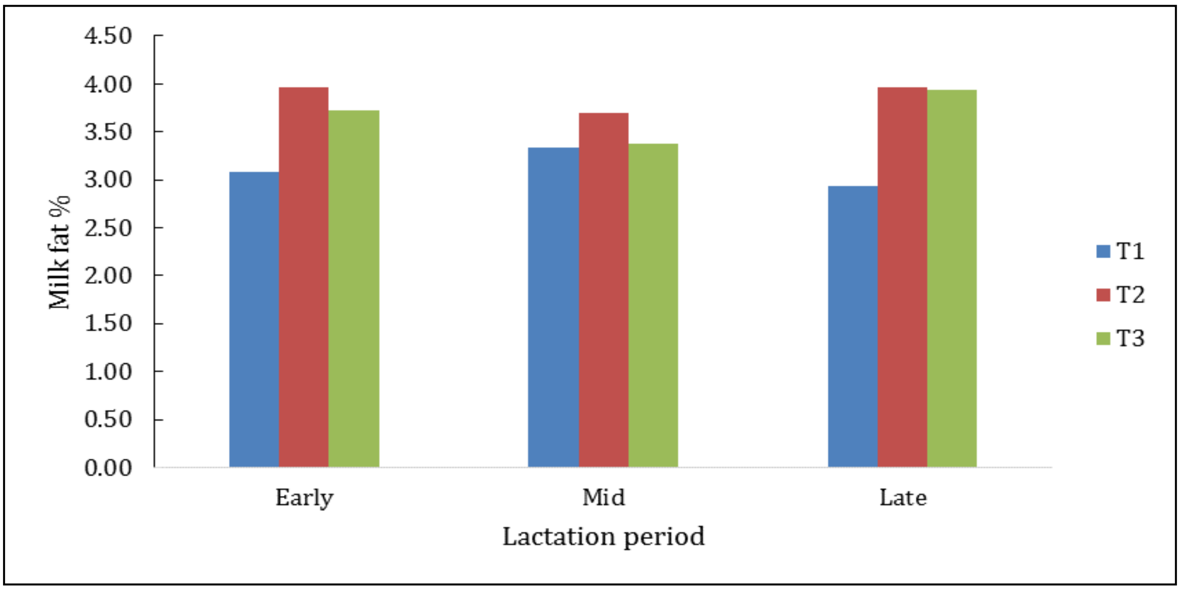

Figure 4.6 Milk fat (%) of lactating goats fed the three total mixed ration diets: T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea.

The milk protein percentages per lactation stage of Tl, T2 and T3 are shown in Figure 4.7. In this study, T2 does had higher milk protein percentages in all the lactation stages, while the milk protein percentage of does on the T3 diet was lowest in mid and late lactation. The diet of T2 goats had a significant effect on milk protein content in all the stages of lactation. A correlation of r = 0.66 was recorded between milk protein content and milk yield.

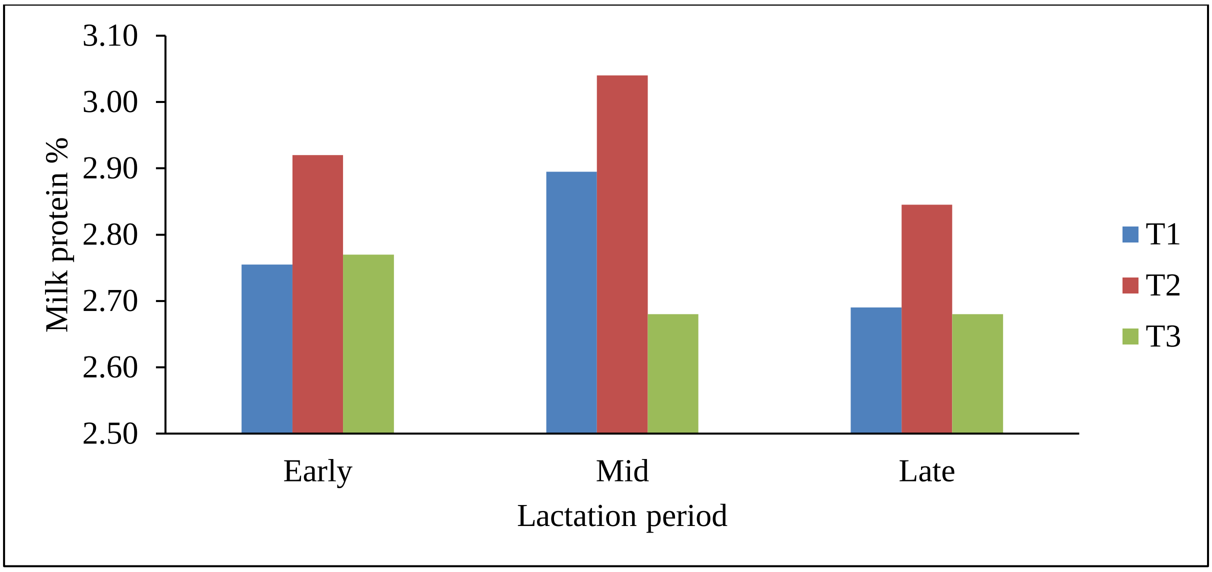

Figure 4.7. Milk protein (%) of lactating goats fed the three total mixed rations: T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea.

Milk lactose was assessed on the lactation stages of the goats as it contributes to the total milk solids in the milk and SNF. Figure 4.8 below shows that goats on T1 produced the highest milk lactose percentage in the early and mid-lactation stages and a drop in late lactation

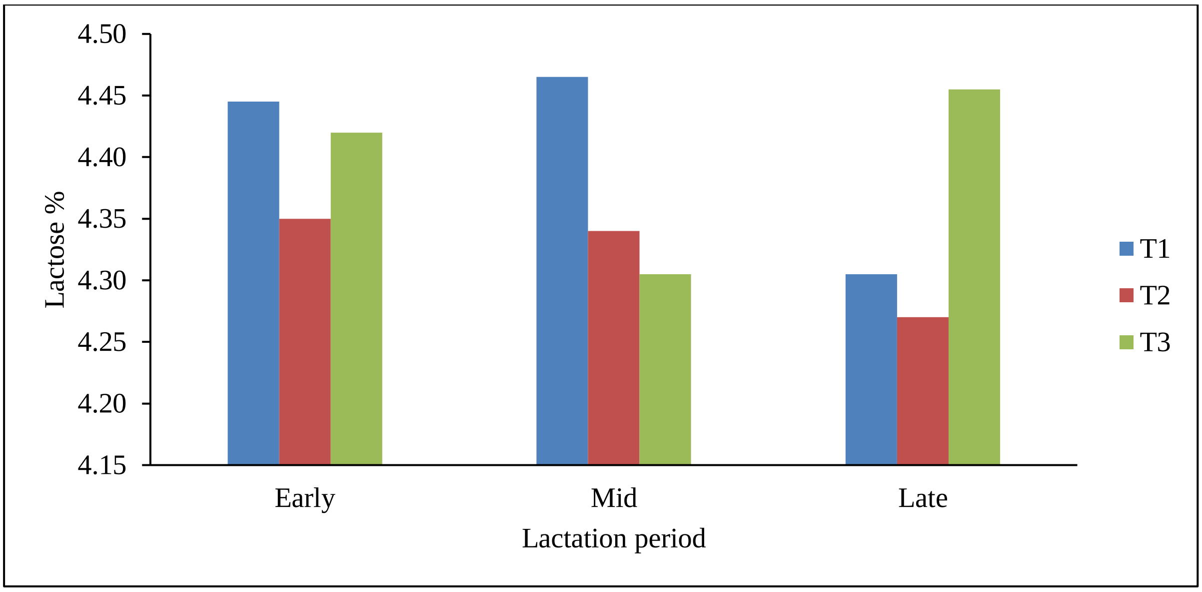

Figure 4.8. Milk lactose percentage of lactating goats fed the three total mixed rations: T1: TMR containing sunflower oilcake; T2: TMR containing urea; T3: TMR containing *Sericea lespedeza* with urea.

Goats fed the T3 diet had the highest SNF percentage in the late months of lactation, while those fed the T2 diet showed their peak SNF percentage during mid lactation (Figure 4.9). The lowest milk SNF percentage was observed on T3 in mid lactation. The SNF percentage varied throughout the observation period for all TMR treatments

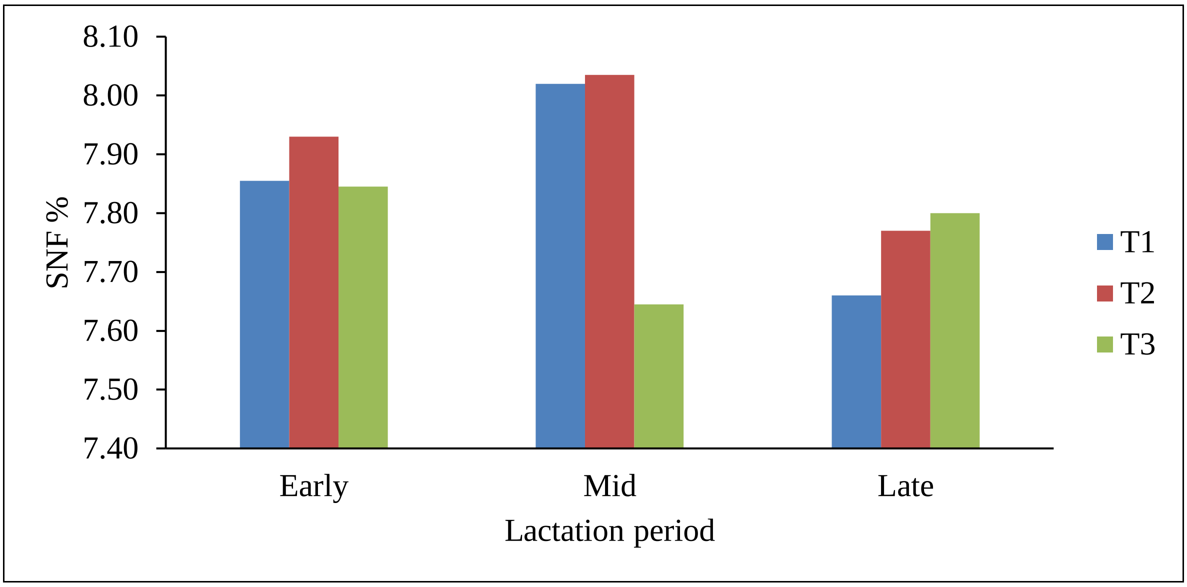

Figure 4.9. SNF: Solid non-fat percentage content of lactating goats fed the three total mixed rations: T1: control (total mixed rations with sunflower oilcake; T2: mixed rations containing urea; T3: total mixed rations containing *Sericea lespedeza* and urea.

4.5 Discussion

The three TMRs were formulated and balanced to be *iso*-energetic, *iso*-nitrogenous and *iso*-NDF to provide the nutrient requirements of lactating goats according to the NRC (2007) tables (see Tables 4.1 and 4.2). The main sources of roughage in the three TMRs were *Eragrostis* hay, lucerne hay and *S. lespedeza* hay. Other feed ingredients were included in different amounts according to the treatment in the TMR to meet the requirements of the goats, improve feed intake and maximize nutrient utilization. The concentrates and vitamin/mineral mix were included in the TMRs in different quantities to provide much-neeeded late gestation and lactation nutrient requirements for dairy goats as recommend by NRC (2007).

4.5.1 Intake and body condition score

The first month after kidding (August) was used as a preliminary study to allocate goats to yield level groups. The goats were fed the control diet during this period, which can partly explain the slow increase in DMI of T3 and T2 treatments during the first month. The feeding of one TMR diet after another could cause lower feed intake, but goats become used to the diet over time, hence the intake increased. Such findings have been reported by Maasdorp *et al.* (1999), who showed lower feed intake of a fodder tree diet in the beginning stages of lactation in ruminants, but intake then increased steadily. The average BCS for goats fed T3 and T2 diets was lower than goats fed on the control T1 diet, although T2 and T3 diets both had a positive effect on the BCS of the goats. *Sericea lespedeza* is known to contain CTs that affect intake and digestibility but Min *et al*. (2005) showed that *S. lespedeza* hay with CTs did not reduce palatability, since consumption by goat bucklings was comparable with that of alfalfa hay. A study by Turner *et al.* (2005) showed that lambs that grazed forages with CTs had higher rates of average daily gain and higher BCS than when grazing Lucerne or ryegrass and white clover. CT-rich forages are sometimes associated with increased weight gain and higher BCS (Waghorn, 2008). Condensed tannins bind to proteins in the rumen and protect protein against rumen degradation. These complex bypass proteins dissociate in the abomasum and small intestine, increasing post ruminal protein digestion (Burke *et al*., 2014), which promotes better bodyweight gain and higher BCS. This explains why goats fed the T3 diet had comparable DMI with T1, which consequently resulted in adequate organic matter, nutrient intake and resulted in increased growth rate in the T3 group. *Sericea lespedeza* is a perennial warm-season legume. Legumes are usually more digestible than grasses, therefore more nutrients are available for growth and hence acceptable BCS that can be compared with high-quality concentrate diets. Urea is known to increase microbial activity when given with a good energy source, thus the observed bodyweight gain from T2 group in the later stage was expected. Rafiq *et al.* (2007) found that increases in bodyweight and BCS were associated with increases in synthesis of microbial proteins from urea-treated feed. Oregui and Vazquez (1991) found a great correlation ($P<0.0.5$) between bodyweight gain and BCS. The combined effect of *S. lespedeza* and urea on T3 diet showed a complementary positive effect on the goats, even though the BCS was lower than the control group.

4.5.2 Milk yield

The treatments had no negative effect on milk yield, since the groups did not differ and the goats recorded above 2 kg/head/day in milk production. This is considered good levels for dairy goats (Mestawet *et al.*, 2012). The results of this experiment show that T1 had better daily milk yield (2.56 kg/day) than T2 and T3 (Table 4.3). Sanz Sampelayo *et al.* (1999) showed higher milk production of goats that were fed a SOC protein source compared with other protein source feeds. The T3 group had close (2.52 kg) daily milk production to the T1 diet. Authors, including Dzimiansky *et al.* (2010), found that *S. lespedeza*, compared with an alfalfa-based diet, in TMRs that were balanced for energy and protein supported high milk production. The average daily milk yield of T2 was less than the other two TMR, but higher than the yield that Stella *et al.* (2007) recorded (2.33 kg/day) for Saanen goats, possibly because of better protein balance with RDP and RUP, which T3 and T1 certainly had. This study revealed no significant differences (P> 0.05) among the treatments in daily milk production and milk yield over the months of lactation. However, in studies conducted elsewhere, Dugmore (2004) reported that *S. lespedeza* hay was successful in replacing Eragrostis hay in the diet of high-producing dairy cows. Min *et al.* (2005) found that urea-treated straw had higher milk yield than untreated straw. The milk yield of T3 is still considered high for Saanen goats. Moore *et al.* (2008) found a better propionate ratio in animals fed *S. lespedeza*, which could explain the positive growth rate and good milk production, because propionate is a high level energy source through gluconeogenesis. Branched-chain VFAs may arise from the degradation of branched-chain amino acids such as valine, leucine, and isoleucine, which cause adequate pH maintenance. A greater pH promotes diverse populations of rumen microbes, leading to greater microbial activity. The balance of rumen undegradable protein in T3 seemed to have a positive effect on milk production. Moreover, the economic advantage of T3 over T1, based on a cheap nitrogen source as opposed to commercial expensive sources, would always add value to any goat production system.

4.5.3 Milk composition

The treatments had no negative effect on milk fat. Milk fat percentages were above 3.3% which is regarded as the standard for normal fat levels in Saanen goats (Greyling *et al.*, 2004). Goats fed T2 diet had better milk fat percentages than the control and T3 diets, which could be due to the presence of high RDP in the T2 diet (Khalid, 2008). Significant differences were found by Agnihotri *et al.* (2002) in goats reared under organized farm conditions, where the percentages of fat, total solids, including casein and ash, were higher (P<0.05) in milk collected from goats fed urea-treated straw compared with those fed non-treated straw. The goats on T3 had milk fat percentage of 3.59 %. *Sericea lespedeza* contains RUP, and an increase in milk fat content because of the increase in RUP content has been reported by Kumar *et al.* (2005). Treatment 3 goats had good milk protein and MUN percentages, which is comparable with the other two treatments. Chaturvedi and Walli (2001) reported significant positive effects of the RUP level on milk fat and protein content in goats. In German Fawn goats, Chowdhury *et al.* (2002) also found that feeding a high RUP diet with dietary protein protection increased the fat and lactose of milk. In the present study, the positive trend in milk fat and milk protein yield is because of the balance in RDP and RUP in the diet from *S. lespedeza* and urea which is evidence of better utilization of nutrients in the diet. Feeding discrepancies could be detected from the concentration of urea in milk (MUN) as a parameter of milk quality (Braghieri *et al.*, 2007). Excess intake of protein during feeding is related to higher urea in the milk. Milk urea concentration is the major index for monitoring protein and energy utilization in ruminants. The results of this study revealed that T2, T3 and T1 had 25.70, 24.84 and 24.34 mg N/dl MUN, respectively. These levels were higher than the recommended range of 10–16 mg/dl suggested by Braghieri *et al.* (1999). Sahoo and Walli (2008) found that feeding RUP, irrespective of the supplementation of molasses, reduced the milk urea concentration compared with control diet, which reflected better efficacy of nutrient utilization. The high concentration of MUN in this study could be due partly to high degradability of proteins, especially urea in the T2 diet and *S. lespedeza* with urea in T3 diet.

Goats that were fed T3 had high milk lactose percentages in late lactation and high SCC. Milk lactose adds value to the total milk solids as part of the SNF in the milk and SCC determines the healthiness of the udder and the animal. The results of this experiment showed that the SCC for afternoon samples of T3 was 2.68 cell/ml (/1000) *vs* 1.98 cells/ml (/1000) recorded for the control diet. These values are above the threshold of 1 x 10^6 cells/ml recommended to classify goat milk for mastitis (White & Hinckly, 1999). However, authors such as Karzis *et al*. (2007) found that SCC is not a good indicator of subclinical mastitis, since it increases when colostrum is produced before the animal settles into lactation. Somatic cell count vary because of many factors, including season, concentration of milk and management effects. The dairy industry pays a premium and incentives to dairy farmers that are consistently lower in SCCs. Hence it is economical for farmers to apply good dairy practices and cleaning standards in their parlours since it affect the SCC results.

Milk yield at early lactation accounted for 40% of the total lactation yield. Total solids and SNF contents increased linearly ($P < 0.01$) with stage of lactation. The fat yield was significantly ($P < 0.05$) affected by stage of lactation. There was a significant decrease in the response of milk protein content and yield to advancing lactation with this decrease being more substantial after mid lactation. Mestawet *et al*. (2012) found that total solids in milk were significantly higher ($P <0 .001$) in the early and late lactation stages than the mid lactation stage. This scenario has been described by Guo *et al*. (2004). The variation at different stages of lactation reported in this study is in line with that reported by Greyling *et al.* (2004), among others. The lactose percentage was high in the early lactation stage and at its lowest in the late lactation stage for goats fed the control and T2 diets, similar to the finding by Prasad *et al*. (2005). The milk fat percentage of T3 goats shows decline from early to mid-lactation stages. This decline was observed by Bouattour *et al.* (2008) who reported that the response of milk fat secretion is usually higher during early lactation, because *de novo* lipogenesis is more active after peak lactation than before it. After peak lactation, dietary fatty acids would be partitioned more to the adipose tissues synthesis. Fernandez *et al.* (2008) found that milk fat and protein content were greater at early lactation than other stages when milk volume decreases. Milk production level is a factor that influences milk components, especially the percentage of fat because of a notion called ‘dilution effect’. The milk lactose percentage of T3 goats declined with a decrease in milk yield, as the lactation period progressed. The milk lactose percentage for goats in T3 diet also exhibited variations between early and late lactation. This confirms that milk lactose is positively correlated with milk yield, which is influenced by the feed status of the animal.

From this study, it can be concluded that there is high potential in feeding goats *S. lespedeza* with urea and possibly replacing SOC in the TMR to reduce cost and obtain a high yield of milk of a suitable quality for cheese making. T3 gives a good percentage of milk fat and milk protein. The total milk solids are the driving factor in commercial goat milk by-product manufacturing, in which *S. lespedeza* combined with urea showed positive outputs. Further research into using *S. lespedeza* and urea is warranted to obtain a solid significant difference in some of the milk components.

CHAPTER 5

5.1 CONCLUSION

It has been well documented that supplementing low-quality feed with forage legumes offers good-quality nutrients at low cost. In this study, *S. lespedeza* legume was used with urea to replace SOC in a TMR diet. SOC is a pricey concentrate for most smallholder farmers. In addition, SOC and other high-quality concentrates are not easily available in the majority of rural areas where most goats are kept, but it is a common protein source that has been well characterized for comparisons to be made. Legumes are a rich source of dietary nitrogen and protein. However, the chemical composition in this study (Chapter 2) shows that the *S. lespedeza* that was used had 10% CP, 60% NDF and 40% ADF, which indicates that this material could be regarded as a roughage, rather than a concentrate. The maturity level of the *S. lespedeza* plant has a direct inverse effect on its nutritive level and digestibility. An additional adverse effect occurs through CTs, which most legumes have. Condensed tannins bind to protein in the rumen, creating unfavourable conditions for the rumen microbes to use RDP, which then affects digestibility and intake. To circumvent the controversial effect of CTs in *S. lespedeza* in this study, it was mixed with 1% urea to provide the rumen microorganism with an RDP source. Subsequently RUP would be available to the animal. Urea is known to increase microbial activity when given with a good energy source. Hence a TMR was formulated to provide the expected nutrient requirements of high producing lactating goats.

The combination of *S. lespedeza* with urea seems to improve goat performance. The results of this study demonstrated that T3, which had this combination, resulted in better DMI, which consequently increased the OMI and nutrient intake. In many cases, these were found to be related to the balance of RDP with RUP from urea and *S. lespedeza*. The *S. lespedeza* with urea treatment had no adverse effects on the digestibility coefficients of DM, OM, CP, NDF and ADF. The TMR treatments had no significant difference in nitrogen utilization and nitrogen excretion.

Milk production level is a factor that influences milk components, especially the percentages of fat and protein, because of a notion called the dilution effect. In this study, the TMR diets resulted in adequate content of milk fat and milk protein. Moreover, the milk yield for all the TMR diets was above 2 kg/head/day, which is considered above standard for most dairy goats in developing countries. The effects of combining *S. lespedeza* with urea in a diet of some milk and nutritional parameters need to be further investigated, possibly by testing an inclusion rate of *S. lespedeza* above that of 12.5%. There is still high potential in feeding goats, a combination of *S. lespedeza* with urea as replacement for SOC in a TMR diet to produce good-quality milk, which can be used for cheese making, yogurt and other dairy products. The results show that a combination of *S. lespedeza* and urea could replace SOC in the TMR as cheaper, more easily available, balanced nitrogen and protein sources (RUP and RDP) to support high production in ruminants.

These are the key findings of the current study, which may be used to help farmers adopt a cheaper feeding system for goats, since *S. lespedeza* could easily be planted, established and harvested as protein supplement or roughage if it has reached the proper maturity stage. Urea is available to most farmers, but some level of education is needed to apply it in animal feed. Government sectors and agricultural services generally provides assistances on such supplementation solutions.

CRITICAL EVALUATION AND RECOMMENDATIONS

For the present study to ascertain the highest degree of confidence and illustrate a solid significant effect on the milk and nutritional parameters, certain limiting factors need further investigation.

- The significant effect of *S. lespedeza* with urea was limited by the low number of animals replicated per treatment. Only three goats were used per treatment to study the nutrient utilization and digestibility coefficients. Hence the researcher recommends the use of more animals (> 6), and possibly goats fitted with rumen cannulas, to study the nutritional parameters and in vivo digestibility more intensely.
- *Sericea lespedeza* with urea has no negative effect on milk yield and some milk solids. Hence they should be included in graded levels (2–3 levels) to test the best level for desired results, for example 12.5%, 15% and 18% and so on.
- The CT level in *S. lespedeza* should be determined and established for the study. Its significant effect on milk and milk quality should be tested as well. However analysing CT in the University Nutri-lab is done on ad-hoc basis because no formal approved CT determination methodology exist in the department and hence it was not prioritized.
- It would be more substantial to test the negative effects of including *S. lespedeza* with urea on the diet for goats as opposed to the positive effects.
- Another cause of insignificance with treatment diet and milk production could be that the lactation study was conducted on group feeding in a camp, which is not specific as individual feeding. Hence for future studies, students are recommended to opt for individual feeding of goats.

If these inputs are considered and incorporated in goat studies for similar or related research questions, surely a greater scientific standpoint with the findings would be realised. However, given this study objectives of replacing SOC with *S. lespedeza* and urea on the goat parameters that were set, the findings are scientifically viable and satisfactory.

REFERENCES

Agnihotri, M.K., Singh, N. & Babjim, Y., 2002. Milk composition of goats reared under field conditions. Indian J. of Anim. Sci. 72, 1019-1021.

Alexandre, G. & Mandonnet, N., 2005. Goat meat production in harsh environments. Small Ruminant Res. 60, 53-66.

AL-Busadah, K.A., 2008. Effects of feeding urea on milk composition in lactating goats. J. King Faisal University. 9, 21429.

Animut, G., Puchala, R., Goetsch, A.L., Patra, A.K., Sahlu, T.V., Varel, H. & Wells, J., 2008. Methane emission by goats consuming diets with different levels of condensed tannins from *Sericea lespedeza*. Anim. Feed Sci. Technol. 144, 212-227.

Association of Analytical Chemists (AOAC), 2003. Official methods of analysis. (14th edition). AOAC. Washington DC, USA.

Babayemi, J. & Bamikoli, M., 2006. Supplementary value of *Tephrosia bracteolata*, *Tephrosia candida*, *Leucaena leucocephala* and *Gliricidia sepium* hay for West African Dwarf goats kept on range. Central European Agriculture. 7, 323-328.

Ball, D. & Mosjidis, J., 2007. *Sericea lespedeza:* A pasture, hay and conservation plant. Alabama Cooperative Extension System. ANR-1318.

Bava, L., Rapetti, L., Crovetto, G.M., Tamburini, A., Sandrucci, A., Galassi, G. & Succi, G., 2001. Effects of a non-forage diet on milk production, energy and nitrogen metabolism in dairy goats throughout lactation. J Dairy Sci. 84, 2450-2459.

Bhatta, R., Shinde, A.K., Sankhyan, S.K., Verma, D.L. & Vaithiyanathan, S., 2002. Effect of feeding tree foliage on milk yield and composition of lactating goats on semi-arid rangeland. Indian J. Anim. Sci. 72, 84-86.

Bouattour, M. A., Casals, R., Albanell, E., Such, X. & Caja, G., 2008. Feeding soybean oil to dairy goats increases conjugated linoleic acid in milk. J. Dairy Sci. 91, 2399-2407.

Braghieri, A., Pacelli, C., Verdone, M., Girolami, A. & Napolitano, F., 2007. Effect of grazing and homeopathy on milk production and immunity of Merino derived ewes. Small Ruminants Res. 69, 95-102.

Burke, J.M., Miller, J.E., Terrill, T.H. & Mosjidis, J.A., 2014. The effects of supplemental *Sericea lespedeza* pellets in lambs and kids on growth rate. Liv. Sci. 159, 29-36.

Casey, N.H. & Van Niekerk, W.A., 1988. The Boer goat: Origin, adaptability, performance testing reproduction and milk production. Small Ruminants Res. 1, 291-302.

Chaturvedi, O.H. & Walli, T.K., 2001. Effect of feeding graded levels of undegraded dietary protein on voluntary intake, milk production and economic return in early lactating crossbred cows. Asian-Aust. J. Anim. Sci. 14, 1118-1124.

Chowdhury, S., Rexroth, A.H., Kijora, C. & Peters, K.J., 2002. Lactation performance of German Fawn goat in relation to feeding level and dietary protein protection. Asian-Aust. J. Anim. Sci. 15, 222-237.

Coffey, L., Hale, M., Terrill, T., Mosjidis, J., Miller, J. & Burke, J., 2007. Tools for managing internal parasites in small ruminants: *Sericea lespedeza*. NCAT/ATTRA and Southern Consortium for Small Ruminant Parasite Control. pp. 1-8.

Conservation Commission of Missouri, 2014. Springfield Conservation Nature Centre. Missouri Department of Conservation. USA.

Directorate, Agricultural Statistics, 2003. Statistics and Economic Analysis of the Department of Agriculture, Forestry and Fisheries. Republic of South Africa.

Directorate Marketing, 2012. A profile of the South African goat market value chain. Department of Agriculture, Forestry and Fisheries, Republic of South Africa.

Djibrillou, O.A., Pandey, V.S., Gouro, S.A. & Verhulst, A., 1998. Effect of urea-treated or untreated straw with cotton seed on performances of lactating Maradi (Red Sokoto) goats in Niger. Livest. Prod. Sci. 55,117-125.

Donkin, E. F., 1998. Milk production from goats for households and small-scale farmers in South Africa. A USAID Programme Workshop, Hogsback, Eastern Cape. pp. 1-2.

Dugmore, T.J., 2004. The evaluation of *Sericea lespedeza* in a partial total mixed ration for dairy cows SA-Anim Sci. vol 5.

Dzimiansky, S.L., Terrill, T.H., Kouakou, B., & Lee, J.H., 2010. Milk production and composition of late-lactating dairy does fed *Sericea lespedeza*, rhizome peanut and alfalfa hay-based diets. pp. 19-23.

Eckerle, G.J., 2011. Mitigation of condensed tannins found in *Sericea lespedeza* (*Lespedeza cuneata*). Ph.D. dissertation, Kansas State University, Manhattan.

Eckerle, G.J., Olson, KC., Jaeger, J.R. & Pacheco, L.A., 2007. Effects of corn steep liquor supplementation on voluntary selection of tallgrass prairie hay contaminated with *Sericea lespedeza* and uncontaminated tallgrass prairie hay. Proc. West. Sec. Amer. Soc. Anim. Sci. 62, 58-61.

Eckerle, G.J., Olson, K.C., Jaeger, J.R., Davidson, J.L., Kraft, T. K. & Pacheco, L.A., 2010. Effects of sun-curing and harvest maturity on concentration and protein-binding capacity of condensed tannins in *Sericea lespedeza (Lespedeza cuneata).* Proc. West. Sec. Amer. Soc. Anim. Sci. 61, 30-34.

Egwu, G.O., Onyeyili, P.A., Chibuzo, G.A. & Ameh., J.A., 1995. Improved productivity of goats and utilisation of goat milk in Nigeria. Small Ruminant Res. 16, 195-201.

Fernandez, G., Capote, J., Castro, N., Caja, G., Briggs, H. & Argüello, A., 2008. Effect of the frequency of milking and lactation stage on milk fractions and milk composition in Tinerfe-a dairy goats. Small Ruminant Res.75, 252-255.

Frutos, P., Hervas, G., Giraldez, F.J. & Mantecn, A.R., 2004. An *in vitro* study on the ability of polyethylene glycol to inhibit the effect of quebracho tannins and tannic acid on rumen fermentation in sheep, goats, cows and deer. Aust. J. Agric. Res.55, 1125-1132.

Galina, M.A., Guerrero, M., Puga, C. & Haenlein, G.F.W., 2004. Effect of a slow-intake urea supplementation on growing kids fed corn stubble or alfalfa with a balanced concentrate. Small Ruminant Res. 53, 29-38.

Galina, M.A., Guerrero, C.M., Serrano, G., Morales, R. & Haenlein, G., 2000. Effect of complex catalytic supplementation with non-protein nitrogen on ruminal ecosystem of growing goats pasturing shrub land in Mexico. Small Ruminant Res. 36, 33-42.

Garg, M.R., Sherasia, P.L., Bhanderi, B.M., Gulati, S.K. & Scott, T.W., 2005. Effect of feeding rumen protected protein on milk production in low yielding cross bred cows. Anim. Nutr. Feed Technol. 5, 1-8.

Greyling, J.P.C., Mmbengwa, V.M., Schwalbach, L.M.J. & Muller, T., 2004. Comparative milk production potential of indigenous and Boer goats under two feeding systems in South Africa. Small Ruminant Res.55, 97-105.

Gujja, S., Terrill, T.H., Mosjidis, J.A., Miller, J.E., Mechineni, A., Kommuru, D.S., Shaik, S.A., Lambert, B.D., Cherry, N.M. & Burke, J.M., 2013. Effect of supplemental *Sericea lespedeza* leaf meal pellets on gastro intestinal nematode infection in grazing goats. Vet. Parasitol.191, 51-58.

Guo, M.R., Dixon, P.H., Park, Y.W., Gilmore, J.A. & Kindstedt, P.S., 2001. Seasonal changes in the chemical composition of commingled goat milk. Journal of Dairy Science 84, E79-E83.

Guo, M., Park, Y.W., Dixon, P.H., Gilmore, J.A. & Kindstedt, P.S., 2004. Relationship between the yield of cheese (Chevre) and chemical composition of goat milk. Small Ruminant Res. 52,103-107.

Haenlein, G.F.W., 2001. Past, present, and future perspectives of small ruminant dairy research. J. Dairy Sci. 84, 2097-2115.

Haenlein, G.F.W. & Hinckley, L., 1994. Somatic cell count situation in USA. In: Rubino, R. (Ed.). Somatic cells and milk of small ruminants. Wageningen Academic Publishers, The Netherlands, pp. 13-23.

Hagerman, A.E., Robbins, C.T., Weerasuriya, Y., Wilson, T. C. & McArthur, C., 1992. Tannin chemistry in relation to digestion. J. Range. Manage. 45, 57-62.

Hassen, A., Rethman, N.F.G. & Apostolides, Z., 2006. Morphology and agronomic characteristics of Indigofera species using multivariate analysis. Tropical Grasslands. 40, 45-59.

Hassen, A., Rethman, N.F.G., Apostolides, Z. & Van Niekerk, W.A., 2008. Forage production and nutritive value of 24 shrubby Indigofera accessions under field conditions in South Africa. Tropical Grasslands. 42, 96-103.

Inostroza, J.F., Shaver, R.D., Cabrera, V.E. & Tricárico, J.M., 2010. Effect of diets containing a controlled-release urea product on milk yield, milk composition, and milk component yields in commercial Wisconsin dairy herds and economic implications. The Professional Animal Scientist 26, 175-180.

Kanani, J., Lukefahr, S.D. & Stanko, R.L., 2006. Evaluation of tropical forage legumes (*Medicago sativa*, *Dolichos lablab*, *Leucaena leucocephala* and *Desmanthus bicornutus*) for growing goats. Small Ruminant Res. 65, 1-7.

Kalscheur, K., Garcia, A., Rosentrater, K. & Wright, C., 2008. Ethanol co-products for ruminant livestock diets. In: The Beef Site Com.

Karzis, J., Donkin, E.F.& Petzer, I.M., 2007. The influence of intramammary antibiotic treatment, presence of bacteria, stage of lactation and parity in dairy goats as measured by the California Milk Cell Test and somatic cell counts. Onderstepoort. J. Vet .Res. 74, 161-167.

Kumar, M.R., Tiwari, D.P. & Kumar, A., 2005. Effect of un-degradable dietary protein level and plane of nutrition on lactation performance in crossbred cattle. Asian-Aust. J. Anim. Sci. 18, 1407-1413.

Lange, K.C., Olcott, D.D., Miller, J.E., Mosjidis, J.A., Terrill, T.H., Burke, J.M. & Kearney, M.T., 2006. Effect of *Sericea lespedeza (Lespedeza cuneata)* fed as hay, on natural and experimental haemonchus contortus infections in lambs.Vet.Parasitol.141, 273-278.

Langston University Goat Research and Extension programs, 2000. Langston University Agricultural Research and Extension Programs. Langston. USA.

LECO, 1994. Instruction manual FP-428 Nitrogen determination. LECO Corporation, St Joseph, Mi, USA.

Leng, R.A., 1990. Factors affecting the utilization of poor-quality forage by ruminant animals particularly under tropical conditions. Nutr. Res. Rev. 3, 277-303.

Maasdorp, B.V., Muuchenje, V. & Titterton, M., 1999. Palatability and effects on dairy cow milk yield of dried fodder from the forage trees *Acacia boliviana, calliandra calothyrsus and Leaucaena leucocephala.* Animal Feed Science and Technology. 77, 49-59.

Mahanta, S.K., Singh, S., Kumar, A. & Pachauri, V.C., 1999. Subabul leaf meal as a replacement of mustard cake in lamb diets. Small Ruminant Res. 32, 37-42.

Makkar, H.P.S., 2003. Effects and fate of tannins in ruminant animals, adaptation to tannins and strategies to overcome detrimental effect of feeding tannin-rich feeds. Small Ruminant Res. 49, 241-256.

Makkar, H.P.S., 2004. Recent advances in the *in vitro* gas method for evaluation of nutritional quality of feed resources. Assessing quality and safety of animal feeds. FAO Animal Production and Health Series 160. FAO, Rome, pp. 55-88.

Mantz, G. K., Villalba, J. J. & Provenza, F. D., 2009. Supplemental polyethylene glycol affects intake of and preference for *Sericea lespedeza* by cattle. J. Anim. Sci. 87, 761-769.

Mapiye, C., Chimonyo, M., Dzama, K., Raats, G.J. & Mapekula, M., 2009. Opportunities for improving Nguni cattle production in the smallholder farming systems of South Africa. Livestock Sci. 124, 196-204.

Mayo, J.M., 2000. The effects of goats grazing on *Sericea lespedeza*. In: Symp. Proc. *Sericea lespedeza* and the Future of Invasive Species, Kansas State University Department of Agronomy, Manhattan, KS. pp. 14-15.

Mellado, M., Rodriguez, A., Villarreal, JA. & Olvera, A., 2005. The effect of pregnancy and lactation of diet composition and dietary preference of goats in a desert rangeland. Small Ruminant Res. 58, 79-85.

Mellado, M., Estrada, R., Oliveres, L., Pastor, F. & Mellado, J., 2006. Diet selection among goats of different milk production potential on rangeland. Arid Environments. 66, 127-134.

Melaku, S., Peters, K.J. & Tegegne, A., 2003. In *vitro* and in *situ* evaluation of selected multipurpose trees, wheat bran and Lablab purpureus as potential feed supplements to tef (Eragrostis tef) straw. Anim. Feed Sci. Technol. 108, 159-179.

Mestawet, T.A., Girmab, A., Adnoyc, T., Devolda, T.G., Narvhusa, J.A. & Vegaruda., G.E., 2012. Milk production, composition and variation at different lactation stages of four goat breeds in Ethiopia. Small Ruminant Res. 105, 176-181.

Min, B.R., Barry, T.N., Attwood, G.T. & McNabb, W.C., 2003. The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: a review. Anim. Feed Sci. Technol. 106, 3-19.

Min, B.R., Pomroy, W.E., Hart, S.P. & Sahlu, T., 2004. The effect of short-term consumption of a forage containing condensed tannins on gastro- intestinal nematode parasite infections in grazing wether goats. Small Ruminant Res. 51, 279-283.

Min, B.R., Hart, S.P., Miller, D., Tomita, G.M., Loetz, E. & Sahlu, T., 2005. The effect of grazing forage containing condensed tannins on gastro- intestinal parasite infection and milk composition in Angora does. Vet. Parasitol.130, 105-113.

Mmbengwa, V.M., Ramalivhana, J.N., Gundidza, M., Fair, M.D., Du Toit, J.E.J. & Greyling, J.P.C., 2008. South African indigenous goat milk: a potential alternative source of macro-nutrients for poverty-stricken rural areas. University of the Free State, Bloemfontein, RSA, Liv.Res. for Rum. Dev. pp. 20-8.

Molina-Alcaide, E., Morales-García, E.Y., Martín-García, A.I., Ben Salem, H., Nefzaoui, A. & Sanz-Sampelayo, M.R., 2010. Effects of partial replacement of concentrate with feed blocks on nutrient utilization, microbial N flow, and milk yield and composition in goats. J. Dairy Sci. 93, 2076-2087.

Morand-Fehr, P., 2005. Recent developments in goat nutrition and application. A review. Small Ruminant Res. 60, 25-43.

Morand-Fehr, P., Fedele, V., Decandia, M. & Le Frileux, Y., 2007. Influence of farming and feeding systems on composition and quality of goat and sheep milk. Small Ruminant Res. 68, 20-34.

Morand-Fehr, P., Boutonnet, J.P., Devendra, C., Dubeuf, J.P., Haenlein, G.F.W., Holst, P. & Mowlem, L., 2004. Strategy for goat farming in the 21st century. Small Rumin. Res. 51, 175-183.

Moore, D.A., Terrill, T.H., Kouakou, B., Shaik, S.A., Mosjidis, J.A., Miller, J.E., Vanguru, M., Kannan, G. & Burke, J.M., 2008. The effects of feeding *Sericea lespedeza* hay on growth rate of goats naturally infected with gastrointestinal nematodes. J. Anim. Sci. 86, 2328-2337.

National Agricultural Marketing Council (NAMC), 2005. Marketing potential for the South African Goat Industry. pp. 1-55.

National Department of Agriculture (NDA), 2009. National livestock statistics. Department of Agriculture and Land Affairs, Pretoria, South Africa.

National Research Council (NRC), 2007. Nutrient requirements of small ruminants: sheep, goats, cervids and new world camelids. National Academic Press. Washington, DC.

Ndemanisho, E.E., Mtenga, L.A., Kimbi, E.F.C., Kimambo, A.E. & Mtengeti, E.J., 1998. Substitution of dry *Leucaena leucocephala* leaves for cotton seed cake as a protein supplement to urea treated maize stover fed to dairy weaner goats. Animal Feed Science and Technology. 73, 365-374.

Oregui, L.L.M. & Vazquez, M.V.B., 1991. Factors affecting mobilization of body reserves at the end of gestation of dairy sheep in Vizeaya. In: Proceedings of the Actas XVI. Jornadas Cientificas Sociedad, Espanalo de Ovinotecniay Caprinotecnia, pp. 113.

Ort´ız, R.M.A., Galina, M.A. & Carmona, M.M.A., 2002. Effect of a slow non-protein nitrogen Ruminal supplementation on improvement of *Cynodonnlem fuensis*or *Brachiariabrizanta* utilization by Zebu steers. Livest. Prod. Sci. 78, 125-131.

Pal, Ajit. & Sharma, R.K., Kumar, Ravindra. & Barman, K., 2010. Effect of replacement of concentrate mixture with isonitrogenous leaf meal mixture on growth, nutrient utilization and rumen fermentation in goats. Small Ruminant Res. 91, 132-140.

Pitman, W.D., 2006. Stand characteristics of *Sericea lespedeza* on the Louisiana Coastal Plain. Agriculture, Ecosystems and Environment 115, 295-298.

Prasad, H., Tewari, H.A. & Sengar, O.P.S., 2005. Milk yield and composition of the beetal breed and their crosses with Jamunapari, Barbari and Black Bengal breeds of goat. Small Ruminant Res. 58, 195-199.

Rafiq, M., Mumtaz, S., Akhtar, N., Khan. & M.F., 2007. Effect of strategic supplementation with multi-nutrient urea molasses blocks on body weight and body condition score of Lohi sheep owned by tenants of Pakistan. Small Ruminant Res. 70, 200-208.

Robbins, C., Hagerman, A.E., Austin, P.J., McArthur, C. & Hanley, T. A., 1991. Variation in mammalian physiological responses to a condensed tannin and it's ecological implications. J. Mamm. 72, 480-486.

Roger, G.P., Webb, E.C. & Mohale, L., 2011. Differences in milk yield and composition of different goats breeds raised in the same environment in South Africa. Agricultural Journal. 6, 237-242.

Sahoo, B. & Walli, TK., 2008. Effect of feeding un-degradable protein with energy on nutrient utilization, milk yield and milk composition of crossbred goats. Small Ruminant Res. 75, 36-42.

Samuel, M.L., 1989. Statistics for the life sciences. Collier MacMillan, London.

Sanz Sampelayo, M.R., Perez, M.L., Gil Extremera, F., Boza, J. J. & Boza, J., 1999. Use of different dietary protein sources for lactating goats: Milk production and composition as functions of protein degradability and amino acid composition.

SAS, 2004. Release 9.13. SAS Institute Inc., Cary, NC, USA.

Statistics and Economic Analysis, 2012. Economic overview of the Department of Agriculture, Forestry and Fisheries . Republic of South Africa.

Shaik, S.A., Terrill, T.H., Miller, J.E., Kouakou, B., Kannan, G., Kaplan, R.M., Burke, J.M. & Mosjidis, J.A., 2006. *Sericea lespedeza* hay as a natural deworming agent against gastro intestinal nematode infection in goats. Vet. Parasitol. 139, 150-157.

Silanikove, N., Gilboa, N., Nitsan, A. & Perevolotsky, A., 1996. Effect of daily supplementation of polyethylene glycol on intake and digestion of tannin-containing leaves (*Quercus calliprinos*, Pistacia lentiscus and Ceratonia siliqua) by goats. J. Agric. Food Chem. 44, 199-205.

Sourabie, KM., Kayouli, C., & Dalibard, C., 1995. The rough treatment of urea forage. A very promising technique in Niger. Wld Anim. Rev. 82, 3-13.

Stella, A.V., Paratte, R., Valnegri, L., Cigalino, G. & Soncini, G., 2007. Effect of administration of live Saccharomyces cerevisiae on milk production, milk composition, blood metabolites and faecal flora in early lactating dairy goats. Small Ruminant Res. 67, 7-13.

Terrill, T.H., Windham, W.R., Hoveland, C.S., Amos, H.E., Kouakou, B. & Gelaye, S., 1995. Nitrogen and fibre digestion in sheep fed fresh-frozen and field-dried high and low tannins *Sericea lespedeza*. Session 8:Tannins: Plant breeding and animal effects. pp. 8-12.

Tjelele, T.J., 2006. Dry matter production, intake and nutritional value of certain Indigofera species. MSc thesis, (University of Pretoria, Pretoria, South Africa).

Turner, K.E., Wildeus, S. & Collins, J.R., 2005. Intake, performance, and blood parameters in young goats offered high forage diets of *Sericea lespedeza* or alfalfa hay. USA. Small Ruminant Res. 59,15-23.

Van Niekerk, W.A., Hassen, A., Snyman, L.D., Rethman, N.F.G. & Coertze, R.J., 2009. Influence of mineral composition and rumen degradability of *Atriplexnummularia* (Hatfield Select F_1) plants on selection preference of sheep. African Journal of Range & Forage Science. 26, 91-96.

Van Soest, P.J., Robertson, J.B. & Lewis, B.A., 1991. Methods for dietary fibre, neutral detergent fibre, and non-starch carbohydrates in relation to animal nutrition. J. Dairy Sci. 74, 3583-3597.

Vermeire, L.T., Bidwell, T. G. & Stritzke. J., 2007. Ecology and management of *Sericea lespedeza*. Oklahoma Cooperative Extension Service PSS. pp. 2874.

Waghorn, G.C., 2008. Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production: Progress and challenges. Anim. Feed Sci. Technol. 147, 116-139.

Wang, C., Zhou, B. & Palm, H.L., 2008. Detecting invasive *Sericea lespedeza (Lespedeza cuneata)* in mid-Missouri pastureland using hyper spectral imagery. Environmental Management 41, 853- 862.

Wang, Y., Douglas, G.B., Waghorn, G.C., Barry, T.N. & Foote, A.G., 1996. The effect of condensed tannins in *Lotus corniculatus* upon lactation performance in ewes. J. Agric. Sci. Camb. 126, 353-362.

White, E.C., & Hinckly, L.S., 1999. Prevalence of mastitis pathogens in goats' milk. Small Ruminant Res. 33, 117-121.