Milk goat feeding systems using *Leucaena leucocephala* in total mixed rations

By

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LIST OF ABBREVIATIONS

AA	Amino acid
ADF	Acid detergent fibre
ADFD	Acid detergent fibre digestibility
ADFI	Acid detergent fibre intake
ADL	Acid detergent lignin
BCS	Body condition score
BW	Body weight
$BW^{0.75}$	Metabolic body weight
CCW	Cold carcass weight
CDP	Commercial dressing percentages
CF	Crude fibre
CP	Crude protein
CPD	Crude protein digestibility
CPI	Crude protein intake
DHP	Dihydroxypyridine
DIM	Days in milk
DIP	Degradable intake protein
DM	Dry matter
DMD	Dry mater digestibility
DMI	Dry matter intake
EBW	Empty body weight
FLW	Live-weight
GIT	Gastro intestinal tract
GLM	General linear model
IVDOM	*in vitro* digestibility of organic matter
LLF	*Leucaena leucocephala* forage
LLFP	*Leucaena leucocephala* forage with pods
ME	Metabolizable energy
MEDUNSA	Medical University of Southern Africa
MP	Metabolizable protein
MUN	Milk urea nitrogen

N	Nitrogen
NDF	Neutral detergent fibre
NDFD	Neutral detergent fibre digestibility
NDFI	Neutral detergent fibre intake
NGOs	Non-government organisations
NPN	Non -protein nitrogen
NRC	National Research Council
NS	Non-significant
OM	Organic matter
OMI	Organic matter intake
OSCM	Oilseed cake meal
PEG	Polyethylene glycol
RDP	Rumen-degradable protein
RUP	Rumen-undegradable protein
SAS	Statistical analysis system
SCC	Somatic cell counts
SLW	Slaughter live weight
TDN	Total digestible nutrients
TMR	Total mixed ration
UIP	Undegradable intake protein
VFA	Volatile fatty acid
VFI	Voluntary feed intake
WB	Warner-Bratzler
WBSF	Warner-Bratzler-shear force
WCW	Warm carcass weight

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MILK GOAT FEEDING SYSTEMS USING *LEUCAENA LEUCOCEPHALA* IN TOTAL MIXED RATIONS

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ABSTRACT

This study was undertaken to determine the effects and nutritive value of *Leucaena leucocephala* when it was incorporated in a total mixed ration (TMR) fed to milk goats. This was to test the use of *Leucaena* to substitute for oilseed cake meals (OSCM) which are believed to be expensive and generally unavailable in many parts of the rural areas of South Africa. Four trials were conducted at the University of Pretoria Research Farm and analyses were carried out at the Nutrition laboratory of the University of Pretoria. *Leucaena* forage contained enough nutrients to allow it to be used as a substitute for OSCM and to a large extent was also the source of protein and roughage in the TMR. The leaves of *Leucaena* had a higher crude protein, mineral and mimosine concentration but lower fibre content than the pods and twigs; while the air dried *Leucaena* forage had a higher crude protein and lower fibre content than sun dried forage. This study showed that there was a higher crude protein and mimosine concentration but a lower fibre concentration from the *Leucaena* harvested in summer than that harvested in autumn.

Milk yield and quality was not adversely affected by the inclusion of *Leucaena* in the milk goat diet at the rate of 25% of the DM, with the exception of milk urea nitrogen. The inclusion of *Leucaena* decreased the milk urea nitrogen as compared to that shown from TMR without *Leucaena*. The body weight and body condition of lactating goats were also not affected by inclusion of *Leucaena* during the three phases of the lactation period. Therefore, the inclusion of *Leucaena* in the milk goat diet has been shown to support production of milk in terms of yield and quality which was similar to that of goats fed a commercial diet. There was no significant difference in milk composition in terms of milk lactose and milk protein

for milk produced in the morning and afternoon between goats fed the two diets, even though the morning milk yield was higher than the afternoon yield because of the unequal milking intervals. However, the milk composition in terms of milk urea nitrogen, milk fat and somatic cell counts varied greatly between morning and afternoon milking.

The apparent digestibility, average daily gain and feed conversion ratio of Saanen male goats were not affected by the inclusion of *Leucaena* in the TMR, as compared to the TMR without *Leucaena*. However the voluntary dry matter and nutrients intake were improved by the inclusion of *Leucaena* in the TMR. No toxicity of mimosine was observed during this study. The results of this study also showed that the inclusion of *Leucaena* in the total mixed ration had no effect on the carcass characteristics and meat quality of goats as compared to those fed a TMR containing OSCM.

GENERAL INTRODUCTION

The dairy goat industry appears to be growing more popular in the developing countries. This is due to the high demand for goat milk for cheese making (Jaubert and Kalantzopoulos, 1996), for its characteristics of being more digestible, than cow's milk due to smaller fat globules, and for feeding young children who are allergic to other sources of milk (Fisberg *et al*., 2000). Goat production plays an important role socially and economically for many households in the rural communities (Shinde *et al*., 2000). Goat milk production has the potential to alleviate poverty and reduce malnutrition especially for the children and people living with HIV (Peacock, 2005).

Dairy goats, in contrast to other dairy animals, are relatively small and easily handled by women and children, are cheaper, require less food, multiply quickly and produce appropriate quantities of milk for households (Donkin, 1997). However, in South Africa dairy cows remain the predominant milk producers for the urban and peri- urban communities even though they are expensive, require more feed and more sophisticated management, a large area to graze and are not appropriate for small households (Donkin and Boyazoglu, 2000). The government of South Africa in its attempt to alleviate poverty and promote rural development has a policy of encouraging small scale farmers to engage in dairy goat farming. Although the milk goat project was established at the Medical University of South Africa (MEDUNSA) in 1987 (Donkin and Boyazoglu, 2000), the production of goat milk in the rural areas is limited by poor quality or unavailability of feeds which prevents goats from expressing their maximum genetic potential of producing a high volume of milk of good quality. One factor might be the escalating prices of commercial feeds, which are not affordable to most small-scale producers in the rural communities.

Under these circumstances, the most practical supplements may be the use of locally available leguminous trees or shrubs such as *Acacia tortilis* and *Leucaena.* These trees might be incorporated in the diet goats as protein and/or roughage supplements and therefore reduces the cost of feeding milk goats. However, the lack of knowledge and limited information regarding the use and chemical composition of *Leucaena* by small scale farmers can be another constraint for the efficient use of *Leucaena* in the rural communities. Earlier experience revealed that the use of *Leucaena* in large quantity might be harmful to the animals, reduce their production or even cause death. However following the work of Jones and Megarrity, (1983) *Leucaena* has been used successfully in many countries. The introduction of the rumen bacteria (*Synergistes jonesii*) where *Leucaena* is used, especially in large amounts, has the effect of detoxifying mimosine. In South Africa the bacteria was initially introduced at Pietermaritzburg in the 1990s (Meissner, 1997) and *Leucaena* was successfully used. The other practical strategy to overcome the toxicity of *Leucaena* would be to limit the level of *Leucaena* consumed by the animals per day (Virk *et al.*, 1991).

So far most studies in relation to *Leucaena* feeding had been conducted to determine the effect of *Leucaena* on goat body weight gain (Virk *et al*., 1991; Ha *et al*., 1995; Ndemanisho *et al*., 1998; Yami *et al*., 2000; Rubanza *et al*., 2007) and on milk production of dairy cows (Ha *et al*., 1995; Waipanya and Srichoo, 1998). However, there is limited information on the effect of *Leucaena* on goat milk. Therefore, it is necessary to determine the potential of *Leucaena* in milk goat diet, and its effect on milk yield and quality when it is included in the total mixed ration (TMR) for milk goats. This study will be very important to the rural communities of South Africa who are facing high feed costs. These people may invest in milk goats using less expensive feed resources and be able to use goat milk and products as a source of protein and for income generation through the selling of surplus production.

General objective

The main purpose to undertake this research study was to investigate whether the inclusion of *Leucaena leucocephala* forage in the feeding programme of milk goats can improve goats' growth, feed intake, feed digestibility, milk yield and quality without adverse effects on animal health and body condition.

Outline of the study

The adaptation to *Leucaena*, its potential as fodder for animals, as well as toxicity and strategies to overcome its toxicity have been reviewed in Chapter 1. The influence of season and drying method of *Leucaena* on chemical composition have been investigated in Chapter 2, while in Chapter 3 effect of *Leucaena* on milk yield, quality and body condition score have been evaluated using Saanen milk goats. In Chapter 4, growth performance and animal health of

Saanen castrated male goats have been studied when fed TMR with or without *Leucaena*, while in Chapter 5 the voluntary intake and digestibility of TMR with *Leucaena* compared with TMR without *Leucaena* have been evaluated using the same animals. In Chapter 6, carcass and meat quality of Saanen male goats fed TMR with or without *Leucaena* were evaluated. Lastly, the conclusion and recommendations for future research will be presented in chapter 7.

Hypotheses and specific objectives

1. The inclusion of *Leucaena* in diet of milk producing and growing goats has no adverse effect on feed intake, body condition, milk yield and quality.

2. The use of *Leucaena* forages as a substitute for oilseed cake meal (OSCM) has no adverse effect on carcass characteristics and meat physical characteristics.

Leucaena can be used by meat and milk producers in the rural communities as low cost source of protein and roughage for their animals. TMR with *Leucaena* might have a similar potential to support meat and milk goat production as the TMR based on the conversional diets.
Therefore the use of trees as fodder for animals is an alternative feed source that needs to be investigated especially for small scale farmers in the rural communities of South Africa.

The focus of this research is on the inclusion of *Leucaena leucocephala* forage in the feeding programme of milk goats with the following specific objectives

- To assess the nutritional value of edible parts of *Leucaena* hay after different drying methods and in relation to the harvesting season. It is expected that the difference will occur in terms of chemical composition due to variation in drying method and growing season.

- To measure the growth performance and health of Saanen male goats fed a TMR with the inclusion of *Leucaena* as a source of protein compared to a TMR formulated using OSCM. The assumption is that *Leucaena* can support the performance of Saanen male goats as well as the commercial diets do.

- To investigate the milk yield, milk composition and body condition score of milk goats fed *Leucaena* as a protein source in a TMR as a substitute for OSCM. It is expected that *Leucaena* can support performance of milk producing goats as well as the commercial diets do.

- To investigate the voluntary intake and digestibility response of Saanen castrated goats fed TMR diet with or without the inclusion of *Leucaena*. It is expected that the differences will occur in terms of digestibility and intake between two TMR with or without *Leucaena* due to variation in chemical composition.

- To measure carcass and meat quality of Saanen male goats fed the TMR with or without *Leucaena*. The assumption is that there will be no difference between the carcass characteristics and meat quality for goats fed TMR with or without *Leucaena.*

CHAPTER 1

LITERATURE REVIEW

1.1 Description, adaptation and geographical distribution of *Leucaena leucocephala*

Leucaena leucocephala is a tropical and subtropical tree which can adapt well under a warm and wet environment. It can tolerate drought (Kudo *et al*., 1989) and high temperatures, but grows poorly in the areas with very low temperatures. *Leucaena* is a seasonal plant in tropics and sub-tropics which may perform below expected yield during cool dry months (Glumac *et al*., 1987). However, the yield may increase two to four times during hot wet months (Winrock, 1985). The plant is characterised by deep roots, which enable it to resist drought and permits it to thrive in a wide range of soils (Kudo *et al*., 1989). The deep root system allows *Leucaena* to produce new leaves even after regular clippings and regenerate from rootstock even if the vegetative part has been affected by freezing temperatures (Glumac *et al*., 1987) or has been completely grazed by the animals. *Leucaena* grows very well in deep well-drained fertile soil, with good water holding capacity. It grows well in soil with a range of pH, but it is most suited to neutral to alkaline soil pH (6.0–7.7).

Leucaena is a multi-stemmed tree because of cluster of stems or suckers which develop after cutting or grazing. These characteristics ensure the availability of enough forage for the animals throughout the year. It has been described as miracle or multi-purpose, rapid-growing tree due to its aggressive growth, adaptability and its wide range of uses (Shelton and Brewbaker, 1994), and its varieties are ranked in the top five fodder trees for biomass production worldwide (Glumac *et al*., 1987). It is a thornless tree with the height range between 7–18 m depending on the cultivar, with 6-400 mm trunk diameter (Shelton and Brewbaker, 1994; Lemcke and Shotton, 2007). Leaves are bipinnate with 6–8 pairs, having 11–23 pairs of leaflets which are 8–16 mm long (Shelton and Brewbaker, 1994). The inflorescence is cream coloured and globular in shape, and it produces clusters of pods 13–18mm long containing 15–30 seeds (Shelton and Brewbaker, 1994). It is well adapted to altitude from sea level to 1500 m (Hughes, 1998), but it is more suitable to low lands as it can be easily killed by early frost on highlands. *Leucaena* survives well with annual rainfall above 600 mm as a lower rainfall can adversely affect its establishment. The range of annual rainfall which will allow development of this shrub is between 600–3000 mm

(Panhwar, 2005). In high rainfall areas it will need soil with good drainage to prevent water logging, which may adversely affect its establishment, development as well as its growth. The growth and good development of *Leucaena* is improved by high light intensity (Panhwar, 2005) and most successful production has occurred in the tropics and sub-tropics where freezing temperatures do not occur (Glumac *et al.*, 1987). This clearly indicates that this shrub does well in the tropical areas rather than in temperate areas**,** but with good care and management it can still thrive well in temperate areas like South Africa.

It is believed that *Leucaena* originated in Mexico and Central America over 400 years ago (Shelton and Brewbaker, 1994; Garcia *et al*., 1996). Even though it existed for many centuries, its potential use for extensive grazing system was only recognised by Australian scientists in the early 1950's. The spread of *Leucaena* to other countries has been because of its value as forage and timber production (Castillo *et al.*, 1997). Since then, intensive research had been conducted to evaluate its importance and hence its production has expanded. It is presently grown throughout areas across the tropics and temperate zones between latitudes 30N and 30S and at altitudes up to 1500 m above sea level (Garcia *et al*., 1996).

Leucaena belongs to the family leguminosae (Mimosoideae) which includes more than 55 species, but there are nine common varieties (Panhwar, 2005) (*L. collinsii*, *L. diversifolia, L. esculenta*, *L. lanceolata*, *L. leucocephala*, *L. macrophylla*, *L. pulverulenta*, *L. retusa, L. shannoni*). According to Garcia *et al*. (1996) *Leucaena* varieties are classified into three types based on their growth habit, "Hawaiian", "Salvador" and "Peru". The first variety ("Hawaii") is characterised by a shrubby form which only grows up to six metres tall and it flowers after six months growth. The second type is "Salvador" (Hawaii Giant), which is a fast growing type and may attain 20 m in height (Hughes, 1998). The third variety is "Peru", which has characteristics of both of the two varieties, namely, aggressive growth of "Salvador" and low branching of "Hawaii" (Garcia *et al*., 1996). "Peru" can attain a height of 10 m.

1.2 Potential of *Leucaena leucocephala* in general

1.2.1 Nutritive value

The chemical composition of *Leucaena* forage is summarised in Table 1.1. Garcia *et al*. (1996) reviewed 65 publications about the nutritive value of *Leucaena* from 1946 to 1992 and summarised them as follows.

Table 1.1: The chemical composition of *Leucaena* forage [leaf (petiole and blade) and stem] and leaf meal (Garcia *et al*., 1996)

Chemical Fraction (DM %)	Forage		Leaf meal	
	Range	Median	Range	Median
	% DM basis (g/100 g DM)			
Crude Protein	10.00–30.05	22.03	24.00–34.40	29.20
Mimosine	0.70– 3.59	2.14	1.40–7.19	4.30
Crude Fibre	32.00–38.00	35.00	18.0–20.40	19.20
Neutral Detergent Fibre	34.00–42.00	39.50	–	–
Acid Detergent Fibre	34.10–36.10	35.10	–	–
Hemicellulose	2.01– 7.40	4.71	–	–
Cellulose	11.00–25.70	18.30	–	–
Lignin	4.20–11.70	7.90	–	–
Ash	6.62– 9.46	8.04	–	–
Tannin	0.51- 1.60	1.05	10.00–11.00	10.50
Sulphur	0.14– 0.29	0.22	–	1.00
Calcium	0.80- 2.90	1.80	–	–
Phosphorus	0.14– 0.38	0.26	–	1.90
Magnesium	0.17– 0.48	0.33	–	0.23
Sodium	0.02– 2.66	1.34	–	0.34
Potassium	0.79– 2.11	1.45	–	0.02
	(mg/kg DM			
Copper	2.00–32.00	26.00	–	1.70
Iron	187.5–575.00	381.30	8.00–11.40	9.70
Zinc	30.0–308.95	169.50	19.20–32.80	907.40
Manganese	55.1–875.00	465.08	–	26.00
Iodine	33.0– 90.00	61.50	–	59.90
Chlorine	0.15 – 0.29	0.17	–	–

Source: Garcia *et al*. (1996)

According to Garcia *et al*. (1996), *Leucaena* meal is highly nutritious with high CP values (sometimes values greater than 30% were recorded). *Leucaena* meal can be used to substitute most of the commercial protein sources such as soya bean meal, cotton seed oil cake meal, groundnut cake meal and fishmeal, which are very expensive, and not locally available in many rural areas (Nyambati, *et al*. 2006). *Leucaena* can be used not only as a protein source, but can supplement poor quality roughage sources especially in dry areas (Maasdorp *et al*, 1999). The pods and twigs of *Leucaena* have a high amount of fibre. According to Garcia *et al*. (1996), the crude fibre of *Leucaena* may range from 18%–35% of DM and this level is within the recommended fibre content required for ruminants to support microbial fermentation. The level of NDF in *Leucaena* forage may range from 34%–42% of DM and is considered as highly digestible (Norton, 1994a). The calcium and phosphorus concentration in *Leucaena* meal may range between 0.8%–2.9% and 0.14%–0.38% of DM, respectively (Garcia *et al*., 1996). According to NRC (2007) this is enough to support the requirement of small stock ruminants at all production stages. The tannin content in *Leucaena* meal may range from 0.51%–1.6%, which is considered as a low to moderate level, which can protect plant protein from rumen degradation and hence decrease ammonia loss (Norton and Poppi, 1995).

1.2.2 Timber, wood and fuel production

Most people in the rural communities have no access to fuel sources such as electricity, petroleum and coal due to their unaffordable prices and their unavailability. Often, the only fuel available is wood. In tropical and sub-tropical areas *Leucaena* trees/and shrubs can provide an average wood volume yield ranging from 30–40 m^3/ha annually (Lulula and John, 1987) which is sufficient to meet fuel wood needs of up to three households. *Leucaena* can also be used as a potential renewable resource for production of biofuel to substitute non renewable crude oil from fossil resources (Keffer *et al*., 2009). It can also be used for pulp production and paper making (Lopez *et al*., 2010).

1.2.3 Soil conservation and improvement

Soil erosion is an important problem worldwide with almost two million hectares globally reported to be affected (Lopez *et al*., 2010). The commonly suggested strategy to combat this substantial problem is to invest in agricultural resources to enhance progressive productivity without jeopardizing potential of land (Lopez *et al*., 2010). It is therefore a challenge to the researchers to find alternative fast growing trees such as *Leucaena* to gradually reduce and/or abate this substantial problem. *Leucaena* has been reported to have the potential of playing a major mechanical role and hydrological role in stabilizing slopes against soil erosion (Normaniza *et al*, 2008).

1.2.4 ***Soil fertility-nitrogen fixation***

Leucaena has potential to improve soil fertility in several ways. The deep roots (Kudo *et al*., 1989), enables it to absorb the nutrients lost through leaching, which at a later stage can be available to shallow rooted plants. The *Leucaena* roots can be sloughed-off and decompose, in this way the nutrients in the roots will be available in the soil for other crops. *Leucaena* is responsible for fixing free atmospheric nitrogen through the Rhizobia in its root nodules (Sanginga *et al*., 1989). The sloughed-off root materials, and decomposition of *Leucaena* nodules and root tissues transfer nitrogen from legumes to other non leguminous plants (Rao and Kenneth, 1993).

1.3 The use of *Leucaena leucocephala* as fodder for animals

1.3.1 Nutrient requirements of the milk goat

Nutrition affects milk production (yield and composition), therefore it is essential to ensure adequate feed intake with all nutrients required by the animals (Sauvant *et al*., 1991). The yield and composition of milk directly depends on the nutritional content of diets (McCormick *et al*., 2001). The same author reported that the increase of CP did not only have an effect on milk quantity but also led to an increase in milk fat and protein. Milk production (yield and composition) is not only influenced by nutrition, but also by non-nutritional factors such as parity, breed, days in milk (DIM) and health of the animal (Arunvipas *et al*., 2003).

Table 1.2: Nutrient requirements of a 50 kg Saanen milk goat during three lactation stages (NRC, 2007)

	Lactation stage		
Parameter	early	mid	late
DDMI(% BW)	4.61	4.53	3.93
DDMI (kg)	2.30	2.26	1.96
PR (g/d)	292.00	253.00	199.00
MP (g/d)	205.00	178.00	140.00
DIP (g/d)	110.00	108.00	94.00
TDN (kg/d)	1.22	1.20	1.04
ME (Mcal/d)	4.41	4.50	3.75
Ca (g/d)	9.90	9.90	9.40
P (g/d)	6.30	6.30	5.90

DDMI: daily dry matter intake, PR: Protein requirement, MP: Metabolizable Protein, DIP: digestible intake protein TDN: Total digestible nutrients, ME: Metabolizable energy

1.3.2 Effect of Leucaena on milk production

Goat milk plays an important role socially and economically for households in many rural communities and it has potential to reduce poverty and malnutrition (Shinde *et al.*, 2000). Because of low incomes of the farmers in these areas, the nutrition of dairy goats is derived from the natural vegetation which is deficient in digestible nutrients (Abdulrazak *et al.*, 2005). These pastures might supply high quality fodder for goats if they are well managed. However, the increase in population poses a threat because of the scarcity of land, which makes it difficult for farmers to have access to enough land for their animals. In addition, the present desertification in arid areas and soil erosion in arid and semi-arid areas also contributes to the inadequacy of the pastures to support animal production without supplementation. Therefore, supplementation with concentrates and other feeds is essential to supply deficient nutrients from the pastures (Bargo and Muller, 2003 cited by Malleson, 2008). However, the access to concentrates and supplementary roughage for rural communities remains the main constraint due to their cost and unavailability (Topps, 1992). The use of locally adapted legume trees can be an alternative solution to provide this supplement for animals in the rural areas of South Africa.

1.3.2.1 Effect of Leucaena on milk yield

Leucaena trees are grown in many parts of the world mainly in tropical areas (Garcia *et al*., 1996) and used as a valuable protein source to improve animal performance (Shelton and Brewbaker, 1994; Yousuf *et al*., 2007). It can improve milk production at a lower cost than concentrate supplements which are highly expensive. Many studies had been conducted to determine the effect of *Leucaena* on the body weight gains of goats (Ndemanisho *et al.*, 1998; Yami *et al.,* 2000) and milk production of dairy cows (Ha *et al*., 1995; Waipanya and Srichoo, 1998; Kakengi, *et al*., 2001). However, there have been few studies aimed to determine the effect of *Leucaena* on the production of goat milk (Richards, *et al*., 1994 and Akingbade *et al.*, 2004) especially in South Africa.

When *Leucaena* is used as a supplement to low quality pasture, it produces the same (Waipanya and Srichoo, 1998) or even a significantly higher (Kakengi *et al*., 2001; Clavero and Razz, 2003) milk yield than from the use of concentrate supplements or other leguminous trees (Maasdorp, 1999). This may be attributed to a higher supply of rumen microbial nitrogen by *Leucaena* (Kakengi *et al*., 2001) and its potential to supply total amino acids, digested and absorbed directly through the small intestine (Mgheni *et al*., 1996). The potential of *Leucaena* to provide a high quantity of rumen degradable nitrogen (RDN) was reported by Richards *et al*. (1994). In their study aimed at substituting cotton seed oil cake with *Leucaena*, Kakengi *et al*. (2001) found higher milk yield from dairy cattle fed with *Leucaena* supplement (14.7 litres/day) than cotton seed oil cake supplement (13.2 litres/day).

However, *Leucaena* cannot provide sufficient energy required by lactating goats especially with high milk production and in early lactation. This might result in too great a utilization of body energy reserves for milk production (Muller and Fales, 1998), and therefore it has to be fed in conjunction with high energy sources such as grains in a total mixed ration TMR. The production of milk is influenced by fermentable carbohydrates and Rumen-degradable protein (RDP) (Reis and Combs, 2000). Carbohydrates are a source of energy for rumen microbes responsible for microbial protein synthesis from RDP. The effectiveness of rumen microbes to synthesize protein requires the optimal ratio of metabolic energy to rumen degradable protein, which allows microbes to capture nitrogen efficiently (Aquino *et al*., 2008). This means *Leucaena* can be used as a substitute for protein concentrates source in TMR as it contains high CP. However, *Leucaena* cannot be used as an energy source to support high milk production.

1.3.2.2 Effect of Leucaena on milk composition (milk fat)

Leucaena has the potential to improve milk composition of cows grazing low quality pastures (Kakengi *et al*., 2001) and has no adverse effect on milk composition if it is used to substitute commercial concentrates. Clavero and Razz (2003) reported no significant difference in terms of total solids obtained from the dairy goats grazing pastures and supplemented with *Leucaena* (17.5%) compared to commercial concentrate diets (17.9%). However, Bargo and Muller (2003) indicated that the percentage of milk fat was influenced more by the roughages than by concentrates and therefore the fibre based diets could result in a higher milk fat percentage than starch based diets. *Leucaena* has high amount of fibre content and due to this it can be used as the source of roughage to supplement low quality pastures without adversely affecting milk fat.

Many studies had showed no effect in terms of fat corrected milk and milk fat percentage when *Leucaena* has been used as a supplement for grazing pastures (Richards *et al*., 1994; Kakengi *et al*., 2001; Clavero and Razz, 2003; Akingbade *et al*., 2004). *Leucaena* contains low to moderate amounts of tannin (Srivastava and Sharma 1998). Tannin protects protein from degradation in the rumen and promotes outflow of protein escaping the rumen, which eventually improves the availability of amino acids in the small intestine. In this way it can substitute concentrate with rumen-undegradable protein (RUP) sources like corn gluten in the TMR and will not adversely affect milk fat.

1.3.2.3 Effect of Leucaena on milk composition (milk protein)

Milk protein is influenced by DMI, energy and protein ratio, quality and digestibility of fibre and nitrogen sources (Aquino *et al*., 2008). There are reports showing that an increase on milk protein yield in cows was due to the increase of microbial protein synthesis (Hoover and Stokes, 1991 and Kakengi *et al*., 2001). *Leucaena* has the potential to supply microbial nitrogen (N) in the rumen (Kakengi *et al*., 2001) and it also has readily fermentable fibre (Clavero and Razz, 2003). McCormick *et al*. (2001) also emphasized that an increase of CP concentration in the animal's diet can increase protein concentration in the milk. The rate at which protein is degraded in the rumen can also have a significant impact on the milk protein. Milk protein concentration was lower from a highly digestible protein diet (RDP) containing soya bean meal compared to that from a low digestibility protein diet (RUP) containing corn gluten meal (Tufarelli *et al*., 2009; Laudadio and Tufarelli, 2010) fed to lactating ewes and dairy goats. In contrast, there was no difference between the milk composition from dairy cows fed diets with urea, soya bean meal and fish meal (Santos *et al*., 1998), from animals fed proteins of different degradability and concentration (Christensen *et al*., 1993) and on different levels of urea in diet (Aquino *et al*., 2008).

1.3.2.4 Effect of Leucaena on milk composition (milk urea nitrogen)

Milk Urea Nitrogen (MUN) is used as an indicator of nutrients imbalance in feeds (Trevaskis and Fulkerson, 1999), nitrogen usage efficiency (Aquino, *et al*, 2008) and protein-energy balance in the ration (Spohr and Wiesner, 1991). A high urea concentration has been associated with negative effects such as poor reproductive performance (Ferguson *et al*., 1993); poor cheese making as milk with high urea prolongs the coagulation time (Geerts *et al*., 2004); environmental pollution through high N excretion (Westwood *et al*., 1998); and excessive use of protein, which is a waste of an expensive resource (Geerts *et al*., 2004). The DMI and chemical composition of the ration influence MUN (Eicher *et al*., 1999) as a high level of protein intake and protein: energy ratio in the diet had been reported to be responsible for high level of MUN (Westwood *et al*., 1998; Aquino, *et al*., 2008). Therefore, the balanced supply of protein and energy might ensure optimal microbial protein synthesis and ammonia (NH_3) utilization by microbes. This happens only if degradation of protein and supply of readily fermentable carbohydrates is sufficient and synchronized (Eicher *et al*., 1999; Geerts, 2004). This can be achieved by using a complete balanced ration (TMR) which is well formulated, mixed and distributed.

Since *Leucaena* is palatable, digestible and nutritious it can be included in a TMR to reduce selectivity and the wastage associated with poor quality roughage, which may lead to over use of concentrates. Since the MUN test is considered to be an easy test for detection of imbalance in feeding and efficiency of use of protein, Jonker *et al*. (1999) suggested that the optimal MUN target range should be from 10–16mg/dl in dairy cows. These values were significantly lower than the values obtained by Geerts *et al*. (2004) in a trial using a complete diet for dairy cows (250mg/l). In a study to determine the effect of TMR with the inclusion of different sources of

RDP on milk yield of dairy goats, Laudadio and Tufarelli (2010) reported that the milk urea nitrogen content was increased by TMR with high digestible protein diet (RDP) containing soya bean meal 23.1 mg/dl compared to TMR with that from a low digestibility protein diet (RUP) containing corn gluten meal 21.7 mg/dl. However, the results were both above the target range reported by Jonker *et al*. (1999).

1.3.3. Leucaena intake, digestibility and their estimation

1.3.3.1. Intake

Feed intake is a tool used to determine the palatability or acceptance of diet. It measures the quantity of feedstuff ingested over a period of time (McDonald *et al*., 2002). The factors influencing feed intake among others are the nutritional value, palatability, anti-nutritive factors, parts of plant, season and feed processing (Norton, 1994a). The interaction between these factors ensures that a highly nutritious feedstuff is well accepted by the animals; therefore more feed is consumed thus improve animal performance. However during the winter, in summer rainfall areas most natural vegetation in rural areas of South Africa consists of plants of poor palatability which are characterized by low digestibility, low CP, a deficiency in minerals. Due to the physical strength of the plants against biting or grazing (Samanta *et al*., 2003), these pastures might be avoided by goats which are known as highly selective animals. An attempt to improve the ingestion of these feeds could be by using a zero grazing system where the inclusion of palatable legumes may be desirable as part of complete diets (TMR).

Leucaena is acceptable as inexpensive and locally available source of protein (Mtenga and Shoo, 1990) and can be incorporated with unpalatable species in order to optimize their consumption in a TMR. Many studies have been conducted to investigate the intake of *Leucaena* as a sole diet (Semenye, 1990; Gupta and Atreja, 1999; Bakshi and Wadhwa, 2007), supplementing low quality roughage (Yousuf *et al*, 2007 and Rubanza *et al*., 2007) and in TMR as a source of protein to substitute expensive commercial diets (Srivastava and Sharma, 1998). The results of these studies have shown an increase of daily DMI of the *Leucaena*. In contrast, Semenye (1990) observed a decline in DMI with time when *Leucaena* was used as a sole diet. Some authors reported that the daily DMI of diets including *Leucaena* was higher when compared to grass herbage alone (Mtenga and Shoo, 1990; Tomkins, *et al*., 1991), crop residues (Banda and

Ayoado, 1986) and other leguminous trees (Nyambati *et al*., 2006; Bakshi and Wadhwa, 2007). This level of intake was to some extent higher or similar to commercial concentrates (Srivastava and Sharma, 1998) when incorporated in the TMR. Although it is not easy to evaluate the feed intake of the animals grazing on pastures, several pen-experiments on feed intake resulted in measurable data.

1.3.3.2. Digestibility

Feed intake is influenced by ruminal fill, ruminal passage and rate of digestion, as highly digestible feed which passes through the gastro intestinal tract (GIT) quickly is consumed in greater amounts as compared to feed that passes through slowly (Norton and Poppi, 1995). Cottrill (1993) reported that highly degradable feeds pass through the rumen quickly and more space is created for feed intake. In this way digestibility of feeds is an important factor affecting nutrient availability, feed intake and animal production. The major part of ruminant digestion takes place in the rumen with the help of microbial activity. The rumen flora comprises over 200 species of bacteria, over 100 species of protozoa and around 15 species of fungi (Kamara, 2005). They are also responsible for the synthesis of microbial protein which is a major source of absorbable amino acids (Rode and Kung, 1996).

Several methods of determining the digestibility of *Leucaena* had been used: "*In vitro* gas production" (Bakshi and Wadhwa, 2007), "*In vivo* digestibility" (Adejumo and Ademosun, 1991), "*In situ* incubation" (Rubanza *et al*., 2007) either as the sole feed or when incorporated with other feeds. It has been observed in most studies that the dry mater digestibility (DMD) of nutrients decreased with increasing proportions of *Leucaena.* Srivastava and Sharma (1998) observed 74.16, 64.83, 56.04 and 51.85 DMD% from control diet, low, medium and high inclusion of *Leucaena* in the diets respectively. This was observed in spite of the fact that DMI increased with the increasing level of *Leucaena* in the diets of goats (29.2, 29.6, 33.0 and 40.0 DMI g/kg LW), from control diet to high level of *Leucaena* respectively (Srivastava and Sharma, 1998). This might be attributed to the high rate of passage or presence of secondary metabolites which affect microbial degradation. D'Mello (1992) cited by Srivastava and Sharma (1998) indicated that *Leucaena* leaves contain moderate amounts (30–43 g/kg) of condensed tannins. This content can result in a positive or an adverse effect on the nutritive value of the forage.

These tannins bind with protein and form complex compounds which resist microbial digestion (Srivastava and Sharma, 1998) and hence affect nitrogen utilization in the animals. On the other hand they play a crucial role in the context of outflow rate of RUP by improving the availability of amino acid in the small intestine mostly needed by high producing dairy animals especially in early lactation**.** It has been reported by Muller and Fales (1998) that in early lactation Metabolizable protein (MP) requirements of dairy animals are higher than the supply from microbial fermentation. Therefore, the animal will mobilize body protein reserves which could have an adverse effect on the health of a cow if it is continuously used (Schor and Gagliostro, 2001). The same principle might apply for the milk goat as well.

1.3.4. Effect of Leucaena on body weight and growth

There have been a number of investigations conducted to determine the effect of *Leucaena* on body weight and performance of goats (Srivastava and Sharma, 1998) and most of these studies showed a linear increase of body weight with days in experiment. Mtenga and Shoo (1990) studied the growth of indigenous goats and documented that *Leucaena* supplementation had a significant effect on daily gain. The goats supplemented with *Leucaena* at the rate of 100g, 200g per day, and *ad libitum* resulted in a body weight gain of 3, 9, 10 g/day more than the animals on the control diet respectively. Rubanza *et al.* (2007) obtained the same results as Mtenga and Shoo (1990) whereby the *Leucaena* forage resulted in higher body weight gain of goats as compared to goats on other browse tree fodders. The authors associated this increase of body weight gain with high crude protein intake and improved digestibility of the *Leucaena* based diet.

In contrast, despite the increase in nutrient intake, including CP percentage in response to increasing level of *Leucaena* inclusion in the diet of goats, Srivastava and Sharma (1998) observed no significant difference in terms of body weight (BW) gain. These authors associated this with poor digestibility of diets in response to increased levels of *Leucaena* in the diets. When *Leucaena* forage was used to supplement poor quality roughages, it resulted in a body weight gain which was similar to that obtained when commercial supplements like full fat soya bean meal, cotton seed oil cake meal and sunflower oil cake (Nyambati *et al*, 2006) were used. It is not only the leaves which provide the increase in body weight gain but the seedpods are also important when compared to other leguminous trees (Nyambati *et al*, 2006). The same authors demonstrated that a *Leucaena* seedpod meal diet resulted in an average daily gain of 486 g per day compared to those fed *Acacia* pods (250 g per day). The increase of body weight gain of goats observed by these authors might be attributed to the high CP value of *Leucaena*, its protein quality, digestibility potential and N-utilization potential in the rumen (Jones, 1994a).

1.4 The Limitation of *Leucaena leucocephala* as fodder for animals

Plants contain both primary and secondary metabolites, of which primary metabolites are considered as the important factors which determine the plant nutritive status (Norton, 1994b). Compared with primary metabolites, secondary metabolites have received relatively little attention, although their role is also of the importance for plant protection. Norton (1994b) indicated that plants compete with the predators in their ecosystem; therefore they have to develop defence mechanisms which can protect them for their survival and their establishment. Among these defence mechanisms plants produce chemicals, which act as deterrents to attack other organisms; however this can affect animals and nutritive value of the plants. The ruminant forestomach with the help of specific microbes is capable of degradation of these chemicals including toxic non protein amino acids and can effectively detoxify them (Jones, 1985).

1.4.1 Mimosine

Leucaena belongs to the family leguminosae (Mimosolidae). Like all species belonging to the sub family Mimosolidae it contains a toxic substance called mimosine (Jones, 1994a). Mimosine is a naturally occurring non-protein, free amino acid with a chemical formula (-[N-(3-hydroxy-4-oxopyridyl)]-α-aminopropionic acid) (Hammond, 1995) which is an antimitotic and depilatory agent (Hegarty *et al*., 1964 cited by Hammond, 1995; Vestena, 2001). The toxicity of *Leucaena* has been reported in chicks (D'Mello and Acamovic 1982), pigs (Muir, 1992), fish (Osman *et al*., 1996) rabbits (Lopez, *et al*., 2009), and in ruminants. Mimosine is present in all parts of the mimosolidae plants but with various proportions. A high concentration of mimosine occurs in the tips of growing shoots (8%–12%), young leaves (4%–6%) and young pods and seeds (45%–5%) (Jones, 1994a). However Adeneye (1991) recorded that the mimosine content of different edible parts of *Leucaena* ranged from 1.9%–12.3% on DM basis (Table 1.3).

Table 1.3: Mimosine content of different edible parts of *Leucaena leucocephala*

Edible part	Mimosine (% DM)
Twigs or shoots	10.8
Young leaflets	8.8
Young petiole	5.0
Young leaf	5.1
Mature leaflets	5.2
Mature petiole	1.9
Mature leaf	2.6
Green seed coat	0.0
Green cotyledon	5.1
Green seeds	3.2
Empty green pods	0.5
Green pods + seeds	2.8
Brown seed coat	0.0
Yellow cotyledon	12.3
Brown seeds	6.2
Empty brown pods	0.0
Brown pods + seeds	3.9

Source: Adeneye (1991)

The mimosine concentration can also be determined by the stage of plant development, season and harvesting time, drying method and treatment (Bray, 1994). Masafu (2006) recorded higher levels of mimosine in autumn than in summer and in air dried samples than in fresh samples in the Highveld of South Africa, although the time of harvesting did not show a significant effect on mimosine concentration in both seasons. Drought or moisture stress and heavy nitrogen fertilization have also been reported to increase the level of mimosine (Kumar and D'Mello, 1992).

Mimosine is considered as an anti-nutritive factor but it has a possible advantage to the plants in their self defence against mammalian herbivores and defoliation and as pharmacological agents

(Bernays *et al*., 1989). Mimosine can also potentially be used as a defleecing agent in the wool or mohair production as it inhibits cell division in wool follicles (Reis *et al*., 1999). However, mimosine may alter plasma concentration of some amino acids such as glycine and lysine (Reis *et al*., 1999). There is an optimal level of mimosine which will not have an adverse effect on the physiological function of the animal (Reis *et al*., 1999). Pharmacological properties include the inhibition of cardiac fibrosis; prevention of neuronal death; as antimicrobial agent (Vestena *et al*., 2001); and to block cell cycle progression in late G1 phase which is associated with human cancer (Chang *et al*.1999).

Although mimosine is considered as a toxic agent it does not cause many problems in the rumen, because most problems (which are rarely acute) are caused by mimosine derivatives (Jones, 1994b). The toxicity of mimosine in animals is associated with the interference of cellular mitosis and with alopecia.

1.4.2 Dihydroxypyridine (DHP)

Rumen fermentation of mimosine by ruminal microorganisms results in the production of the dihydroxypyridine (3, 4-DHP) and its isomers 2, 3- DHP (Hammond, 1995). The toxicity of *Leucaena* is mainly caused by this mimosine derivative (DHP) for unadapted ruminants and it is a potent goitrogen. The adverse signs of *Leucaena* toxicity in ruminants are alopecia, reduced weight gain, reduced fertility, excessive salivation, reduced appetite, enlarged thyroid, and depressed serum thyroxine (Hammond, 1995; Jones, 1994a). However, there was evidence that ruminant animals in certain areas did not show clinical symptoms after introduction of *Leucaena* (Jones and Megarrity, 1983). The absence of toxicity of *Leucaena* to ruminants was associated with the areas where *Leucaena* was native and it was concluded that the animals in these areas were adapted to *Leucaena.* In contrast, in areas where *Leucaena* was newly introduced, the animals were still susceptible and clinical symptoms were noticed (Jones and Megarrity, 1983; Jones, 1994b). The work of Jones and Megarrity (1983) resulted in the discovery of anaerobic rumen bacteria for detoxifying DHP to non toxic substances. It took almost a decade to assign the bacteria to a new genus and species-*Synergistes jonesii* (Allison *et al*., 1992).

1.4.3 Tannins

Tannins are polyphenolic compounds which have the ability to bind proteins and can be grouped as hydrolysable and condensed tannin**.** The content of tannin might result in positive or adverse effects in terms of feed efficiency and MP supply to the animals (Min *et al*., 2003). Tannins are anti-nutritional compounds in woody forage including *Leucaena* which impede the efficient use of nutrients by limiting intake and digestibility (McSweeney *et al*., 2001). The same author further indicated that tannin reduces digestibility by inhibiting digestive enzymes and rumen microbes, binding with feeds and forming complexes with polysaccharides. Tannin has also been shown to make protein, energy and minerals unavailable for microbial activity (McMahon *et al*., 2000) as it binds with protein and carbohydrates. These can reduce microbial growth and affect animal production and performance if woody legumes are fed in combination with grass containing low crude protein content (Mbugua *et al*., 2008). Hess *et al*. (2004) reported that the supplementation of lower quality grass with legumes of lower tannin content enhanced microbial activity and resulted to the effective degradation of organic matter and fibre. However, the supplementation of lower quality grass with legume of higher tannin and high protein quality content did not improve the value of diet. An advantage is that although the degradation of protein in the rumen by microbes provides ammonia and amino acids for microbial protein synthesis, tannin may form complexes with plant protein and this decreases protein degradability in the rumen. This then decreases rumen ammonia and amino acid concentration available for microbial protein synthesis, but increases plant protein escaping the rumen (Norton, 1994a). The proteins which bypass the rumen are important as they provide additional protein for absorption in the lower gut. The inhibition of protein degradation in the rumen is also beneficial to ruminants as it reduces the risk of bloat (Norton, 1994a).

1.4.4 Psyllid damage

The Psyllids (jumping lice) are small aphid like insects living on the shoots of *Leucaena* (Shelton and Brewbaker, 1994). These insects may result in a huge loss of biomass production of *Leucaena*. The production loss of *Leucaena* due to Psyllid infestations has been reported in different areas, Southern Queensland Australia (Bray and Woodroffe, 1991) and ln Sembawa in eastern Indonesia (Palmer *et al*., 1989). However, psyllid infestation has not yet reported in South Africa.

1.5 Management strategies to overcome toxicity of mimosine in animals

There were many approaches that have been used as attempt to reduce the toxicity of leguminous trees to animals. However, some of these methods have proved to be ineffective as the side effects of toxicity were still observed. Some of these approaches are believed to be not able to eradicate the toxicity completely for long term use although the clinical symptoms are not observed (Jones, personal communication).

1.5.1 Breeding of cultivars low in toxic compounds

Breeding programmes can be used successfully to produce varieties which are low in toxic amino acids but have high nutritive value. This can be achieved through crossing two cultivars of same family, one which is less toxic with another which is toxic but highly nutritious. The CSIRO division of Tropical Crops and Pastures successfully produced low mimosine *Leucaena* through crossing *L. pulverulenta* and *L. leucocephala* (Bray, 1986). However the use of this breeding strategy requires clear identification of various characteristics which are highly heritable. Untargeted traits may become more dominant, as Jones (1994a) showed that low mimosine levels were associated with high tannin levels.

1.5.2 The development of optimum level of inclusion of Leucaena in the diets of different animals

The proportion of *Leucaena* included in the diets of ruminants that do not possess the DHP - degrading bacteria should be reduced. *Leucaena* has been shown to be safely included up to 30 % of diet of goats without adversely affecting the production and health (Virk *et al*., 1991). In monogastric animals a level of *Leucaena* below 5% is recommended in their diets (Gupta and Atreja, 1999). However the long term use of this toxic plant can result to the cumulative toxins, therefore it is recommended that *Leucaena* should be used only for fattening the animals (Jones, 1994b).

1.5.3 Restriction and averting

Animals can be restricted from free access to the forage. This can be more easily achieved under zero grazing systems where the fodder can be cut and fed to the animals. In areas where legume is browsed, the toxic plant can be allowed to grow above browsing height (Wildin, 1985 cited by Jones, 1994a). The animals under this system can also be trained to avoid high consumption of toxic plants without completely eliminating them.

The successful aversive conditioning goats for reducing high consumption of *Leucaena* have been achieved by Gorniak *et al*. (2008). In their study the authors used lithium chloride to dose the animals immediately after consuming *Leucaena* forage and this dosage caused nausea to the dosed goats resulting in aversive behaviour.

1.5.4 The use of rumen micro-organisms capable of detoxifying the toxic compounds in legumes

The rumen hosts many microbes which are responsible for rumen fermentation. Allison *et al*. (1992) assigned the newly discovered bacteria a genus and species-*Synergistes jonesii* following the work done by several researchers after Jones and Megarrity (1983) reported their work. This bacterium is capable of detoxifying mimosine and its derivatives DHP into non toxic compounds. Following the work of Jones and Megarrity (1983), the bacteria were successfully distributed through rumen inoculation by dosing unaffected animals with affected rumen fluid and by natural distribution through faeces of affected animals grazing with unaffected animals (Jones, 1994a).

1.5.5 Strategies to overcome tannin problems

The treatment of tanniniferous feeds with alkalis and oxidizing agents have been reported to decrease both extractable tannin and condensed tannin (Makkar and Singh, 1993). However, these treatments have been reported to result in the loss of soluble nutrients (Ben Salem *et al.*, 2005). The use of higher affinity additives (polyethylene glycol (PEG)) to bind with tannins and the protein has been reported to improve nutritive value of legumes when it was used to deactivate tannin (Ben Salem *et al*., 2005). However, the problem of the use of PEG lies with its cost and unavailability and this therefore restricts its practical use (Ben Salem *et al*., 2005) especially in the rural areas of South Africa.

There have been other easy and cheap methods used to solve the tannin problem in animal feeds. Norton (2000) suggested the tannin dilution method to minimize the effect of tannin on the degradation of protein. In his work the author showed that the incorporation of tannin-rich legume with low tannin legume could optimise the benefits of tannin on the feed value and Metabolizable protein supply. Ben Salem *et al*. (2005) introduced a physical method of deactivating tannins as an alternative to the use of expensive and unavailable methods in the rural areas. The authors reported that the chopping and water spraying decrease the level of tannins after 7 days storage under anaerobic conditions. They also reported the use of 20 g/kg urea for 7 days and water soaking and wood ash or activated charcoal as other alternative methods to reduce tannin in the legumes.

1.6 Conclusion

Leucaena leucocephala is described as a tropical and subtropical tree. However under good management it can still survive in temperate areas including some parts of South Africa. Its characteristics of being deep rooted, multi-stemmed, having aggressive growth and adaptability under diverse environment can ensure the availability of enough forage for the animals throughout the year. Its nutritive value, intake and digestibility also ensure its potential as a fodder tree for animal production. But inadequate scientific information regarding its toxicity can limit its maximum utilization especially for the rural communities. The ingestion of *Leucaena* in large quantity might be harmful to the animals, reduce their production or even cause death. However, recently there have been several management strategies and efforts implemented in the attempt to overcome toxicity of *Leucaena* in animals. These strategies have been proved to improve the utilization of *Leucaena* by the animals hence improve production.

CHAPTER 2

Effect of harvesting season and drying method on chemical composition of *Leucaena leucocephala* forage

2.1 Abstract

This study was conducted to determine the chemical composition of *Leucaena* edible parts at different seasons and after different methods of drying. The different plant components from two drying methods (air and sun-drying) were analysed for dry matter (DM), ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), acid detergent lignin (ADL), calcium (Ca) and phosphorus (P). The air dried *Leucaena* leaves and pods had a significantly ($P<0.001$) higher percentage of CP than the sun dried *Leucaena* leaves and pods. In contrast, the CP values in the sun dried twigs were similar from the air dried twigs. The pods and twigs of *Leucaena* which were sun dried had a higher ADF than the air dried *Leucaena* pods and twigs. However, the *Leucaena* harvested during summer had higher CP concentration than the *Leucaena* harvested during autumn. There was a higher percentage of NDF and ADF for *Leucaena* pods and twigs harvested during autumn as compared to *Leucaena* harvested during summer. Mimosine content was higher in the leaves than in the pods and the twigs. In addition, the concentration of mimosine in the *Leucaena* leaves and pods was significantly higher during summer than in the autumn. The proportion of DM of the leaves was higher than that of the pods or twigs during the harvesting seasons.

Keywords: *Leucaena* forage, chemical composition, harvesting time, mimosine

2.2 Introduction

Leucaena has been known as a major and important source of protein for livestock in tropical areas for many decades due to its high protein content compared to other tropical legumes (Brewbaker, 1986). There are many reports on the utilisation of this leguminous shrub as fodder for animals that improved production (Ndemanisho *et al*., 1998; Waipanya and Srichoo, 1998; Yami, 2000; Nyambati *et al*., 2006). However, the use of *Leucaena* in the diet of goats is limited by the anti-nutritional factors present in this shrub (Hammond, 1995) and inadequate information on the feeding and nutritive value of this legume (Ngwa *et. al*., 2003) for milk goats. The most important anti-nutritional factor present in *Leucaena* is a toxic non protein amino acid called mimosine. The rumen fermentation of mimosine results in Dihydroxypyridine (DHP) (Hammond, 1995). Mimosine and its derivative DHP are responsible for metabolic disorders and poor performance associated with *Leucaena* feeding. The other anti-nutritional factors in *Leucaena* include tannin and lignin. These factors affect the normal degradation of feeds in the rumen which result in unavailability of nutrients for rumen microbes for protein synthesis. Environmental factors have a significant effect on the forage quality, where an increase in temperature increases the cell wall content and lignification and decreases the soluble carbohydrates (Hassen, 2006).

It is therefore crucial to determine the nutritional value of the individual edible parts of the *Leucaena* forage to avoid the over or under estimation of the use of any part when it is incorporated in the diet animals. Garcia *et al*. (1996) showed that there was more CP and mimosine in the leaves than in the twigs and the pods. In contrast, the leaves contained lower amounts of crude fibre, tannin and lignin when compared to the twigs and the pods. The chemical composition of the plant varies with species, plant part, season and soil type (Norton, 1994a), as well as state of hydration and drying procedure (Maasdorp *et al*., 1999). The stage of maturity or plant age also has a significant influence on the chemical composition of the plant at different seasons (Buxton, 1996) whereby the older plant has a decrease in soluble nutrients and an increased of cell wall as compared to young plants. Therefore it is important to determine the chemical composition of the *Leucaena* in different growing seasons. This information will help the farmers in the rural areas of South Africa to adjust the amount of plant fraction that is needed to meet specific requirements of animals. The major focus of this study was therefore to assess the nutritional value of edible parts of *Leucaena* hay after using different drying methods and in relation to the harvesting season.

2.3 Materials and methods

2.3.1 Harvesting of Leucaena leucocephala

Leucaena forages were harvested during autumn of 2008 where the plants had been cut down to approximately 30cm at the end of the growing season. The new growth had begun to resprout at the beginning of the rainy season (November 2008) and was harvested during summer (January to March). The harvesting period was extended to March in order to obtain the pods which were few and had not matured during the commencement of harvesting. After harvesting, the forages were dried with exposure to the sun (sun dried) or under the shade (air dried). The harvested components were stored in an old animal shed with open windows and entrance to provide sufficient ventilation. The place was well roofed which kept it dry and with normal room temperatures.

2.3.2 Preparation of Leucaena leucocephala edible components

After drying, the *Leucaena* edible components (leaves, twigs and pods) were carefully separated from branches and sorted into leaves, pods and twigs. The twigs were regarded as part of shoots and small stems<3 mm in diameter as it was assumed that goats would eat twigs up to this diameter. The individual components were separately ground in order to evaluate proportion of *Leucaena* edible components. The dried plant components/fractions were stored under the shaded area until required time for feed formulation. Prior to the laboratory analysis, the samples were thoroughly mixed, dried and milled through a 1 mm sieve. Representative samples were taken in duplicates or triplicates for chemical analysis at the Nutrition Laboratory, at the University of Pretoria.

2.3.3 Samples analysis

Representative samples were prepared and analysed for dry matter, ash, organic matter, crude protein, neutral detergent fibre, acid detergent fibre, acid detergent lignin, calcium and phosphorus concentration. All samples were analysed in duplicates or triplicates to estimate experimental error. If the error was over 5% a third sample was prepared and analysed until the average percentage of less than 5 was achieved.

2.3.3.1 Dry Matter determination

The dry matter was determined by weighing 2 g of each sample into crucibles in duplicates which were oven dried at a temperature of 105°C throughout the night. On the next day the crucibles were cooled in desiccators and weighed again. The dry matter percentage was obtained as:

$$\frac{\text{Mass of sample after oven dried}}{\text{Initial sample mass}} \times 100$$

2.3.3.2 Ash determination

The procedure was the same as the one used for DM determination. After weighing, the samples were then placed in muffle furnaces at 250°C for 1 hour then at 55°C for 4 hours. After 5 hours, the furnace was switched off and crucibles were left over night. The next morning the crucibles were cooled as stated under DM determination and the ash samples were then weighed.

Ash was determined as:

$$\frac{\text{Mass of Ash}}{\text{Initial sample mass}} \times 100$$

Ash on a DM basis:

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

2.3.3.3 Organic Matter determination

The OM was obtained as the difference between %DM and %Ash

%OM=DM % - Ash %

OM as DM basis

%OM (DM based)=100% - %Ash (DM)

2.3.3.4 Determination of Neutral Detergent Fibre (NDF)

The air dried samples were milled to pass through a sieve with 1mm diameter circular open. They were then accurately weighed to 1gram into glass crucibles.

The NDF determination was performed following the procedure described by Robertson and Van Soest (1994).

NDF percentage (% NDF) was expressed as

$$\frac{RCD - RCA}{\text{Original sample mass}} \times 100$$

Where: RCD = residue in crucible after drying

RCA = residue in crucible after ashing

$$\text{NDF as DM basis} = \frac{\%NDF}{\%\ DM} \times 100$$

2.3.3.5 Determination of Acid Detergent Fibre (ADF)

The air dried samples were milled to pass through a sieve with 1mm diameter circular open. They were then accurately weighed to 1gram into glass crucibles.

The ADF determination was done following the procedure described by Goering and Van Soest (1970).

ADF percentage (% ADF) was expressed as

$$\frac{W_2 - W_3)}{W_1} \times 100$$

Where: W_1 = Mass of original sample, in g

W_2 = Mass of residue in crucible after drying, in g

W_3 = Mass of residue in crucible after ashing, in g

Safety precautions and normal laboratory practices were followed.

2.3.3.6 Determination of Acid Detergent Lignin (ADL)

The ADL determination was performed following the procedure previously described by Goering and Van Soest (1970).

The samples were treated in accordance with the method used for ADF; however the samples were retained in crucibles after the overnight and drying. The samples were not ashed but were treated as described by Goering and Van Soest (1970).

ADL percentage (% ADL) was expressed as

$$\frac{RCD - RCA}{\text{Original sample mass}} \times 100$$

Where: RCD = residue in crucible after drying

RCA = residue in crucible after ashing

As DM basis = $\frac{\%ADL}{\% DM} \times 100$

2.3.3.7 Determination of Nitrogen concentration and Crude Protein (CP)

Nitrogen was determined following the procedure described in the instructions of 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:

$$\% N \times 6.25$$

This was then corrected to DM as indicated earlier for Ash, OM, NDF and ADF.

2.3.3.8 Determination of Mimosine

The determination of mimosine was performed following these procedures

- Extraction of samples
- Extraction of mimosine from *Leucaena* samples was done as described by Garg *et al*. (2001).
- Mimosine was extracted in dilute HCl and gave colour reaction with $FeCl_3$ and absorbance was measured at 535nm. This was followed by decolourisation of extract, preparation of standard curve and estimation of mimosine concentration.

2.3.4 Statistical analysis

The data were subjected to analysis of variance (ANOVA) using procedure of General Linear Model (GLM) procedure of SAS (2004) to investigate the effect of drying method and growing season to chemical composition of *Leucaena*. The means were ranked using Duncan's multiple range test for different season data and Turkeys' test for drying methods data by processing in personal computer (Samuel, 1989).

2.4 Results

2.4.1 Effect of different drying methods on chemical composition

The results of the chemical composition of *Leucaena* dried with two different methods (air and sun dried) are presented in the Table 2.1.

Table 2.1 : Chemical composition of air dried and sun dried *Leucaena* (Least square means ±se)

	Method of drying				
Parameters (g/kg DM)	air-dried	Sun-dried	±se	p-value	Effect
Leaves					
CP	240.30	208.70	±7.180	0.0001	***
NDF	282.70	318.30	±11.200	0.1014	NS
ADF	209.00	208.70	±6.200	0.9404	NS
Ca	13.00	11.00	±0.240	0.0913	NS
P	1.80	1.90	±0.080	0.2879	NS
Mimosine	0.11	0.09	±0.005	0.0340	*
Pods					
CP	183.30	103.30	±18.360	0.0001	***
NDF	492.30	663.70	±30.460	0.0019	**
ADF	379.30	548.30	±43.890	0.0001	***
Ca	2.50	3.50	±0.730	0.0325	*
P	2.00	1.80	±0.210	0.0213	*
Twigs					
CP	131.70	129.70	±3.840	0.0983	NS
NDF	594.30	602.30	±6.930	0.0614	NS
ADF	414.70	494.30	±20.690	0.0087	*
Ca	6.10	5.70	±1.260	0.0705	NS
P	1.80	1.70	±0.230	0.2879	NS

NS: not significant, *P<0.05, **P<0.01, ***P<0.001

2.4.1.1 Crude protein

The CP values in the air dried *Leucaena* leaves and pods were significantly (P<0.001) higher than CP values in the sun dried leaves and pods. In contrast the CP values in the twigs were similar from the air and sun drying methods (131.7 and 119.7 ± 3.84 g/kg DM respectively).

2.4.1.2 Fibre content

Similar values were recorded for air dried or sun dried *Leucaena* leaves in terms of NDF and ADF (282.7 *vs* 318.3±11.20 and 209.0 *vs* 208.7±6.20 g/kg DM, respectively), and for *Leucaena* twigs fraction in terms of NDF. However, notable differences were recorded for the pods in terms of NDF and ADF, as well as for the twigs in terms of ADF. The sun dried method resulted in significantly (P<0.05) higher NDF (663.7± 30.46 g/kg DM) and ADF (548.3 ± 43.89 g/kg DM) values for the pods than from air dried pods (492.3 ±30.46 and 379.3±43.89 g/kg DM). The value of ADF for twigs followed similar trends, whereby the sun dried *Leucaena* twigs had significantly (P<0.05) higher ADF than air dried *Leucaena*.

2.4.1.3 Minerals

The concentration of P and Ca were similar in the leaves and twigs for air and sun dried *Leucaena*. Similarly the concentration of Ca in the air dried pods (2.5± 0.73 g/kg DM) was lower than Ca in the sun dried pods (3.5± 0.73 g/kg DM). In contrast, the concentration of P in the air dried pods was significantly (P<0.05) higher than P concentration recorded in the sun dried pods.

2.4.1.4 Mimosine concentration

The difference between drying methods of *Leucaena* leaves in terms of mimosine concentration was significant (P<0.05). Air dried *Leucaena* leaves (0.11 ± 0.005 g/kg DM) had significantly higher (P<0.05) mimosine concentration than the sun-dried *Leucaena* leaves (0.09 ± 0.005 g/kg DM).

2.4.2 Effect of season of harvest on nutritional value of Leucaena edible components

The *Leucaena* harvested during summer was the re-growth of the established *Leucaena* plants that had occurred from the start of the rainy season in November of the previous year. The harvest during summer was performed twice and differed in the availability of pods (early harvest excluded the pods and late harvest included the pods).

The nutritional value of *Leucaena* components during three different harvesting seasons (summer and autumn) are presented in Table 2.2

Table 2.2 : Chemical composition of *Leucaena* components harvested at different seasons (Least square means ±se)

	Season of harvest					
Parameters (g/kg DM)	Early Summer	Late Summer	Autumn	±se	p-value	Effect
Leaves						
CP	227.3^{a}	226.3^{a}	201.00^{b}	±5.600	0.0097	**
NDF	286.7^{b}	266.7^{c}	309.30^{a}	±8.000	0.0010	**
ADF	220.0	205.7	203.70	±5.400	0.8281	NS
Ca	2.0	2.0	1.70	±0.100	0.5906	NS
P	20.4^{a}	20.5^{a}	0.17^{b}	±2.000	0.0013	*
Mimosine	–	0.12^{a}	0.07^{b}	±0.010	0.0020	**
Pods	–					
CP	–	154.0^{a}	108.30^{b}	±11.710	0.0001	***
NDF	–	558.3^{b}	632.70^{a}	±30.710	0.0013	**
ADF	–	454.7^{b}	525.70^{a}	±30.580	0.0001	***
Ca	–	1.90^{a}	1.40^{b}	±0.290	0.0036	**
P	–	5.60	4.50	±0.490	0.7486	NS
Mimosine	–	0.11^{a}	0.03^{b}	±0.020	0.0024	**
Twigs						
CP	136.70^{a}	137.00^{a}	96.70^{b}	±8.010	0.0265	*
NDF	494.30^{c}	593.00^{b}	630.00^{a}	±21.19	0.0001	***
ADF	408.70^{c}	479.70^{b}	541.30^{a}	±22.800	0.0256	*
Ca	1.60	1.50	1.50	±0.100	0.2307	NS
P	11.60^{a}	11.60^{a}	5.70^{b}	±1.060	0.0001	***
Mimosine	–	0.05	0.05	±0.003	0.8394	NS

Means with different superscript ($^{a, b, c}$) along the same rows differ significantly (P<0.05)

NS: not significant, *P<0.05, **P<0.01, ***P<0.001

2.4.2.1 Crude protein

The CP values in the leaves, pods and twigs during different harvesting seasons differed significantly (P<0.05). The CP values in the leaves pods and twigs during the autumn harvest were significantly (P<0.05) lower than CP values during summer harvest, while the CP values between early and late summer harvest did not differ (P>0.05) for leaves and twigs.

2.4.2.2 Fibre concentration

There were significant differences between different harvesting seasons in terms of NDF and ADF for *Leucaena* leaves pods and twigs. *Leucaena* leaves and pods had higher (P<0.05) NDF concentration during the autumn harvest than the summer harvest. However, there were no differences in terms of ADF for *Leucaena* leaves harvested during early summer (220.0 ± 5.43

g/kg DM), late summer (205.7 ± 5.43 g/kg DM) or autumn (203.7 ± 5.43 g/kg DM). *Leucaena* pods had a significantly higher (P<0.001) NDF and ADF during the autumn harvest than in summer.

2.4.2.3 Mineral concentration

Leucaena leaves and twigs had higher (P<0.05) P concentration during the summer harvest than during the autumn. A similar trend was recorded in the *Leucaena* pods in terms of Ca concentration. In contrast, harvesting season had no effect on the Ca composition of the leaves and twigs of the *Leucaena*. The concentration of P in the pods appeared to be lower during the autumn season than the late summer, but the difference was not significant (P>0.05).

2.4.2.4 Mimosine concentration

The effect of harvesting season on the concentration of mimosine in the *Leucaena* edible components in different harvesting seasons are presented in Table 2.3. Season had significant effect (P<0.01) on the *Leucaena* leaves and pods in terms of mimosine concentration. The concentration of mimosine was significantly higher (P<0.001) in both leaves and pods during late summer as compared to autumn. In contrast, the harvesting season had shown no significant effect (P>0.05) in terms of mimosine concentration of *Leucaena* twigs.

2.4.3 Proportion of dry biomass of individual edible components of Leucaena in three harvesting periods

During April 2008, January and March 2009 the area of one hectare was harvested and edible branches were randomly picked to separate the biomass into three *Leucaena c*omponents in order to determine their proportion in *Leucaena* meal.

The results for the proportion of *Leucaena* edible components for the three harvesting season are presented in Table 2.3.

Table 2.3: Proportion of dry biomass of *Leucaena* components in three harvesting periods (Least square of means)

Leucaena components (kg/tonne)	Harvesting periods		
	Early summer	Late summer	Autumn
Leaves (kg/tonne)	723.30^{a}	590.00^{a}	516.70^{a}
Pods (kg/tonne)	-	236.70^{b}	338.30^{b}
Twigs (kg/tonne)	276.70^{b}	173.30^{c}	111.70^{c}
±se	±100.30	±65.21	±58.77
Sig. level	0.0001	0.0001	0.0001

Means with different superscript (^{a,b,c}) along the same column differ significantly ($P<0.001$)

There was a highly significant difference ($P<0.001$) between the amount of *Leucaena* biomass edible components in terms of kg per tonne during all harvesting periods. The amount of *Leucaena* leaves (723.3 ± 100.30 kg/tonne) was significantly higher ($P<0.001$) than the *Leucaena* twigs (276.7 ± 100.30 kg/tonne) during early summer harvest (January), however the pods were not available during this time. The amount of *Leucaena* leaves (590.0 ± 65.21 kg/tonne and 516.7 ± 58.77 kg/tonne) was also significantly higher ($P<0.001$) than both the *Leucaena* pods (236.7 ± 65.21 kg/tonne and 338.3 ± 58.77 kg/tonne) and the *Leucaena* twigs (173.3 ± 65.21 kg/tonne and 111.7 ± 5 8.77 kg/tonne) during both late summer harvest (March) and autumn harvest respectively. However, the proportion of pods was also significantly higher ($P<0.001$) than the proportion of the twigs during these two harvesting seasons.

2.4 Discussion

It was important to evaluate and compare effect of two drying methods (sun and air dried) on the chemical composition as previously undertaken by Masafu (2006) for *Leucaena* forage. The present study has demonstrated that *Leucaena* edible components differed significantly ($P<0.05$) in chemical composition, whereby there was higher nutrient content of the leaves as compared to twigs and pods. There was a higher amount of CP content in leaves (208–240 ± 7.18g/kg DM) as compared to pods and twigs (103–183 ± 18.3g/kg DM and 120–132 ± 3.8g/kg DM) respectively. These values were within the range reported by Karachi (1998) for leaves and twigs of different varieties of *Leucaena*. However, the values of the present study were slightly lower than values reported by Garcia *et al*. (1996) for leaves, pods and twigs of the same plant. The fibre content was found to be significantly lower ($P<0.01$) in leaves than in twigs and pods. A similar pattern of higher CP in leaves with low values of NDF and ADF as compared to other components had been previously reported for other leguminous species such as *Acacia nilotica* (Rubanza *et al*., 2007), *Calliandra calothyrsus* and *Acacia boliviana* (Maasdorp *et al*., 1999), *Gliricidia sepium* (Richards *et al*. 1994) and five *Indigofera* species (*I. amorphoides, I. arrecta, I. brevicalyx, I. castata and I. cryptantha*) (Hassen *et al*., 2007).

The P values appeared to be similar for the different *Leucaena* components (leaves (1.8–1.9 ±0.08g/kg DM; twigs 1.8–2.0 ±0.21g/kg DM and pods1.7–1.8±0.23 g/kg DM). These values should be sufficient to meet maintenance requirements of mature lactating goats (NRC, 2007) depending on the DMI. However, appreciable differences were observed between *Leucaena* components for calcium concentration. The results for the present study showed that the values for calcium in the *Leucaena* leaves were significantly higher ($P<0.05$) than for either *Leucaena* twigs or *Leucaena* pods. The level of calcium for *Leucaena* components ranged between 2.5–13.0 g/kg DM and this level is within the recommended range for lactating goats (NRC, 2007). The results for phosphorus and calcium content were in agreement to report by Karachi (1998), who reported the similarity in phosphorus analysis and variation in calcium analysis between *Leucaena* leaves and twigs with a range of 1.8–2.2 g/ kg DM and 3–9 g/kg DM, respectively.

Method of drying forage is one of the factors which can affect the nutritional value of the forage. Poor storage will expose the forage to environmental effects which makes effective drying difficult. This was observed when almost half of the forage was lost during the autumn harvest period after rain fell at a time it was not anticipated during sun drying. In the present study it was observed that the air-drying method was the better method of drying *Leucaena* as compared to sun-drying. Consistent with the results of Masafu (2006), the sun drying method reduced the CP value of leaves and twigs as compared to air-drying. The CP values obtained in this study were similar to the findings reported by Aletor and Omodara (1994) for leguminous browse plants. The fibre and lignin content of *Leucaena* components were also reduced by the air drying method as compared to the sun drying, and this was in agreement with results previously reported by Masafu (2006). The Ca concentration (13 g/kg DM) and P concentration (2.0 g/kg DM) recorded in this study for air dried *Leucaena* leaves were similar to the results reported by Aletor and Omodara (1994).

The maturity stage is another factor which can affect the nutritional value of the plant. The older plants had higher fibre and lignin, while there was less CP and digestible organic matter. This has been confirmed by the results of Hassen *et al.* (2007) for the effect of season on nutritive value of five *Indigofera* species (*I. amorphoides, I. arrecta, I. brevicalyx, I. castata and I. cryptantha*). These authors showed that all species studied had increased ($P<0.05$) ash, CP and IVDOM concentration in the spring when plants were young as compared to autumn when plants were old. In the present study there was also higher CP and lower NDF and ADF concentration of *Leucaena* components during the summer harvesting than in the autumn. Similar results showing a decline in CP and ash and an increase in NDF with age were reported by Garcia *et al.* (1996).

There was a relationship between the level of mineral concentration and the season of growth as previously observed for five *Indigofera* species (Hassen *et al*., 2007). The authors observed high levels of minerals in the spring compared to the autumn. In the present study it was observed that mineral content also decreased with the age of the plant and that there were significantly ($P<0.05$) higher minerals (Ca and P) concentrations during the summer compared to autumn.

The results of the present study showed that there was variation of mimosine concentration in the leaves, twigs and pods. A similar variation between the leaves and twigs in air dried summer samples were observed by Masafu (2006) for *Leucaena*. The mimosine value was high in the young leaves (during summer harvest) as compared to the old leaves (autumn harvest). A similar pattern of a decline of mimosine concentration with extended growth for the leaves was previously observed by Tangendjaja *et al*. (1986) for *Leucaena* leaves. The authors observed high levels of mimosine (40–50 g/kg dry weight) in young leaves but the level fell rapidly within five weeks to 10 g/kg DM, and at week 10 the level then gradually decreased to about 2 g/kg DM. In the present study the level of mimosine dropped significantly from 0.12 ± 0.01 g/kg DM and 0.11 ± 0.02 g/kg DM in summer to 0.07±0.01 g/kg DM and 0.03±0.02 g/kg DM in autumn for leaves and pods, respectively. The findings of this study also revealed that the immature pods (summer harvest) contained higher mimosine concentration than the dry pods (autumn harvest). This could be attributed to the fact that the dry pods might have ruptured and lost the seeds, which have been reported to contain higher mimosine content than any other *Leucaena* part (Adeneye, 1991). In contrast to what was observed in the leaves and pods, the concentration of mimosine in the twigs was not affected by the age of plant or season of harvest. However the levels of mimosine measured in this study for the leaves were relatively low as compared with the results observed by other authors (Tangendjaja *et al*., 1986; Adeneye, 1991). This might be attributed by the use of the dried *Leucaena* forage in this study.

The proportion of pods recorded during three harvesting months increased with time while the proportion of twigs decreased with the age of plant. This can be attributed to the fact that the pods develop late in the growing season of the plant and most harvest is attained during the last growing months. On the other hands the edible twigs are only obtained during the early stage of the plant but when the plant gets older the plant stems become tougher and hence are neglected by the animals. The plant cell wall and plant lignin increases with the age of the plant, therefore there was a relatively lower proportion of stem (<3mm) obtained during the last month. The proportion of leaves also decreased with time due to an increase in amount of pods with time.

CHAPTER 3

The inclusion of *Leucaena leucocephala* forage in the diet of milk goats: Effect on the milk yield, milk quality and body condition.

3.1. Abstract

The purpose of this study was to compare the effect of a total mixed ration (TMR) with or without *Leucaena* on body condition score (BCS), milk yield and milk quality of Saanen milk goats. The results indicated that the inclusion of *Leucaena* in a TMR had no effect on most parameters, with the exception of milk urea nitrogen (MUN) (mg/dl) and milk protein. The mean daily milk yield was 1.65 and 1.67 ± 0.125 litres for the goats fed the TMR with *Leucaena* and for the goats fed the TMR without *Leucaena* (control diet), respectively**.** There was no significant (P>0.05) difference between goats fed the TMR with or without *Leucaena* in terms of milk fat (%), milk lactose (%), somatic cell count (SCC) (x10^6 cell/ml) during the entire lactation period**.** In contrast, the goats fed the TMR without *Leucaena* had a significantly higher (P<0.001) MUN than the goats fed TMR with *Leucaena* for both morning and afternoon milk. The animals fed the TMR with *Leucaena* produced higher (P<0.05) milk protein in the morning milk than goats fed TMR without *Leucaena* (3.0 *vs* 2.8% ± 0.05%), respectively. There was also no significant difference between the goats fed two diets in terms of BCS and body weight (BW) during the lactation period.

It is therefore concluded that the *Leucaena* diet supported a similar level of milk yield and quality as that from goats fed the conversional diet and had no adverse effect. There was also no adverse effect on body weight and body condition.

Key words: Milk goats, TMR, *Leucaena*, milk yield and milk composition

3.2. Introduction

Goat milk production is expected to play a crucial role in rural communities as it has potential to alleviate malnutrition and poverty. The nutritive value of the milk is directly influenced by the nutritive value of the feedstuff ingested, its palatability, digestibility and its chemical composition. If the feed is not palatable, the dry matter intake (DMI) may be inadequate to supply the nutrients required by milk goats for maintenance and production. There is high energy demand during late pregnancy and during lactation (NRC, 2007) and therefore care must be taken to avoid nutritional diseases and metabolic disorders such as ketosis that could arise due to high glucose demand (Donkin, 1997). The milk goat requirements during lactation may differ depending on breed, lactation stage, age, body weight as well as the number of kids born.

The major constraint hindering the performance of milk goats in the rural communities is poor nutrition (seasonal shortage of energy, protein and minerals) (Donkin, 1997). The high cost of commercial concentrates makes it difficult for small-scale farmers to solve this problem. Therefore the use of trees as fodder for animals is an alternative feed source that needs to be investigated especially for smallholder farmers (Donkin, 1997) as they are locally available. The inclusion of *Leucaena* in the diets of livestock has been shown to improve the palatability of feedstuffs, especially when supplemented to poor quality hay during droughts and in dry areas (Jones, 1979; Mtenga and Shoo, 1990; Waipanya and Srichoo, 1999).

The objective of this study was to measure the performance of milk goats fed a TMR with the inclusion of *Leucaena* as source of protein compared to a TMR without *Leucaena*, formulated using oilseed cake meal (OSCM).

3.3 Materials and methods

3.3.1 Experimental diets

Two experimental diets were prepared for this trial. The first diet contained 25% of *Leucaena* forages which replaced OSCM in the TMR. The second diet was a positive control without *Leucaena* but contain approximately 26% OSCM. In the first diet there were times when the pods were included (LFP) (October, November, March and April) and where they were excluded (LF) (December to February) depending on their availability during the growing season as this had a small effect on the analysis (Table 3.1). The experimental diets were thoroughly mixed and fed to the animals as a TMR to minimise selection by the goats and to maximise intake of the roughages included in the TMR. The DMI was estimated in this experiment.

Table 3.1: Chemical composition of TMR with and without *Leucaena* fed to milk goats

	Nutrient (DM %)						
Parameter	CP	NDF	ADF	ADL	Ash	Ca	P
TMR+LFP	13.9	54.8	27.5	6.6	6.7	0.4	0.3
TMR+ LF	13.6	51.8	27.7	7.1	7.2	0.8	0.4
TMR without *Leucaena*	13.5	50.4	27.4	6.2	6.0	0.8	0.5
±se	±0.13	±0.74	±0.18	±0.18	±0.14	±0.06	±0.02

Source: analysis Nutrition laboratory, University of Pretoria. TMR+LFP: TMR with *Leucaena* forage with pods. TMR+LF: TMR with *Leucaena* forage without pods

3.3.1.1 Preparation of diets

Leucaena was harvested three times during the growing season as described in Chapter 2 Section 2.3.2. The other ingredients were purchased from the local market. *Eragrostis* hay and *Leucaena* forages were chopped using a hammer-mill with 25 mm diameter sieve, and then they were thoroughly mixed with the concentrates to prevent feed selectivity. Both TMRs with or without *Leucaena* were formulated to be iso-caloric, iso-nitrogenous and iso-NDF. The main source of protein was *Leucaena* forages comprising 25% of the first experimental diet and OSCM (full fat soybean meal, cotton seeds meal and sunflower meal) comprising 26% of control diet (Table 3.2). The feeds were formulated using the Langston University Goat Research and Extension programs (2000) and balanced to achieve the required nutrient content for the lactating goats

(NRC, 2007) based on the recommendation for moderate yielding goats because the goats used in this experiment were not high yielding. However the formulation of diet would have been adjusted for higher yielding goats as described by NRC (2007) if they would have been used.

Table 3.2: Ingredients and chemical composition of total mixed rations fed to Saanen milk goats.

	Total mixed ration		
Ingredients (%)	[1]without *Leucaena* pods	[2]with *Leucaena* pods	[3]without *Leucaena*
Yellow maize meal	22.0	20.0	27.0
Eragrostis curvula	18.0	24.0	30.0
Leucaena	25.0	25.0	0.0
Wheat bran	8.0	8.0	8.0
Cotton seed oil cake meal	9.0	7.0	11.0
Sunflower oil cake meal	9.0	7.0	11.0
Full fat soybean meal	0.0	0.0	4.0
Molasses meal	7.0	7.0	7.0
Mineral mix[4]	2.0	2.0	2.0
Chemical composition[5]			
CP	15.0	15.0	15.0
CF	16.8	16.9	15.7
TDN	60.0	60.0	62.0

[1]Total mixed ration without *Leucaena* pods, [2]Total mixed ration with *Leucaena* pods,
[3]TMR: Total mixed ration without *Leucaena*
[4]Limestone flour, Salt, Di- calcium phosphate, sodium bicarbonate vitamin pre-mix.
[5] Expected analysis as feeds were formulated as described by Langston University Goat Research and Extension programs (2000)

3.3.2 Experimental animals

Thirty Saanen milk goats in their first, second and third lactations were used in this trial. Mean initial body weight of the goats used was 54.8 ± 1.95 kg. The goats were divided into two groups: *Leucaena* group and control group. There were a total of 15 goats in each group where each group was blocked into three according to lactation number (five goats in each block). The goats were also assigned to the groups on basis of their milk yield history. There were only lower to moderate yielding goats used as to achieve this number (30 goats), and the higher yielding goats in the herd were not used as they were fewer in number at the commencement of this experiment.

3.3.3 Experimental design

The Complete Randomised Block Design (CRBD) was used in this experiment. There were two treatments allocated to three groups of goats that had five goats per group resulting in thirty experimental units.

3.3.4 Milking procedure and recording

The goats were milked in a milking parlour which allowed six goats to be milked at a time. The strip cup was used to collect foremilk from each quarter at every milking time to all goats. Milk yield was measured with Waikato milk meters during milking and manually recorded. The goats were milked twice a day at 07:00 to 09:00 in the morning and 14:00 to 16:00 in the afternoon. The first goats to be milked in the morning were also the first to be milked in the afternoon.

3.3.5 Milk sampling and analysis

The milk samples from two consecutive morning and afternoon milking were collected monthly for seven months. The milk samples were drawn from the milk meter to small bottles (50 ml) containing preservative. The preservative was allowed to dissolve and was well mixed, by carefully shaking the bottles. The samples were then transported to Lactolab at Irene and analysed for milk fat, lactose, protein, somatic cell count (SCC) and milk urea nitrogen (MUN) using a Milko-Scan-Foss Electric Analyser.

3.3.6 Body condition score and body weight

The Body Condition Score (BCS) and body weight were assessed on fortnightly basis, throughout the entire experiment. However the weight was recorded as monthly weight as two fortnight weights were added together and divided by two. The BCS was used to indicate the fat reserves during lactation. The score used ranged from 1.0–5.0 and half scores were used as intermediate point as described by Santucci *et al*. (1991). BCS was used to estimate fat cover in the lumbar region and the brisket fat-pad. The animals were also weighed at the beginning of the experiment then fortnightly using an electronic scale.

3.3.7 Statistical analysis

The parameters were subjected to analysis of variance (ANOVA) in a Complete Randomised Block Design (CRBD) using the General Linear Model (GLM) procedure of SAS (2004) to test for statistical difference between treatments. The treatment means were ranked using Tukey's test by programming and processing in a personal computer (Samuel, 1989).

3.4 Results

3.4.1 Milk yield

The results for the milk yields of goats fed TMR with or without *Leucaena* are presented in Table 3.3. There was no significant difference (P>0.05) in milk yield of goats fed TMR with or without *Leucaena* during morning milking, afternoon milking and for the average daily milk.

Table 3.3: Milk yield from Saanen milk goat fed TMR with and without *Leucaena* (Least square of means)

	Total mixed ration				
Parameter (kg/head/day	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
Morning milk yield	1.28	1.25	±0.09	0.9398	NS
Afternoon milk yield	0.39	0.38	±0.07	0.8435	NS
Average daily milk yield	1.70	1.70	±0.02	0.8748	NS

NS: Non significant

The mean milk yields recorded during the seven months of lactation period are presented in Fig. 3.1. Genetically the goats in both groups were not high yielding animals (Table 3.3 and Fig. 3.1, Section 3.4.1) as all animals showed moderate levels of milk production. The milk yield was lower for the first month of lactation period; however milk gradually increased on the second and third month then significantly declined during the last four months. Peak milk yield occurred in the second and third month with a mean of 2.0 and 2.4 ± 0.16 litres for goats fed TMR without and with *Leucaena*, respectively. The mean daily milk yield of animals fed TMR without the *Leucaena* appeared to be slightly higher in the first two months than during the fifth and sixth months as compared to animals fed the TMR with the *Leucaena*. However, the goats fed the TMR with *Leucaena* appeared to produce higher milk yield than goats fed the TMR without *Leucaena* during the third, fourth and on the last month. But these apparent differences observed in all these periods were not statistically significant (P>0.05).

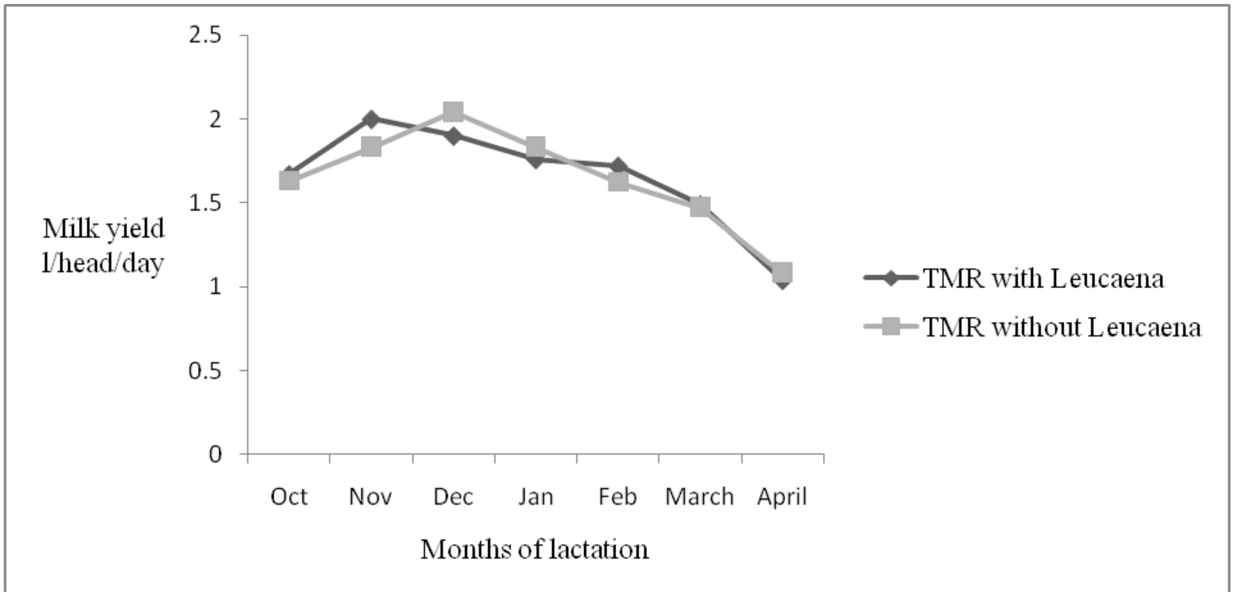

Fig 3.1 Lactation curves for Saanen milk goats fed TMR with or without *Leucaena*

3.4.2 Milk composition and weighted daily averages

The milk produced during the seven months of lactation period was analysed for milk fat, protein, lactose, milk somatic cell count and milk urea nitrogen.

The weighted daily milk composition averages were calculated as follows;

The milking times were at 07:00 and 14:00 each day, which resulted in unequal intervals between milkings. Therefore weighted averages for daily milk composition criteria were calculated from the percentage composition and milk yield at each milking. From these, the mean milk composition was calculated for each day that measurements were then recorded.

The results for milk composition and weighted daily averages are presented on Table 3.5.

Table 3.4: Milk composition and weighted daily averages of Saanen goats fed TMR with or without *Leucaena* (Least square of means)

Parameters	Time	Total mixed ration with *Leucaena*	Total mixed ration without *Leucaena*	±se	P-value
Milk composition					
Milk fat (%)	am	2.50	2.40	±0.0900	0.3272
	pm	3.90	3.80	±0.1000	0.6077
Milk protein (%)	am	3.00[a]	2.80[b]	±0.050	0.0471
	pm	3.00	2.90	±0.060	0.3329
Milk lactose (%)	am	4.50	4.40	±0.050	0.4163
	pm	4.30	4.40	±0.050	0.2788
Milk urea nitrogen (mg N/dl)	am	25.00[b]	28.30[a]	±0.560	0.0003
	pm	26.20[b]	29.90[a]	±0.510	0.0001
Somatic cell count (cell/ml)	am	1.50×10^6	2.1×10^6	±0.44	0.3634
	pm	3.70×10^6	4.4×10^6	±0.70	0.5001
Weighted daily averages					
Milk fat (%)		2.84	2.82	±0.050	0.8458
Milk protein (%)		2.90	2.89	±0.040	0.9328
Milk lactose (%)		4.44	4.35	±0.030	0.2135

Means with different superscript ([a,b]) along the same raw differ significantly ($P<0.05$)

3.4.2.1 Milk fat

The inclusion of *Leucaena* had no effect on milk fat as there was no significant difference ($P>0.05$) in terms of milk fat percentage as well as weighted average milk fat produced by goats fed TMR with or without *Leucaena* for both morning (2.5 *vs* 2.4 ± 0.09%), afternoon (3.9 *vs* 3.8 ± 0.10%) and weighted average daily yield (2.84 *vs* 2.82 ± 0.05) respectively.

3.4.2.2 Milk protein

Milk produced by goats fed TMR diet with *Leucaena* had a significantly higher ($P< 0.05$) protein content when compared to goats fed TMR without *Leucaena* (3.0 *vs* 2.8 ± 0.05 %) for milk obtained in the morning (Table 3.4). In contrast, there was no significant difference ($P>0.05$) in terms of milk protein percentage as well as the weighted average milk protein obtained from goats fed both TMR diets at the afternoon milking.

3.4.2.3 Milk lactose

The inclusion of *Leucaena* had no effect in terms of milk lactose as there was no significant difference (P>0.05) in terms of milk lactose percentage as well as weighted average milk between goats fed the TMR with or without *Leucaena* for samples collected at the morning (4.5 *vs* 4.4 ± 0.05) and afternoon milking (4.4 *vs* 4.4 ± 0.03 %), respectively.

3.4.2.4 Milk urea nitrogen

The inclusion of the *Leucaena* in the TMR had a significant influence on MUN when compared to the milk from goats fed TMR without *Leucaena*. Milk produced by the goats fed the TMR with *Leucaena* had less MUN as compared to the goats fed the control diet for both samples collected during morning milking (25.0 *vs* 28.3 ± 0.56 mg N/dl) and afternoon milking (26.2 *vs* 29.9 ± 0.51 mg N/dl), respectively.

3.4.2.5 Milk somatic cell counts

There was no significant difference for milk somatic cell counts produced by goats fed both TMR with or without *Leucaena*. This was true for the milk produced at the morning and afternoon milking.

3.4.3 Body condition score and body weight

The body condition scores of milk goats fed a TMR with and without the inclusion of *Leucaena* were measured every two weeks throughout the seven months of lactation period. The results for BCS and BW are presented in Table 3.6 and Fig.3.2. There was no significant different (P>0.05) between animals fed TMR with or without *Leucaena* in terms of BCS and BW. Figure.3.2 showed that BCS of the animals in both groups increased linearly with time, and there was a positive correlation (r = 0.98 and r =0.90) over time and BCS for goats fed TMR with and without *Leucaena* respectively. The BCS measured during the first lactation months were lower, and increased during the later lactation months. During the first lactation month (October) there were slightly higher BCS for goats fed TMR with *Leucaena* when compared to those fed TMR without *Leucaena*. The goats in both treatments achieved similar BCS during the second month of lactation but the animals fed TMR with *Leucaena* appeared to have higher BCS compared to the goats fed TMR without *Leucaena* from the third month until the last month, but these differences were not statistically significant (P>0.05) (Fig.3. 2).

Table 3.5: Mean values for body condition score and body weight for goats fed TMR with or without *Leucaena* during the lactation period

Parameter	TMR with *Leucaena*	TMR without *Leucaena*	±se	P-value	Effect
BCS	2.3	2.4	±0.11	0.4246	NS
BW(kg)	53.4	56.1	±2.78	0.5230	NS
IW(kg)	50.3	56.0	±2.82	0.2126	NS
FW(kg)	57.3	58.1	±2.75	0.8174	NS
TG(kg)	7.0	2.1	±0.83	0.0003	***

NS: Non Significant, *P<0.05, **P<0.01
The score used ranged from 1.0–5.0, BCS: Body condition score, BW: Body weight for seven months. IW: Initial body weight. FW: Final body weight. TG: Total weight gain

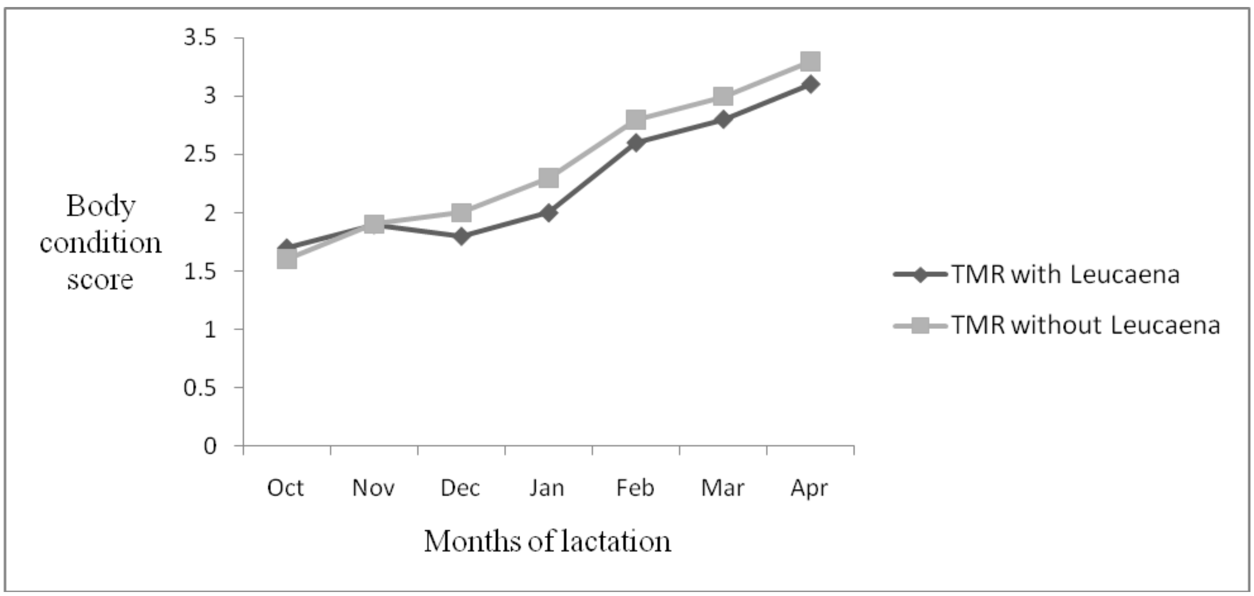

Fig. 3.2 Mean body condition score for lactating goats fed TMR with or without *Leucaena*

Table 3.6: Monthly body weights of lactating goats fed TMR (Least square of means)

	Total mixed ration				
Month	without *Leucaena*	without *Leucaena*	±se	P-value	Effect
October	50.5	55.9	±3.00	0.2126	NS
November	50.2	56.5	±2.08	0.2935	NS
December	52.1	54.7	±1.97	0.5117	NS
January	55.5	53.2	±1.94	0.5665	NS
February	54.1	56.2	±1.90	0.5926	NS
March	55.2	56.7	±1.91	0.7061	NS
April	57.6	56.7	±1.91	0.8174	NS

NS: Non Significant

There was no difference (P>0.05) between animals fed a TMR with *Leucaena* and those fed the TMR without *Leucaena* in terms body weight gain. The weight of the goats appeared to increase slightly from the fourth month onwards until the last month of the experimental period. The mean body weights of the goats fed TMR without *Leucaena* appeared to be higher than those of goats fed TMR with *Leucaena* during the entire experimental period (Table 3.7), but the difference was not statistically significant (P>0.05).

3.4.4 Effect of time of milking on milk composition

The effect of time of milking on milk composition of Saanen milk goats fed TMR with or without the inclusion of *Leucaena* is presented in the Table 3.7, while the weighted daily averages are shown in Table 3.5.

Table 3.7: Effect of time of milking on the milk composition of goats fed TMR with or without *Leucaena* during lactation

TMR	Time	Fat (%)	Protein (%)	Lactose (%)	MUN (mg N/dl)	SCC(x10^6)
Leucaena	am	2.5	3.0	4.4	25.7	1.8
	pm	3.9	2.9	4.4	26.7	3.2
No *Leucaena*	am	2.4	2.8	4.4	28.1	2.6
	pm	3.8	2.9	4.4	29.0	4.1
±se		±0.1	±0.03	±0.03	±0.35	±0.32
			Significance			
Treatment		NS	**	NS	***	NS
Time		***	NS	NS	**	***
Interaction		NS	NS	NS	NS	NS

NS= Non Significant, **P<0.01, ***P<0.001

There were great differences between the morning and the afternoon milk produced by the goats fed TMR with or without *Leucaena* in terms of milk composition. Goats produced significantly higher (P<0.001) fat, milk urea nitrogen concentration and somatic cell counts in the afternoon than the morning milking for both goats fed TMR with or without *Leucaena*. In contrast, the time of milking had no statistical difference in terms of milk lactose and milk protein for both treatment diets.

3.5 Discussion

Dairy goats have a high demand for nutrients during late gestation and lactation and can therefore be expected to consume more feeds to fulfil their nutrient requirement (NRC, 2007). Under-nutrition during these periods can lead to ketosis and milk fever while over- nutrition and insufficient roughage intake can result in acidosis (NRC, 2007). Therefore to avoid these metabolic disorders the diets in the present study were formulated into TMR using the Langston University Goat Research and Extension Programs (2000). The TMRs were balanced to be iso-caloric, iso-nitrogenous and iso-NDF and able to meet the required nutrient content for the lactating goats (NRC, 2007). A TMR should improve feed intake, especially of roughage, and in this way it should reduce the risk of acidosis. Both TMRs used in the present study were formulated to provide approximately the same TDN (60%) and CP (14%). The main source of roughage in the control diet was *Eragrostis* hay which contained relatively low levels of CP and soluble nutrients. The level of inclusion of *Eragrostis* hay was restricted to approximately 30%, so that the level of energy sources ingredients might be increased (e.g. 27% maize meal) to reduce the need of goats to draw energy from body reserves during the lactation.

The results for this experiment showed that the mean daily milk production was similar for the goats fed TMR with or without *Leucaena* (1.7±0.09 litres). However, the milk yield was relatively lower for the goats in both groups, throughout the seven months of lactation period compared to the results reported elsewhere, because these were goats of average genetic potential. Stella *et al*. (2007) recorded milk yields of 2.38 *vs.* 2.08± 0.14 kg/day for Saanen goats fed TMR supplemented with live *Saccharomyces cerevisiae* and those on the control diet. Laudadio and Tufarelli **(**2010) recorded the milk yield of over 2.2±0.05kg/day for Jonica dairy goats fed TMR with different RDP**.** The lower milk yield observed in this study might also be attributed to their age (parity). The fact that the goats in their first lactation produced a relatively less milk throughout lactation and this would affect the overall mean**.** The goats in their second and third lactations produced a higher amount of milk with the mean of 2.3 and 2.1± 0.12 litres/d, respectively, but the overall milk yield was reduced due to the inclusion of one third of primiparous goats in the experiment. However, Laudadio and Tufarelli (2010) used only multiparous lactating Jonica dairy goats and Stella *et al*. (2007) included only 8 primiparous goats out of a total of 36 animals used. Donkin (1997) recorded lower milk yields for goats in their first lactation (1.92±0.3 kg/d) and these increased in the second lactation (2.48±0.39 kg/d)**.**

The goats fed the TMR with *Leucaena* appeared to produce less milk during the initial stages of the experiment. This might be attributed to the lower feed intake for goats in this group at this time as the TMR contained a high proportion of pods and twigs. This was in agreement with the study by Maasdorp *et.al*. (1999) that showed a lower feed intake of a diet including fodder trees such as *Acacia boliviana, Calliandra calothyrsus* and *Leucaena leucocephala* during the adaptation period, but this increased steadily with time. Before the commencement of the present experiment all the animals were fed the TMR which was later used as control diet during the experiment. The animals fed TMR with *Leucaena* had to adjust to the new feeds, while the goats fed TMR without *Leucaena* were already used to their diets. During the third and the fourth months of the trial the milk yields from goats fed the *Leucaena* diet appeared to be higher than the yields from goats fed TMR without *Leucaena* but the difference was not statistically significant.

The findings of this study revealed that there was no significant differences (P>0.05) between goats fed TMR with or without *Leucaena* in terms of milk yield during the experimental period and for mean daily milk production. This clearly proves the hypothesis that the inclusion of *Leucaena* in the TMR for milk goats had no adverse effect on milk production. This has been previously reported in dairy cows (Saucedo *et al*. 1980; Waipanya and Srichoo, 1999; Maasdorp *et al*, 1999), in dairy goats (Richards *et al*., 1994) and indigenous goats (Akingbade *et al*., 2004; Tedonkeng Pamo *et al*., 2006).

This study also showed that there was no significant difference between goats fed the TMR diet with or without *Leucaena* in terms of milk fat (%), milk lactose (%), SCC ($x10^6$) and milk protein (%). This agrees with other studies which showed that *Leucaena* had no negative effect on milk fat and protein for dairy cows (Flores- Ramos, 1977) and other dairy goats (Richards *et al*., 1994). However the results of this study do not agree to the findings of Akingbade *et al*. (2004) in terms of protein and lactose percentage recorded in South African Nguni goats. In this study the results observed in terms of weighted average milk protein and milk lactose were in line with results reported by Donkin (1997).

The results of this experiment showed the SSC of $1.5x10^6$ *vs* $2.1x10^6 \pm 0.45$ cells/ml for morning samples and 3.7×10^6 vs $4.4 \times 10^6 \pm 0.70$ cells/ml afternoon samples, for the goats fed TMR with or without *Leucaena* respectively. These values are above a threshold of $1x10^6$ cells/ml recommended to classify goat milk for mastitis (White and Hinckly, 1999). The values were also above the values reported by Seifu *et al.* (2007) for Saanen goats at Onderstepoort University of Pretoria. However, SCC are not a good indicator of subclinical mastitis in goats (Karzis *et al.*, 2007).This study further revealed that there was less MUN ($P<0.001$) produced by goats fed TMR with *Leucaena* compared to those fed TMR without *Leucaena*. This might be attributed to the nutritional factors that affect milk urea including feed intake, feed protein and protein to energy ration in diet (Trevaskis and Fulkerson, 1999; Geerts *et al.* 2004).

According to Hof *et al.* (1997) the concentration of urea in milk is a parameter that can be used to detect feeding imbalances. Urea in milk mainly reflects the protein content of diets and results could be related to an excess of protein intake during grazing or feeding (Braghieri *et al*, 2007). The increase of urea in milk is also associated with insufficient energy supply, as urea will be formed when protein is used for gluconeogenesis (Schepers and Meijer, 1998). Cabiddu *et al.* (1999) reported an increased urea content in milk, which was correlated to an excess of protein in the ration when Saanen goats were stall fed with hay and concentrates. In this study, it was observed that the goats fed the TMR without *Leucaena* were more selective and tended to select the concentrates and leave roughage. However, the goats fed the TMR with *Leucaena* consumed almost all the feed offered. Mtenga and Shoo (1990); Nyambati *et al*. (2006) also observed that *Leucaena* increased feed intake and resulted in better utilisation of forage. Despite the significant differences between goats fed TMR with or without *Leucaena*, goats on both groups had higher milk urea nitrogen than the range target suggested by Jonker *et al*. (1999) of 10–16mg/dl. It was also higher than the value recorded by Laudadio and Tufarelli (2010), (21.7 to 23.1 ± 0.2 mg/dl) who studied Jonica dairy goats fed pelleted diets.

Despite the change in milk production over time, the BCS did not follow the same pattern as the milk production. This trend was also reported by Stella *et al*. (2007) in Saanen goats fed TMR supplemented with live *Saccharomyces cerevisiae* and those on the control diet where BCS of goats in experimental diets never deteriorated in spite of high milk production of the animals. There was no significant weight change throughout the experiment and this remained similar for animals fed TMR with or without *Leucaena*. The same pattern was also reported by Richards (1994). There were no clinical symptoms that were manifested during this study as the goats appeared healthy in both groups throughout the entire study. The presence of mimosine and DHP in milk and blood was not measured in the present study due to limited time and materials. In South Africa, however, the presence and level of mimosine in the milk and blood serum in Saanen dairy goats fed TMR with *Leucaena* still needs to be established. This had been done elsewhere (Gupta and Atreja, 1999).

CHAPTER 4

The inclusion of *Leucaena leucocephala* in Total Mixed Rations (TMR) for goats: Effect on intake, growth performance and animal health

4.1 Abstract

This experiment was conducted to determine the influence of *Leucaena* forage on feed intake, growth performance and health of milk goats when *Leucaena* hay was included in the diet. Sixteen castrated Saanen male goats (8 months; 23 ± 1.5 kg) were first stratified according to their bodyweight (BW) and then allocated into two groups. The goats were individually housed in the metabolic cages and the goats in each group were offered randomly one of the two experimental diets for a period of 63 days. The diets were formulated as total a mixed rations (TMR) with or without the inclusion of *Leucaena*. The goats fed the TMR with *Leucaena* had a significantly higher (P<0.05) dry matter intake (DMI) g per day (g/d) and g per unit metabolic body weight (g/kgBW$^{0.75}$/day). However, average daily gain (ADG) g/d and food conversion ratio (FCR) were not differed for the goats fed TMR with or without *Leucaena*. Gastrointestinal tract size did not significantly differ (P>0.05) between goats fed TMR diet with or without *Leucaena*. No clinical symptoms of toxicity were observed during the trial for the goats fed both diets. However the histology examination revealed that the thyroid glands of goats fed *Leucaena* appeared to be larger (1.2 *versus* 1.0 ± 0.15 g) than of the goats fed the control diet, but the difference was not statistically significant. Moreover, mild changes of colour around the oesophagus were observed for goats fed *Leucaena* diet compared to the goats fed control diet. The finding suggests the feasibility of substituting oil seed cake meals (OSCM) with *Leucaena* hay as protein source in the diet of Saanen male goats. However, the effect on lactating milk goats still needs to be investigated over a longer period of time.

Key words: Saanen goats, *Leucaena*, intake, growth performance and health.

4.2 Introduction

Leucaena is considered as a potential feed for ruminants due to its high protein content and palatability (Vadiveloo, 1988). It can improve the production of the animals and benefit small scale farmers who cannot afford other expensive protein sources and who have limited access to good quality pasture (Brewbaker, 1986). Most reports suggested that *Leucaena* contains sufficient nutrients (Bakshi and Wadhwa, 2007) and its inclusion can improve palatability (Waipanya and Srichoo, 1999), intake (Melaku *et al*., 2005,) and digestibility (Tomkins *et al*. 1991) of poor quality grass. It also improves live weight gain (Rubanza *et al.*, 2007) and milk production (Tedonkeng Pamo *et al*., 2006) of goats. However the utilisation of *Leucaena* can be limited by the presence and level of anti-nutritional factors which can be harmful to goats. There is a little information with regard to the *Leucaena* utilization by farmers in the rural areas of South Africa especially for milk production. More research is needed in the context of small-scale farmers to improve effective and efficient use of these feed resources. This study investigates the inclusion of *Leucaena* in a TMR as a protein source to substitute OSCM and the effect on growth and health of Saanen male goats.

4.3 Materials and methods

4.3.1 Experimental diets

The diet used on this experiment was exactly the same as the one used for the milk experiment (Chapter 3). One treatment diet that contained 25% *Leucaena* (without pods) was compared with TMR without *Leucaena* that contained 30% *Eragrostis* hay and approximately 60% concentrates. The experimental diets were formulated to be iso-caloric, iso-nitrogenous and iso-NDF as TMR to supply 15% CP and 60% TDN on dry matter basis (Chapter 3, Table 3.2). The TMR were offered *ad libitum* during the first few days and then adjusted to the previous feed intake plus 15% more. The offered feeds and orts were measured daily. During the second week to the last week the feeds were offered three times per day in equal proportions to avoid spillage of feeds to the floor.

4.3.1.1 Feeds and sampling

Representative samples of feeds offered and refusals were collected daily and bulked on weekly basis. The representative samples of feeds offered were collected once per day while for the refusal samples were collected twice per day. The samples for feeds and orts were then bulked separately in the labelled plastic bags for each animal within each diet. They were later thoroughly mixed and sub samples were taken for subsequent laboratory analysis. Representative samples for both diets and orts were collected daily for estimation of DMI and for chemical analysis.

4.3.2 Experimental animals

Sixteen castrated male Saanen goats were used in this experiment. The goats were seven to eight months old and had mean BW of 23±1.5 kg at the beginning of this experiment. The experiment lasted for 63 days from May to July 2009. The goats were individually housed in metabolic cages (1m x 75cm x 1m) made of welded wire-mesh with removable feeders and water troughs; therefore the animals had access to fresh water daily.

4.3.3 Experimental design

The experimental diets were offered in a Completely Randomised Design (CRD) where there were two groups with eight animals in each group. Two experimental diets were then randomly allotted to these two groups. Eight animals were offered TMR containing *Leucaena* forage, while another eight animals received TMR without *Leucaena*.

4.3.4 Body weight gain estimation

The animals were weighed using an electronic balance scale for two consecutive days at the beginning of the trial and results were averaged to obtain the initial body weight. They were then weighed at weekly intervals thereafter, until the termination of the trial. Initial and final weights were used to estimate the body weight gain of the animals. The feed and water were withdrawn from the animals at midnight preceding the weighing day. Then the weighing was performed early in the morning before they had access to feed and water.

4.3.5 Feed conversion ratio estimation

The feed conversion ratio was calculated according to the following formula

$$\text{Feed conversion ratio} = \frac{\text{Quantity of feed taken per time}}{\text{Weight increased per time}}$$

4.3.6 Chemical analysis

Representative samples for feed and orts were prepared in duplicates for subsequent laboratory analysis as explained in Chapter 2. (Sub section 2.3.3). The samples in duplicate were then analysed for dry matter, ash, nitrogen concentration, neutral detergent fibre, acid detergent fibre, acid detergent lignin, calcium and phosphorus concentration in duplicates. When the error between the two samples exceeded 5% a third sample was prepared and analysed until the average error percentage of less than 5 was obtained.

4.3.7 Statistical analysis

The data were subjected to an analysis of variance (ANOVA) in a complete randomise design using procedure of General Linear Model (GLM) of SAS (2004) to test for statistical differences between treatments. Treatment means for the two diets were separated using Fisher's t-tests (Samuel, 1989).

4.4 Results

The experimental diets were fed to the goats to determine feed intake, feed conversion ratio and growth of castrated Saanen goats for two months. The goats used in the experiment had the same initial mean weight (23 ± 1.5 kg) at the commencement of the experiment. The goats were first stratified according to their body weight and randomly allocated to the two groups. At the end of the study the goats fed TMR with *Leucaena* appeared to have slightly higher body weight (29.3 *versus* 28.9 ± 2.27kg) than the animals fed the control diet but the difference was not statistically significant. There was also no significant difference (P>0.05) between goats fed TMR with *Leucaena* and without *Leucaena* in terms of average FCR and ADG (g/head/day). However, there was significant difference (P<0.05) between goats fed TMR with *Leucaena* and without *Leucaena* in terms of total DMI per metabolic weight (g/kg W^{75}) and DMI per day (g/head/day).

Table 4.1:Body weight, body weight gain, feed intake and conversion ratio of castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ±s e)

	Total mixed ration				
Parameter (g)	without *Leucaena*	without *Leucaena*	±se	P-value	Effect
Body weight					
Initial body weight (kg)	22.9	23.1	±1.50	0.9529	NS
Final body weight (kg)	29.3	28.9	±2.27	0.6553	NS
Body weight gain (kg)	6.4	5.8	±1.66	0.1428	NS
Growth rate(g/head/day)	101.6	92.1	±10.35	0.1434	NS
Feed Intake					
Dry matter intake (g/head/day)	995.0	865.0	±43.00	0.0448	*
Feed conversion ratio	10.0	11.5	±2.37	0.1443	NS

NS: Non Significant, *P<0.05

4.4.1 Body weight change

The body weight change of the goats fed TMR with *Leucaena* appeared to have been higher (6.4 kg ±1.66 kg) than the goats fed TMR with *Leucaena* (5.8±1.66 kg) but was not significantly different. There was slight decrease in the mean BW observed in both groups during the first week, but there was a steady increase from the second week and for the rest of the study period on both experimental diets.

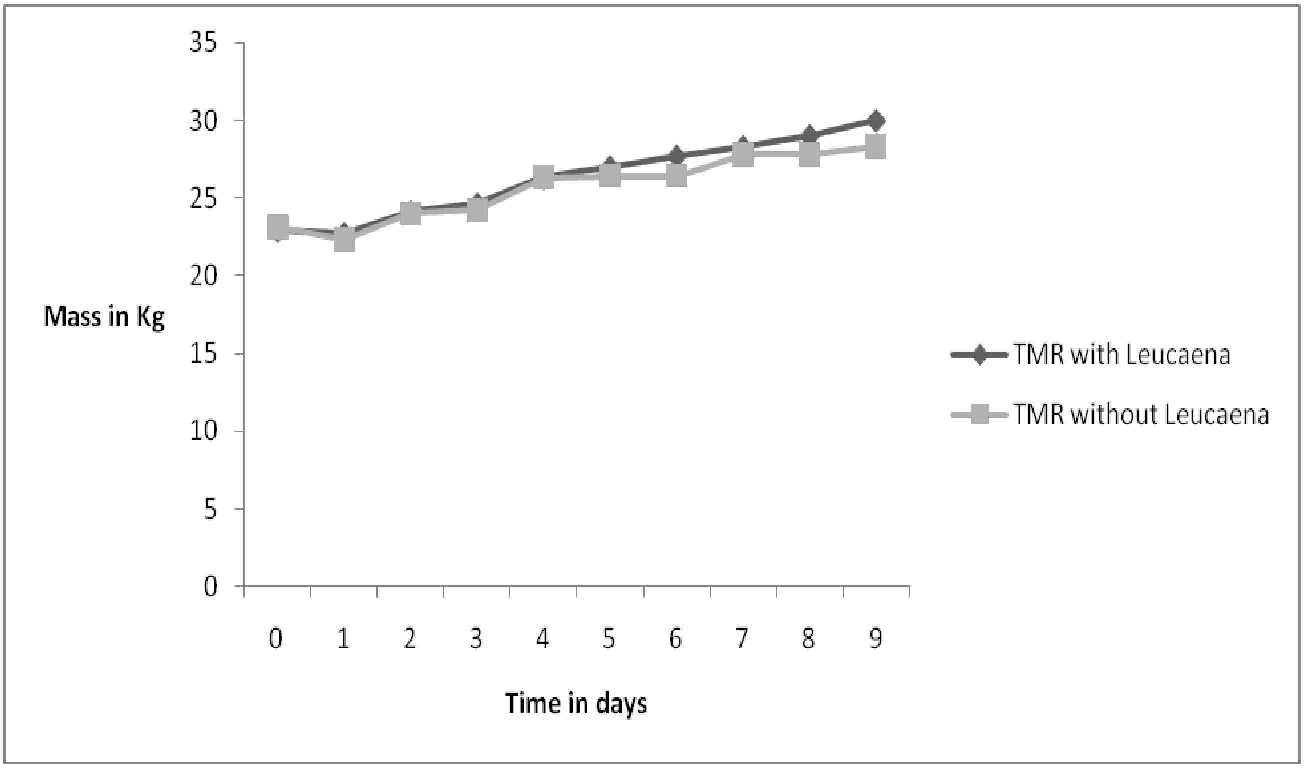

Fig. 4.1: Body weight change pattern of castrated Saanen goats fed TMR with and without *Leucaena*

4.4.2 Dry Matter Intake

The DMI of both TMR with or without *Leucaena*, are presented in Table 4.2

Table 4.2: DMI for Saanen castrated goats fed TMR with or without *Leucaena* (Least square means)

Parameter	Week	TMR with *Leucaena*	TMR without *Leucaena*	±se	P-value	Effect
	1	884	842	±43.0	0.9718	NS
	2	972	841	±45.7	0.7311	NS
	3	999	920	±46.6	0.4784	NS
	4	982	956	±39.2	0.3482	NS
DMI (G)	5	1006	929	±56.4	0.2998	NS
	6	1095	895	±55.5	0.0473	*
	7	1090	867	±58.3	0.0298	*
	8	1102	923	±61.0	0.0356	*
	9	1099	899	±63.2	0.0441	*

NS: Non Significant; *P<0.05

The results indicated that the goats fed the TMR with *Leucaena* appeared to have higher DMI than the goats fed the TMR without *Leucaena* during the first five weeks of the study period, but the difference was not statistically significant. However, the goats fed TMR with *Leucaena* had a significantly higher (P<0.05) DMI compared to goats fed TMR without *Leucaena* during the last four weeks. Over the course of the experiment there was a steady increase in DMI for the goats offered the TMR with *Leucaena* with time, while the DMI of the goats offered the TMR without *Leucaena* did not follow the same trend.

4.4.3 Average Daily Gain (ADG)

The weekly ADG for the goats offered TMR with or without *Leucaena* are presented in Table 4.3.

Table 4.3: Weekly average daily gain (ADG) for castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ±se)

Parameter	Week	TMR with *Leucaena*	TMR without *Leucaena*	±se	P-value	Effect
ADG (g)	1	-47	-66	±12.10	0.0440	*
	2	83.6	77.6	±9.87	0.8202	NS
	3	77.9	71.4	±11.69	0.2421	NS
	4	120.5	118.5	±11.01	0.2312	NS
	5	112.4	106.1	±8.46	0.2921	NS
	6	129.1	110.4	±10.42	0.3992	NS
	7	111.5	106.4	±9.87	0.6671	NS
	8	109.4	98.6	±9.54	0.6852	NS
	9	106.5	102.1	±8.36	0.7451	NS

NS: Non Significant; *P<0.05,

Goats offered TMR with *Leucaena* seemed to have higher ADG than the goats fed TMR without *Leucaena*, but except for week one the difference was not statistically significant during the second week to the ninth week. During the first week the goats lost body weight and this was observed for both groups. However, the goats fed TMR without *Leucaena* had significantly higher (P<0.05) loss of body weight than the goats fed the TMR with *Leucaena* (-66 *versus* -47 ± 12.1g), respectively. The ADG recorded in this study showed a decrease in the first week followed by the steady increase from the second week until the 6th week, then followed by decrease from 7th week up to the last week for goats offered TMR with *Leucaena*. Similar trends were observed for goats offered TMR without *Leucaena* where the highest ADG was recorded during the 4th week, and this was followed by slightly decrease until the 9th week.

4.4.4 Feed Conversion Ratio (FCR)

Feed conversion ratio is a tool used to measure the animals' efficiency in converting feed mass into body mass, therefore there is a relationship between FCR, DMI and body gain. The weekly mean FCR pattern of the experimental goats in this study is presented in the Table 4.4. During the first week of the experiment, FCR was negative for goats fed both TMR with or without *Leucaena*. The pattern was similar from the second week until the last week of the study in both groups.

Table 4.4: Weekly feed conversion ratio (FCR) for castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ± se)

		TMR				
Parameter	week	with *Leucaena*	without *Leucaena*	±se	P-Value	Effect
	1	-18.8	-13.0	±4.67	0.576	NS
	2	11.5	11.7	±0.99	0.976	NS
	3	12.1	12.9	±3.00	0.860	NS
	4	8.2	8.0	±0.86	0.897	NS
FCR	5	8.6	8.7	±1.67	0.965	NS
	6	7.9	8.2	±1.14	0.789	NS
	7	9.1	9.3	±0.80	0.892	NS
	8	9.7	10.2	±0.84	0.784	NS
	9	9.9	9.9	±0.76	1.000	NS

NS: Non significant

4.4.5 Animal Health and Histological examination

4.4.5.1 Clinical symptoms

Except the loss of appetite for one or two goats in both groups for few days, there were no clinical symptoms that were manifested during this study. A slight loss of hair was observed during the study and this was not associated with toxicity of *Leucaena* as it was observed on the goats received TMR with or without the inclusion of *Leucaena*. Generally the goats on both groups appeared healthy throughout the entire study, except for few goats that had slower rate of growth. This was also not associated to the inclusion of *Leucaena* as they were among the goats that received diet with and without inclusion of *Leucaena*. In addition, there was no salivation or vomiting observed in both groups during the study period which might have been expected if there were adverse reactions to the *Leucaena*.

The digestive organs of goats offered TMR with or without *Leucaena* appeared normal. The weights of these are presented in Table 4.5. Except for omasum the weights were similar for the goats fed TMR with or without *Leucaena*. For omasum, however, a significantly higher weight (P<0.05) was recorded in the goats fed *Leucaena* diet compared to the control diet.

Table 4.5: Weights of the digestive parts and thyroid glands of castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ± se)

	Total mixed ration				
Parameter (g)	without *Leucaena*	without *Leucaena*	±se	P-value	Effect
Rumen	513.12	528.1	32.11	0.8258	NS
Reticulum	151.1	127.7	7.18	0.0975	NS
Omasum	107.2	84.6	5.64	0.0379	*
Abomasum	214.8	274.0	29.80	0.1832	NS
Intestine	1250	1310	47.71	0.5189	NS
Intestinal fats	857.3	917.8	88.77	0.7460	NS
Thyroid glands	1.2	1.0	0.15	0.4136	NS

NS: Non significant, *P<0.05

4.5 Discussion

4.5.1 Dry Matter Intake

In this study the observation of tendency for higher DMI for the goats fed TMR with *Leucaena* compared to the goats fed the TMR without *Leucaena* was similar to the observation of other authors who reported higher DMI of *Leucaena* compared to other legume trees, such as *Acacia nilotica*, *Acacia polyacantha* as supplements, as well as native pasture hay plus 100g maize bran as control (Rubanza *et al*., 2007) and positive control TMR with concentrates (Srivastava and Sharma, 1998; Anbarasu *et al*., 2004). This can be associated with good palatability (Srivastava and Sharma, 1998), higher CP content and high digestibility of protein in *Leucaena* (Rubanza *et al*. 2007). In the present study the goats fed the TMR with *Leucaena* on average consumed 79 g DM /kgW$^{0.75}$ compared to 68.5 g DM /kgW$^{0.75}$ for the goats fed TMR without *Leucaena*. The above results for DMI are similar to the findings by Srivastava and Sharma (1998), who observed average consumption of 72.11g DM /kgW$^{0.75}$ for adult Jamunapari goats fed pelleted sun dried *Leucaena*.

4.5.2 Body weight change

The results of the present experiment showed a possible tendency of higher weight gain for goats fed the TMR with *Leucaena* (6.4kg) compared to those fed TMR without *Leucaena* (5.8kg), but the difference was not significant. Other results have shown a significant difference in studies of leaf meal as protein source *versus* conventional diets (Ndemanisho *et al.*, 1998; Anbarasu *et al*., 2004).

There are also reports which indicated that *Leucaena* has low to medium level of tannins which might protect protein degradation in the rumen (Anbarasu *et al*., 2004). This can be important in promoting by-pass protein flow from the rumen to the intestine.

The goats lost weight during the first week of the experiment on both groups (Table 4.3) for goats fed the TMR with or without *Leucaena.* The new environment of which the goats were exposed to during the commencement of this experiment appeared to have resulted in stress to the goats. Despite the fact that the whole week was used for adaptation, the young goats under any circumstances were not relaxed in the metabolic cages, as most goats were found to have escaped and to be out of the crates the next morning. This means they failed to consume the required amount of diet per day for growth and maintenance; however this problem was solved by making the metabolic crates more secure.

4.5.3 Feed Conversion Ratio (FCR)

The results of this study indicated that the overall FCR appeared to be slightly higher for goats fed TMR without *Leucaena* (11.5±0.93) as compared to the goats fed TMR with *Leucaena* (10.0 ±2.37), but the differences were not significant across the nine weeks of the study. However *Leucaena* was proved to be effectively utilised by goats compared to other leguminous plants (Yousuf *et al.,* 2007). The same authors recorded FCR for Cassava leaf meal and *Leucaena* which were not significantly different and for *Gliricidia*-leaf meals which was less than the two former meals ($P<0.05$) respectively.

4.5.4 Animal Health and Histological examination

4.5.4.1 Clinical symptoms

The clinical symptoms of *Leucaena* toxicity could among others include reduced weight gain, excessive salivation (Kudo *et al*., 1989; Semenye, 1990; Hammond, 1995), depressed growth and production, death of newborn animals and hair loss (Jones, 1983; Semenye, 1990). In the present study, however, there were no clinical symptoms observed in the two groups, except the loss of appetite for one or two animals on both groups for few days. Megarrity and Jones (1983) observed loss of appetite in animals introduced to *Leucaena*, where the animals took the whole day to consume their feeds while their counterpart animals were consuming most of the feed in the first hour. There were also low level of mimosine measured (Chapter 2, Sub-Section 2.4.3) in the *Leucaena* forge used in this study. Therefore the loss of appetite observed in this study was not associated with *Leucaena* toxicity as it happened to very few animals in both groups, and this problem did not last long. The slight loss of hair observed during the study was also not associated with toxicity of *Leucaena* as it was observed in both groups. It might be attributed to scratching of animals against wire mesh as animals were not resting in the metabolic crates as was the case for the sheep. The animals appeared to be healthy in both groups throughout the entire study except individual animals which had slower rate of growth which is also not associated with *Leucaena*. This poor growth was attributed to the fact that the animals were severely affected to coccidiosis at young age which resulted in over 30% mortality of young goats for that particular year before the commencement of the trial.

4.5.4.2 Post-mortem Findings

4.5.4.2.1 Thyroid gland

The thyroid glands of the goats fed TMR with *Leucaena* appeared to be slightly larger (1.2 *versus* 1.0±0.15 g) than their contemporaries on the control group but the differences were not significant (P>0.05) (Table 4.5). This was consistent with the observation of Jones and Megarrity (1983) who found no difference in *Leucaena* toxicity study in Hawaii goats. The authors observed 1.4, 1.5 and 1.7g for thyroid glands of goats fed *Lucerne* chaff, 50% chaff + *Leucaena* and *Leucaena*, respectively. Their results were attributed to the presence of *Leucaena* degrading bacteria (*Synergistes jonesii*) (Allison *et al.*, 1992). The introduction of *S.jonesii* in the University of Pretoria Research Farm was performed by Masafu (2006) in 1999. The persistence of this bacterium in this area remained untested. It was the intention of the researcher to investigate this, however the limited time and resources prevented this. It is, therefore suggested that this still has to be studied further in the future. There was also low level of mimosine measured in the *Leucaena* forage used in this study (Chapter 2 sub-section 2.4.1.5), which it is believed that it should not be toxic to the goats. *Leucaena* has been shown to be safely used when the level of up to 30% is included in the diet of goat (Virk, *et al*., 1991)

4.5.4.2.2 Oesophagus

There was slight difference for the colour at the junction of oesophagus and rumen. The colour for goats fed TMR with *Leucaena* appeared to be darker as compared to the goats fed TMR without *Leucaena.* The findings might be attributed to the effect of *Leucaena* as the goats were more selective and they used to neglect the hay and consume mixture of *Leucaena* and concentrates when it was not thoroughly mixed. In contrast to findings of Megarrity and Jones (1983) for Australia goats and Semenye (1990), there were no lesions, necrosis and ulcers at the oesophagus or even at the reticulo-rumen in this study.

4.5.4.2.3 Gastrointestinal tract (GIT)

The weights of GIT organs differed but not significantly between the goats fed the TMR with *Leucaena* and the goats fed the TMR without *Leucaena*. The exception was only observed with the omasum where there was a higher weight (P<0.05) for goats fed TMR with *Leucaena* as compared to the goats fed TMR without *Leucaena*. The parts of the digestive tracts which were similar in this study among the two groups of goats were in the same range to those reported for other goat breeds from various areas at the same age and live weight, but offered different diets (Dhanda *et al*., 2003; Marichal *et al*., 2003).

CHAPTER 5

The effect of *Leucaena leucocephala* on feed intake and *in vivo* digestibility of the TMR fed to Saanen male goats

5.1 Abstract

The feed intake and digestibility of a Total Mixed Ration (TMR) with or without the inclusion of *Leucaena* was studied using castrated male goats (33±1.8kg BW). Ten castrated goats approximately eight months old at the end of growth performance study were randomly selected (but stratified according to their body weight) and allocated to two groups and offered two experimental diets. The TMR with *Leucaena* had a significantly higher ($P<0.01$) content of neutral detergent fibre (NDF) and acid detergent lignin (ADL) compared to the TMR without *Leucaena*. In contrast, crude protein (CP) and acid detergent fibre (ADF) were not influenced by the inclusion of the *Leucaena*. However, goats fed TMR with *Leucaena* had a significantly higher ($P<0.05$) dry matter intake (DMI), organic matter intake (OMI) as well as all other nutrients when compared to goats fed TMR without *Leucaena*. Despite the variations in feed intake, the rations did not differ significantly ($P>0.05$) in terms of Apparent Digestibility coefficient (%). However, the goats fed the *Leucaena* TMR had a significantly higher ($P<0.05$) digestible dry matter intake (DDMI) per animal per day than goats fed TMR without *Leucaena*. In contrast, *Leucaena* had no significant effect ($P>0.05$) on OM, CP and NDF digestibility and intake when compared both in g per head per day as well as g per metabolic weight per day.

Key words: Saanen goats, TMR, *Leucaena*, intake, *in vivo* digestibility.

5.2 Introduction

The use of leguminous trees and shrubs as forage for ruminants in tropical and subtropical regions has become more popular in research programmes (Shelton *et al*., 1991). Among the many species used, *Leucaena* is widely grown and has become more important as protein supplement (Norton, 1994a; Aganga and Tshwenyane, 2003) due to its good palatability, digestibility and intake (Ha *et al*., 2000) and low fibre content (Wheeler, 1994). *Leucaena* is used in many areas as animal forage and has been shown to improve animal performance (Rubanza *et al*. 2007). Chemical composition and the nutritive value are the factors which may influence the palatability, intake and digestibility of the plant. In general, feeds with high nutritive value are more palatable and acceptable to the animals.

Some reports have suggested that *Leucaena* has enough undegradable protein (UDP) to provide a sufficient source for post- ruminal digestion (Morrison and Mackie, 1996). However, it contains secondary metabolites (Norton, 1994b) which have negative effect on its intake and digestibility and affect animal production. It is important especially for smallholder farmers in South Africa who use *Leucaena* to have adequate information to enable proper use of *Leucaena* in milk goat feeding systems. The present study investigated the intake and digestibility response of TMR diet with or without the inclusion of *Leucaena* fed to the Saanen castrated goats as it was not possible to use lactating goats for this purpose.

5.3. Materials and methods

5.3.1 Experimental diets, procedure and animal management

The digestibility trial was commenced immediately after the termination of the performance trial (Chapter 4). The experiment lasted for 12 days with five days for adaptation to faecal bags and seven days for collection and measurement. The details of the formulation and preparation of the diets used in this experiment were previously described (Chapter 3, section 3.3).

Ten castrated Saanen goats were used in this experiment. The goats had a mean live body weight of 33±1.8kg at the start of this trial. The use of the goats for this experiment was approved by the Ethics Committee of the University of Pretoria (Reference: EC025-08). Goats were individually housed in the metabolic cages (1m x 75cm x 1m) made of welded wire - mesh with removable feeders and water troughs.

The animals had access to fresh water and the experimental diets throughout the day. The experimental diet offered to each individual goat, was weighed and recorded before feeding. The orts were removed, measured and recorded daily for each animal.

The daily faecal output was collected, weighed, sub-sampled and bulked over the seven days collection period and then kept frozen (-10 °C) prior to the laboratory analysis. After the seventh day of collection the bulked faecal output from each animal was thoroughly mixed and approximately 10% sub samples were dried overnight at 55 °C in a hot air oven. This was done until there was a constant weight for DM estimation. Prior to the laboratory analysis, the samples of feeds, refusal and faeces from each animal were thoroughly mixed, dried and milled through a 1mm sieve.

5.3.2 Chemical analysis

Samples of feeds offered, refusals and faeces were analysed for DM, ash, OM, N-concentration, NDF, ADF and ADL. The methods, procedures and references used have been described (Chapter 2, Sub- Section 2.3.3).

5.3.3 Statistical analysis

All the parameters were subjected to an analysis of variance (ANOVA) using procedure of General Linear Model (GLM) procedure of SAS (2004) to test for statistical differences between treatments. Significant difference between least square means for the two diets was separated using Fisher's test (Samuel, 1989).

5.4 Results

5.4.1 The chemical composition of TMR with or without Leucaena forage

Table 5.1 illustrates the chemical composition of the TMR formulated with or without the *Leucaena* forage. The two diets did not differ (P>0.05) significantly in terms of CP and ADF concentration. TMR with *Leucaena* had significantly (P<0.01) lower concentration of NDF (465 *versus* 515 ± 12.3 g/kg DM). In contrast, TMR with *Leucaena* had higher (P<0.001) concentration of ash (73 *versus* 61 ± 2.3 g/kg DM) and ADL (73 g/kg DM *versus* 61 ±2.7 g/kg DM) compared to TMR without *Leucaena*.

Table: 5.1 Chemical composition of TMRs with or without *Leucaena* forage fed to castrated Saanen goats (Least square means ±se)

Parameter	Total Mixed Ration				
(g/kg DM)	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
CP	11.9	12.0	±0.09	0.330	NS
ASH	7.3	6.0	±0.23	0.000	***
NDF	46.5	51.5	±1.23	0.040	**
ADF	27.3	26.5	±0.38	0.360	NS
ADL	7.3	6.1	±0.27	0.010	**

NS : Non significant; * *P < 0.01, ***P < 0.001

5.4.2 The Apparent Digestibility of TMR

There were no significant differences (P>0.05) between the two TMRs in terms of apparent digestibility of DM, OM, CP, NDF and ADF (Table 5.2).

Table 5.2: Apparent digestibility (%) of TMR fed to castrated Saanen goats (Least square means ±se)

Parameter	Total Mixed Ration				
	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
Number of animals	5	5			
Initial weight	34	32	2.7	±0.60	NS
Apparent digestibility Coefficient (%)					NS
DM	65.6	67.7	1.45	±0.18	NS
OM	65.0	69.8	1.45	±0.09	NS
CP	58.6	62.0	2.02	±0.20	NS
NDF	56.2	60.6	1.93	±0.30	NS
ADF	50.6	51.8	2.40	±0.82	NS

NS: Non significant

5.4.3 Voluntary Dry Matter Intake of TMR

The Goats fed TMR with *Leucaena* had a significantly higher (P<0.01) DMI and OMI, compared to goats fed TMR without *Leucaena*. The CPI and NDFI of the goats fed TMR without *Leucaena* were significantly (P<0.01) lower (90 g/d and 382 g/d), respectively than goats fed TMR with *Leucaena* (131 g/d and 517 g/d), respectively.

The same variations were observed in terms of ADFI (198 g/d *versus* 300 g/d), for both TMR with or without *Leucaena* diet respectively. Similar differences were observed in these parameters when voluntary intake was expressed in terms of g per kg metabolic body weight per day (g/kg $BW^{0.75}$/day). In contrast, the goats fed the TMR with *Leucaena* had significantly (P<0.05) higher NDFI (37 g/kg $BW^{0.75}$/day) than goats fed the TMR without *Leucaena* (29 g/kg $BW^{0.75}$/day)

Table 5.3: Voluntary feed intake of TMR with or without *Leucaena* fed to castrated Saanen goats (Least square means ±se)

Parameter	Total Mixed Ration				
	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
Voluntary intake (g/kg/day)					
DM	1102.4	741.0	±76.52	0.013	**
OM	1022.0	696.6	±65.80	0.012	**
CP	131.0	89.6	±9.05	0.011	**
NDF	517.0	381.8	±36.00	0.034	**
ADF	300.0	197.6	±22.25	0.012	**
Voluntary intake (g/kg BW/day)					
DM	78.5	56.2	±4.30	0.014	**
OM	72.9	52.7	±4.26	0.015	**
CP	9.4	6.8	±0.56	0.014	**
NDF	36.7	28.8	±1.98	0.043	**
ADF	21.4	15.0	±1.33	0.004	***

**P < 0.01, ***P < 0.001

Unlike the voluntary intake, the digestible organic matter intake (OMDI) expressed in g per head per day of the TMR with *Leucaena* (604 g/day) was significantly (P<0.05) lower than that of TMR without *Leucaena* (656 /day) (Table 5.4). However this difference of OMDI was not significant when expressed in terms of g per metabolic body weight per day. The OMDI (g /kg $BW^{0.75}$/day) of goats fed TMR with *Leucaena* (44 g/kg $BW^{0.75}$/day) was not significantly different (P>0.05) from those fed TMR without *Leucaena* (49 g/kg $BW^{0.75}$/day). The goats fed TMR with *Leucaena* did not differ in terms of their DCPI, DNDFI and DADFI (g/kg/day) when compared to the goats fed the TMR without *Leucaena*. This similarity was also recorded when the digestible nutrient intake comparison was done in terms of g per metabolic body weight per day (g/kg $BW^{0.75}$/day).

Table 5.4: Digestible intake of TMR fed castrated Saanen goats fed TMR (Least square means ± se)

Parameter	Total Mixed Ration with *Leucaena*	Total Mixed Ration without *Leucaena*	±se	Effect	P-value
Digestible intake (g/goat/day)					
OM	604.0	656.0	±13.23	*	0.041
CP	71.5	77.1	± 2.62	NS	0.202
NDF	157.1	137.6	±17.73	NS	0.152
ADF	138.8	137.6	± 7.36	NS	0.944
Digestible intake (g/kg $BW^{0.75}$/day)					
OM	43.7	49.4	±1.95	NS	0.151
CP	5.0	5.8	±0.28	NS	0.204
NDF	19.0	23.8	±1.31	NS	0.062
ADF	10.0	10.4	±0.70	NS	0.793

NS : Non Significant; *P < 0.05

5.5 Discussion

It is important to analyse the chemical content of feeds to assess the quality in order to know whether the feeds can satisfy the animal requirements at different stages of production. Babayemi and Bamikoli (2006) indicated that the critical minimal level of CP content required for effective optimal ruminal function was 7% of DM. The CP value in this experiment for both TMR with or without *Leucaena* had been set at a higher level, almost double this optimal function described, because the TMR used in this experiment were formulated for lactating goats (Chapter 3). However compared to the CP values (30%) and (50%) reported by Srivastava and Sharma (1998) for goats fed pelleted diets containing *Leucaena*, and Anbarasu *et al*. (2004) for goats fed leaf meal mixture containing *Leucaena*, respectively the value of CP (12%) for both diets in this study was relatively low. The reason was that the former authors used *Leucaena* alone as a source of roughage.

The fibre content of the feed also plays a crucial role for ruminants as it is important for effective ruminal function. The NDF and ADF contents for both diets were higher than the values obtained by Richards (1994) where *Leucaena* was incorporated with concentrates and Kingrass; and as reported by Anbarasu *et al*. (2004) when *Leucaena* was included in TMR; and also as reported by Akingbade *et al*. (2004) using *Leucaena* and grass pasture. The NDF and ADF contents in the present study range from 47–52% and 26–27% respectively which were also higher than the level recorded by Tufarelli, *et al*. (2009) and Laudadio and Tufarelli. (2010) who used wheat straw and bran as source of roughage in the TMR.

There was significantly higher ($P<0.01$) amount of NDF content in the TMR with *Leucaena* than in the TMR without *Leucaena* in this study which might be attributed to the high amount of cell wall content present in *Leucaena* leaves and especially in the twigs (Anbarasu *et al*. 2004). The goats consumed considerably higher amounts of DM when fed TMR with *Leucaena* (1102 g/day) as compared to TMR without *Leucaena* (741 g/day). On average the goats fed TMR with *Leucaena* consumed 79 g/kg $BW^{0.75}$ in this study, which is in agreement and even higher than several studies where *Leucaena* was used as the sole feed and/or as a supplement diet (Mtenga and Shoo, 1990; Srivastava and Sharma, 1998; Yousuf *et. al* 2007).

Apart from DMI, there were also significantly higher OMI, CPI, NDFI and ADFI observed in the TMR with *Leucaena* than TMR without *Leucaena* as expressed in grams per animal per day as well as g/kg $BW^{0.75}$/day. The higher intake of TMR with *Leucaena* indicated the good palatability of the diet resulting in more nutrients ingested by the goats fed that TMR, which may improve their production.

In addition to feed intake, the quality of feed can be measured by its potential for releasing the nutrients in it; this is referred to as digestibility (McDonald, *et al.* 2002). The OMD is the tool indicating microbial activity in the rumen and hence protein synthesis. The observation of this study was that despite higher intake of the *Leucaena* TMR diet by the goats there was no significant differences between the two TMR in terms of apparent digestibility as well as digestible intake, even though the TMR without *Leucaena* appeared to have higher digestibility and digestible intake than TMR with *Leucaena.* In addition, the TMR without *Leucaena* had a significantly higher ($P<0.05$) DOMI than the TMR with *Leucaena.* D'Mello (1992) indicated that *Leucaena* leaves contain moderate amounts (30–43 g/kg) of condensed tannins (pronthocyanidins), however it was not measured in this study. This content can result in a positive or adverse effect on nutritive value of forage and N-utilization (Srivastava and Sharma, 1998).

Even though this substance was not measured in this study it is pertinent to consider its effect. It can have a negative impact on the digestibility and efficiency of nutrients used by the animals. Maasdorp *et al.* (1999) and Singh and Bhat (2001) reported that despite high CP content in the leguminous trees, they can also have high level of polyphenolic compounds which can bind the protein and make it unavailable to animals consuming it. However, they can also have a beneficial effect as they can protect protein from rumen degradation, and hence increase rumen escape protein and decrease the ammonia loss (Norton, 1994a). The result obtained in the present study regarding the lower digestibility of the *Leucaena* diet as compared to other diets has been previously reported (Mtenga and Shoo, 1990; Babayemi and Bamikole, 2006; Hassen, 2006). Depression in digestibility of nutrients in this study regardless of high DMI and other nutrient intake can also be associated with the time the feed is exposed to rumen activity through both microbes and enzymes (Van Soest, 1994). The results of DMD, OMD, NDFD and ADFD in this study for both diets were in line with the findings of Tufarelli *et al*. (2009) and Laudadio and

Tufarelli (2010) using RUP and RDP for their TMR, while the CPD in this study was less when compared to their findings.

However lack of difference in digestibility values in this study was in agreement with the findings of other authors (Anbarasu *et al*., 2004), who used diets based on tree forages and commercial diets. The OMI of TMR with or without *Leucaena* in the present study ranged from 43.7 to 49.4 g/kg $BW^{0.75}$/day. Therefore, the TMR with *Leucaena* had a similar potential to support meat goat production as the TMR based on the commercial diets.

CHAPTER 6

Carcass and meat quality of Saanen male goats as affected by the inclusion of *Leucaena leucocephala* in a Total Mixed Ration

6.1 Abstract

The experiment was conducted to compare the carcass characteristics and meat quality of castrated Saanen male goats fed on Total mixed ration (TMR) with or without *Leucaena* forage. Sixteen castrated Saanen male goats (28.4 ± 0.65 kg) were slaughtered at the end of growth performance study. The animals were slaughtered and the carcasses were evaluated. There were no differences in terms of slaughter body weight (SBW), empty body weight (EBW) and carcass weight between the goats fed TMR with or without the inclusion of *Leucaena*. Dressing percentage based on EBW of goats ranged from 50.5–52.0% although the goats fed TMR with the *Leucaena* appeared to reach a greater weight, the difference was not significant (P>0.05). The differences in terms of the weights of internal organs and non-carcass external components between goats fed TMRs with or without the *Leucaena* forage were not significant. In addition *Leucaena* had no influence on the cooking loss percentage, back fat cover, and area of eye muscle (*longissimus dorsi* Muscle) and Warner-Brazler shear force (WBSF) of Saanen goat meat after cooking as compared to the TMR without *Leucaena*.

Key words: Saanen goat, *Leucaena*, carcass characteristics, meat quality.

6.2 Introduction

Goat meat plays a crucial role in the economy of most developing countries in arid and semi arid areas. The high population of goats in these countries is concentrated in dry regions where many domestic animals cannot thrive (Madruga, 2008). The raising of goats in dry areas is attributed to the fact that they can use the natural vegetation efficiently in these areas and convert them into the useful products, primarily meat.

The claimed rapid increase in the consumption of goat meat in some countries (Stankov *et al*., 2002) is due to the perception that it reduces the risk of cardiovascular diseases (Giese, 1992) because of low fat content, compared to other types of red meat (Park *et al*., 1991; Atti *et al.*, 2004). Kannan *et al.* (2006) indicated that a large proportion of goat fat is deposited in the viscera, with less than 1–4 mm (Webb *et al*., 2005) as subcutaneous fat and less as intramuscular fat compared to the cattle and sheep. Therefore, the appearance of fat in the carcass would be more acceptable to the consumers looking for lean meat. It is important to improve goat meat quality, particularly tenderness, flavour and aroma in order to widen its market further in the areas where it is still neglected. This can be facilitated by assessing and improving the feeding systems used for the goats. Previous reports have indicated that diets with a high concentrate content resulted in high - quality carcasses and improved palatability, hence influence the carcass composition (Hornick *et al*., 1999), muscle pH decline (Kannan *et al*., 2006) and muscle connective tissue characteristics (McCormick, 1989).

However most of these reports were based on feeding programmes using concentrates, which tend to be expensive. There are limited studies conducted to evaluate the effect of leguminous trees which may be locally available in arid areas and their effects on goat carcass and meat quality. Therefore, the aim of the present study was to measure carcass and meat quality of Saanen male goats fed the TMR with or without *Leucaena*.

6.3 Materials and methods

6.3.1 Animal management and experimental design

The study was conducted at the Hatfield Research Farm of the University of Pretoria in the Small Stock section. Sixteen castrated Saanen male goats approximately nine months old were used in this experiment. The animals were fed the experimental diet for 73 days during the growth performance trial and digestibility trial (Chapter 4 and 5 respectively). The management and experimental designs have been described in Chapter 5. The use of the animals for the growth and slaughtering was approved by the University of Pretoria Animal Ethics Committee (Animal Use and Care Committee) under approval reference number EC025–08.

6.3.2 Slaughtering procedure, carcass and meat quality measurements

The day prior to slaughtering, the goats were weighed for final live-weight (FLW) measurement as part of a digestibility trial (Chapter 5). The goats were then fasted by withholding the feed for about 18 hours, but allowing free access to water. The following day the goats were weighed again to get the slaughter body weight (SBW). The experimental abattoir of the University of Pretoria was used to slaughter the animals. The slaughter was done by captive bolt pistol (humane killing)**,** followed by severing the throat and major blood vessels in the neck (Halal-method).

After slaughtering, the head was removed at the atlanto-occipital joint and the blood drained out, then the hind and fore feet were removed at the tarsal-metatarsal joints and carpal-metacarpal joints, respectively. Afterwards, the animals were suspended by the hind legs for further blood draining and skinning. The carcasses (with kidneys, kidney and pelvic fat) were weighed to measure Warm carcass weight (WCW) after skinning, (within 1 hour after slaughtering). The carcasses were chilled at 4°C over night before other parameters were measured and recorded. The weights of non-carcass components were also measured separately and recorded. These included skin, head, feet, thoracic organs (heart, lungs + trachea) and viscera (digestive tract, liver and kidney). The omental fat was also removed from the viscera and separately weighed and recorded.

Carcasses were weighed cold on the following day after storage for 24 hours at 4°C to obtain cold carcass weight (CCW) and recorded. The commercial dressing percentages (CDP) based on (Full body weight) and real dressing percentages (RDP) based on (Empty body weight) were calculated as described by Atti *et al*. (2004):

$$CDP\ (\%) = 100 \times \frac{WCW}{BW}$$

$$RDP\ (\%) = 100 \times \frac{CCW}{EBW}$$

After 24 hours of refrigeration at 4°C, cold carcass weight (CCW) was subtracted from warm or hot carcass weight (WCW) to calculate drip loss. Drip loss was calculated as the difference between (WCW) and (CCW) (Atti *et al*., 2004). The rack and loin cuts were separated between the 11^{th} and 13^{th} ribs. The cross-sectional surface of the *longissimus dorsi* muscle between the 11^{th} and 13^{th} ribs was traced immediately, and the eye muscle area (cm^2) was subsequently measured using a tracing squared paper.

Back fat depth was measured on left side at the 11^{th}–13^{th} rib and rump using a calliper.
The tissues over these cuts were then separately dissected (lean, subcutaneous and inter-muscular fat and bone) then weighed to obtain muscle: fat: bone ratio. The samples of lean meat were cut out, weighed, recorded and then boiled in the sealed polythene bags and cooked in a thermostatically controlled water bath at 75°C for approximately one hour. The samples were dried with paper towel then cooled and stored at 4°C overnight. The next day each sample was dried with a paper towel again and weighed, and the cooking loss percentage was determined. The cooking loss percentage was expressed as the difference between the weight of the sample before cooking and weight of sample after it had been chilled. The cooked samples were then used to obtain shear force. The numbers of cores were cut out parallel to myofibres and each core was sheared perpendicularly to the myofibres using Warner Bratzler (WB) blades on an Instron universal testing machine. The average shear force for each steak was determined then recorded.

6.3.5. Statistical analysis

All parameters were subjected to analysis of variance using GLM programme of SAS (2004) software to test for statistical differences between treatments. Significance of difference between least square means was determined by Tukey's test at P<0.05 (Samuel, 1989).

6.4. Results

6.4.1 Carcass characteristics

The carcass characteristics of Saanen goats fed the TMR are shown in Table 6.1.

Table 6.1: Slaughter body weight, empty body weight, carcass weight, dressing percentage and Drip loss of castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ±se)

	Total Mixed Ration				
Parameter	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
Slaughter body weight (kg/goat)	29.4	27.5	±2.60	0.669	NS
Empty body weight (kg/goat)	26.5	24.5	±2.20	0.7892	NS
Warm carcass weight	13.3	12.7	±1.23	0.8871	NS
Cold carcass weight	12.6	11.9	±1.21	0.8976	NS
Dressing (a) (%)	54.9	54.3	±0.94	0.6378	NS
Dressing (b) (%)	52.6	50.5	±0.86	0.609	NS
Drip loss (kg/goat)	0.7	0.8	±0.11	0.7897	NS
Digestive tract (kg/goat)	3.1	3.3	±0.24	0.8765	NS
Digestive tract (g/kg BW)	10.6	12.4	±0.66	0.5950	NS

NS: Non Significant, Dressing (a) Dressing out percentage based on SBW; Dressing (b) Dressing out percentage based on EBW.

The goats fed both diets attained more or less equivalent body weights during slaughtering, the mean weights being (SBW and EBW) 29.4 vs. 27.5±2.60 kg and 26.5 vs. 24.5 ± 2.20 kg for goats fed the TMR with *Leucaena* and goats fed TMR without *Leucaena* respectively. Total warm carcass and cold carcass traits among goats showed no significant differences (P>0.05) between goats fed TMR with or without *Leucaena*. Similarly the inclusion of *Leucaena* in goat diets had no effect on dressing out in terms of live SBW and EBW as well as on dripping loss. The digestive tract (as kg and in g per kg BW) was also similar among goats in both treatment groups.

6.4.2 Non-carcass characteristics and meat quality

The non-carcass characteristics and dissected ribs and thoracic vertebrae of Saanen castrated goats fed TMR with or without *Leucaena* are shown in Table 6.2 and 6.3 respectively.

Table 6.2: Visceral organs and non - carcass components for castrated Saanen goats: (Least square means ±se)

Parameter (kg/goat)	TMR with *Leucaena*	TMR without *Leucaena*	±se	P-value	Effect
Head	1.50	1.49	±0.121	0.759	NS
Skin	1.90	2.00	±0.122	0.8893	NS
Feet	0.70	0.68	±0.06	0.7874	NS
Reticule-rumen	1.00	1.10	±0.08	0.8976	NS
Intestine	1.25	1.31	±0.111	0.6578	NS
Heart	0.09	0.89	±0.812	0.789	NS
Kidney	0.07	0.08	±0.021	0.7897	NS
Lungs	0.19	0.21	±0.08	0.8765	NS
Liver	0.38	0.41	±0.022	0.6951	NS
Spleen	0.04	0.06	±0.061	0.6582	NS
Omental fat	1.65	1.71	±0.172	0.8741	NS
Kidney & pelvic fat	0.62	0.68	±0.015	0.7521	NS

NS: Non significant

Table 6.3: Dissected ribs and thoracic vertebrae of castrated Saanen goats fed TMR with or without *Leucaena* (Least square means ± se)

	Total Mixed Ration				
Parameter	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
11th–13th ribs thoracic vertebrae (g)	269.0	251.4	±27.4	0.6584	NS
Muscle (%)	56.1	56.5	±1.53	0.8651	NS
Bone (%)	26.0	25.4	±1.40	0.7582	NS
Fat (%)	18.1	18.5	±1.77	0.8834	NS
Muscle/bone ratio	2.2	2.3	±0.14	0.7615	NS
Muscle/fat ratio	3.2	3.1	±0.27	0.6582	NS
Muscle eye (cm)	8.9	9.9	±0.78	0.3787	NS
Back fat thickness (mm)	2.9	2.9	±0.46	0.9070	NS

NS: Non significant

There were no statistical differences in terms of non-carcass components (head, skin, and feet), visceral organs (heart, kidney, lungs liver and spleen) gastrointestinal tract and fat content between goats fed TMR with or without *Leucaena*. There were similar weights recorded for 11th to 13th ribs and thoracic vertebrae for the goats fed TMR with *Leucaena* and TMR without *Leucaena*. The goats in both diets attained similar muscle, bone and fat percent based on the total weight of dissected ribs, and thoracic vertebrae. A similar relationship was observed for the muscle/bone ratio (2.2 *vs.* 2.3) and the muscle/fat (3.2 *vs.* 3.1) ratio for goats fed TMR with or without *Leucaena*.

The meat quality characteristics of *longissimus dorsi* muscle from castrated Saanen goats fed TMR with the *Leucaena* and TMR without *Leucaena* are presented in Table 6.4.

Table 6.4: Carcass quality characteristics of Saanen castrated goats fed TMR wit or without *Leucaena* (Least squares means)

	Total Mixed Ration				
Parameter	with *Leucaena*	without *Leucaena*	±se	P-value	Effect
Cooking loss (%)	27.4	25.9	±1.96	0.6084	NS
Shear force (N)	18.2	17.4	±1.42	0.7063	NS

NS: Non significant

The meat tenderness was not influenced by the inclusion of *Leucaena* in the TMR of castrated goats. The drip loss from the carcass of goats fed TMR with *Leucaena* appeared to be lower (5.4%) than in the carcass of goats fed TMR without *Leucaena* diet (6.2 %) but the difference was not significant. The cooking loss ranged from 25.9% to 27.4% with apparently less value being obtained from goats fed TMR without *Leucaena* as compared to goats fed the TMR with *Leucaena*, but again these apparent differences were not significant (P>0.05). The difference observed between goats fed TMR with *Leucaena* as compared to TMR without *Leucaena* in terms of shear force of the *longissimus dorsi* muscle at 18.2 N and 17.4 N respectively was not significant. Loin muscle eye (cm^2) area for goats fed TMR with *Leucaena* ($8.9cm^2$) and fed TMR without *Leucaena* ($9.9cm^2$) followed the same pattern.

The thickness of subcutaneous fat at the 11^{th} –13^{th} vertebrae on the *longissimus dorsi* muscle was similar for both goats fed TMR with *Leucaena* or without *Leucaena*. These showed that the inclusion of *Leucaena* in the TMR substituting oilseed cake meal (OSCM) had no adverse or beneficial effect on carcass characteristics and meat physical characteristics. Therefore, *Leucaena* can be used by meat producer farmers in rural communities as low cost source of protein and roughage.

6.5 Discussion

The proportions of various visceral organs, parts of digestive tract and non-carcass components were similar in this study and they were in the same range to those reported for various breeds at the same age and live weight but offered different diets (Johnson *et al*., 1995; Dhanda *et al*., 2003; Marichal *et al*., 2003). However, the present study revealed lower proportions of these organs compared to those reported for Sudanese desert goats in the feedlot (El Khidir *et. al*., 1998). There are limited reports of research to evaluate the effect of *Leucaena* and/or other leguminous trees on the carcass characteristics of goats; however, the results of this present study were similar to previous reports when goats were introduced to TMR based on commercial diets and lucerne (Kadim *et al*., 2003; Marichal *et al*., 2003).

This study showed that the goats have more internal fat (omental, kidney and pelvic) than other ruminant animals and this observation is in agreement with the reports of Gibb *et al*. (1993) and Dhanda *et al*. (2003). Dressing percentage (based on EBW) ranged from 50.5% to 52.6% in the present study. This appeared to be slightly less in the goats fed on the TMR without *Leucaena* as compared to the goats fed the TMR with the *Leucaena*, but this was not statistically significant. This range 50.5%–52.6% was in agreement with what had previously been reported (Mahgoub *et al*., 2005; Ryan *et al*., 2007) for Boer crossbred goats fed the different levels of dietary concentrates; and by Santos *et al*. (2008) for indigenous Portugal breeds.

The weight of slaughtered goats based on (EBW) and the dissected weight of the whole three ribs samples and thoracic vertebrae appeared to be higher for the goats fed TMR with *Leucaena* than the goats fed TMR without *Leucaena* though the differences were not statistically significant. Similar trends were observed for bone - to - muscle ratio as well as bone - to - fat ratio. The percentages of muscle (56%) bone (26%) and fat (18%) were similar to the findings reported by Marichal *et al*. (2003) who recorded 58% carcass, 28% bone for the dairy goat breeds and the results of El Khidir *et al.* (1998) for desert Sudanese goats at similar slaughter body weight in terms of bone and muscle. However, the fat content obtained in this study was higher than the values recorded by Marichal *et al*. (2003) who found 11% of total fat; but it was in line with the observations by El Khidir *et al*. (1998) for desert Sudanese goats. The muscle/bone ratio of 2.2 measured in this study was similar to Canary Caprine male dairy goats that had muscle/bone ratio of 2.09, reported by Marichal *et al*. (2003), and for male black goats that had a ratio of 2.2 reported by Abdullah and Musallam (2007) with the same age although these goats were raised under different systems of management. However, the muscle/bone ratio observed in this study was lower than the values reported by Santos *et al*. (2008), for Portugal indigenous breeds and by El Khidir *et al.* (1998), for Sudanese desert breeds. These authors measured a muscle/bone ratio of 3.0. The muscle/fat ratio of 3.1 in this study differed considerably from that measured by Abdullah and Musallam (2007), for male black goats which showed a ratio of 2.5.

This study revealed that the inclusion of *Leucaena* in the TMR had no significant effect on the loin muscle eye area for goats fed TMR with *Leucaena* (mean 8.9 cm^2) compared to goats fed the TMR without *Leucaena* (mean 9.9 cm^2). Dhanda *et al*. (2003) reported the similar values for Saanen x Alpine goats, but this value was slightly lower than the values reported by the authors for other breeds such as Boer x Angora and Boer x Feral.

The back fat cover on the *longissimus dorsi* muscle was similar for the goats fed the TMR with *Leucaena* and TMR without *Leucaena* (2.9 ± 0.46mm). Similar values were reported by Dhanda *et al*. (2003). The thin layer of subcutaneous fat in the present study confirmed previous reports that showed that goats tend to deposit less fat in the carcass (Colomer-Rocher *et al*. 1992; Gibb *et al*., 1993; Dhanda *et al*., 2003). However, the appearance of fat in the carcass would be more acceptable in the market value for small stock, and according to Webb *et al*. (2005) 1–4mm subcutaneous fat is the optimum fat range suggested for flavour and hence acceptability to the consumers.

The remaining water after cooking the meat product is the main indication of its juiciness during eating (Webb, 2005), and therefore this will reflect acceptance of that meat to the consumers. The cooking loss in the present study range from 26% to 27% where the muscles from goats fed TMR with *Leucaena* appeared to have a slightly higher loss of water from the meat than the goats fed TMR without *Leucaena*. As these values were not statistically different it means that the inclusion of *Leucaena* in TMR to replace OSCM had no effect on the cooking loss of castrated Saanen goats. Kannan *et al*. (2006) indicated that neither the protein nor energy level may have an effect on the cooking loss of loin/rib of goats. Similarly Abdullah and Musallam (2007) found that there was no effect of feed energy level on cooking loss of *longissimus dorsi* muscle of male black goats. The cooking loss obtained in this study was within the range of values reported by Dhanda *et al*. (2003) for Boer-Saanen breeds and by Abdullah and Musallam (2007) for black goats. However, the values obtained in this study were higher than the values recorded by Kannan *et al*. (2006) who found the cooking loss value range from 16%–20.8% using castrated Saanen goats fed different diets. However, the values in this study were in line with the findings by Dhanda *et al*. (1999) who recorded the range from 34%–39% for five genotypes including Saanen cross breeds on *longissimus dorsi* muscle though the age of slaughter was different. The above differences could be attributed to the fact that the cooking loss can be influenced by factors such as pH, cooking condition and type of muscle used (Trout, 1988 cited Abdullah and Musallam, 2007).

There were no significant differences in terms of shear force values among the samples of meat from goats that were fed the TMR with the *Leucaena* or the TMR without *Leucaena*. These values were less than the values recorded by Kannan *et al*. (2006) who recorded 3.15–3.48 kg/cm^2 in the loin/rib chops of Saanen goats fed dietary treatments of energy and protein levels; Kadim *et al*. (2003) who recorded (7.2–7.7 kg/cm^2) in the *longissimus dorsi* muscle of Omani goat breeds; Ryan *et al*. (2007) who recorded 5.3–5.8 kg in *longissimus dorsi* muscle of Boer crossbred goats fed the different levels of dietary concentrates. However, the present results for shear force are in line with the values recorded by Abdullah and Musallam, (2007), in the *longissimus dorsi* muscle of castrated and intact male goats (1.9–2.3 kg/cm^2) fed different levels of energy. The shear force reported by various workers might vary considerably due to different factors including nutrition, treatment of animal prior to slaughtering and carcass post-slaughtering, preparation of samples, age, temperature during cooking, pH and type of muscle used (Kadim *et al*. 2003.; Webb *et al*., 2005). In general, Warner –Bratzler- shear force (WBSF) values that are above 5.5 kg can be considered as tough meat and will be rejected by a sensory panel (Johnson *et al*., 1995) and not be accepted for consumption. In addition, Field (1971) cited by Abdullah and Musallam (2007) suggested that shear force values below 3.6 kg are considered to fall within the range of tenderness for goat and sheep meat. Therefore, the values obtained in this study showed that the castrated Saanen goat meat fed TMR with or without *Leucaena* can be a tender meat which is likely to be acceptable for the market.

CHAPTER 7

CONCLUSIONS AND RECOMMENDATIONS

Leucaena leucocephala forage can be used as a source of protein to supplement poor quality pastures for rural communities in South Africa. The high level of crude protein found in this leguminous plant confirms that it can substitute the commercial diets such as OSCM which are often not affordable to people in the rural communities. There was high amount of fibre in the pods and twigs compared to the leaves of *Leucaena*. This makes it is possible for it to be used as a source of roughage as well. The present study revealed that the use of *Leucaena* at the rate of 25% of DMI did not have negative effect on the milk yield, milk composition, and body weight and condition of Saanen milk goats when compared to OSCM as a protein source. However, the inclusion of *Leucaena* in a TMR diet fed to Saanen goats was shown to reduce the amount of urea in the milk indicating efficient use of nitrogen from *Leucaena* ingested by these milk goats compared to OSCM as a protein source.

The results of this study also showed that the inclusion of *Leucaena* in the TMR improved the palatability of the diets of goats, and therefore increased DMI. In addition *Leucaena* forage had no adverse effect on the DMI and digestibility in Saanen male goats. Therefore it improved the body weight gain, feed conversion ratio, and milk and meat production of Saanen goats as well as the commercial diets do. The present study investigated the intake and digestibility response of TMR diet with or without the inclusion of *Leucaena* fed to Saanen castrated goats as it was not possible to use lactating goats for this purpose because they were not fed individually. The growth, intake and digestibility experiment for female Saanen goats should be investigated, but the results can be expected to be similar.

The carcass measurements in this study were also not affected to the inclusion of *Leucaena* in the TMR diet fed to the male goats. However it is not clear if *Leucaena* has any effect on chemical composition of meat. This also needs to be investigated in South Africa.

The anti nutritive factors such as mimosine and condensed tannin found in the *Leucaena* forage might inhibit the use of this legume. The relatively low level of energy as well as level of rumen undegradable protein in this legume might be the additional factors adversely affecting the potential of *Leucaena* in milk goat production. However, the incorporation of 25% *Leucaena* used in this study with other protein sources which are highly digestible and/or energy source concentrates can be used to balance the diet of lactating goats. The amount of these resources could be reduced in the diet of goats if *Leucaena* is included and can be achieved by formulating diets for goats as a total mixed ration. Since the formulation and mixed of the ingredients might be not practicable in many rural areas where goats use pastures, the farmers might limit intake by restricting the time allocated to goats to eat *Leucaena*. It is important for the farmers to cut, chop and then dry *Leucaena* before feeding the goats, as this will enable them to restrict the amount of *Leucaena* fed to the goats and reduce the risk of mimosine. In addition DHP-bacteria (*Synergistes jonesii*) should be introduced in the areas where *Leucaena* is used, and especially in the unadapted areas, this should be facilitated by the government or NGOs.

The scope of the present study was limited by several factors, which warrant further investigation. These include:

- The possible presence and level of mimosine in the milk and blood serum in Saanen dairy goats fed TMR with *Leucaena* in South Africa as it has been done in other countries (Gupta and Atreja, 1999).
- The chemical composition of meat has to be studied as affected by *Leucaena*, as it is not well discussed in the literature.
- The introduction of DHP - degradation bacteria and the persistence of these bacteria.
- The use of goats fitted with rumen cannulas are also needed to be able to study all parameters of nutrition of the feeds used in the experiment.

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