PRODUCTIVITY OF SOUTH AFRICAN INDIGENOUS *NGUNI* GOATS POSSESSING *Synergistes jonesii* BACTERIA ON *LEUCAENA LEUCOCEPHALA*-GRASS AND NATURAL PASTURES

by

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THESIS

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Thesis Summary

The main objectives of the study reported in this thesis were to investigate the cause of poor conception and high pre-weaning kid mortality rates among South African indigenous *Nguni* goats (SAING) maintained on *Leucaena leucocephala*-grass pasture (LGP), and the potential of natural pasture (NP) and improved pasture (LGP) for the productivity of the mimosine-susceptible SAING breed after receiving dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) via animal-to-animal transfer.

Seasonal variation in forage quality and mimosine contents of two *Leucaena leucocephala* varieties, detection of *S. jonesii* from rumen digesta, effects of feeding *Leucaena* foliage on semen quality, grazing activities and blood metabolite profiles during gestation and reproductive performance prior and post kidding were evaluated. Aspects relating to reproductive performance prior and post kidding, colostrum and milk constituents, growth performance and blood profiles of weaned and unweaned kids, dams-to-kid transfer of *S.jonesii*, protein and energy requirements of the SAING kids were also examined.

Cultivar Cunningham was better suited for the location of the study than cv. Spectra because it was available during ten months of the year compared to the six months of cv. Spectra availability. Growth performance, reproductive performance and overall productivity of SAING maintained on LGP were better than those of their counterparts on NP. Benefits of LGP during gestation include higher body weight gain of does, higher incidence of twin multiple births and higher birth weight of kids compared to values on NP. Higher milk yield, earlier return to first postpartum oestrus and better pre-weaning growth of kids relative to values obtained on NP, were the benefits of maintaining SAING on LGP during lactation.

Over the entire study, conception on LGP treatment compared favourably to that on NP. Feeding *Leucaena* foliage did not have any detrimental effect on semen quality and fertility of the SAING bucks. Feeding LGP as gestation or/and lactation feed had no detrimental carry-over effect on the post kidding reproductive performance of SAING does and kids. The kids were also able to acquire *S. jonesii* from dams via animal-to-animal transfer.

Declaration

I Mr Adebayo Abel Akingbade hereby declare that the research reported in this thesis is the result of my own investigations, except where acknowledged, and has not, in its entirety or in part been previously submitted to any University or Institution for degree purposes

Signed..

I Dr Nsahlai, I.V., Chairperson of the Supervisory Committee, approve release of this thesis for examination.

Signed..

Dedication

This thesis is dedicated to my mother

Mrs Kehinde Abigail Akingbade

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ii. Akingbade, A. A., Nsahlai, I. V., Bonsi, M. L. K., Morris, C. D. and Du Toit, L. P. (2001a). Reproductive performance of South African indigenous goats inoculated with DHP-degrading rumen bacteria and maintained on Leucaena leucocephala/grass mixture and natural pasture. ***Small Ruminant Research* 39(1): 73-85.**

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Accepted papers

i. Akingbade, A. A., Nsahlai, I. V. and Morris, C. D. (In Press) The effects of *Leucaena leucocephala* on semen quality, fertility and reproductive performance of dihydroxy pyridone-adapted South African *Nguni* goats. ***Journal of Agricultural Science (Cambridge).***

ii. Akingbade, A. A., Nsahlai, I. V. and Morris, C. D. (In Press). Growth performance and blood profile of South African *Nguni* goat kids on concentrates or pasture. ***The Indian Journal of Animal Sciences.***

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ii. Akingbade, A. A. (2001). Natural vegetation and *Leucaena leucocephala*-grass pasture as feed resource to South African *Nguni* goats. **ANS-UNATAL Seminar**.

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iv. Akingbade, A. A., Nsahlai, I. V. and Morris, C. D. (2001). Potential of natural vegetation and improved pastures (*Leucaena leucocephala*-grass pasture) for the production of South African *Nguni* goat. South African Society of Animal Science Symposium. ***Proceedings, Animal Production Research in Kwazulu-Natal,*** **24th July, 2001, p. 9 (Abstract).**

v. Nsahlai, I. V., Akingbade, A. A. and Morris, C. D. (2002). Energy requirements of early weaned kids of South African Nguni goat kids. Grassland Society of South Africa (GSSA)/South Africa Society of Animal Science (SASAS) Congress 2002 Abstract. Pg. 75.

CHAPTER 1

1.1 General introduction and review of literature

Small (sheep and goats) and large (cattle and equines) ruminants have the ability to utilise forage feeds and crop byproducts that are unsuitable for human or monogastrics consumption (De Villiers, 1996). Livestock products include meat and milk which are essential in the diet of growing animals (Akinsoyinu and Longe, 1982). Animal products assist in preventing protein deficiency in human diets (Donkin, 1998). Malnutrition can set in when the intake of animal products is inadequate (Cronje, 1998) and intake of plant proteins is poor.

Goats are more important to the subsistence needs and economic development of the rural poor because they provide a year round regular supply of meat, milk and cash (FAO, 1990 cited by Adogla-Bessa and Aganga, 2000). Small ruminants have shorter gestation length (5 vs 9 months; Amoah *et al.*, 1996) and require lower initial capital to establish than large ruminants. The shorter gestation length enhances rapid increase in stock numbers via accelerated parturition (three parturitions in two years; Wheeler and Land, 1977). Among the small ruminants, goats (*Capra hircus*) generally are drought tolerant (Mohy El-Deen *et al.*, 1985) and can withstand and adapt well to extreme climatic and nutritional constraints compared to sheep in the tropics and sub-tropics. These advantages could explain why goats are more numerous than sheep and cattle in the tropics and sub-tropics (Ehoche and Buvanendran, 1983).

Goats were possibly among the earliest domesticated ruminants (Steele, 1996). There are approximately 446 million goats in the world (Steele, 1996) and they constitute about one third of the population of the three main ruminants (cattle, sheep and goats; Table 1.1). Most developing countries are within the tropical and subtropical regions of the world and are associated with high environmental temperatures and humidity (Mohy El-Deen *et al.*, 1985).

Forage species in the tropics mature and become fibrous earlier than forage species in temperate zone (Payne, 1990) resulting in forage species with high and low crude fibre and crude protein (CP) contents, respectively, and poor digestibility (Elliott and Fokkema, 1963).

Table 1.1. Distribution of farm animals in the world (Payne, 1990)

Ruminants	World Population (10^6)	Ratios (%)
Goats	446	30.2
Sheep	470	31.8
Cattle	563	38.1

The majority of the world's goat population are located in developing countries (FAO, 1984) and is largely responsible for the substantial portions of the total world goat products coming from these countries (Table 1.2). Nutritional constraints lower animal reproductive potential, reduces the supply of animal products, increases the price of animal products and decreases the intake of animal products (Devendra, 1987); coupled with low plant protein, such shortages can contribute to high incidence of malnutrition in most developing countries. There are approximately 300 breeds and types of goats world wide; the majority of these are located in the tropics and subtropics (Payne, 1990). Goats or goat products serve immense agro-technical, economic, health and cultural benefits.

1.1.1. Agro-technical benefits of goats

Goats are hardy animals and can thrive on depleted rangelands, where browse forms most of the feed or on land unsuitable for other livestock (Cuenca, 1977). Goats are predominantly browsers or top horizon grazers (Huston, 1998), a trait that enhances their use as a biological control tool in overcoming problems of shrubby weeds and bush encroachment (Poppi and Norton, 1995).

Dung and urine of goats can also serve as manure in improving soil fertility of pastures or crops in a mixed farming system.

Table 1.2. The contribution of goats to the total world meat, milk and skin production (FAO, 1984)

Goat products	**Production (10^3 metric tons)**	**% of total world production**
Milk	5490	73.2
Meat	1894	92.8
Skins	359	93.9

1.1.2. Economic benefits of goats

Goat products comprise mainly of meat, milk, skins, leather or cashmere (De Villiers, 1997). Goats are known as the poor man's cow because they provide milk in enough quantity for household consumption. Goat's milk is easily digestible and serves as an alternative milk for humans allergic to cow milk or who suffer from skin conditions such as eczema (Steele, 1996). Goats also provide meat in manageable quantities for household consumption. Goats can be used as an alternative for cash and collateral and could serve to minimise risk (Ørskov and Viglizzo, 1994) especially during crop failure or an unexpected financial predicament (Adebowale *et al.*, 1992).

1.1.3. Health benefits of goats

As from the middle of last century, foods high in fat content or containing a lot of milk are increasingly being rejected in the affluent societies, because such foods have been associated with a high incidence of coronary heart disease (Keys, 1953). Goat meat, however, contains lower fat than for example chicken, beef and mutton (Coetzee, 1998) and also has a high protein content (Huston, 1998). The less tendency of goats towards less fat deposition has been attributed to the high protein content of goat meat (Huston, 1998).

1.1.4. Cultural benefits of goats

There is wide cultural and religious acceptance for goats and their products. Goats are widely used in cultural ceremonies. Mkhwanazi (1997) has shown that Zulus, the most populous tribe in the Republic of South Africa (RSA), prefer goats to sheep for their ceremonial, ritual and cultural practices. The preference of Zulus for goats (Mkhwanazi, 1997) has been attributed to the substantial portions of goats in the RSA being marketed in KwaZulu-Natal Province (KZNP) (Slippers *et al.*, 1997).

1.2. **Goats in the Republic of South Africa**

The goat population in RSA was approximately 6.46 million in 1995 (De Villiers, 1996). The goats in the RSA constitute 18% of the total population of small ruminants. KwaZulu-Natal Province in the RSA has 13.2 % of the total national goat band (group of goats kept together). The province ranks third in total national goat population in RSA after the Eastern Cape (48.9 %) and Limpopo (formerly known as Northern Province) Provinces (13.8%; Directorate Agricultural Statistics, 1996). Most of the goats in KZNP are indigenous goats commonly known as "*Nguni* goat" (Slippers *et al.*, 1997).

Indigenous plants or animals worldwide constitute valuable sources of genetic material because of their adaptation to the harsh local climatic and nutritional constraints (Cronje, 1998; Mamabolo, 1999). These indigenous animals also require less improved management practices compared to exotic breeds and are less susceptible to prevailing local parasites, diseases and infections. Reports by other workers (Webb *et al.*, 1998) have shown South African indigenous goats (SAIG) to be hardier, more resistant and less susceptible to internal parasites than sheep.

The South African indigenous *Nguni* goat (SAING) breed is one of the RSA unimproved SAIG breeds. *Nguni* goats are small in size and have a short-haired coat. The coat colours vary, ranging from black, brown and white, to a combination of the three colours. South African indigenous *Nguni* goats constitute a substantial portion (85 %) of the goats found in the less developed areas of KZNP (Livestock and Meat Statistics cited by De Villiers (1996)). Slippers *et al.* (1997) attributed the high population of SAING in the less developed areas of KZNP to the substantial human population in the rural areas in the province. Besides, rural dwellers are mainly the custodians of indigenous breeds. Based on the criteria used by Devendra and Burns (1983) to classify goats, the *Nguni* goat breed falls into the group referred to as a small breed with mature body weights ranging between 19 and 37 kg. *Nguni* goats are kept primarily for meat and cultural practices (Mkhwanazi, 1997).

Previous studies (Akingbade, unpublished data) among rural dwellers with small holdings of indigenous goats and sheep (West African Dwarf goats and West African Dwarf sheep, respectively) in the south western part of Nigeria revealed that the farmers attach more importance to flock (group of sheep) or band (group of goats) numbers (fertility rate, prolificacy twins and multiple birth types) rather than growth performance (live weight gains) of the small stock. Total number of weaned goats depends on the number of kids delivered by the does in the band (Steinbach, 1988) and also on the pre-weaning kid survival rate. However, the efficiency of improving goat productivity depends on the reproductive performance of both does and bucks in the band. Reproductive performance is influenced by age, genotype, season and nutrition (Dunn and Moss, 1992), but nutrition remains the most vital factor (Rhind, 1992), because of its influence on reproductive traits.

1.3. Nutrition and goat productivity

Economically viable livestock production systems depend on the use of inexpensive and easily available feed resource. Inadequate nutrition is a major constraint to livestock production in the tropics and subtropics (Abdulrazak *et al.*, 1997). The poor quality of the forage species in the tropics and subtropics limits intake and digestibility (Remenyi and McWilliam, 1986) and animal performance. Nutrition during breeding influences ovulation (Isaacs *et al.*, 1991), conception (Randel, 1990; Tegegne *et al.*, 1993), foetal development and survival (O'Callaghan and Boland, 1999), while nutrition during gestation influences body weight change during gestation, foetal development (Dunn and Moss, 1992), colostrum and milk yield (Kassem, 1988) and live weights of offsprings at parturition (Rattray, 1992).

Feeds offered during lactation influence milk yield (Sibanda *et al.*, 1997), pre-weaning growth performance and survival of kids (Mukassa-Mugerwa *et al.*, 1991) and return to postpartum oestrus (Nugent *et al.*, 1993). Inadequate nutrition adversely affects growth, age at puberty and oestrus, and also prolongs parturition intervals (Stagg *et al.*, 1995). Of all nutrients, protein remains the most limiting in the diet of ruminants (Preston and Leng, 1987). Protein content of natural vegetation in the tropics and subtropics, limits growth, reproductive performance and animal productivity (Harb, 1994). Ovulation, an important factor that influences litter size, is also positively correlated with diet protein content (Rhind, 1992).

South African indigenous goats are mostly reared under extensive systems of management (Cronje, 1998). The main feed available to indigenous goats is the natural pastures on uncultivated and fallow lands around the villages or on rangeland. Indigenous goats are rarely offered any supplementary feed or mineral supplement. The nutritional constraint is precarious, especially in places that experience drought, frost and winter (including the site of this study). The cold temperature and frost in winter result in a low quantity and poor quality of grass species

(Zacharias, 1990) and partial to complete leaf-fall of foliage of most leguminous browses (Kirkman, 1988). However, in coastal and lowland areas of the RSA, and in the sub-tropical north, temperature does not constraint growth and availability of most leguminous browses (Morris personal communication, 1999).

The adverse effects of seasonal vegetational change in the tropics and sub-tropics on herbage quality result in a search of methods for improving forage quality (Aletor and Omodara, 1994). Chemical (Adebowale *et al.*, 1989; Goodchild, 1990) and enzyme (Al-Saghier and Campling, 1991) treatments have been advocated for improving the quality of roughage diets. However, these methods are either expensive or too technical for a majority of illiterate and small scale farmers in developing countries to conveniently adopt. These financial and technical constraints limit full adoption of such methods (Mero and Uden, 1990). However, reports of other workers (Machado *et al.*, 1978; Bonsi *et al.*, 1994) have shown that feeding of some perennial leguminous browses (trees and shrubs), notably *Leucaena* species, to be a cheaper alternative to the expensive and too technical methods of improving forage quality.

Among leguminous browses used as animal fodder, the *Leucaena* species have been credited with some of the highest values for soil nitrogen fixation (Abdel Magid *et al.*, 1988). *Leucaena* species contain appreciable quantities of protein, carotene and vitamins (Machado *et al.*, 1978). The crude protein contents of *Leucaena* species range between 22 and 29 % (Wahvuni *et al.*, 1982; Siaw *et al.*, 1993) and could improve soil fertility (Sanginga *et al.*, 1985). *Leucaena* species are also drought tolerant (Topark-Ngarm and Gutteridge, 1990; Akinola *et al.*, 1999). Livestock productivity in a situation where the available feed resource is of low nutritive value depends on the rate of feed intake. Voluntary dry matter intake (VDMI) is one of the factors that determine growth and reproductive performance (McDonald *et al.*, 1990). *Leucaena* improves the rumen environment which consequently increases the microbial population and enhances roughage degradation (Bonsi and Osuji, 1997), and improves dry matter intake of poor quality roughage basal diet (Bonsi *et al.*, 1995).

1.4. *Leucaena* species

1.4.1. History and botanical description

The genus *Leucaena* originated in South America (Jones, 1986) and the Yucatan Peninsula of Mexico (Brewbaker *et al.*, 1985) but is now naturalised throughout the tropics (Garcia *et al.*, 1996) covering 2 to 5 million ha world wide (Brewbaker and Sorenson, 1990). *Leucaena* has been in the RSA for more than 70 years (Fenn, 1987; Underwood, 1993). Morphologically, the *Leucaena* plant ranges from shrubs (5 m high) to trees (20 m high; Kruger and Grossman, 1990). They are perennial summer growing plants that can exist for decades, with half-life of 50 years (Jones and Carter, 1989). *Leucaena* species are thornless shrubs or trees with bi-pinnate leaves and a deep root system (Shelton and Brewbaker, 1994).

Leucaena species belong to the family *Leguminosae* and subfamily *Mimosoidae* (Jagan and Azeemoddin, 1988). The 16 recognised *Leucaena* species are *L. leucocephala, L. revoluta, L. collinsi, L. cuspidata, L. esculenta, L. salvadorensis, L. trichodes, L. shannoni, L. macrophylla, L. greggi, L. pallida, L. lanceolleta, L. diversifolia, L. multicapitula, L. retusa and L. pulverunleta* (Sorenson and Brewbaker, 1994). *Leucaena* species are differentiated on the basis of inflorescence and size of tree, leaflet, and pod (Anonymous, 1990). Of all the *Leucaena* species, *Leucaena leucocephala* remains the most widely distributed, researched and utilised species for fodder (Casas and Caballero, 1996). *Leucaena leucocephala* cultivars include Cunningham, El-Salvador, Guatemala, Hawaii, Peru and Spectra.

1.4.2. Climatic and soil requirements

Leucaena species are adapted to a wide range of climatic conditions. They are tropical species and require a warm climate, performing best between 22 and 30 °C and rarely do well below 15 °C (Brewbaker *et al.*, 1985). However, temperature does not constrain growth and the availability of *Leucaena* in coastal and lowland areas of the RSA (Morris personal communication, 1999). According to Skerman (1977), the latitudinal requirements for the *Leucaena* species are 30 °N and S of the equator. *Leucaena* species tolerate frost, but production is reduced. These species are susceptible to extreme cold or heat (Isarasenee *et al.*, 1984). Most seedlings of *Leucaena* species die, while mature *Leucaena* stands drop their foliage during the frost/winter season (Jurado *et al.*, 1998), but there are differences in cold tolerance between various species and cultivars within species of the *Leucaena* (Kruger and Grossman, 1990).

Leucaena species grow rapidly in soils with adequate water and nutrients (Ruaysoongnern, *et al.*, 1985) and do not thrive on acidic soils (Mullen *et al.*, 1998). *Leucaena* species do well on well-drained neutral to calcareous soils, but can also adapt to clay soils (Chamberlain, 1998). Soil mineral status also influences the mineral content of *Leucaena* foliage (Akbar and Gupta, 1985b). Precipitation (rainfall) requirements of the *Leucaena* species contained in literature (Bodgan, 1977; Skerman, 1977) are between 750 and 1700 mm, however, their deep roots aid in efficient exploitation of underground water in dry environments, where precipitation is as low as 380-600 mm (Akinola *et al.*, 1999). *Leucaena* survives prolonged period of drought by dropping its leaves and rapidly regenerates, once the rains fall (Kruger and Grossman, 1990), while they are able to thrive in areas with over 3000 mm rainfall (Swasdiphanich, 1992).

1.4.3. Establishing *Leucaena* species

The establishment of *Leucaena* species ranks high as a major limitation to *Leucaena* propagation (Lascano *et al.*, 1995). The major constraint in establishing *Leucaena* is competition from weeds which slows down the rate of establishment (Cooksley, 1974). Regular weeding during the establishment is therefore essential. The *Leucaena* psyllid (*Heteropsylla cubana* Crawford) attack and disease infestation are additional constraints in the establishment of *Leucaena* species (Lesleighter and Shelton, 1986).

Another constraint to *Leucaena* development is shade (Rushkin, 1977), as it tolerates partial shade but grows slowly under heavy shade (Underwood, 1993). *Leucaena* species can be established either via asexual (stem cuttings) or sexual (seeds) method (Duguma, 1988), with the former being the most rapid method of establishment. The seedlings grow very slowly due to a large quantity of the seedling energy being devoted to root development. However, once it survives the seedling stage, *Leucaena* has the ability to tolerate misuse, can compete with grass species and can recover rapidly from adverse climatic conditions (Kruger and Grossman, 1990).

The main constrain with the propagation by seed is the hard-seededness which inhibits germination. However, this is easily overcome by seed treatment. Seed treatment methods employed to overcome hard-seededness so as to enhance germination, include abrasion (Lulandala, 1981), mechanical scarrification, treatment with hot water (Gonzalez and Mendoza, 1995) and treatment with acid (Pathak *et al.*, 1974). Hot water treatment, beside facilitating germination, also reduces the risk of fungal infections (Prabhu *et al.*, 1982).

Inoculating *Leucaena* seeds with effective rhizobia strains prior to sowing in the nursery improves forage growth, forage yield and nodulation. The *Leucaena* plant has the ability to fix atmospheric nitrogen (Sanginga *et al.*, 1985) due to a symbiosis with rhizobium bacteria (Kruger and Grossman, 1990).

1.4.4. Dry matter (DM) yield and chemical composition of *Leucaena*

Leucaena is one of the highest producers of forage protein among tropical legumes (Brewbaker and Hutton, 1979). A number of comparative studies on dry matter yield reported by Kang and Reynolds (1986) showed that *Leucaena* species yield more than alternative legumes in the tropics. The forage yield of *Leucaena* species depends on the soil nutrient status, precipitation (Akinola *et al.*, 1999), plant genotype (Baston, 1987), environment (Halliday, 1981) and grazing/agronomic practices (Krishnamurthy and Gowda, 1983). Yields which range between 20 and 25 t/ha/yr under ideal conditions (Guevara *et al.*, 1978) depends on agronomic management practices employed (i.e. plant spacing, cutting height, harvesting frequency; Maclaurin *et al.*, 1982).

However, annual dry matter yield of *Leucaena leucocephala* at the Ukulinga Research and Training Farm of the University of Natal, Pietermaritzburg, reported by Maclaurin *et al.* (1982) was less than 10 t/ha. This low yield could be attributed to the conditions of the site not being ideal for the plant. Reports of Kruger and Grossman (1990) stated that a yield of 20 tons DM/ha can only be achieved in the sub-tropics under irrigation or where annual precipitation exceeds 800 mm. Under favourable conditions, *Leucaena leucocephala* yields forage of excellent nutritive value, which compares favourably with other desirable leguminous species (Tables 1.3 and 1.4). Amino acid profiles of proteins contained in *Leucaena* foliage is comparable with that of soyabean, fish meal (Ter Meulen *et al.*, 1979) and other animal proteins (Kale, 1987). Mineral and chemical composition of *Leucaena* foliage varies considerably between and within species and varieties (Sethi and Kulkarni, 1995), with stage of growth (Deshmukh *et al.*, 1987) and parts of plant (Yadav and Yadav, 1988).

Seeds and immature leaves of *Leucaena* plant contain the highest crude protein (CP) content and the stem and dry pods the lowest values (Hilal *et al.*, 1991). Crude protein content ranges from 18.8 to 29.4% (Table 1.3), digestible dry matter exceeds 55% while 70% of the CP is digestible (Kang'ara *et al.*, 1998). Crude protein content increases with cutting frequency and increased leaf : stem ratio (Yadav and Yadav, 1988).

Table 1.3. Chemical composition of *Leucaena leucocephala* leaves (g/kgDM)

L. leucocephala	CP	Ash	NDF	ADF	Lignin	Tannin	Reference
,,	269	-	383	226	68	-	Van Eys *et al.* (1986)
,,	267	57	312	226	99	37	Robertson (1988)
,,	258	69	309	234	87	55	Goodchild (1990)
,,	294	83	216	104	32	-	Siaw *et al.* (1993)
,,	-	-	250	160	-	-	Bonsi *et al.* (1994)
,,	188	-	453	190	79	-	Nsahlai *et al.* (1995)
,,	-	-	280	158	-	-	Bonsi and Osuji (1997)

DM: dry matter; CP: crude protein; NDF: neutral detergent fibre; ADF: acid detergent fibre.

Table 1.4. Mineral element composition of *Leucaena leucocephala* leaves (g/kgDM)

L. leucocephala	N	S	P	N:P	K	Ca	Ca:P	Reference
,,	45	-	3	15	-	5.4	1.9	Gohl (1981)
,,	33	-	2	20	13	23	14.4	Brewbaker (1986)
,,	43	3	2	23	-	-	-	Robertson (1988)
,,	42	2	2	26	-	-	-	Ahn *et al.* (1989)
,,	-	-	3	-	11	15	-	Aletor and Omodara (1994)
,,	41	2	2	23	11	20	11.1	Bonsi *et al.* (1995)

DM: dry matter; N: nitrogen; S: sulphur; P: phosphorous; K: potassium; Ca: calcium.

1.4.5. Pests of *Leucaena* species

For leguminous browse cultivated as a forage resource, the effects of foliage pests cannot be underestimated. The commonly known insect pest in *Leucaena* species is the *Leucaena* psyllid (*Heteropsylla cubana* Crawford). The *Leucaena* psyllid is a pantropical pest that causes devastating damage to young shoots and mature plants (Austin *et al.*, 1995). The devastating effect of psyllid has restricted the use of *Leucaena* species (Bray and Sands, 1987). Psyllid was spotted on the *Leucaena leucocephala*-grass plots at Ukulinga Research and Training Farm, University of Natal, Pietermaritzburg in 1998 (Du Toit personal communication, 1999).

The most psyllid-resistant *Leucaena* species (*L. Pallida*, *L. esculenta* subsp. paniculata, *L. diversifolia* subsp. stenocarpa and *L. trichandra*) lack the versatility and forage attributes of *Leucaena leucocephala* (Dzowela *et al.*, 1998). Psyllid infestation can be stemmed biologically by using the predator *Curinus coeruleus* (Oka and Bahagiawati, 1988). Propagation of disease resistant *Leucaena* cultivars also was found to be an effective control measure against psyllids, but this measure was reported (Rumakom, 1986) to be detrimental to forage yield.

1.4.6. General benefits of *Leucaena* species

Leucaena is a multipurpose leguminous browse. Pods, young leaves and seeds of *Leucaena* species are nutritious and relished by ruminants (Casas and Caballero, 1996). *Leucaena* forage is generally available (except in winter/frosted areas), when the quantity and quality of natural grass pastures are poor (Das and Sendalo, 1991). *Leucaena* leaves and seeds are used for human consumption in Central America, Indonesia and Thailand. Edible oil (Raie *et al.*, 1982) has been extracted from *Leucaena* seeds. Medicinal properties of *Leucaena* forage have been employed in relieving pain, stomach ache, worm infestation and also as a contraceptive (Rushkin, 1984).

Leucaena species also serve as shade and nurse crop in the cocoa and coffee nursery (Rika, 1998), and as support for vines, creeping vegetables and arable crops (Moat *et al.*, 1998). The wood of some *Leucaena* species serves as poles for making fences, while the plants are used for demarcating land boundaries (Abdulrazak and Ondiek, 1998) and wind breaks. Dried *Leucaena* wood is even used as firewood (Preston and Vaccaro, 1982).

Leucaena plants also enrich soil fertility via nodules located on their fine lateral roots, i.e. *Leucaena* root nodules are responsible for nitrogen fixation (NAS, 1984). The green *L. leucocephala* has produced favourable results in trials when compared to application of inorganic fertilizers (Underwood, 1993). *Leucaena* species can also prevent soil erosion and are valuable in the rehabilitation of eroded land (Moat *et al.*, 1998).

In spite of these numerous benefits of *Leucaena*, it has remained a neglected crop in the RSA from a pastoral point of view that it is toxic to animals (Underwood, 1993; Henderson, 2001). *Leucaena* species are categorised as a weed (Category 1) in Western Cape Province of the RSA and an invader plant (Category 2) elsewhere in RSA (Henderson, 2001). In the recent report of Henderson (2001), category 1 plants are prohibited plants that must be controlled, while category 2 plants are commercial plants that may be propagated in demarcated areas- provided that permission has been granted and adequate steps taken to prevent their uncontrollable spreading.

1.4.7. Anti-nutritional constituents of *Leucaena* species

That plants did not evolve to serve animals could be attributed to their possession of defence mechanisms such as odour, toxins (Barry and Blaney, 1987), thorns, fibrous foliage, chemicals, secondary compounds (anti-nutritional factors/anti-nutrients) and growth habits (Kumar and D'Mello, 1995). These serve to protect plants from defoliation, fungal and insects attack and extinction (Woodward and Coppock, 1995). Secondary plant compounds become more of a problem when browse herbage containing such compounds is fed as a sole diet (Kaitho,1997) to susceptible ruminants. Anti-nutritional factors in plants lower nutritive value (Nsahlai *et al.*, 1994) and are deleterious to animal health and performance and thus limit the use of such plants as a feed resource. The main secondary plant compounds in *Leucaena* species are mimosine and condensed tannins (D'Mello, 1992).

Tannins: Tannins have both negative and positive effects on nutritive value (Reed *et al.*, 1990). Condensed tannins adversely affect palatability, intake (Makkar, 1991), digestibility (Woodward and Reed, 1989) and animal performance (Nherera *et al.*, 1998). Tannin-protein/enzyme complexes decrease rumen ammonia concentrations (Driedger and Hartfield, 1972) thus inhibiting fermentation of structural carbohydrates (D'Mello, 1992). Tannin-protein complexes can also render protein unavailable for digestion in the small intestine (Norton *et al.*, 1992), increase faecal nitrogen and consequently lower nitrogen retention (Reed, 1995).

The beneficial roles of tannins include prevention of protein degradation in the rumen, thereby increasing bypass proteins (Jones and Mangan, 1977) for hind-gut protein digestion. Tannins also confer advantage in ruminant nutrition by safeguarding against the occurrence of bloat (Gupta *et al.*, 1992) due to their ability to precipitate protein (Kumar and D'Mello, 1995).

Feeding of concentrate diets (Raghavan, 1990), urea supplementation (Kumar, 1992) and drying (Ahn *et al.*, 1989) of high tannin forage reduces tannin concentrations. Blytt *et al.* (1988) reported that polyvinyl polyrolidone (PVP) can be used to reverse tannin inhibition of digestive enzymes. Tannin binding materials (e.g. adsorbent such as polyethylene glycol (PEG)) alleviate problems associated with tannins (Jones, 1994). Polyethylene glycol inactivates or displaces tannin from tannin-protein complexes and thus improve nitrogen digestibility (D'Mello and Acamovic, 1989). However, costs of PVP and PEG use are prohibitive. Apart from the prohibitive costs of

PEG which render its use uneconomical (Kumar and D'Mello, 1995), its indiscriminate use compromises bloat-retarding traits of tannins (D'Mello, 1992).

Mimosine: Mimosine (Figure 1.1) is the main obstacle to the utilisation of *Leucaena* by ruminants (Sethi and Kulkarni, 1995). Mimosine is a non-protein amino acid (β-N-(3-hydroxy-4-pyridone)) contained mainly in the seeds and leaves of *Leucaena* species.

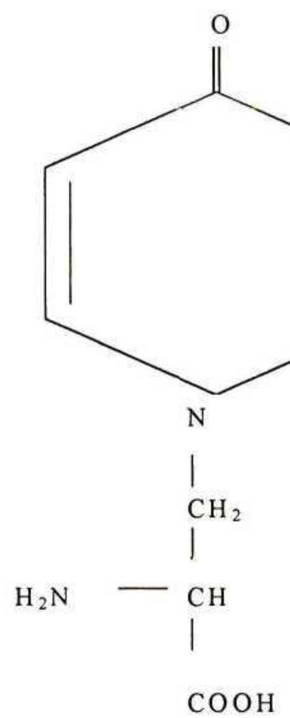

Figure 1.1. Chemical structure of mimosine (Sethi and Kulkarni, 1995)

Mimosine constitutes 60% of the total amino acid in *Leucaena* (Sethi and Kulkarni, 1995) and is higher in the seeds than in the leaves (Gupta and Atreja, 1998a). Mimosine is rapidly hydrolysed or degraded in the rumen by rumen microbes or certain plant enzymes in the leaves which are released during maceration (Tangendjaja *et al.*, 1983) to yield two metabolites; 3-hydroxy-4(1H)-pyridone (3,4-DHP) and 2-hydroxy-3(1H)-pyridone (2,3-DHP) (Gupta and Atreja, 1998a). The metabolites are less toxic than mimosine (Hegarty *et al.*, 1979) and probably explains why animals that are able to degrade mimosine to DHP tolerate higher levels of *Leucaena* in their diets compared to those that are unable to break down mimosine (Sethi and Kulkarni, 1995).

Mimosine is anti-mitotic (Boehme and Lenardo, 1993) and goitrogenic (El-Harith *et al.*, 1981; Jones and Megarrity, 1986) in unadapted ruminants fed *Leucaena* forage above 30% of the daily diet (Shukla *et al.*, 1990). Research by Smuts *et al.* (1995) showed that mimosine lowers plasma amino acid concentrations through its chelating effect. Mimosine inhibits the activities of metal-containing enzymes by competing with metal ions through chelate formation (Tsai, 1961; El–Harith *et al.*, 1981). The mineral element-chelating ability of the 3-hydroxy-4-oxo functional group of the pyridone ring in mimosine {β-N(3-hydroxy–4-pyridoone)-α-amino propionic acid} has been implicated in promoting deficiencies of mineral elements such as zinc (Sethi and Kulkarni, 1995) and phosphorous (Girdhar *et al.*, 1991).

Mimosine, acting as a tyrosine analogue, influences various serum enzyme activities and thus interferes with the metabolism of some amino acids (El-Harith *et al.*, 1981). 3,4-dihydroxypyridone (DHP), is anti-mitotic (Reis *et al.*, 1975), thyrotoxic (Elliott *et al.*, 1985), cytotic (Lowry *et al.*, 1983) and a potent goitrogen (Hegarty *et al.*, 1979) and has mineral chelating ability (El-Harith *et al.*, 1981). A metabolite of mimosine (i.e.3,4-DHP) has been linked to poor conception (Holmes *et al.*, 1981) and low semen motility in unadapted cows and bulls, respectively, fed a diet high in *Leucaena* (> 30% basal diet; Lohan *et al.*, 1988) continuously over a long period (Shukla *et al.*, 1990). In cattle, mimosine adversely affects reproduction by lowering calving percentage (Jones *et al.*, 1989), increasing the occurrence of still births (Jones *et al.*, 1976) and death in extreme cases (Hammond, 1995). Low serum Zn and higher Cu concentrations due to mimosine chelation was highly correlated with foetal loss and opportunistic infections (Apgar, 1992; Graham *et al.*, 1994). Deficiencies resulting from chelation (binding) of Zn, Cu and Fe by mimosine impair the immune response (Ward and Spears, 1999).

Livestock in the RSA succumbs to *Leucaena* toxicosis, if *Leucaena* forage constitutes more than 25% of the daily diet (Henderson, 2001). Other symptoms of mimosine or DHP toxicity in ruminants that are not adapted to excess *Leucaena* (> 30% of basal diet as *Leucaena*) include low feed intake (Puchala *et al.*, 1996), decrease in body weight gain or loss of body weight (Ahn *et al.*, 1989), alopecia (Hegarty *et al.*, 1964), thyroid gland abnormalities (Jones and Megarrity, 1983), depressed serum thyroxine levels (Elliott *et al.*, 1985), listlessness, inflammation of the buccal cavity, oral, ear and eye lesions, cataracts and conjunctivitis (Ram *et al.*, 1994). Other physiological symptoms are the reduction in conception and birth weight (Holmes *et al.*, 1981) and low semen quality (Lohan *et al.*, 1988).

Mimosine concentrations vary between *Leucaena* cultivars, seasons, sites, stage of growth and plant parts (i.e. leaves, pods, seeds and stem; Kewalramani *et al.*, 1987). The onset, nature and severity of the clinical symptoms of *Leucaena* (mimosine) toxicity depends on the animal species, *Leucaena* species, cultivar and hybrid, plant component fed (leaves, seeds and pods; Hongo *et al.*, 1987) and stage of growth of the *Leucaena* stand (Deshmukh *et al.*, 1987; D'Mello and Acamovic, 1989).

The proportion of *Leucaena* fed in the diet (Jones and Hegarty, 1984), duration of exposure to *Leucaena* forage or diet (Jones and Megarrity, 1983) and pre-feeding treatment (Ahn *et al.*, 1989) and processing of *Leucaena* forage (fresh, dry or wilted; grind or pelleting; Kumar and D'Mello, 1995) also influence the onset, nature and severity of the clinical symptoms of *Leucaena* toxicosis. Reports have also shown that agronomic/grazing management practices (e.g. cutting frequency and height at cutting; Kasthuri and Sadasivam, 1991), extent of rumen breakdown of mimosine and geographical differences in rumen microbial ecology (D'Mello, 1992) affect mimosine concentration and manifestation of clinical symptoms of mimosine toxicity.

Prevention or amelioration of mimosine toxicity can also be achieved by practising controlled feeding (feeding < 30% of the daily diet as *Leucaena*; Jones and Hegarty, 1984; Van Eys *et al.*, 1986) or gradual replacement of the basal diet with *Leucaena* and timely withdrawal of affected animals from the forage (Jones and Hegarty, 1984). Adaptation over a protracted duration was not found to overcome *Leucaena* toxicity in mimosine-susceptible goats in Kenya (Semenye, 1990).

Offering grasses together with *Leucaena* was found to alleviate mimosine toxicity in mimosine susceptible ruminants (Larsen *et al.*, 1998), probably by effectively reducing the percentage of *Leucaena* in the diet. The *Leucaena* component of a mixed *Leucaena*-grass pasture (LGP) enhanced the nutritive value of the grass species and dry matter intake of the grass (Crosse *et al.*, 1998) and growth rate of animals grazed on the mixed pasture (Van Eys *et al.*, 1986). Tudsri *et al.* (1998) ascribed the increased dry matter intake of animals grazed on LGP to an increased microbial population that accompanied improved rumen environment (Bonsi and Osuji, 1997) brought about by the influence of high crude protein content of the *Leucaena* component of the LGP.

Mimosine content of *Leucaena* leaves can be reduced by heat treatment, air drying (Tangendjaja *et al.*, 1990), sun-drying (Benge and Curran, 1981), boiling or dipping leaves in hot water, and freezing or soaking of leaves and seeds in water (Wee and Wang, 1987). Offering amino acids as supplement to mimosine susceptible animals ameliorates the adverse effects of mimosine and 3,4-DHP (Rozenthal and Jansen, 1979). Agronomic management practises such as stage of cutting and frequency of cutting of *Leucaena* plants can influence the chemical composition and mimosine content (Maclaurin *et al.*, 1982; El-Bedawy *et al.*, 1999). Although agronomic management practices such as frequent harvesting and fertilizer application increase crude protein content (El-Ashry *et al.* 1993; El-Bedawy *et al.* 1999), reports (Deshmukh *et al.*, 1987; Hongo *et al.* 1987; Kale 1987) have shown that mimosine content increases with an increase in *Leucaena* foliage protein content.

Mineral supplementation (Chang, 1987) or treating of *Leucaena* leaves with iron salts (ferric chloride or ferrous sulphate; Acamovic and D'Mello, 1981; Gupta and Atreja, 1998b) blocks or reduces the adverse effects of mimosine. Iron supplementation lowers the dietary pH- the low pH curtails microbial degradation of mimosine and thus enhances mimosine excretion in the faeces and urine (D'Mello and Acamovic, 1989). The mineral elements in supplemented salts act by chelating (binding) with mimosine (Tsai and Ling, 1973) and thus lower quantities of available free mimosine (D'Mello and Acamovic, 1989) in mimosine-susceptible animals.

Thyroxine supplementation (Megarrity and Jones, 1983) and molasses supplementation Elliott *et al.* (1985) of goats fed *Leucaena* partially alleviates mimosine toxicity. Molasses tended to decrease the rate and extent of mimosine degradation (Encarnacion and Hughes-Jones, 1981), and the DHP is excreted via the faeces in conjugated form (Elliott *et al.*, 1985). Suffice to say that the processing or treatment of *Leucaena* forage prior to feeding is laborious, and supplementation with amino acids, minerals and thyroxine could be rather too costly for the majority of farmers in most developing countries to afford.

1.4.8. **Breakthrough in mimosine problems**

Ruminants in some regions, notably Central America, Hawaii and Indonesia where *Leucaena* is indigenous, have been found to consume *Leucaena* species with impunity. Further studies led to the discovery that ruminants in those regions are naturally endowed with the DHP-degrading bacteria (*Synergistes jonesii*) in their rumen (Jones and Megarrity, 1986). *S. jonesii* is a beneficial rumen bacterium capable of detoxifying toxic pyridinediols (2,3 and 3,4-dihydroxypyridones (DHP)) from the *Leucaena* species (Sethi and Kulkarni, 1995; Ricon *et al.*, 1998a). The pyridine ring is enzymically reduced by *S. jonesii* bacteria in reactions that demand reducing power provided by hydrogenase activity or by metabolism of pyruvate (Ricon *et al.*, 1998b).

Ruminants possessing *S. jonesii* bacteria showed no symptoms of mimosine toxicity when *Leucaena* forage was offered *ad libitum* (Jones and Megarrity, 1986; Hammond *et al.*, 1989b). The absence of *S. jonesii* bacteria in ruminants in regions outside *Leucaena* indigenous areas (including Africa) has been attributed to the geographical limitations in the rumen microbial ecology (Jones, 1994). Ruminants in RSA are susceptible to *Leucaena* toxicosis (Underwood, 1993; Henderson, 2001) due to their lack of the *S. jonesii* bacteria in the rumen. The recent and most successful breakthrough in controlling *Leucaena* (mimosine) toxicosis has been the transfer of *S, jonesii* to ruminants in Australia, Florida (Hammond *et al.*, 1989b), Kenya (Semenye, 1990), Papua Guinea, some Pacific islands and to South African Boer goats (SABG) in the Republic of South Africa (Morris and Du Toit, 1998).

The transfer of *S. jonesii* bacteria has enabled mimosine-susceptible ruminants to become mimosine-adapted and capable of consuming high levels (> 30% of their basal diet as *Leucaena*), without any deleterious effects (Shelton and Brewbaker, 1994). Mimosine-adaptation in this context implies that the ruminants acquired the ability to ruminally degrade the toxic constituents of *Leucaena* known to be responsible for *Leucaena* toxicosis, but does not imply that lengthy exposure to *Leucaena* forage, in the absence of *S. jonesii*-adapted ruminants to the forage (Hammond, 1995). The transfer of *S. jonesii* bacteria to SABG using rumen digesta of Australian ruminants allowed the goats to subsist fully on *Leucaena* forage without any adverse external (visible) signs and the goats rather displayed high productivity (Morris and Du Toit, 1998).

1.5. Background to the study

South African indigenous *Nguni* goats (SAING) reared at the Ukulinga Training and Research farm of the University of Natal, Pietermaritzburg, RSA received the *S, jonesii* bacteria from inoculated SABG via animal-to-animal transfer as described in the report of Hammond *et al.* (1989b). The absence of any external symptoms of mimosine toxicity and the absence of mimosine and DHP in the urine (colometric tests of urine; Morris and Du Toit, unpublished report) of the SAING goats transferred *S. jonesii*, suggested a complete biodegràdation of mimosine by the bacteria that were transferred from the South African Boer goats (SABG). However, after some years of grazing the SAING on *Leucaena leucocephala*-grass pastures (LGP), their reproductive performance declined (i.e. poor conception and high pre-weaning kid mortality rates) despite the absence of any visible symptoms of mimosine toxicity (Morris and Du Toit personal communication, 1999). Similar reproductive problems were experienced in Ethiopian goats and sheep (Nsahlai personal communication, 1999).

Besides the problem of a decline in reproductive performance of SAING on a high *Leucaena* diet, there is no research reports on the potential of pastures improved by incorporating *Leucaena* and natural pasture for the productivity of SAING after animal-to-animal transfer of *S. jonesii* bacteria from an inoculated stock. Also very few studies in the past have been conducted using SAING. Most studies on goats in the past were carried out on SABG and the usual practice was to extrapolate data obtained from studies conducted with cattle, sheep or other breeds of goats in determining the nutrient and energy requirements of the SAING. This is inappropriate as response to nutrition, management and environment could differ among breeds and from one species to another (Odeyinka, 2000). The absence of scientifically verified information on SAING has hindered any meaningful developmental planning and proper assessment of the *Nguni* goat breed regarding the reproductive performance and productivity.

Furthermore, in view of the costs of procuring exotic goat breeds, a research using the indigenous breeds that are acknowledged to be more adaptable to local constraints is imperative in order to sustain small ruminant rural animal production in the developing countries.

1.5.1. Objectives of the study

The main objectives of the study were to investigate:

i. The cause of poor conception and high pre-weaning kid mortality rates of SAING on LGP;

ii. The potential of NP and LGP for the productivity of mimosine-susceptible SAING after receiving dihydroxypyridone (DHP)-degrading ruminal bacteria (*Synergistes jonesii*) via animal-to-animal transfer.

In the course of achieving the above objectives, this study will evaluate:

- Seasonal variation in forage quality and mimosine content of two varieties (cultivars Cunningham and Spectra) of *Leucaena leucocephala* at the site of the study;
- Presence of *Synergistes jonesii* in the rumen digesta of SAING maintained on LGP or NP;
- Effects of feeding *Leucaena leucocephala* foliage on semen quality, fertility and reproductive performance of dihydroxypyridone (DHP)-adapted SAING;
- Field activities and blood profiles (blood packed cell volume, mineral elements and protein

metabolites) of gravid SAING grazed on LGP or NP;

- Reproductive performance of SAING maintained on LGP or NP during gestation;
- Post kidding reproductive performance (pre-weaning growth and mortality of kids and milk yield and return to first postpartum oestrus in does) of SAING grazed on LGP or NP during gestation;
- Reproductive performance, colostrum and milk constituents of SAING maintained on LGP or NP during gestation and lactation;
- Growth performance and blood profiles of unweaned SAING on LGP or NP; and
- Growth performance, blood profiles protein and energy requirements of early weaned SAING kids.

1.5.2. **Thesis outline**

General introduction, review of literature, background and objectives of the study constitute Chapter 1. Chapter 2 focuses on detection of *S. jonesii* bacteria in the rumen digesta of SAING grazed on LGP or NP. The seasonal variation in forage quality and mimosine content of the two *Leucaena* cultivars (cvs Cunningham and Spectra) at the site of the study was also covered in Chapter 2. Chapter 3 reports the effects of feeding *Leucaena leucocephala* foliage on semen quality, fertility, and reproductive performance of SAING. Chapter 4 covers field activities and blood profiles of gravid SAING grazed on LGP or NP.

A-two year report on the effects of grazing LGP or NP as gestation feed resource on reproductive performance of SAING is presented in Chapter 5, while Chapter 6 assesses post kidding reproductive performance of SAING grazed on LGP or NP during gestation. Another two years study on the effects of LGP or NP as gestation and lactation diets on reproductive performance, colostrum and milk constituents of SAING is reported in Chapter 7. Chapter 8 deals with the growth performance and blood profiles of unweaned SAING kids maintained LGP or NP. Chapter 9 report covers growth performance, blood profiles and protein and energy requirements of early weaned SAING kids Chapter 10 comprises general discussion, summary and conclusion.

CHAPTER 2

Detecting the presence of *Synergistes jonesii* in the rumen digesta of South African indigenous *Nguni* goats and seasonal variation in forage quality and mimosine content of two varieties of *Leucaena leucocephala*[1]

Abstract

The aims of the study were to examine the presence of dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) in the rumen digesta of South African indigenous *Nguni* goats (SAING) and the chemical composition of two cultivars (Cunningham and Spectra) of *Leucaena leucocephala*. Two female goat were used for the rumen digesta study (one each from *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) treatments). Young (pre-flowering) and mature (post-flowering) leaves of the two cultivars were harvested over a year (12 month) period. Rumen digesta of goat on LGP contained *S. jonesii* bacteria while that of goat on NP lacked the bacteria. Absence of the bacteria in rumen digesta of NP goat despite the occasional close contact with goats on LGP treatment during weekly weighing suggests that, *Leucaena* has to be a diet component for the bacteria to survive and thrive. Presence of *S. jonesii* in the rumen digesta of LGP goat indicates the presence of the bacteria in the rumen of other LGP goats not used in the study. This is because *S. jonesii* bacteria are known to be easily transferred via animal-to-animal transfer. In spring season, cv. Cunningham was available for browsing while cv. Spectra was unavailable. Both cultivars were available during summer, autumn and early winter season, but were unavailable during mid and peak winter. Differences in crude protein (CP) and mimosine contents of young Cunningham and Spectra leaves were not significant. The difference in mimosine contents of mature leaves of both cultivars was also not significant. But mean CP content of mature Spectra leaves was significantly higher (24.9 vs 18.7 %; $p = 0.023$) than that of mature Cunningham. Mean P content of young Spectra leaves was significantly higher (1.6 vs 2.10 g kg^{-1}; $p = 0.046$) than that of young Cunningham. But mean Cu content of young Cunningham was higher (10.5 vs 9.0 mg kg^{-1}; $p = 0.06$) than that of young Spectra leaves. Mature leaves of cv. Spectra also had higher P content (2.3 vs 1.6 g kg^{-1}; $p = 0.06$), but lower Ca (20.8 vs 30.5 g kg^{-1}; $p = 0.06$) and Mg (5.6 vs 7.6 g kg^{-1}; $p = 0.06$) content than mature Cunningham. Apart from the CP, fat and mimosine contents, other analysed constituents increased with plant maturity. Mimosine and CP contents were higher in season with high precipitation. Foliage regeneration post winter was faster in cv. Cunningham than in Spectra- an indication that the cultivar was the better of the two at the location of the study. Establishing cv. Cunningham at the site of study would provide feed resource for flushing prior to breeding in late spring or early summer and would also provide more year-round feed resource than cv Spectra.

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[1]Part of this study has been published in: African Journal of Range and Forage Science, 2001, 18: 131-135.
Co-authors: Nsahlai, I.V. and Morris, C. D.

2.1 Introduction

The goat population in the Republic of South Africa (RSA) was approximately 6.46 million in 1995 (De Villiers, 1996). Goats constitute 18% of the total population of small ruminants in the country (Directorate Agricultural Statistics, 1996). *Nguni* goats are one of the South African un-improved indigenous goat breeds. *Nguni* goats which are mostly owned by small-scale subsistence farmers, constitute a substantial portion (85%) of goats found in the less developed areas of KwaZulu-Natal Province in the RSA (Livestock and Meat Statistics cited by De Villiers (1996)).

The low growth and reproductive performance of South African indigenous goats (SAIG; Cronje, 1998) has been blamed on poor nutrition, especially in those areas that experience a decline in quality of natural pastures during winter season. Leguminous fodder trees or shrubs have been used to ameliorate the feed constraint (Topark-Ngarm and Gutteridge, 1990) in developing countries and also to enhance soil fertility.

Among the shrubs and trees used as animal fodder, the *Leucaena* species, and especially *Leucaena leucocephala* (*L. leucocephala*) remain the most widely distributed, researched and utilised leguminous forage shrub (Casas and Caballero, 1996). The most widely used cultivars of *L. leucocephala* are Cunningham, El-Salvador, Guatemala, Hawaii, Peru and Spectra. *Leucaena Leucocephala* is susceptible to frost which reduces animal intake and productivity or kills trees in severe winters (Isarasenee *et al.*, 1984).

However, goats in the RSA are susceptible to the mimosine contained in the *Leucaena* species (Henderson, 2001). The discovery of dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) and the transfer of the bacteria to South African Boer goats (SABG) via inoculation overcame this *Leucaena* or mimosine toxicosis (Morris and Du Toit, 1998). Consequently, South African indigenous *Nguni* goats (SAING) also received dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) from inoculated SABG via animal-to-animal transfer (Hammond *et al.*, 1989b). The SAING were then grazed on *Leucaena leucocephala*-grass pastures (LGP) and their reproductive performance was observed to decline (i.e. poor conception and high pre-weaning kid mortality rate) after many years of exposure to LGP despite the absence of any visible symptoms of mimosine toxicity (Morris and Du Toit personal communication, 1999).

The urine of the SAING were tested for mimosine metabolites (2,3 and 3,4-dihydroxypyridones) using colometric urine test. The results of the test showed a complete degradation and detoxification of mimosine and its metabolites (2,3 and 3,4-DHP; Morris and Du Toit, unpublished data)- an indication that *S. jonesii* was present in the rumen of the SAING (Allison *et al.*, 1990).

The objectives of this study were as follows:

i. To validate the colometric urine test of Morris and Du Toit (Unpublished data) using rumen digesta of the SAING;

ii. To evaluate the seasonal variation in forage quality of the two varieties of *Leucaena leucocephala* at the site of the study.

The result from the first objective of the study would aid to ascertain the presence of *S. jonesii* in the rumen of the SAING on LGP that are to be used in determining the cause of poor conception and high pre-weaning kid mortality rates in the SAING maintained on LGP. The second objective would assist in identifying the better of the two cultivars of *Leucaena* species for use as a feed resource in the study area.

2.2. **Materials and methods**

2.2.1. Site

The study was carried out at the Ukulinga Research and Training Farm of the University of Natal. The Research Farm is located in Pietermaritzburg, in the south eastern hinterland of Republic of South Africa (29^0 40S; 30^0 24E; 700 m above sea level) with a total annual precipitation (rainfall) of 849 mm.

2.2.2. Experimental procedure

Detection of Synergistes jonesii: Two multiparous female SAING, one from each treatment (*Leucaena leucocephala*-grass pasture; LGP and natural pasture; NP) were used for the study. The health of the two does from both treatments was good and the experimental measurements were real treatment effects. The does were slaughtered at 3 hr intervals, with the doe on NP slaughtered first to avoid contamination of rumen microbes from the LGP doe. The rumen samples of the does were collected into separate rumen flasks and immediately taken to the Microbiology Department of the University of Natal, Pietermaritzburg, RSA) for analysis.

Forage study: Two varieties (cvs' Cunningham and Spectra) of *Leucaena leucocephala* planted in silt-loam soil (Morris, 1999) were investigated. Leaves of the cultivars were separately harvested from young (pre-flowering) and mature (post-flowering) plants. Harvesting was carried out once a month over a 12-month period between 08:00 and 9:00 h on the day of sampling. Harvested foliage was dried at 60 °C for 48 h and ground with the aid of a laboratory mill through a 1- mm sieve and preserved, pending analyses.

2.2.3. Laboratory analysis

Detection of S. jonesii: Six x ten ml prepared culture media Fe-1 (supplied by Professor Allison of IOWA State University), was used for the test. The rumen digesta of both does were clarified, as described by Holderman and Moore (1972) so as to obtain rumen fluid free of particulate matter. Three replicates of one dilution level (10^2) were used for the rumen fluid of each treatment. One ml of each replicate dilution was pipetted into each 10 ml of the prepared culture media Fe-1 and incubated at 37 °C. for seven days

Forage study: Preserved foliage samples of both cultivars were separately analysed for crude protein (CP) (Dumas combustion using Leco Model No. 602-600 for nitrogen determination and crude protein calculated as N x 6.25), ether extract (EE) and ash (AOAC, 1990). Acid detergent fibre (ADF) and neutral detergent fibre (NDF) were determined according to the procedures of Van Soest *et al.* (1991). Mineral element content (Ca, P, Mg, Zn, Fe and Cu) was determined by atomic absorption spectrometry in accordance with AOAC procedure (1990). Mimosine content was analysed by the analytical laboratory of the International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia, using near infrared reflectance spectroscopy (Tangendjaja *et al.*, 1986).

2.2.4. Statistical analysis

Monthly crude protein, mimosine and mineral element data were subjected to analysis of variance (ANOVA) using the following General Linear Model (GLM) in the Minitab statistical package (Minitab 1998): $Y_i = \mu + C_i + e_i$, where Y_i = individual observation, μ = overall mean, C_i = effect of cultivar and e_i = unexplained variation assumed to be randomly and independently distributed.

2.3. **Results**

2.3.1. Seasonal precipitation

The seasonal demarcation and monthly precipitation are presented in Table 2.1

2.3.2. Detection of *Synergistes jonesii*

The colour of the culture medium Fe-1 was orange. When the Fe-1 media were inoculated and incubated with the three replicates of rumen contents of the NP doe, the medium orange colour remained unchanged. With three replicates of rumen contents of the LGP doe, the Fe-1 media lost its orange colour and changed to a light yellowish colour, similar to rumen fluid, and then finally to a black colour, 72 h post incubation.

2.3.3. Forage study

Chemical composition and mimosine contents: There was no frost at the site during the study. Of the two cultivars (Cunningham and Spectra), it was only the young Cunningham cultivar that was available in spring. Results of proximate and mimosine composition are presented in Table 2.2. In autumn, the mean CP (24.9 vs 22.8 %) and mimosine (1.7 vs 1.4 %) content of young Spectra leaves was slightly higher than that of comparably-aged Cunningham leaves, but the differences were not significant. Similarly, during winter, the means of CP (24.6 vs 21.4 %) and mimosine (1.8 vs 1.2 %) content of leaves of young Spectra were slightly higher than those of young Cunningham leaves but the differences were not significant.

The averages of NDF of young and mature leaves of cv. Cunningham were slightly higher than those of mature Spectra (Mature leaves: 31.8 ±6.1% vs 30.3 ±4.7% and Young leaves: 29.5 ±1.4% vs 28.8 ±1.5%). Similarly, averages of ADF of young and mature leaves of cv. Cunningham was higher than those Spectra (Mature leaves: 23.6 ±2.4% vs 20.5 ±2.1%; and Young leaves: 22.3 ±2.9% vs 20.3 ±2.4%). During winter, mean CP (23.4 vs 19.0 %; $p = 0.09$) and mimosine (1.4 vs 1.3 %) content of leaves of mature Spectra was higher than that of mature leaves of cv. Cunningham. The averages of CP content of both cultivars during summer and autumn seasons were 27.2 ±4.99 and 23.6 ±3.84 %, while the mimosine contents were 1.8 ±0.74 and 1.5 ±0.41%, respectively.

Mineral element content: Leaves of mature Spectra recorded a higher P content (2.3 vs 1.6 g kg^{-1}; $p = 0.06$) compared to the leaves of mature Cunningham. However, Ca (20.8 vs 30.5 g kg^{-1}; $p = 0.06$) and Mg (5.6 vs 7.6 g kg^{-1}; $p = 0.06$) contents of leaves of mature Spectra were lower than those of mature Cunningham leaves. Mimosine content of leaves of young (1.7 vs 1.5 %) and mature (1.5 vs 1.2 %) Spectra were slightly higher than those of leaves from young and mature Cunningham leaves, but these differences were not significant.

Mineral elements content of the young and mature leaves of cvs Cunningham and Spectra over a six-month period is presented in Table 2.3. The average P content of leaves of young Spectra leaves was significantly higher (1.6 vs 2.10 g kg^{-1}; $p = 0.046$) than that of leaves of young Cunningham leaves. The mean Cu content of leaves of young Cunningham leaves tended to be higher (10.5 vs 9.0 mg kg^{-1}; $p = 0.06$) than that of young Spectra leaves.

Table 2.1. Seasonal variation in precipitation (mm) at the Ukulinga experimental site between December 1999 and November 2000

Month	**Season**	**Precipitation (mm)**
December	Summer	306
January	,,	124.5
February	,,	57.5
March	Autumn	72.5
April	,,	45.5
May	,,	42
June	Winter	5
July	,,	0
August	,,	0
September	Spring	50
October	,,	48.5
November	,,	97.5
Total precipitation		849

Table 2.2. Chemical composition (%) and mimosine content (%) of oven-dried foliage samples of two cultivars of *Leucaena leucocephala* at the Ukulinga experimental site, over a 12-month period

	Jan.	Feb.	Mar.	Apr.	May	June	July	Oct.	Nov.	Dec.
Crude protein	32.1^{CY}	22.3^{CY} 23.5^{SY}	20.8^{CY} 20.7^{SY}	26.1^{CY} 25.5^{SY}	21.4^{CY} 18.1^{CM} 28.5^{SY} 27.9^{SM}	22.0^{CY} 19.3^{CM} 25.9^{SY} 24.8^{SM}	20.7^{CY} 18.6^{CM} 23.3^{SY} 22.0^{SM}	24.4^{CY}	27.8^{CY}	30.8^{CY}
Neutral detergent fibre	**	39.9^{CY} 37.7^{SY}	38.3^{CY} 34.3^{SY}	29.8^{CY} 25.6^{SY}	31.0^{CY} 31.2^{CM} 29.7^{SY} 30.2^{SM}	27.2^{CY} 28.7^{CM} 27.7^{SY} 29.1^{SM}	24.6^{CY} 28.7^{CM} 27.0^{SY} 27.2^{SM}	**	**	**
Acid detergent fibre	**	26.7^{CY} 24.4^{SY}	23.7^{CY} 21.2^{SY}	19.9^{CY} 17.6^{SY}	23.8^{CY} 25.9^{CM} 20.6^{SY} 22.8^{SM}	20.2^{CY} 23.8^{CM} 19.8^{SY} 20.2^{SM}	19.3^{CY} 21.2^{CM} 18.3^{SY} 18.6^{SM}	**	**	**
Fat	2.6^{CY}	3.1^{CY} 3.4^{SY}	4.0^{CY} 3.7^{SY}	4.4^{CY} 2.5^{SY}	3.8^{CY} 2.4^{CM} 2.7^{SY} 2.3^{SM}	3.1^{CY} 2.2^{CM} 2.5^{SY} 2.1^{SM}	3.2^{CY} 2.1^{CM} 3.6^{SY} 3.0^{SM}	2.1^{CY}	2.2^{CY}	1.3^{CY}
Ash	**	7.3^{CY} 5.5^{SY}	7.7^{CY} 7.5^{SY}	7.4^{CY} 6.4^{SY}	9.1^{CY} 9.2^{CM} 7.6^{SY} 8.1^{SM}	9.2^{CY} 10.4^{CM} 8.8^{SY} 9.0^{SM}	10.4^{CY} 10.8^{CM} 9.8^{SY} 9.8^{SM}	**	**	**
Mimosine	1.7^{CY}	1.2^{CY} 1.5^{SY}	0.8^{CY} 1.3^{SY}	1.8^{CY} 2.1^{SY}	1.6^{CY} 1.1^{CM} 1.6^{SY} 1.6^{SM}	1.0^{CY} 0.9^{CM} 1.2^{SY} 1.9^{SM}	1.3^{CY} 1.7^{CM} 2.3^{SY} 0.9^{SM}	1.4^{CY}	1.5^{CY}	2.9^{CY}

Nb: ^{CY}Young Cunningham leaves; ^{CM}Mature Cunningham leaves; ^{SY}Young Spectra leaves and ^{SM}Mature Spectra leaves. ** implies ^{CY}Young Cunningham samples were not enough for the analysis or there were no standing ^{CM}Mature Cunningham, ^{SY}Young Spectra and ^{SM}Mature Spectra plants during the month.

Table 2.3. Macro and trace elements content of oven-dried foliage samples of two cultivars of *Leucaena leucocephala*, harvested over a six-month period at the Ukulinga experimental site

Macro/trace elements (gkg^{-1} DM)	Feb.	Mar.	Apr.	May	June	July
Calcium	16.9^{CY} 10.2^{SY}	16.7^{CY} 18.6^{SY}	13.9^{CY} 12.5^{SY}	22.1^{CY} 28.0^{CM} 16.3^{SY} 16.6^{SM}	28.0^{CY} 28.0^{CM} 19.8^{SY} 19.9^{SM}	29.1^{CY} 35.4^{CM} 22.3^{SY} 25.9^{SM}
Phosphorous	2.1^{CY} 2.1^{SY}	1.7^{CY} 1.4^{SY}	1.6^{CY} 2.6^{SY}	1.4^{CY} 1.7^{CM} 2.5^{SY} 2.7^{SM}	1.5^{CY} 1.6^{CM} 2.1^{SY} 2.2^{SM}	1.5^{CY} 1.6^{CM} 1.9^{SY} 1.9^{SM}
Magnesium	4.4^{CY} 3.3^{SY}	5.0^{CY} 6.0^{SY}	4.2^{CY} 3.8^{SY}	5.7^{CY} 7.1^{CM} 4.1^{SY} 4.4^{SM}	6.4^{CY} 7.8^{CM} 5.7^{SY} 5.6^{SM}	6.8^{CY} 7.8^{CM} 5.8^{SY} 6.9^{SM}
Trace elements ($mgkg^{-1}$ DM)						
Zinc	23.2^{CY} 45.4^{SY}	32.5^{CS} 28.9^{SS}	34.9^{CY} 31.1^{SY}	28.3^{CY} 40.8^{CM} 34.6^{SY} 42.2^{SM}	38.6^{CY} 38.7^{CM} 36.4^{SY} 39.5^{SM}	29.3^{CY} 39.7^{CM} 33.7^{SY} 37.5^{SM}
Iron	118.0^{CY} 132.0^{SY}	196.0^{CY} 153.0^{SY}	125.0^{CY} 151.0^{SY}	168.0^{CY} 194.0^{CM} 228.0^{SY} 238.0^{SM}	261.0^{CY} 322.0^{CM} 261.0^{SY} 371.0^{SM}	360.0^{CY} 435.0^{CM} 475.0^{SY} 465.0^{SM}
Copper	9.9^{CY} 8.0^{SY}	9.9^{CY} 9.2^{SY}	12.4^{CY} 10.1^{SY}	11.0^{CY} 13.0^{CM} 9.7^{SY} 17.4^{SM}	11.3^{CY} 13.2^{CM} 9.7^{SY} 16.8^{SM}	8.5^{CY} 11.9^{CM} 7.5^{SY} 8.5^{SM}

Nb: ^{CY}Young Cunningham leaves; ^{CM}Mature Cunningham leaves; ^{SY}Young Spectra leaves; and ^{SM}Mature Spectra leaves.

contrast, Boer goats are predominantly sexually active in autumn (Greyling, 2000). Peak sexual activity in *Nguni* goats occurring in late spring/early summer can be ascribed to the abundant lush pastures and cooler ambient temperature during the period at the location of the study.

The availability of cv. Cunningham during summer and autumn compares favourably with the reports of Caceres and Gonzalez (1998) that the cultivar is available during both the rainy and dry seasons. Edible dry matter yields of both cultivars were not determined in this study. However, the availability of leaves of cv. Cunningham from the second month of spring did suggest that foliage of this cultivar might become more available than cv. Spectra and could possibly be used to flush male and female *Nguni* goats prior to breeding in late spring/early summer.

Mimosine values of both cultivars were lower than 3.6% reported by Hongo *et al.* (1983) for fresh foliage of *Leucaena leucocephala*. The lower value was probably due to the effect of oven drying in that oven-drying has been reported (D'Mello and Acamovic, 1980; Tangendjaja *et al.*, 1990) to lower mimosine content. The decrease in mimosine content with age concurs with reports that mimosine content differs according to the stage of growth (Deshmukh *et al.*, 1987) and was higher in immature tender leaves (Hongo *et al.*, 1987; Kale, 1987). In this study, however, the mimosine concentration did not differ significantly between cultivars of young and mature plants.

Precipitation is one of the factors that influence chemical composition of forage (Nsahlai *et al.*, 1998). Precipitations were higher during summer than autumn season at the site. Abundant young plants are associated with period of high precipitation. There were also reports that protein and mimosine contents of immature plants are higher than those of mature plants (Tangendjaja *et al.*, 1986; Deshmukh *et al.*, 1987). The higher CP and mimosine contents recorded during the summer relative to autumn season can be attributed to the difference in total precipitation between the two seasons.

The concentration of macro and trace elements in both cultivars differed from that contained in a report by Aletor and Omodara (1994)- probably due to the difference in methods (oven-drying compared to air-drying) of preserving samples prior to the laboratory analyses. The variation between the chemical composition, mimosine and mineral element contents among species and between cultivars agrees with the reports of other workers (Yeh, 1983; Kewalramani *et al.*, 1987; Sethi and Kulkarni, 1995) that these parameters vary considerably among species and between cultivars.

2.5. **Conclusions**

The results showed the presence of the bacteria in the rumen of the LGP doe and confirmed the colorimetric urine test in previous study (Morris and Du Toit, Unpublished data). The results also indicate that though *S. jonesii* spreads easily among animals kept in close proximity, *Leucaena* has to be a component of the diet fed for the bacteria to survive.

Considering all the parameters examined and period of availability of both cultivars at the site, cv. Cunningham was lower in mimosine content than cv Spectra and was available for a longer period during the year than the cv. Spectra. Cultivar Cunningham would be more suited for propagation than cv Spectra at this specific location. Establishing cv. Cunningham at the site would assist in alleviating the perennial feed constraints of SAING.

CHAPTER 3

The effects of feeding *Leucaena leucocephala* on semen quality, fertility and reproductive performance of dihydroxypyridone (DHP)-adapted South African indigenous *Nguni* goats[1]

Abstract

The main objective of the study was to examine whether semen quality and fertility of dihydroxypyridone (DHP)-adapted South African indigenous *Nguni* goat (SAING) bucks fed solely on *Leucaena leucocephala* (LL) were affected by mimosine and its toxic metabolites. Four DHP-adapted (26.4 ±4.11 kg) and four DHP-unadapted (35.8 ±7.50 kg) bucks were used for the study that lasted 84 days. The DHP-adapted bucks were fed air-dried *Leucaena leucocephala* (LL) forage (*Leucaena* group), while the DHP-unadapted bucks were maintained on a cereal based concentrate (C) diet (Concentrate group) containing 122 g crude protein (CP) kg^{-1} over an 84-day period. There were equal numbers of mature SAING does (n = 19) on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) treatments. Does on LGP treatment and bucks on LL group possessed DHP-degrading rumen bacteria (*Synergistes jonesii*) in their rumen, while their respective counterparts on NP and C group lacked the bacteria. Semen samples of bucks on both treatments (LL and C) were collected on days 0 and 77 of the study using electro-ejaculation technique. On the last day of the study (day 84), bucks on *Leucaena* group were divided into two equal sub-groups; a subgroup (n = 2) was assigned to 10 does on LGP, while the second sub-group was assigned to mate 9 does on NP. Similarly, the two concentrate sub-groups were assigned to mate another set of 9 and 10 does on LGP and NP treatments, respectively. The proportions of normal semen on both groups were not significantly different. However, semen quality on the LL group increased significantly ($p = 0.004$) between days 0 and 77. This increase explains the significant ($p < 0.01$) difference between the fertility rates of bucks on LL and C groups. There was no evidence that, feeding LL was detrimental to semen quality, fertility of bucks and conception among females mated by the bucks. Poor conception on LGP treatment previously associated with SAING does transferred *S. jonesii* and maintained on LGP plot cannot be attributed to the adverse effects of LGP on semen quality and fertility of SAING bucks.

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3.1. **Introduction**

The economic, nutritional and health status of the rural community can be improved by increasing the productivity of their indigenous goats. In view of the costs of procuring exotic goat breeds, there is a need to evaluate the potential of indigenous goat breeds, known to be more adapted to local conditions. High fertility and prolificacy are desirable and pre-requisites for increasing goat productivity. The total number of offspring weaned per dam exposed is closely related to the quantity of animal products available for sale, consumption and stock replacement; and is a yardstick for assessing flock productivity (Sidwell and Muller, 1971). However, overall low reproduction rate has been identified as the most important constraint to goat production in the tropics (Chifamba *et al.*, 1995).

Productivity depends on the number of offspring delivered by females at parturition (Steinbach, 1988). Successful conception depends on both the dam and sire and implies that litter size can be increased if the reproductive performance of both sexes are improved. Nutrition plays an important role in the body condition at mating and consequently ensures a high fertility (Kassa and Tegene, 1998) and reproductive performance (Abecia *et al.*, 1993). Adequate nutrition, especially protein intake of sires at breeding is essential, for optimal and viable sperm cell production (Rekwot *et al.*, 1988).

Many species of leguminous browse plants (e.g. *Leucaena)* contain appreciable quantities of protein, carotene and vitamins (Machado *et al.*, 1978). However, mimosine is the main obstacle to full utilisation of *Leucaena* by ruminants (Sethi and Kulkarni, 1995). Mimosine is a non-protein amino acid (β-N-(3-hydroxy-4-pyridone)) contained mainly in the seeds and leaves of *Leucaena* species. Dihydroxypyridone (DHP), the toxic metabolite of mimosine, has been linked to poor conception (Holmes et al., 1981) and low semen motility (Lohan *et al.*, 1988) in unadapted cows and bulls, fed a diet high in *Leucaena* continuously over a long period (>60 days; Shukla *et al.*, 1990).

The transfer of *S. jonesii* bacteria to mimosine-susceptible female South African indigenous *Nguni* goats (SAING; Akingbade *et al.*, 2001a) improves the reproductive performance of does grazed on *Leucaena leucocephala*-grass pastures (LGP). However, after some years, the conception rate of does on LGP declines, despite the absence of any visible symptoms of mimosine toxicity (Morris and Du Toit personal communication, 1999). This is a concern for rural goats grazed on *Leucaena* species. This study was designed to examine whether the effect of *Leucaena leucocephala* on semen quality was responsible for the poor conception observed among SAING does grazed on LGP.

3.2. **Materials and methods**

3.2.1. Site

Details of the site had been previously reported in subsection 2.2.1 (Chapter 2).

3.2.2. Animals

Eight and 38 mature SAING bucks and does, respectively, were used for the study. The *Nguni* goats are one of the South African un-improved indigenous goat breeds. They are smaller in size than the Boer goats and have a short-haired coat. The coat colours vary, ranging from black, brown and white and combination of the three colours. *Nguni* goats are kept primarily for meat and cultural practices. The bucks and does were introduced into a group of SABG in which the goats were previously inoculated with DHP-degrading rumen bacteria (*S. jonesii* strain) from Australia and maintained on LGP. The animals were able to acquire the *S. jonesii* bacteria via animal-to-animal transfer (Jones and Megarrity, 1986). The animals were in good condition and acceptable health status. Prior to the commencement of the current study, equal numbers of mature males and females were grazed solely on *Leucaena leucocephala*-grass (LGP) and natural pasture (NP). The does on LGP treatment possessed DHP-degrading rumen bacteria (*S. jonesii*), while those on NP treatment lacked the bacteria (Chapter 2). The absence of common visible symptoms of mimosine toxicity (alopecia and poor coordination) among the bucks on LGP treatment prior to the study was an indication that they had acquired the *S. jonesii* bacteria from the SABG.

3.2.3. Experimental design and feeding practice

In order to avoid unplanned breeding, bucks on LGP (n = 4) and NP (n = 4) treatments were removed and reared intensively in a roofed house with pens fitted with feed and water troughs. Bucks from the LGP treatment were fed *Leucaena leucocephala* (LL; *Leucaena* group/treatment), while a cereal-based concentrate diet (C; concentrate group/treatment) was offered to bucks from the NP treatment over a 12 week period (84 days). The 84 days of feeding duration was to ensure that the semen quality during the following breeding are due to dietary effect. The study reported by Byebwa, (2001) has shown that the time lag between spermatogenesis and ejaculation is approximately 60 days. The initial average live weights of bucks on the LL and C treatment groups were 26.38 ±4.11 and 35.75 ±7.50 kg, respectively.

The LL leaves were harvested in advance on a weekly basis and were air-dried by spreading on a slated floor in a roofed paddock. The cereal-based concentrate diet contained 122 g CP kg^{-1} and fresh feeds were milled every six weeks. Bucks on both treatments were served their respective diets daily to ensure *ad libitum* feeding. The feed refusals were emptied from the feed troughs every morning (between 07:00 and 07:15 h) before fresh diets were served (between 07:15 and 07:30 h). The bucks were introduced to does for mating on the last day of the study (day 84). Nutritional or mineral supplements were not offered throughout the study. No records of feed intake were kept because of uncontrollable feed spillage.

3.2.4. Semen collection

Semen samples were collected from all the eight bucks on days 0 and 77 (a week prior to breeding) using the electro ejaculation technique (Zemjanis, 1970). Semen collection was carried out by a professional veterinarian from the Allerton Provincial Veterinary Laboratory, Cascades, South Africa. Prior to semen collection, the area around the prepuce was shorn and wiped clean. A Watson transtimulator model Mk2 (Cameron, 1977) was used for collecting semen and manually controlled to vary the voltage applied to the probe. The bucks were laid down one at a time and held firmly while a lubricated probe was inserted into the rectum. Two minutes of acclimatization were allowed between probe insertion and application of electrical stimuli. After 40-50 seconds of stimulation, the buck ejaculated into a labeled test tube. By sandwiching each labeled test tube between the palms, warmed the test tube and prevented sperm death from cold shock and direct light (Ibrahim and Yousri, 1992). The collected semen samples were immediately transferred to the Allerton Provincial Veterinary Laboratory in a temperature controlled container.

3.2.5. Semen evaluation

The procedures used in evaluating the semen quality, i.e. semen motility and semen morphology (major and minor defects), were as described by Cameron (1977), Bertschinger (1985) and Barth and Oko (1989). A drop of each buck semen was placed on a warm (36 °C) glass slide so as to prevent spermatozoa death from cold shock, and examined microscopically. A motility score of between 0 and 5 was employed in assessing the proportion of spermatozoa that displayed forward progressive motion. Percentage normal semen (semen quality) in this report refers to the percentage of spermatozoa in the semen that exhibited individual progressive motion ≥ 4 and morphological abnormalities (major and minor defects) $\leq 20\%$.

At least 500 spermatozoa were examined from each sample. Major defects noted were: Knobbed acrosome; pyriform heads; abnormal loose heads; midpiece reflex and other midpiece defects; dag or dag-like defects. The appearance of dag defect in spermatozoa was described by Barth and Oko (1989) as folding and coiling of the midpiece with the axis of the main fold in the distal half of the midpiece. Minor defects assessed were: normal loose heads, degenerative loose acrosome and abaxial implantation.

3.2.6. Oestrus synchronization, mating and fertility evaluation

The bucks were allowed a seven day period of recovery from the stress of semen collection, before being used for breeding. S4-Folligon sponges were inserted on day 70 of the study and retained in the vagina for 14 days. The sponges were removed on the 14th day, i.e. day 84 of the study. Each doe was immediately injected intra-muscularly with 2.5 ml S4-Folligon (1000 i.u.) at sponge withdrawal. On day 84, the bucks on LL and C treatment groups were randomly divided into two equal sub-groups ($n = 2$).

Bucks on the first sub-groups of the LL group was assigned to service ten does on the LGP treatment. The second sub-group of bucks on LL group serviced nine does on the NP treatment. Similarly, a sub-group ($n = 2$) of bucks from C group were mated to 9 does on the LGP treatment, while the other sub-group ($n = 2$) mated 10 does on the NP treatment. Bucks and does remained within their sub-groups for 21 days and the sub-groups were herded separately. Overall fertility rate and reproductive performance of bucks in LL and C groups were deduced from the number of does that kidded and number of kids.

3.2.7. Gestation diet

Following mating, does were maintained on the following diets: Predominant grasses on the *Leucaena* plots were *Eragrostis curvula* and *Panicum maximum*. Browses on the natural pasture included: *Acacia karoo, Acacia nilotica, Acacia sieberana, Coddia rudis, Dalbergia obovata, Ehretia rigida, Peristrophe natalense, Rhus dentata, Rhus pentheri, Maytenus senegalensis, Hippobromus pauciflorus* and *Ziziphus mucronata*. Predominant grasses were *Cynodon dactylon, Chloris gayana, Eragrostis plana, Panicum maximum, Setaria sphacelata, Setaria nigrirostoris, Sporobolus africanus, Themeda triandra, Heteropogon contortus, Tristachya leucothrix* and leaves from Bamboo stands.

3.2.8. Grazing management practice

All does (n = 38) had access to their respective treatment diets between 08.00h and 15:00h daily and were moved to separate night camps between 15:00h and 15:30h. In the night camps, all does were allowed unlimited grazing access to Kikuyu grass (*Pennisetum clandestinum*) and clean water and remained there till 07:30 h the following morning before being moved to their respective day camps. Mineral or nutritional supplements were not offered during the study.

3.2.9. Measurement

Live weight: Live body weights of bucks on the LL and C treatments were measured on day 0 and subsequent weighing was carried out every fortnight, using a RUUDWEIGH, KM-2E electronic weighing system (RUUDSCALE, Durbanville. South Africa). Live weight gains of each buck between days 0 and 84 were deduced using the following mathematical expression:

Live weight gain = Live weight on day 84 - Live weight on day 0.

Sperm morphology and semen quality: Semen quality of bucks fed the LL or C diet was determined from the results obtained from the semen analysis.

Reproductive performance: Since oestrus was synchronized in all does, overall fertility rate (%) and reproductive performance of the does and bucks in LL and C treatment groups was derived from the reproductive records.

3.2.10. Diet analysis

Leucaena leucocephala foliage and the concentrate diet were analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ether extract (EE), ash and mineral elements (Ca, P, Mg, Zn, Fe and Cu) using procedures reported under forage study in subsection 2.2.3 (Chapter 2).

3.2.11. Statistical analysis

Live weight gains and the percentage normal spermatozoa of bucks on LL and C treatments between days 0 and 84 were subjected to analysis of variance (ANOVA) using the General Linear Model (GLM) of Minitab statistical package (Minitab, 1998).

(i) Statistical model for live weight gains was: $Y_{ij} = \mu + T_i + W_j + e_{ij}$, where Y_{ij} = individual observation, μ = overall mean, T_i = effect of dietary treatment, W_j = effect of live weight on day 0 and e_{ij} = unexplained variation assumed to be randomly and independently distributed.

(ii) The model used to analyse the percentage normal spermatozoa was: $Y_{io} = \mu + T_i + W_o + e_{io}$, where Y_{io} = individual observation, W_o = effect of live weight on the day of semen sampling and e_{io} = unexplained variation assumed to be randomly and independently distributed.

(iii) Breeding and kidding records were used to determine overall fertility rate and reproductive performance of bucks previously maintained on LL and C treatments and also used in assessing the reproductive performance of the does on the LGP and NP treatments. Male fertility was deduced using the following expression:

Male fertility = Number of females that kidded /Number of females mated.

Chi-square (χ^2) test was employed to test for significance of conception and birth types as described by Steel and Torrie (1980). Treatment means were compared using standard error of the difference between means (s.e.d.) for significance at $p< 0.05$.

3.3. **Results**

3.3.1. Animal health

Bucks on the LL treatment showed no symptoms of mimosine toxicity (e.g. alopecia, weight loss etc.) despite the feeding of LL foliage as the sole diet for 84 days. The sub-group of bucks on the C treatment assigned to does on LGP treatment, also showed no symptoms of mimosine toxicity during their 21 days exposure to LGP. The bucks on both treatments were apparently healthy throughout the study and the experimental measurements were real treatment effects.

3.3.2. Diets

The chemical composition of the LL foliage and concentrate diets are presented in Table 3.1, showing that LL foliage had higher crude protein content than the concentrate diet. Except for phosphorous and zinc, the LL foliage was better than the C diet in all the mineral elements analysed.

3.3.3. Live weight change

Although bucks on C group were heavier ($p = 0.071$) than those on the LL group (due to the slight age difference) in two of the bucks on C group, the weight difference was not significant. However, all bucks on both groups were mature and their respective live weights were incorporated as covariate during statistical analyses.

On the last day of the buck study (day 77), mean body weight of bucks on LL and C treatments were 32.4 ±3.8 kg and 39.0 ±7.5 kg, respectively. One way analysis of weight gains of bucks on the LL and C treatments indicated that LL bucks gained 2.75 kg significantly ($p < 0.012$) more than the bucks in C group (6.00 ±1.29 vs 3.25 ±0.87 kg, respectively). However, incorporation of live weights on day 0 as covariate decreased the gain to 2.43 kg and the level of significance to insignificant ($p = 0.083$).

3.3.4. Semen quality

Semen morphological parameters measured on days 0 and 77 of the study are presented in Tables 3.2 and 3.3, respectively. The mean percentage of normal spermatozoa (semen quality) in samples collected on day 0 and 77 were above 85% (Table 3.2) and 90% (Table 3.3), respectively. Defects classified as minor were absent in samples collected from bucks in the LL treatment group on day 77. The percentage of normal spermatozoa in the LL (91.0 ±0.82% to

96.00 ±1.41 %) and C (88.75±1.89% to 91.5±3.32 %) treatments increased between days 0 and 77- but the difference between treatments was not significant. There was a significant ($p = 0.004$; s.e.d. = 0.37) difference between semen quality from bucks on the LL foliage (collected on days 0 and 77). Live weight at semen collection positively influenced semen quality ($p = 0.028$). Unlike their counterparts on LL foliage, no difference was recorded between the quality of semen collected from bucks on the C diet on day 0 and 77. The spermatozoa quality of bucks on the C treatment was also not influenced by body weight at semen collection.

3.3.5. Fertility and reproductive performance

The reproductive performance of does from the 4 buck sub-groups is presented in Table 3.4. Proportion of fertile bucks fed LL foliage was 0.31 (1.00 vs 0.69) significantly ($p < 0.01$) higher than the bucks on the C diet. Regardless of bucks used for mating, number of pregnant does on LGP that conceived and kidded was higher (17 vs 15; $p = 0.735$) than that of does on NP. Also, does on LGP kidded 6 more kids (16.5 ±3.54 vs 10.5 ±2.12 kids) than that of does on NP. Mean kidding rate of does on the LGP treatment was 61.2% (172.8 ± 24,3% vs 111.6 ±30.6%) higher than that of their counterparts on the NP treatment. The total number of kids sired by bucks fed LL foliage was more than that of bucks maintained on C diet, however, the difference was not significant. The number of multiple births recorded was found to be independent of the bucks' dietary treatments prior to breeding.

Table 3.1. Proximate and mineral element composition of *Leucaena leucocephala* foliage (LL) and concentrate diet fed to South African indigenous *Nguni* bucks

	LL	Concentrate diet
Proximate composition (%)		
Crude protein	18.55	12.24
Neutral detergent fibre	28.72	33.12
Acid detergent fibre	21.2	16.79
Fat	2.07	5.93
Ash	10.43	6.84
Macro elements (gkg^{-1} DM)		
Calcium	29.1	9.1
Phosphorous	1.5	3.6
Magnesium	6.85	2.24
Trace elements ($mgkg^{-1}$ DM)		
Zinc	29.3	45
Iron	360	288
Copper	8.5	6

Table 3.2. Morphology of semen sampled on day 0 of feeding South African indigenous *Nguni* bucks on *Leucaena leucocephala* foliage and a concentrate diet

	Leucaena leucocephala foliage				Concentrate diet			
	Buck 1	Buck 2	Buck 3	Buck 4	Buck 1	Buck 2	Buck 3	Buck 4
Major defects								
Knobbed acrosome	0	0	1	0	1	0	1	1
Pyriform heads	0	0	0	0	0	0	0	0
Abnormal loose heads	0	0	0	0	0	0	0	0
Midpiece reflex	1	1	1	0	1	1	1	1
Other midpiece defects	2	0	2	1	1	2	0	2
Dags	0	1	0	0	0	1	2	2
Minor defects								
Normal loose heads	4	3	2	3	8	4	4	1
Degenerative loose acrosome	3	4	3	4	3	3	2	3
Abaxial implantation	0	0	0	0	0	0	0	0
Motility	4	5	4	5	4	4	5	4
% Normal semen	90	91	91	92	86	89	90	90

Table 3.3. Morphology of semen sampled on day 77 of feeding South African indigenous *Nguni* bucks on *Leucaena leucocephala* foliage and a concentrate diet

	Leucaena leucocephala foliage				Concentrate diet			
	Buck 1	**Buck 2**	**Buck 3**	**Buck 4**	**Buck 1**	**Buck 2**	**Buck 3**	**Buck 4**
Major defects								
Knobbed acrosome	0	0	0	0	1	0	0	1
Pyriform heads	0	0	0	0	0	0	0	0
Abnormal loose heads	0	0	0	0	0	0	0	0
Midpiece reflex	1	2	1	2	0	1	1	1
Other midpiece defects	5	1	2	1	0	1	0	1
Dags	0	1	0	0	3	0	0	3
Minor defects								
Normal loose heads	0	0	0	0	9	4	4	3
Degenerative loose acrosome	0	0	0	0	0	0	1	0
Abaxial implantation	0	0	0	0	0	0	0	0
Motility	4	5	5	5	4	5	4	4
% Normal semen	94	96	97	97	87	94	94	91

Table 3.4 Summary of reproductive performance of South African *Nguni* bucks fed *Leucaena leucocephala* foliage (Leu-Bucks) and a concentrate diets (Con-Bucks) treatments mating South African indigenous *Nguni* does on *Leucaena leucocephala*-grass and natural pastures

	***Leucaena leucocephala-grass* pasture**		**Natural pasture**		
	Leu-Bucks	**Con-Bucks**	**Leu-Bucks**	**Con-Bucks**	χ^2
No of bucks	2	2	2	2	
" of does mated	10	9	9	10	
" of does that conceived & kidded (%)	100	77.8	100	6	7.125[a]
Male fertility (proportion)	1	0.78	1	0.6	
No of live kids at birth	19	14	12	9	
Kidding rate	190	155.6	133.3	90	
" of still birth	1	1	0	0	
" of single birth	2	2	6	3	0.042[ns]
" of multiple birth (≥2 kids)	8	5	3	3	

[a]P<0.01

[ns]P>0.05

3.4. **Discussion**

The absence of any visible external symptoms of mimosine/*Leucaena* toxicosis (e.g. alopecia, weight loss etc.) in bucks on LL treatment despite their full exposure to foliage as the sole diet for 84 days showed that the goats were possibly fully adapted to overcome the detrimental effect of mimosine and its toxic metabolites (2, 3 and 3, 4-DHPs). This adaptation was an indication that the bucks possessed the *S. jonesii* bacteria in their rumen. Previous studies (Jones and Megarrity, 1986; Hammond *et al.*,1989a) have shown that unadapted animals in which the bacteria were transferred, were able to consume excessive quantities of *Leucaena* species without any deleterious effects.

Though bucks on the C subgroup that were assigned to does maintained on LGP plot were DHP-unadapted, absence of any visible external symptoms of mimosine toxicity can be attributed to the short duration (21 days) of their exposure to *Leucaena* plant. This is in line with the report by Jones and Megarrity (1983) that duration of exposure to *Leucaena* forage influences the onset, nature and severity of the clinical symptoms of *Leucaena* toxicosis.

The high protein and low phosphorous content of the LL forage was similar to that reported in previous studies (Nsahlai *et al.*, 1995; Morris and du Toit, 1998) confirming that *Leucaena* grown at this site is inherently low in phosphorous. Though incessant feed spillage prevented recording of feed intake, the higher live weight gains on LL treatment may have resulted from a higher feed intake of bucks on the treatment. However, the higher nutritive value (high CP content) of LL foliage relative to the C diet seems to explain the better gains obtained in bucks fed LL foliage, relative to their counterparts maintained on the C diet.

Cameron (1977) has shown that the electro-ejaculation technique had no significant influence on motility of spermatozoa as a measure of fertility (Terry, 1993). The recent study of Dana *et al.* (2000) did show that *Leucaena* supplementation increased semen motility, yield and concentration. Mass motility of all the bucks in this study compared favourably with the mean value (3.8) reported by Mann (1980) in assessing viability of semen. This implies that the ejaculates from bucks on both treatments were viably normal.

Greyling and Grobbelaar (1983) did show the electro-ejaculation technique of semen collection to produce lower spermatozoa motility, when compared with semen collection using the artificial vagina technique. However, mean semen motility on *Leucaena* treatment in this study using electro-ejaculation technique exceeded the 40 - 80 % value contained in the report of Lohan *et al.* (1988). The lower semen motility obtained in their study was possibly due to the fact that the bulls used in their study were not DHP-adapted and the bulls lacked *S. jonesii* bacteria in their rumen.

Although there were a few major defects in the semen of the bucks on the LL treatment, the high conception rate recorded among does that were serviced by the bucks on this treatment, suggests that the defects were not severe enough to cause poor conception. This confirms the findings by Byebwa (2002) and Nsahlai *et al.* (2000a) with rams fed on *Leucaena*

The lower mean conception rate of does and lower number of kids produced by does on the NP treatment relative to that of does on the LGP treatment, probably was due to the difference in the CP content of available and accessible forage resource on both treatments. The diet quality might have influenced body condition and semen quality. Most of the browses on the NP plots were shrubs and trees (>1.5 m tall) and beyond the reach of the goats on the treatment. The problem of accessibility to browse species on NP plot probably limited the NP goats protein intake. The low protein intake explains the lower conception rate of does and lower number of kids on NP treatment. Rekwot *et al.* (1988) reported that a diet rich in protein content improves semen quality, while Rodriguez *et al.* (1998) claimed that incorporation of leguminous browse as complement to grass species can improve growth and reproductive output of ruminants, by enhancing male fertility and female fecundity via improved nutrition.

The current study found no evidence suggesting that feeding *Leucaena leucocephala* as a sole diet to the South African indigenous *Nguni* goat bucks was detrimental to their semen quality and fertility. The presence of *S. jonesii* bacteria seems to have adapted the goats to mimosine and its toxic metabolites (2,3 and 3,4 DHPs) and thus protected the animals from mimosine/*Leucaena* toxicosis.

3.5. **Conclusions**

This trial found no evidence suggesting that feeding *Leucaena leucocephala* as a sole diet to the SAING bucks was detrimental to the bucks' semen quality and fertility. The high reproductive performance of SAING does on a high quality feed (LGP) irrespective of the previous diets of the SAING bucks used for mating, showed that nutrition at conception plays a major role on female reproductive performance.

This study revealed that the poor conception previously associated with bucks on the LGP was not due to the adverse effects of *Leucaena* component of the pastures on semen quality. Suffice to conclude that once the SAING bucks are inoculated or transferred *S. jonesii* bacteria, *Leucaena* species can be safely fed to the bucks without any adverse effects on their semen quality and fertility.

CHAPTER 4

Field activities and blood profile of pregnant South African indigenous *Nguni* goats after receiving dihydroxy pyridone (DHP)-degrading rumen bacteria and grazing *Leucaena leucocephala*-grass or natural pastures[1]

Abstract

The aims of the study were to monitor the time spent by pregnant South African indigenous *Nguni* goats (SAING) on various field activities and also to examine their blood protein and mineral element status during the 2nd (weeks 8, 11 and 14) and 3rd (weeks 18, 19 and 20) trimesters of gestation. Twenty four multiparous female SAING maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) were used for the study. Once a week during the 2nd and 3rd trimesters, between 08.00 and 15.00 h, four pregnant females per treatment were randomly selected and observed every 1 min for time spent grazing, browsing, ruminating and idling. Blood samples were also taken once a week during both trimesters for measurements of some mineral elements and protein metabolites. Goats on NP grazed 54.8 min ($p < 0.001$) more and browsed 53 min ($p < 0.001$) less than goats on LGP during the 2nd trimester. During the 3rd trimester, goats on NP goats grazed and idled more (24.7 min, $p = 0.004$; 15.8 min, $p = 0.044$, respectively) but ruminated less (-24.1 min, $p < 0.001$) than LGP goats. Time allotted to each field activity by the goats on both treatments within trimester seemed to be dependent on forage species composition and accessibility to forage while activities between trimesters were possibly influenced by season, accessibility to forage, and stage of gestation. Blood Mg level on NP was significantly ($p = 0.051$) higher than on LGP during the 2nd trimester, while blood Cu and albumin contents on LGP were significantly higher ($p = 0.029$ and 0.022, respectively) than on NP during the 3rd trimester. Furthermore, blood concentrations of all hematological parameters (except serum protein) on both treatments were within the normal range for goats in the tropics and subtropics. This explains the absence of mineral and nutrient deficiency symptoms on both treatments. Goats on the LGP treatment also showed no visible symptoms of mineral deficiency and mimosine toxicity-an indication that the goats possessed *S. jonesii* bacteria in their rumen, which are known to prevent mineral-chelating tendency of mimosine and its metabolites. Poor conception on LGP treatment previously associated with goats transferred *S. jonesii* and maintained on LGP cannot be attributed to mineral chelating tendencies of mimosisne and its metabolites. Pregnant SAING can be safely maintained on LGP once their rumen is colonised by *S. jonesii* bacteria.

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4.1. **Introduction**

Of the factors such as photo period, temperature, disease and nutrition which influence reproduction in ruminants, nutrition remains to be the most important (Dunn and Moss, 1992; Ibrahim and Yousri, 1992). Pasture grasses, legumes and browse are natural and economic feeds for ruminants. However, the nutritive value of the forage varies with season (Reay and Grace, 1981).During pregnancy, inadequate feed may lead to poor body condition and conception, foetal loss or low birth weight of the offspring. Overfeeding on the other hand has been reported (Rattray, 1986) to increase kids birth weight and high incidence of dystocia.

There have been many studies on field activities of sheep and cattle but a few on pregnant goats. Usually data from studies conducted with cattle or sheep are extrapolated to goats. However, goats differ from other ruminants in their ability to select from a wider range of forage species (Morand-Fehr *et al.*, 1991). Goats can also adopt a bipedal stance and possess greater mobility of the upper lip (Papachristou and Nastis, 1992; Odeyinka, 2000).

Variation in forage quality has been attributed to the differences in time spent on various field activities by grazing ruminants (Preston and Leng, 1987). Other factors that have been found to influence the field activities of ruminants include environmental temperature (Askins and Turner, 1972), physiological state (Forbes, 1983) and age of the animal (Biselling *et al.*, 1999). A full understanding of the field activities (especially grazing and browsing) of goats during gestation would aid not only in pasture management but could also give a clearer picture as to the eating pattern of gravid goats in response to seasonal variation in forage quality and changes in stage of gestation.

The quality of standing forage can be calculated either from chemical analysis of the extrusa from oesophageal fistulates of goats grazed on the forage or analysis of forage samples obtained directly from the field using a hand sampling method (Faure *et al.*, 1983; Coates *et al.*, 1987). Results from such methods cannot, however, be used to confirm whether nutritional requirements are met. The blood profile technique has assisted in circumventing this constraint and has been used in determining nutrient, mineral element and vitamin status of animals (Bremmers *et al.*, 1988; Cronje and Gollah, 1996) and also in diagnosing metabolic and production related diseases. A blood profile includes metabolites representing protein and energy status, mineral elements and vitamins (Mohy El-Deen *et al.*,1985). Blood constituents are related to feed type (Saba *et al.*, 1995), environmental temperature (Hassan and Roussel, 1975) and physiological state of the animal (Cozler *et al.*, 1999).

The high costs of conventional protein diets and inorganic fertilizers in the developing countries have led to the incorporation of legumes such as the *Leucaena* species into farming systems. *Leucaena* species are a good source of protein and sulphur for the rumen microbes and flourish well during the dry season- serving as an important source of fodder for ruminants when most pasture grasses are low in quantity and of poor nutritive value (D'Mello, 1992). *Leucaena* species also improve the intake of roughage diets and soil nitrogen status (Minson, 1982). Increased utilization of *Leucaena* in the nutrition of unadapted ruminants is constrained by the constituent mimosine which reduces feed intake and retards growth (Al-Dehneh *et al.*, 1994; Sethi and Kulkarni, 1995).

Mimosine is rapidly hydrolysed to 3, 4-DHP in the rumen (Gupta and Atreja, 1998b). The metal-chelating ability of the 3-hydroxy-4-oxo functional group of the pyridone ring in mimosine {β-N(3-hydroxy–4-pyridoone)-α-amino propionic acid} has been implicated in promoting deficiencies of mineral elements such as zinc (Sethi and Kulkarni, 1995) and phosphorous (Girdhar *et al.*, 1991) and a poor blood amino acid profile (Smuts *et al.*, 1995). The metal-chelating trait of mimosine also impairs the activity of metal-containing enzymes. Low serum Zn and higher Cu concentration are highly correlated with foetal loss and opportunistic infections (Apgar, 1992;

Graham *et al.*, 1994). Zinc, Cu and Fe deficiencies impair the immune response (Ward and Spears, 1999). Toxicity of some elements may also lead to deficiency of others (Miller, 1985). Although Samanta *et al.* (1994) and Faria-Marmol *et al.* (1996) advocated mineral supplementation to overcome mineral deficiencies, this practice is too costly to adopt in most developing countries.

Dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) assist in overcoming mimosine toxicity (Jones and Megarrity, 1986; Hammond *et al.*, 1989b). Morris and Du Toit (1998) reported that the presence of *S. jonesii* bacteria in South African Boer goats (SABG) enhanced growth performance of the goats on *Leucaena* and there were no symptoms of mimosine toxicity. However, conception rates in South African indigenous *Nguni* goats (SAING) possessing *S. jonesii* and maintained on *Leucaena leucocephala*-grass pasture (LGP) was lower than those grazed on Natural pasture (NP; Morris and Du Toit, unpublished data).

Chapter 3 has shown that *Leucaena* species had no detrimental effects on semen quality of bucks possessing *S. jonesii* bacteria. However, there are no reported studies on the blood profiles of pregnant SAING after receiving DHP-degrading rumen bacteria. This aim of this study was thus:

i. To monitor the time spent by the pregnant SAING on various field activities during the 2nd (weeks 8, 11 and 14) and 3rd (weeks 18, 19 and 20) trimesters of gestation;

ii. To examine the blood profiles (protein metabolites and mineral elements status) of pregnant SAING possessing *S. jonesii* and maintained solely on LGP during the 2nd (weeks 8, 11 and 14) and 3rd (weeks 18, 19 and 20) trimesters of gestation period.

4.2. **Materials and methods**

4.2.1. Site

The location of the study was similar to that reported in subsection 2.2.1 of Chapter 2. The averages of temperatures during the 2nd and 3rd trimesters of gestation at the site were 20 and 30 ^{0}C, respectively.

4.2.2. Animals

Twenty six South African indigenous goats, popularly referred to as "*Nguni* goats", comprising 24 multiparous females and two mature males were used for the study. The *Nguni* goat breed has been described in subsection 3.2.2 (Chapter 3). The goats were in good condition and acceptable health status. The does were introduced into a group of goats in which *S. jonesii* bacteria had been previously transferred via animal-to-animal transfer (Hammond, 1995). The does were randomly divided into two equal groups (n = 13); one group was assigned to LGP while the other group was maintained on NP. The means of live weights of the females at the onset of blood sampling and field observation during the 2nd trimester on LGP and NP treatments were 39.8 ±4.24 kg and 37.2 ±3.97 kg, respectively. Averages of the live weights at the commencement of blood sampling and field observation during the 3rd trimester were 45.8 ±5.18 kg and 47.2 ±4.85 kg for the LGP and NP treatment groups, respectively.

4.2.3. Grazing management

Forage species on both LGP and NP treatments and grazing management practice were described in Chapter 3 (subsections 3.2.7 and 3.2.8, respectively). Most of the browses on the NP plots were trees (>1.5 m tall) and were beyond the reach of the goats, but their canopies served as shade during hot days. The animals had unlimited access to drinking water on the night and day camps.

4.2.4. Reproductive management

Details of oestrus synchronization and other reproductive management practices have been previously reported under subsection 3.2.6 in Chapter 3.

4.2.5. Evaluation of field activities

Once a week, four pregnant goats were randomly selected from each treatment group and observed every one minute whether the goats were engaged in grazing, browsing, ruminating or idling activities at close range between 08.00 and 15.00 h for one day during the 2nd (weeks 8, 11 and 14) and 3rd (weeks 18, 19 and 20) trimesters of pregnancy.

4.2.6. Forage sampling

Treatment diets were sampled on each day that the goats were monitored for field activities, using the four pregnant goats that were randomly selected. About 500 g of each forage species eaten (grazed + browsed) by the goats were harvested by hand and air-dried separately. From the sample, 75 g sub-samples were weighed out of each air-dried forage samples on each treatment. The sub-samples for the 2nd and 3rd trimesters of gestation on each treatment were then pooled and stored pending laboratory analysis.

4.2.7. Blood sampling

With due regards to the animal ethics procedures of the University of Natal, South Africa, 10 ml blood was sampled from the jugular vein (Van Niekerk *et al.*, 1990). Blood sampling was carried out once a week between 08.00 and 09.00 h on the day of sampling during the 2nd (weeks

8, 11 and 14) and 3rd (weeks 18, 19, 20 and 21) trimesters of gestation into two 5 ml pre-cooled vacuum tubes, one heparinized and the other un-heparinized (Becton Dickinson Vacutainer Systems, Europe). On collection, the blood samples were immediately transferred to Allerton Provincial Veterinary Laboratory, Cascades, South Africa for analysis.

4.2.8. Forage and blood analysis

The sub-samples of the forage species eaten by the goats on both treatments were separately analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ether extract (EE), ash and mineral elements (Ca, P, Mg, Zn, Fe and Cu) using the procedures described under forage study in subsection 2.2.3 (Chapter 2). Haematological parameters determined include mineral elements (Ca, P, Mg, Zn, Cu and Fe), packed cell volume (PCV) and protein metabolites (serum protein, globulin and albumin). The difference between total serum protein and albumin gives globulin levels. The blood analysis were carried out by Allerton Provincial Veterinary Laboratory as described by Wolf *et al.* (1972).

4.2.9. Statistical analysis

(i) The field activities data were analysed using repeated measures analysis as described by Rowell and Walters (1976) using the following General Linear Model (GLM) of SAS (SAS, 1987): $Y_{ilk} = \mu + G_i + W_l + N_k + e_{ilk}$, where Y_{ilk} = individual time spent on each activity, μ = overall mean, G_i = effect of gestation diet, W_l = effect of live weight during the first week of field observation in each trimester, N_k = effect of litter size and e_{ilk} = unexplained variation assumed randomly and independently distributed.

(ii) Blood profile data used in analysis were from the 15 goats that had a complete record and the data were also similarly using the following General Linear Model (GLM) (SAS, 1987):

$Y_{ijk} = \mu + G_i + W_j + N_k + e_{ijk}$

where Y_{ijk} = individual observations, W_j = effect of live weight at first week of blood sampling in each trimester and e_{ijk} = unexplained variation assumed randomly and independently distributed.

Treatment means were compared using standard error of the difference between means (s.e.) for significance ($p < 0.05$).

4.3. **Results**

4.3.1. Conception rate and animal health

Although there were 24 female goats in the study, nine and twelve pregnant goats were finally used on the LGP and NP treatments, respectively. Only 15 pregnant goats (seven and eight goats on LGP and NP treatments, respectively) out of the 21 does that were pregnant had complete blood profile records. During the 3rd trimester, one goat on LGP treatment carrying twins died of acidosis (as revealed by the *post mortem* examination) from accidental consumption of corn intended for steers in a nearby pen. In the rest of the goats, pregnancy proceeded normally and symptoms of nutrient or mineral deficiency or mimosine toxicity were not recorded throughout the study. The health all goats with a complete record was good and the experimental measurements were real treatment effects.

4.3.2. Diets

The chemical composition of the forage species (Table 4.1) sampled during field observations showed that forage species on the LGP treatment contained more than twice the amount of CP and less crude fibre (ADF and NDF) than forage on NP treatment. Except for iron, forage resource on LGP treatment was superior in all the mineral elements analysed.

4.3.3. Time spent on field activities during the 2nd trimester

The term grazing implies consumption of grass while browsing refers to consumption of leaves, pods and succulent twigs of standing shrubs and trees that are within the goat's reach. Time spent eating represents the summation of time spent grazing and browsing (i.e., grazing + browsing). Except during: 12.00-13.00 h and 14.00-15.00 h, goats on the NP treatment spent more time grazing. Differences between treatments during 08.00-12.00 h were significant ($p < 0.001$; Table 4.2). Throughout the seven hours of field observation, goats on LGP browsed more than those on NP treatment except between 12.00 and 13.00 h, and differed significantly during 08.00 - 11.00 h ($p < 0.001$, = 0.042 and 0.003) and 13.00-15.00 h ($p < 0.001$ and = 0.034). Differences between treatments in time spent ruminating and idling were not significant.

Overall time spent grazing on NP treatment was 54.8 min ($p < 0.001$; Figure 4.1) more than on LGP treatment, but goats on LGP browsed significantly more (53 min; $p < 0.001$) than their counterparts on NP treatment. Differences between treatments in total time spent eating, ruminating and idling were not significant.

4.3.4. Time spent on field activities during the 3rd trimester

Differences between treatments in hourly time spent grazing between 08.00 and 15.00 h tended towards significance during 08.00-09.00 h ($p = 0.071$) and 13-14.00 h ($p = 0.060$) but was highly significant during: 09.00-10.00 h ($p < 0.001$) and 11.00-13.00 h ($p = 0.002$ and < 0.001; Table 4.3). Goats on LGP treatment browsed significantly more ($p < 0.001$, $= 0.028$ and < 0.001) than their counterparts on the NP treatment between 09.00 and

12.00 h while between 12.00 and 15.00 h, NP goats browsed significantly more ($p = 0.008$, 0.011 and < 0.001). NP goats ruminated significantly more ($p = 0.016$) than the LGP goats during the second hour (09.00-10.00 h) of field observation, while the latter ruminated significantly more ($p < 0.001$) during the last two hours (13.00-15.00 h) of field observation. Time spent idling by the goats on NP between 11.00 and 13.00 h was significantly higher ($p = 0.004$ and 0.040) than on LGP. Over the seven hour period of field observation, goats on NP treatments grazed (24.7 min, $p = 0.004$) and idled (15.8 min, $p = 0.044$) significantly more, however, the goats ruminated significantly less (-24.1 min, $p < 0.001$) than LGP goats (Figure 4.2). The difference between treatments in overall time spent eating was not significant. However, the difference in time spent browsing between treatments tended towards significance ($p = 0.073$).

4. 3.5. Blood mineral elements and protein metabolites

Treatment differences in blood Ca, P and Zn and PCV contents were not significant during the 2nd trimester of pregnancy, but blood Mg and Cu contents differed ($p = 0.051$ and 0.076, respectively; Table 4.4). There was also a steady decrease in Ca concentration on both treatments during the periods of sampling in the 2nd trimester (LGP: 2.64, 2.49 and 2.33 m mol/l; NP: 2.61, 2.47 and 2.24 m mol/l) of pregnancy. During the 3rd trimester, however, differences between treatment means of blood Ca, P, Mg, Zn, Fe, PCV, serum protein and serum globulin concentrations were not significant, although goats on LGP treatment had significantly higher blood copper levels (2.09 ppm, $p = 0.029$) and albumin (1.03 g/l, $p = 0.022$) than pregnant goats on the NP treatment.

Table 4.1. Proximate and mineral element composition of forage species on *Leucaena leucocephala*-grass pasture (LGP) and natural pastures (NP) plots

	LGP	NP
Proximate (g/kg DM)		
Crude protein	258.3	103.3
Neutral detergent fibre	292	613.6
Acid detergent fibre	189.6	349
Fat	30.5	21
Ash	94.1	96.2
Minerals (g/kg DM)		
Calcium	30.5	21
Phosphorous	15.1	7.8
Magnesium	14.8	10.5
Zinc	0.4	0.3
Iron	4	4.6
Copper	0.1	0.1

Blood Ca, Cu, Zn and PCV contents decreased between 2nd and 3rd trimesters on both treatments, but the Mg level increased. Serum albumin contents of goats on both treatments increased consistently during weeks 19 and, 20 and 21 (LGP treatment: 28.56 to 29.16 to 31.79 g/l; NP treatment: 28.05 to 28.40 to 33.37 g/l, respectively). Serum protein and serum globulin on both treatments decreased between weeks 20 and 21 of gestation (serum protein: LGP: 66.25 to 57.00 g/l; NP: 65.10 to 58.53 g/l; serum globulin: LGP: 37.04 to 25.23 g/l; NP: 36.75 to 25.14 g/l).

Table 4.2. Time (minutes) spent grazing, browsing, ruminating and idling by the gravid goats during the 2nd trimester of pregnancy

	LGP	NP	s.e.	P-value
No of observations	12	12		
GRAZING				
08.00-09.00 h	3.9	18.8	2.16	0.001
09.00-10.00 h	8.5	22	2.74	0.001
10.00-11.00 h	9.5	24.4	3.02	0.001
11.00-12.00 h	5.2	19.8	2.54	0.001
12.00-13.00 h	8.2	7	2.14	0.582
13.00-14.00 h	18.1	22.3	4.06	0.337
14.00-15.00 h	25.9	20	4.78	0.251
RUMINATING				
08.00-09.00 h	0	0	**	-
09.00-10.00 h	0	0	**	-
10.00-11.00 h	6.5	8.5	4.59	0.673
11.00-12.00 h	13.6	8.6	6.41	0.468
12.00-13.00 h	10.7	8.4	4.45	0.624
13.00-14.00 h	6.4	10.5	4.9	0.435
14.00-15.00 h	2.5	8.7	2.4	0.219

	LGP	NP	s.e.	P-value
No of observations	12	12		
BROWSING				
08.00-09.00 h	38	26.3	2.7	0.001
09.00-10.00 h	26.7	18.9	3.44	0.042
10.00-11.00 h	22.9	10.7	3.42	0.003
11.00-12.00 h	20.9	15.5	3.27	0.133
12.00-13.00 h	21	21.7	5.13	0.901
13.00-14.00 h	18.8	8.4	2.66	0.001
14.00-15.00 h	13.7	7.4	2.66	0.034
IDLING				
08.00-09.00 h	18	14.9	2	0.146
09.00-10.00 h	24.8	19.1	4.4	0.221
10.00-11.00 h	21.2	16.3	2.8	0.111
11.00-12.00 h	20.3	16.1	4.54	0.381
12.00-13.00 h	20	22.9	4.31	0.528
13.00-14.00 h	16.6	18.8	2.7	0.452
14.00-15.00 h	17.8	23.8	4.18	0.185

s.e. and ** imply standard error of the difference between means and cases where denominator of F-test is zero, respectively.

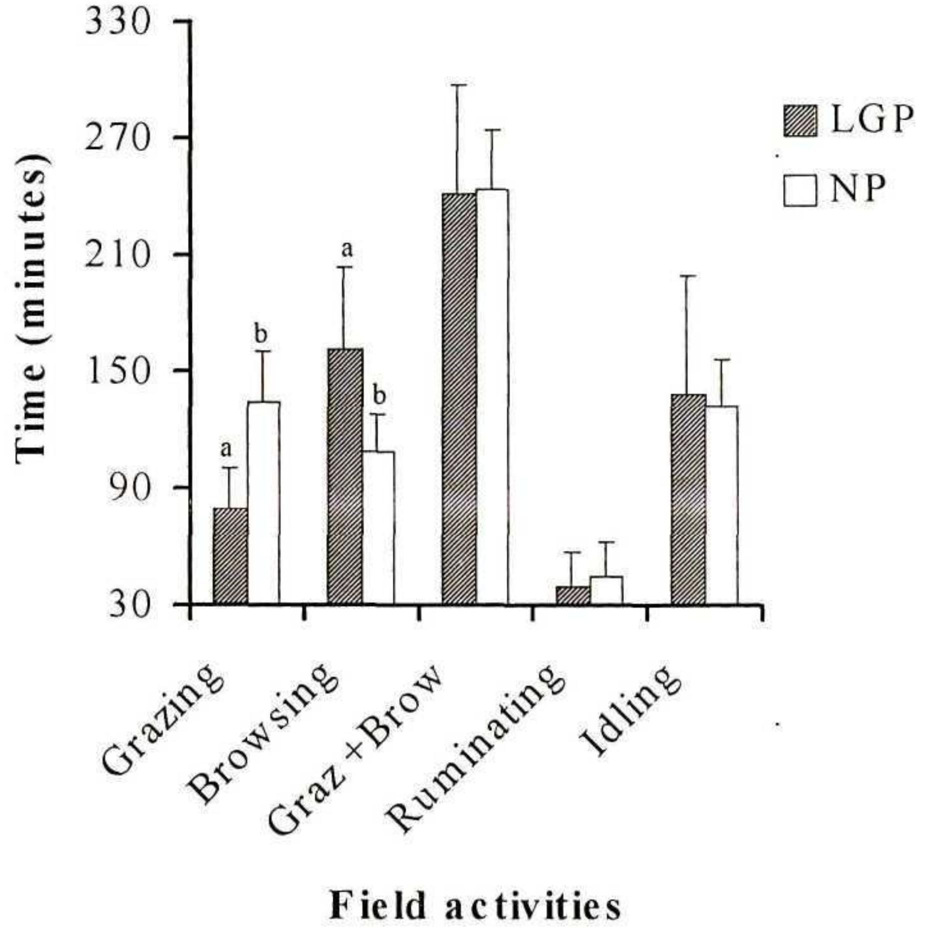

Figure 4.1. Total time (minutes) spent grazing, browsing, eating, ruminating and idling by the gravid goats over the 7 hour period (08.00-15.00 h) of field observation during the 2nd trimester of pregnancy

Nb: LGP :*Leucaena leucocephala*-grass pasture; NP: natural pasture; bars are standard deviations and different superscripts imply a significant difference ($p < 0.001$).

Table 4.3. Time (minutes) spent grazing, browsing, ruminating and idling by the gravid goats during the 3rd trimester of pregnancy

	LGP	NP	s.e.	P-value
No of observations	12	12		
GRAZING				
08.00-09.00 h	3	6.1	1.62	0.071
09.00-10.00 h	0	16.7	1.47	0.001
10.00-11.00 h	13.8	17.4	3.77	0.344
11.00-12.00 h	5.8	14.2	2.32	0.002
12.00-13.00 h	21.6	8.5	2.52	0.001
13.00-14.00 h	7.7	12.1	2.23	0.06
14.00-15.00 h	4.2	5.7	1.24	0.246
RUMINATING				
08.00-09.00 h	0	0	**	-
09.00-10.00 h	0	5.5	2.08	0.016
10.00-11.00 h	12.7	14.7	3.8	0.607
11.00-12.00 h	13.2	11.5	3.11	0.602
12.00-13.00 h	0	0	**	-
13.00-14.00 h	12	0	2.74	0.001
14.00-15.00 h	17.3	0	2.08	0.001

	LGP	NP	s.e.	P-value
No of observations	12	12		
BROWSING				
08.00-09.00 h	36.1	33.8	2.89	0.444
09.00-10.00 h	34.2	14.4	2.13	0.001
10.00-11.00 h	12.2	6	2.6	0.028
11.00-12.00 h	17.3	3.2	2.85	0.001
12.00-13.00 h	12.5	21.9	3.15	0.008
13.00-14.00 h	12.9	19.1	2.19	0.011
14.00-15.00 h	8	17.9	2.52	0.001
IDLING				
08.00-09.00 h	20.9	20.2	1.5	0.66
09.00-10.00 h	25.8	23.2	1.58	0.128
10.00-11.00 h	21.4	21	1.73	0.823
11.00-12.00 h	23.8	29.9	1.92	0.004
12.00-13.00 h	25.9	28.8	1.34	0.04
13.00-14.00 h	27.4	28.7	1.34	0.336
14.00-15.00 h	30.5	34.7	2.54	0.117

s.e. and ** imply standard error of the difference between means and cases where denominator of F-test is zero, respectively.

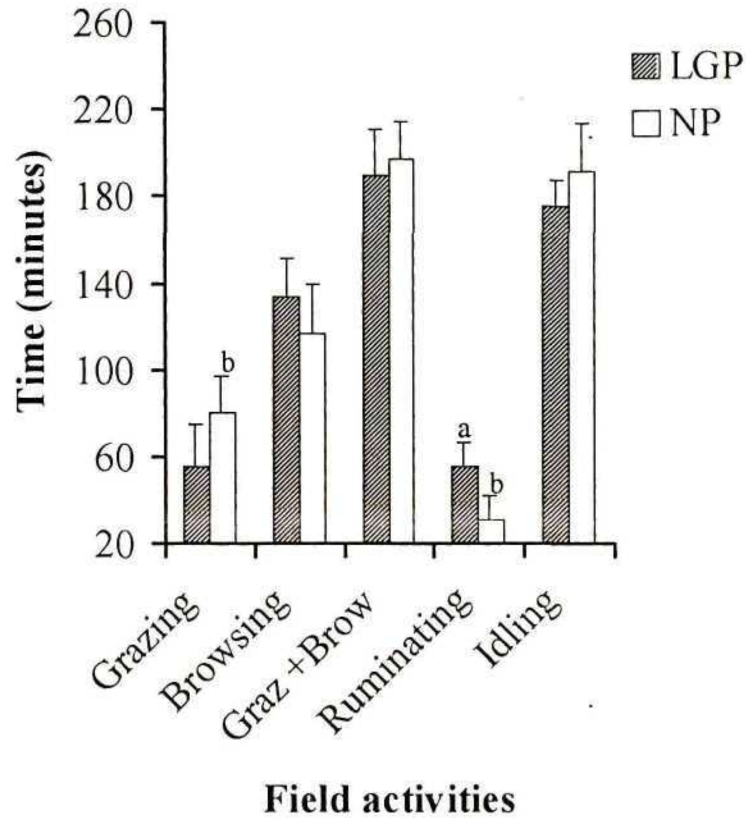

Figure 4.2. Total time (minutes) spent grazing, browsing, eating, ruminating and idling by the gravid goats over the 7 hour period (08.00-15.00 h) of field observation during the 3rd trimester of pregnancy

Nb: LGP :*Leucaena leucocephala*-grass pasture; NP: natural pasture; bars are standard deviations and different superscripts imply a significant difference ($p = 0.004$)

Table 4.4. Mean (± s.e.) concentration of mineral elements, packed cell volume (PCV) and protein metabolites in the blood of gravid indigenous goats grazed on *Leucaena leucocephala*-grass pasture (LGP) and natural pasture (NP) during gestation

	2nd trimester of gestation				3 rd trimester of gestation			
	LGP	**NP**	**s.e.**	**P-value**	**LGP**	**NP**	**s.e.**	**P-value**
No. of animals	7	8			7	8		
Macro elements (mmoll^{-1})								
Calcium	2.49	2.44	0.1	0.38	2.29	2.31	0.06	0.756
Phosphorous	2	1.92	0.12	0.52	1.92	1.93	0.1	0.888
Magnesium	0.99	1.04	0	0.1	1.07	1.08	0.05	0.893
Trace elements (ppm)								
Copper	16.13	14.7	0.72	0.1	15.69	13.6	0.83	0.029
Zinc	18.3	18.5	0.93	0.81	12.84	12.33	0.4	0.23
Iron	-	-	-	-	28.8	26.86	2.5	0.454
PCV (%) & Protein metabolites (g/l)								
Packed cell volume	32.14	32.9	1.55	0.63	29.92	27.91	1.1	0.094
Serum protein	-	-	-	-	53.7	55.4	1.9	0.394
Serum globulin	-	-	-	-	30.84	32.09	1.8	0.5
Serum albumin	-	-	-	-	30.44	29.41	0.4	0.022

s.e. implies standard error of the difference between means.

4.4. **Discussion**

4.4.1. Diets

Faure *et al.* (1983) and Coates *et al.* (1987) claimed that the chemical composition of hand collected forage samples was not a true representation of the plants consumed by free grazing animals. The hand sampling of forage carried out during the field observation was to provide a general idea of the nutritive value of the available pastures eaten (grazing + browsing) by the goats on both treatment plots and does not necessarily represent the quality of the goats' actual intake. Goats are known to select the more nutritious diets than the average of the available vegetation (Huston, 1998) and also possess the ability to select for higher protein forage than sheep (Qinisa and Boomker, 1998).

That the goats selected forage of higher nutritive value than the mean of the hand samples was revealed in the blood analyses. This observation is consistent with earlier reports (Engels, 1972; Faure *et al.*, 1983; Coates *et al.*, 1987) that grazing animals select forage that is of higher nutritive value than hand collected forage samples.

4.4.2. Field activities

Goats on both treatments were observed to prefer the youngest plant parts during grazing or browsing. Van-Mele *et al.* (1994) attributed this behaviour to the better nutritive value and palatability of the young plant or young plant parts. Ruminants on the field apportion their time to various field activities which comprise mainly grazing, browsing, ruminating and idling. Time allocated to each activity depends on season (Arthur and Ahunu, 1992), herbage quantity and quality (Papachristou and Nastis, 1992), time of day after turning out to pasture, environmental temperatures and physiological state of the animal (Woodward, 1997).

Plant type, herbage quantity and herbage quality vary between seasons (Stronge *et al.*, 1997; Huston, 1998) and influence intake and digestibility (Arthur and Ahunu, 1992) and consequently the time spent on various field activities. The higher and significant time spent grazing by goats on NP during the 2nd and 3rd trimesters of pregnancy when compared to that of goats on the LGP treatment can be attributed to the abundance of grass species on the NP plot- unlike the *Leucaena* plot that predominantly had only two grass species. Although there were more browse species on the NP plot, most of these were >1.5 m tall and out of the goats' reach. LGP goats browsed significantly more during the first semester of pregnancy, probably because of their easy reach to the *Leucaena leucocephala* on the plot. Thus forage species composition seemed to dictate the time goats allocated to grazing or browsing.

Even though the change in plant type between trimesters was not assessed in this study, the marked reduction in time spent on most of the field activities between the 2nd and 3rd trimesters of pregnancy on both treatments was probably brought about by change in plant type. This concurs with the findings of Allden and Whittaker (1970) and Thomas and Anastasios (1992) that a sharp decline in grazing time is accompanied by seasonal changes in plant type.

The quality of feed resources fluctuates with season (Preston and Leng, 1987). The increase in time spent ruminating between the 2nd and 3rd trimesters of pregnancy on the LGP treatment could be ascribed to the poor nutritive value of grass species associated with the peak of summer. The poor nutritive value of the grass species on LGP plot in peak summer probably necessitated the increased processing (rumination) time. Unlike the LGP plot that had *Leucaena leucocephala* species as the only leguminous browse species, the NP plot had more leguminous browse species that are good sources of protein for rumen microbes. Browsing time on the NP treatment increased slightly between the 2nd and 3rd trimesters. The increase probably enhanced effective microbial degradation of ingested forage species and consequently accounted for the reduction in rumination time (Warly *et al.*, 1994).

The 3rd trimester coincided with the peak of summer when environmental temperature was consistently high (30 °C). Environmental temperature has been found to influence the productive efficiency of grazing/browsing in ruminants (Fuquay, 1981) through its influence on feed intake (Silanikove, 1992; Qinisa and Boomker, 1998). The trend observed, whereby goats on both pastures types during both trimesters spent the first three hours of the field observation on eating activities (grazing + browsing), agrees with other studies (Worden *et al.*, 1963 cited by Arthur and Ahunu, 1992). They attributed the trend to the cooler morning temperatures. The occasionally unexpected long time spent grazing and or browsing observed after 12.00 h when the environmental temperature was high, was probably due to the fact that individual responses to adverse conditions differ (Engeland *et al.*, 1997) or the goats were indigenous breed and adapted to the usual season of hot climate at the experimental site.

The time allocated to each field activity depends on the physiological state of the animal (Woodward, 1997). Beside the influence of temperature, season, herbage quantity, herbage quality and plant type on feed intake, as pregnancy advances, so the foetal size increases and rumen capacity to accommodate more feeds decreases (Forbes, 1983). The decreased time spent eating by the goats on both treatments between the 2nd and 3rd trimesters of gestation could be attributed to the adverse effect of advanced pregnancy on feed intake. Decrease in voluntary food intake has also been ascribed to a reduction in the blood zinc level (Neathery *et al.*, 1973). The decrease in time spent eating between the 2nd and 3rd trimesters could have been further exacerbated by the marked decrease in Zn content between the two trimesters.

The increased time spent idling between the 2nd and 3rd trimesters of gestation can also be attributed to the increased foetal size between the two trimesters. Besides, the significantly higher time spent idling on the NP treatment relative to the idling time on the LGP treatment can be ascribed to the canopies of some of the browse trees on the NP plot providing a cooler environment. The low ruminating time recorded on both treatments during the two trimesters relative to the other field activities was most likely due to the period of the day during which the goats' field activities were monitored. Previous workers (Das *et al.*, 1999) have reported that goats spent more time eating during the day (06.01-18.00 h) than at night (18.001-06.00 h).

4.4.3. Blood Profiles

Packed cell volume (PCV): The normal PCV value for goats in the tropics and subtropics contained in the report by Puls (1994) ranges between 15 and 30%. Several factors might account for the changes observed in PCV in this study. These factors include season (Larson *et al.*, 1980; Hidiroglou, 1983); stage of gestation (Dutta and Baruah Jr., 1996; Ambatkar *et al.*, 1997), iron and nitrogen intake (Nikokyris *et al.*, 1991). Changes observed between 2^{nd} and 3^{rd} trimesters of gestation were similar to those described by Gonzalez-Montana (1994) and Mohy El-Deen *et al.* (1985). The latter authors ascribed the fall in blood profiles to an increasing demand for haemoglobin for the foetal circulation.

An additional factor may be haemodilution. As environmental temperatures increased, so is the rise in body temperature (Gwazdauskas *et al.*, 1973). This may increase water intake (Hassan and Roussel, 1975; Lee *et al.*, 1976) with a resulting haemodilution (Bassett *et al.*, 1995). In the 3^{rd} trimester, mean environmental temperature was 30^0, about 10^0 greater than during the 2^{nd} trimester of gestation.

Serum proteins: The range values of normal blood protein metabolites reported by Puls (1994) for goats in the tropics and subtropics are: serum protein: 65-78 gl^{-1}; serum albumin: 27-39 and serum globulin: 38-39 gl^{-1}; PCV:15 - 30%. The total serum protein concentration decreased near term (end of gestation period) as reported by other workers (Henz and Hode, 1969; Bayoumi *et al.*, 1986). In this study, a decrease was recorded for serum globulin, but serum albumin recorded an increase. Bayoumi *et al.* (1986) attributed the decrease in serum globulin to the increased demand for protein by the foetus and by the dam for the synthesis of globulin-rich colostrum. However, serum protein synthesis is also influenced by dietary protein (Khattab *et al.*, 1998) and blood albumin concentration has even been used to assess protein intake (Saba *et al.*, 1995). In this study, the greater serum albumin concentration in goats on the LGP treatment compared to those on the NP treatment probably indicates superior protein intake by goats maintained on the LGP.

Mineral elements: Blood Ca, P, Mg, Cu, Zn and Fe contents of 2 - 2.7, 1.4 - 2.6, 0.8 - 1.4 $mmoll^{-1}$, 0.7 - 1.2, 0.6 - 2.7 and 50 - 100 ppm, respectively, were reported to be the normal levels in tropical and subtropical goats (Puls, 1994). Blood mineral levels fluctuated during both trimesters similar to the trend observed by El-Naggar (1975) in the buffalo. The decreased blood Zn level between the 2nd and 3rd trimesters on both treatments is in line with the reports of Benedito *et al.* (1997) and Azab and Abdel-Maksoud, (1999) who claimed that Zn level decreases during late pregnancy. This is contradictory to the results of Bhattacharyya *et al.* (1995). The steady decrease in Ca concentration on both treatments during the periods of sampling in 2nd trimester seemed to suggest that the foetal need of Ca for ossification occurs relatively early. Result from previous studies (El-Naggar, 1975; Mohy El-Deen *et al.*, 1985) indicated a decline in Ca level towards term. A high protein diet favours high P absorption (Myburgh and Du Toit, 1970), however, the mean blood P concentration recorded for the goats on LGP with appreciable CP content was not significantly different from that of goats on NP treatment. This probably suggests there are other factors other than protein intake that influence P absorption in ruminants, or that confirming that goats selected forage richer in minerals than the hand collected field samples (Huston, 1998).

Increased blood Mg concentration between 2nd and 3rd trimesters on both treatments probably indicates that goats' Mg absorption increased with changes in the stage of gestation. Previous studies (Saba *et al.*, 1995) have shown that blood Cu concentrations depend on the mineral element (Cu) composition in the ingested forage or diet. The significantly higher blood Cu level of goats on LGP relative to the blood Cu level of the NP goats during the 3rd trimester, despite the proximate composition of the diets showing almost similar Cu level, probably indicates that the goats select forage species that are better in nutritive values than hand collected field samples. This is in line with other reports (Faure *et al.*, 1983; Coates *et al.*, 1987; Huston, 1998). The decrease in blood Cu levels on both treatments between the 2nd and 3rd trimesters of pregnancy perhaps was in response to the need of the foetus(es) which increased towards term.

Blood concentrations of the mineral elements and protein metabolites (except serum protein) considered in the study during both trimesters were within the normal range for goats in the tropics and subtropics (Puls, 1994). This could probably explain the absence of mineral and nutrient deficiency symptoms on both treatments during gestation. In view of the widely acknowledged chelating properties of mimosine and its toxic metabolite (3,4-DHP), the blood constituents of the goats assigned to the NP were expected to be superior than those of goats on LGP. However, blood mineral element levels of LGP goats compared favourably with those of their counterparts on the NP. The values of blood protein metabolites of the LGP goats were higher than those of NP does and no external symptoms of blood mineral elements and protein metabolites deficiencies and mimosine toxicity were observed. The absence of visible mimosine toxicity symptoms in the LGP goats during the study can be attributed to the successful transfer of DHP-degrading rumen bacteria (*Synergistes jonesii*) to the goats prior to pregnancy. The *S. jonesii* bacteria seem to play a beneficial role in carrying out the complete bio-degradation and detoxification of mimosine and its metabolites and thus overcoming the chelating tendency of mimosine and its metabolites on the hematological parameters considered in this study.

4.5. Conclusions

Time allotted to each field activity by the goats on both treatments within trimester seemed to be dependent on forage species composition and reach (accessibility to forage) while activities between trimesters were possibly influenced by season, reach, and stage of gestation. However, interaction of these factors is presumed to occur.

The blood profiles showed that field goats select forage species better in terms of nutritive value than forage species sampled using the hand sampling technique. A comparison between the two treatments show no significant differences in most of the hematological parameters evaluated.

Blood concentrations of all hematological parameters (except serum protein) on both LGP and NP treatments were within the normal range for goats in the tropics and subtropics. This explains the absence of any mineral and nutrient deficiency symptoms on both treatments. Goats maintained on the LGP treatment also showed no visible symptoms of mineral deficiency and mimosine toxicity-an indication that the goats possessed *S. jonesii* bacteria in their rumen. The bacteria are known to prevent mineral-chelating tendency of mimosine and its metabolites. The poor conception among SAING possessing *S. jonesii* bacteria and maintained on LGP in previous reports at the site of study, cannot be attributed to the mineral chelating tendencies of mimosisne and its metabolites on the hematological constituents that enhance conception.

CHAPTER 5

Reproductive performance of South African indigenous *Nguni* goats inoculated with DHP-degrading rumen bacteria and maintained on *Leucaena leucocephala*-grass and natural pastures[1]

Abstract

This study examined the reproductive performance of female South African indigenous *Nguni* goats (SAING) over a 2-year period. Thirty and twenty four goats were used in Years 1 and 2 , respectively. The does were maintained on *Leucaena leucocephala*-grass (LGP) or natural pastures (NP) prior to conception, and during gestation. Does on the LGP treatment possessed dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*), while their counterparts on NP lacked the bacteria. Records kept were forage chemical composition, gestation live weight, birth type, kids and does live weight at kidding (recorded within 24h of birth) and pre-weaning kid mortality. *Leucaena leucocephala*-grass pasture was nutritionally superior (crude protein and mineral elements) than the NP. The average daily gain, products of pregnancy and foetal development in gravid goats raised on LGP were significantly ($p < 0.03$, $p < 0.009$ and $p < 0.005$, respectively) higher than those raised on NP. *Leucaena leucocephala*-grass pasture-fed goats had kids that were heavier at birth than their counterparts on NP. Pre-weaning kid mortality on LGP was significantly ($p < 0.01$) higher than on NP treatment. Colostrum from kidded goats fed LGP was viscous and difficult to sample. The high viscocity probably impedes kids ability to suckle enough colostrum. The significantly ($p < 0.01$) higher pre-weaning kid mortality on LGP treatment (Year 1 : 46.7 vs. 5%; Year 2: 13.3 vs. 4.4%) compared to NP treatment in both years can be attributed to starvation and opportunistic infections from inadequate consumption of colostrum known to be rich in nutrients and antibodies. *Leucaena leucocephala*-grass pasture had higher incidence of multiple birth type (≥3 kids) than NP. Multiple birth kids on LGP were heavier at birth than their counterparts on NP. The high incidence of multiple births on LGP treatment suggested that, LGP enhanced ovulation rate. Goats on the LGP treatment did not show any symptoms of mimosine toxicity- and indication that *S. jonessi* bacteria were present in the rumen of the goats. Overall reproductive performance of SAING maintained on LGP was better than that on NP. The difference in conception rates between treatments was not significant; this indicates that the poor conception previously associated with the SAING does on LGP treatment at the site of study, was not due to *Leucaena* component of the LGP. *Leucaena* component of the LGP had no detrimental effects on conception of SAING goats possessing *S. jonesii* bacteria.

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[1]Part of this chapter has been published in: Small Ruminant Research 2001, 39: 73-85.
Co-authors: Nsahlai, I.V., Bonsi, M.L.K., Morris, C.D. and Du Toit, L.P.

5.1. Introduction

In subsistence agriculture, common to developing countries, farmers keep small ruminants for sale, consumption and personal use. Gross income is determined by the number of offspring produced (Steinbach, 1988)- which implies that high fertility and prolificacy are desirable and pre-requisites towards increased productivity (Bradford and Berger, 1988). However, one of the greatest constraints to high productivity is poor nutrition and low protein rather than energy is the most limiting nutrient in ruminant diets (Preston and Leng, 1987).

Animal productivity from tropical native pastures is limited by the poor soil fertility. Fertilization or incorporation of some leguminous forage such as the *Leucaena* species can partly alleviate this problem. *Leucaena* flourishes well in the absence of expensive nitrogen fertilizer (Cocks and Thomson, 1988) and rejuvenates soil fertility through nitrogen fixation.

The *Leucaena* species improve the nitrogen status of the soil and are useful animal fodder with considerable potential towards meeting the protein needs of ruminants, especially in the developing countries- where the use of protein concentrates is too expensive. Substantial benefits on feed intake, digestibility and growth of the ruminants has been reported from short term studies on *Leucaena* under zero grazing conditions (Bonsi *et al.*, 1996; Kaitho *et al.*, 1998).

Plants generally evolve thorns, fibrous foliage, secondary compounds and peculiar growth habits as protective mechanisms to prevent defoliation and guarantee their continued existence (Rozenthal and Janzen, 1979). Common secondary compounds in the *Leucaena* species comprise mimosine and tannins which vary in proportion, depending on the species, plant parts and climate (Yeh, 1983; Kewalramani *et al.*, 1987; Nsahlai *et al.*, 1995). In ruminant nutrition, tannins bound to proteins are beneficial at moderate levels, but detrimental at high levels (Kaitho, 1997). The extensive use of *Leucaena* is, however, hindered by the presence of mimosine (Jones, 1981). In cattle, mimosine adversely affects reproduction by reducing the calving percentage (Holmes, 1980;

Jones et al., 1989), increasing the incidence of still births (Jones *et al.*, 1976) and even death (Pratchett *et al.*, 1991; Hammond, 1995) in extreme cases.

As the Republic of South Africa (RSA) does not fall within the *Leucaena* naturalised areas, indigenous ruminants cannot consume excessive quantities of *Leucaena* fodder with impunity (Henderson, 2001), because the ruminants lack DHP-degrading rumen bacteria (*Synergistes jonesii*). The introduction of mimosine detoxifying microbes (*Synergistes jonesii*) to the rumens of South African Boer goats (SABG) eliminates the need to restrict the levels of *Leucaena* species in their diets, to avoid mimosine toxicity (Morris and Du Toit, 1998). South African indigenous *Nguni* goats (SAING) inoculated with DHP-degrading rumen bacteria were raised at the Ukulinga Research and Training Farm of the University of Natal, RSA, with the aim of building a group of mimosine-resistant goats for the institution. The inoculated female goats were exposed to *Leucaena* and their reproductive performance (poor conception and high pre-weaning kid mortality) declined persistently (Morris and Du Toit, unpublished report). The inoculation of unadapted ruminants with DHP-degrading rumen bacteria (contained in the rumen digesta of stock from *Leucaena* naturalised areas) was reported to overcome *Leucaena* toxicity associated with the extensive *Leucaena* feeding (replacing >30% of basal diet with *Leucaena* forage) of the forage (Jones, 1985; Jones and Megarrity, 1986).

The potency of inoculating SAING with DHP-degrading rumen bacteria has not been officially documented. Although inoculated goats at the Ukulinga Research and Training Farm exposed to *Leucaena* did not exhibit alopecia or in-coordination- poor reproductive performance in the form of poor conception and high pre-weaning kid mortalities continued to occur (Morris and Du Toit personal communication, 1999). This study was aimed at evaluating the potential of *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) in terms of productivity of mimosine-susceptible South African indigenous *Nguni* goats (SAING) after receiving dihydroxypyridone (DHP)-degrading rumen bacteria.

5.2. **Materials and methods**

5.2.1. Site

The site was similar to that reported in subsection 2.2.1 of Chapter 2. The study covers a-two year period. The precipitations during Years 1 and 2 were 748.5 mm and 543.0 mm, respectively. The means of ambient temperatures in both years of study during winter and summer were 10 ^{0}C and 30 ^{0}C, respectively.

5.2.2. Animals

Thirty and 24 four multiparous South African indigenous goats popularly referred to as "*Nguni* goats", purchased locally were used in Years 1 and 2 of the study, respectively. The *Nguni* goat breed has been fully described in Chapter 3 (subsection 3.2.2). The animals were in good condition and acceptable health status. The animals were randomly divided into two equal groups and assigned to *Leucaena leucocephala*-grass (LGP) or natural pastures (NP) treatment. The means live weights at bucks introduction on the LGP and NP treatments were 36.12 ±12.00 and 38.62 ±8.52 kg, respectively.

5.2.3. Experimental treatments

The two experimental treatments comprised, LGP and NP. Grasses and browse species on both treatments have been reported under subsection 3.2.7 (Chapter 3). The animals were allowed to acclimatize for a period of three months, in order to become accustom to their respective dietary treatments. To avoid unplanned breeding, males were not allowed to interact with the females. The grazing management practice was also similar to that described in Chapter

3 (subsection 3.2.8). Animals on both treatments had unlimited access to Kikuyu grass (*Pennisetum clandestinum*) and clean water in the night camps between 15.30 and 07:30 h, and were not offered any mineral supplements throughout the study.

5.2.4. Reproductive management

Oestrus of the does (n = 30) was not synchronized in Year 1. Oestrus was synchronized in Year 2 (n = 24) in a similar procedure described in subsection 3.2.6 (Chapter 3), but Progesterone Releasing Intravaginal Drug (PRID) was used in place of S4-Folligon. The mating ratios (male : female) in Years 1 and 2 were 1:15 and 1:12, respectively. The SAING bucks were retained permanently in their treatment for subsequent heat detection and servicing of does that failed to conceive during natural oestrus or synchronized oestrus.

5.2.5. Hand sampling of treatment diets

Samples of treatment diets were first obtained by setting out two days each week (a day for each treatment) during Year 2 study. Two does from each treatment were randomly selected and observed at a close range between 08:00 h and 15:00 h and samples of all forage species grazed or browsed taken by hand and pooled. The samples were air-dried and stored pending laboratory analysis.

5.2.6. Measurements

During Year 1, the records kept were parturition date, birth type, kids birth weight (recorded within 24 hours of birth) and pre-weaning kid mortality. The Year 2 measurements comprised:

Live weight changes of does during gestation: The does were weighed immediately at the introduction of the bucks and subsequently at week 3, 5, 9, 11, 14, 16, 18, 19, 20 and 21, post bucks introduction, using an electronic weighing apparatus described under live weight in Chapter 3 (subsection 3.2.9).

Conception rate and birth type: Conception rate and birth type (single, twins and multiples (≥ 3 kids)) in both treatments were first determined 50 days after introduction of the bucks in Year 2 and foetal development was monitored by measuring the foetal external brain case diameter on the 76th, 91st and 105th day post buck introduction using a Scanner 200 VET (Pie Medical Philipsweg 16227 AJ MASTRICHT, The Netherlands.) fitted with linear array probe which enhanced coverage and viewing.

Pregnancy variables: Pregnancy variables (products of pregnancy, foetal growth rate, average daily weight gain of does) were derived from the live weight changes of the gravid does during Year 2 based on the assumptions that live weight of pregnant goats during gestation often indicates prenatal foetal development (Amoah *et al.*, 1996) and secondly, if pregnant goats grew at a constant rate during gestation. Based on these assumptions, the cumulative body weight of the products of pregnancy were derived.

i. PGADG = (PGLWP- PGLWB)/GL

ii. $PGLW_t$ = PGLWB + $PGADG_t$

iii. FGRG is the mean weekly changes in products of pregnancy during gestation and was estimated weekly by regressing the difference between the pregnant goats live weight during gestation (products of pregnancy inclusive) and pregnant goats live weight during gestation (excluding products of pregnancy) on gestation length (in days). Gestation length was calculated retrospectively based on the kidding date and gestation length of 151 days (Amoah *et al.*, 1996).

PGADG is the pregnant goats average body weight daily gain;

PGLWP, pregnant goats live weight at parturition;

PGLWB, pregnant goats live weight at buck introduction;

$PGLW_t$, pregnant goats live weight at time t;

$PGADG_t$, pregnant goats average daily body weight gain at time t and

FGRG, foetal growth rate during gestation.

Does and kids live weight at kidding: The does and kids were weighed within 24 hour of kidding.

Colostrum sampling: Hand milking of colostrum was carried out only in Year 2 of the study (within the first 12 hours of kidding).

Reproductive traits: The following expressions were used in determining fertility

i. Pre-weaning kid mortality = (No of dead kids prior to weaning /No of live kids at birth) x 100.

ii. Prolificacy = No. of live kids at birth/No. of kidded goats.

iii Fertility rate = (No. of kidded goats/No. of female goats joined to buck) x 100.

iv Kidding rate = (No. of kids born/No. of female goats joined to buck) x 100.

5.2.7. Laboratory analyses

Treatment diets (hand sampled forage species) were analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ether extract (EE), ash and mineral elements (Ca, P, Mg, Zn, Fe and Cu), using the same procedures described under the forage study in Chapter 2, subsection 2.2.3.

5.2.8. Data derivation and statistical analysis

(i) Scanner accuracy was calculated for goats considered pregnant and non-pregnant, based on number that actually kidded. Statistical analysis of kids birth weight entailed analysis of variance using the General Linear Model (GLM) of Minitab software statistical package (Minitab, 1998) in which the body weights of the does at introduction of the bucks were used as a covariate.

(ii) The live weights of the pregnant goats at buck introduction, their gross live weights increase 21 weeks post introduction of the bucks, pregnancy variables, foetal external brain case diameter and kids weights at birth during Year 2 were appropriately paired and subjected to regression analysis according to Snedecor and Cochran (1971).

(iii) Foetal growth rate, pregnant goat's average daily gain and products of pregnancy were subjected to analysis of variance (ANOVA) with the live weights of goats at buck introduction and birth type as covariates using, the General Linear Model available in SAS (SAS, 1987).

(iv) Years 1 and 2 breeding records were used to determine the does reproductive performance-conception and fertility rates, prolificacy, kidding rate, birth type and pre-weaning kid mortality in both treatments, using the appropriate mathematical expression and where possible chi-square test as described by Steel and Torrie (1980) was employed.

5.3. **Results**

5.3.1. Health of animals

There was no incidence of doe mortality during pregnancy or at parturition in Year 1. In Year 2, one of the pregnant does on the *Leucaena* treatment died due to acidosis (as contained in the Pathological report) from accidental consumption of an excessive quantity of corn-based concentrate diet intended for steers in nearby pens. Another doe also died 72 h post kidding from intestinal verminosis and fatty hepatosis as revealed in the post mortem. Two of the three kids of the doe died a few hours later. However, the health of other animals in both treatments was good and the experimental measurements were real treatment effects.

Pregnancy generally lasted 22 weeks and kidding on both treatments took place in the same season (month of May) in Years 1 and 2, but was more widely spread in Year 1. All pregnant does in both treatments kidded within one week and there was no sign of dystocia. However, one still birth each was recorded on both treatments. Post mortem reports of dead kids revealed no obvious pathological cause. Data of dead kids and does were not included in the statistical analysis. The most common symptoms associated with mimosine toxicity were not observed during the study.

5.3.2. Chemical composition of the forage on the experimental plots

The chemical composition of the forage on the experimental plots is contained in Table 5.1. Crude protein (CP) content of the forage on the LGP plots was approximately 150% more than that of the natural pasture. The poor quality of the easily accessible forage resource on NP was reflected in its lower CP (10.3%), higher neutral detergent fibre(NDF) (61.4% vs 29.2%) and acid detergent fibre (ADF) (34.9% vs 19.0%) values relative to those of forage resource on the LGP plot. With the exception of iron, *Leucaena* plots had a superior concentration for all the mineral elements analysed.

5.3.3. Scanner accuracy and foetal development

The scanner was 79.2% accurate when used 50 days post introduction of the bucks to determine pregnancy. The accuracy was, however, poor (31.2%) when employed to determine birth type. In both treatments, no goats were diagnosed as carrying multiples. There were inconsistencies when foetal external brain case diameter and kid birth weight were compared in goats that were diagnosed correctly as carrying singles or twins (Table 5.2). Between 76 and 105 days post introduction of the bucks, the average increase in external brain case diameter of singletons and twins were 1.6 and 2.0 cm, respectively. The pattern of foetal growth during gestation (Figure 5.1) shows a linear trend from the 3rd to 20th week of gestation, but unlike the first two trimesters of gestation, the products of pregnancy of goats on LGP treatment were consistently heavier than those on NP.

A positive and low correlation coefficient (r) was obtained between the foetal external brain case diameter and kid birth weight in both treatments. This coefficient was higher for animals in the NP treatment (Table 5.3). The correlation coefficients (r) of the other reproductive parameters were, however, higher for goats on the LGP treatment, relative to those on NP.

5.3.4. Growth during gestation

In Year 2, all pregnancy variables (products of pregnancy and foetal development rates) in the LGP treatment were significantly higher ($p < 0.01$) than on the NP treatment (Table 5.4). At introduction of the bucks, does assigned to the NP treatment were marginally heavier than their LGP counterparts. However, pregnant does maintained on LGP recorded a higher growth rate and were significantly heavier ($p < 0.05$) than the pregnant goats on the NP by the 21st week of gestation (Figure 5.2). Does on the LGP gained body weight ($p < 0.03$) during gestation, while their counterparts on NP lost weight. Does on *Leucaena* treatment had significantly ($p < 0.009$) superior products of pregnancy and foetal growth rates by 9.8% and 14%, respectively.

5.3.5. Reproductive performance

The NP treatment, with more pregnant goats, tended to have more live kids than goats raised on the *Leucaena* treatment (Table 5.5). Over the two year period, the does on LGP that kidded, successfully weaned 70% of their kids, while their counterparts on the NP treatment successfully weaned 95% of their kids. Pre-weaning kid mortality recorded for goats on the LGP treatment over the 2 year period was significantly ($p < 0.05$) higher than that on the NP treatment.

Prolificacy, fertility and conception rates over the two year period were higher for the NP treatment than for the LGP treatment. Mean birth weight of multiple kids in the *Leucaena* treatment was significantly higher ($p < 0.05$) than that in the NP treatment (Year 2). The birth weight of kids in Years 1 and 2 for the different birth types showed that kids from the does on the LGP treatment were heavier than kids of does maintained on NP treatment.

Over the two year period, the birth weight of all kids was inversely related to the litter size. In Year 1, pregnant goats on the natural pasture treatment recorded a significant higher proportion ($p < 0.001$) of twins at kidding. But over the 2 year period, singles and multiple birth proportions were more in the LGP treatment (Table 5.6). Female to male kids (sex ratio) was 60: 40 of the total live kids at birth in the LGP treatment, while 43:57 was the female to male kids ratio on NP treatment. Over the entire study, proportions of singleton and multiple (≥ 2) birth types in does maintained on LGP were 35% and 116% more than those of their counterparts on NP. However, goats maintained on the NP treatment recorded 33% more twins than goats maintained on the LGP treatment. Doe and buck kids constitute 60 and 40%, respectively, of the total live kids at birth in the LGP treatment, while 43 and 57% of doe and buck kids were kidded by dams reared on the NP, respectively.

The hand milked colostrum sample obtained from goats that kidded on the LGP treatment was less in quantity and more viscous in appearance than samples obtained from goats that kidded on the NP treatment. The thick or viscous nature of the colostrum made sampling difficult and thus warranted the application of intense pressure during hand milking.

Table 5.1. Proximate and mineral elements composition of forage species on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP)

	Experimental Treatments	
Nutrients and minerals	**LGP**	**NP**
Proximate (% DM)		
Crude protein	25.83	10.33
Neutral detergent fibre	29.2	61.36
Acid detergent fibre	18.96	34.9
Fat	3.05	2.1
Ash	9.41	9.62
Major elements (g kg^{-1} DM)		
Calcium	30.5	21
Phosphorous	15.1	7.8
Magnesium	14.8	10.5
Trace elements (mg kg^{-1} DM)		
Zinc	370	270
Iron	3980	4620
Copper	130	120

Table 5.2. Birth weight (kg) of kids and foetal external brain case diameter (cm) of correctly diagnosed birth type using a scanner at various stages of gestation[a]

	Birth weights	Brain case diameter (cm)		
Parameters	**(kg)**	**76 days**	**91 days**	**105**
Singletons				
L8	3.34	3.57	4.34	4.87
L12	2.36	2.98	3.7	4.83
Twins				
V2	1.63	3	3.47	4.64
V9	3.5	2.97	3.84	4.98
V20	1.7	2.62	4.3	4.82
L7	2.09	-	4.8	5.32
L14	1.67	-	3.32	4.31

Nb: Values of twins were derived as means for both kids.
L: tag alphabet used for goats assigned *Leucaena* treatment
V: tag alphabet used for goats assigned natural pasture treatment.

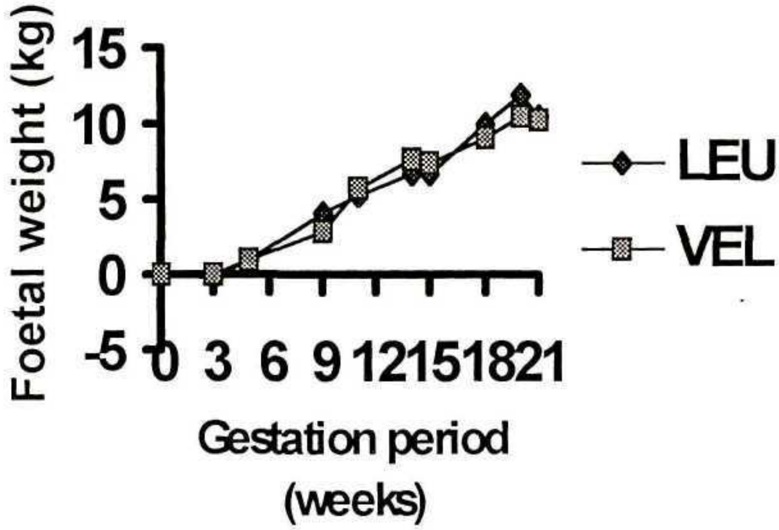

Figure 5.1. Foetal growth rate in pregnant South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass (LEU) and natural pastures (VEL)

Nb: The derivation of foetal growth rate (irrespective of litter size) was based on the assumptions stated under pregnancy variables in subsection 5.2.6.

Table 5.3. Regression analysis of certain reproductive parameters in pregnant South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP)

Parameters compared	LGP	NP
Foetal external brain case diameter (BCD) vs kids birth wt (KBW).	KBW= -0.14+0.52BCD r = 0.30	KBW=-23.7+5.39BCD r = 0.87
Products of pregnancy (PP) at wk 21 of gestation vs kids birth wt (KBW).	KBW=1.95+0.262PP** r = 0.92	KBW= 3.11+0.122PP* r = 0.67
Pregnant goats average daily gains (PGDG) vs products of pregnancy (PP).	PP=13.4-0.03035PGDG** r = 0.85	PP=9.76-0.0186PGDG** r = 0.71
Pregnant goats average daily (PGDG) gains vs foetal growth rate (FGR).	FGR=112-0.235PGDG* r = 0.73	FGR=80.6-0.119PGDG* r = 0.60

*P < 0.05; **P < 0.01

Table 5.4. Mean (±s.e.) Live weight changes of pregnant South African indigenous *Nguni* goats during gestation and derived pregnancy variables maintained on *Leucaena leucocephala*-grass pasture (LGP) or natural pastures (NP)

Parameters	**LGP**	**NP**	**s.e.**[a]
No of pregnant goats	8	12	
Wt. (kg) of female goats at:			
Buck introduction	36.12	38.62	4.57
21 weeks of gestation	48.69	48.33	5.69
24h post-kidding	39.06	38.12	4.28
Gross weight gain as at wk 21 of gestation.	12.57	9.71	1.51; $p < 0.05$
Net weight gain during gestation	2.94	-0.5	1.82
Pregnancy variables			
Pregnant goats average daily gain(g^{d-1})	86.19	-19.78	74.26; $p < 0.03$
Products of pregnancy (kg)	10.96	9.98	1.57; $p < 0.009$
Foetal growth rate during gestation(gd^{-1})	93.21	81.5	16.04; $p < 0.005$

Treatment means were not adjusted for the effects of covariates.
[a]Standard error of the difference between treatment means.

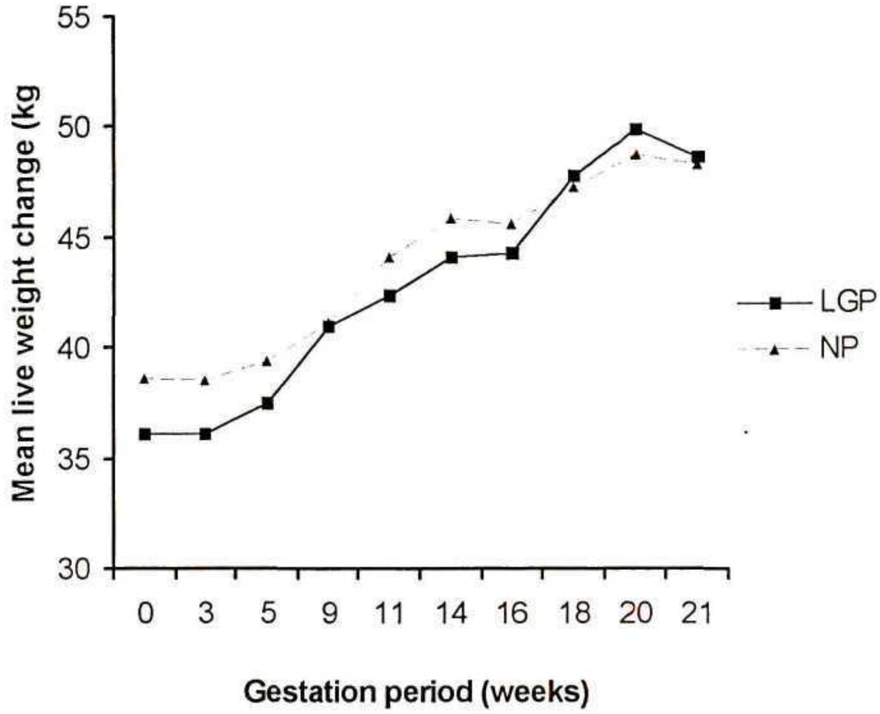

Figure 5.2. Changes in mean live weight of pregnant South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass pasture (LGP) or natural pastures (NP)

Table 5.5. Summary of the reproductive performances (fertility rate, prolificacy and pre-weaning kid mortality) of South African indigenous *Nguni* does maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP)

	Year 1			Year 2		
	LGP	NP	χ^{2b}	LGP	NP	χ^{2a}
Reproduction record						
No of female goats	15	15		12	12	-
No of kidded goats (%)	60	73.3		66.7	100	3.57NS[b]
No of non-preg. goats	6	4		3	0	
No of live kids at birth	15	20		15	23	0.77NS[b]
No of still birth	1	0		1	1	-
No of kids weaned	8	19		13	22	-
Pre-weaning kid mortalities	7	1		2	1	8.88[c]
Reproductive traits (%)						
Pre-weaning kid mortality	46.67	5		13.33	4.35	-
Prolificacy	167	182		188	192	-
Fertility rate	60	73.33		66.67	100	-
Kidding rate	106.67	133.3		125	191.67	-
Birth weight (kg)						
Singles	2.5	2.2	-0.57	2.85	2.88	(0.57)[b]
Twins	3	2.6	-0.28	2.24	2.34	(0.21)[b]
Multiples	1.63	-	-	2.5	1.92	(0.17)[c]

Treatment means were not adjusted for the effects of covariates.
[a]Chi-square; [b]$P > 0.05$; [c]$P < 0.05$; [d]Standard error.

Table 5.6. Distribution of kids by birth type and gender in South African indigenous *Nguni* does maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP)

	Year 1			Year 2		
	LGP	NP	χ^{2a}	LGP	NP	χ^{2a}
Birth type (%)						
Singles	33.3	18.2	-	25	25	-
Twins	55.6	81.8	20.17[c]	50	58.3	2.30NS[b]
Multiples	11.1	0	-	25	16.7	-
Kid's gender						
Male	-	-	-	6	13	-
Female	-	-	-	9	10	1.00NS[b]

Treatment means were not adjusted for the effects of covariates.
[a]Chi-square; [b]$P > 0.05$; [c]$P < 0.05$

5.4. Discussion

5.4.1. Gestation diets

Engels (1972) reported that there was a marked difference between the nutritive quality (crude protein and fibre content) of forage species obtained using the hand-sampling technique and that from oesophageal fistulates. Recent studies of Coates (1999) went further and showed that the chemical composition of the extrusa and the intake were different. However, the use of the hand-sampling technique reported in this study was to assist in having a general idea of chemical composition of the forage resources on both treatments. The results from the hand-sampling techniquedid not necessarily represent the chemical composition of the actual intake of the goats. The goats on both treatments were expected to select better nutritive quality forage than the hand clipped samples- bearing in mind that goats are very selective (Huston, 1998).

5.4.2. Effects of gestation diet on health, foetal development and growth during gestation

The absence of any detectable adverse effects on the health of animals assigned to the LGP treatment and the non-incidence of symptoms of mimosine toxicity throughout the trials, suggest that the goats were effectively transferred the *S. jonesii* bacteria capable of degrading and detoxifying mimosine and its metabolites (2, 3 and 3, 4 -dihydroxypyridones (DHP) to non-toxic compounds (Allison *et al.*, 1990). This is in harmony with the report of Jones and Megarrity (1986) that presence of *S. jonesii* bacteria in ruminants enhances high tolerance of *Leucaena* intake with no deleterious consequences (Hutton, 1983; Kudo *et al.*, 1990). The absence of dystocia during kidding on both treatments and years could be ascribed to the low birth weights recorded (McSporran *et al.*, 1977; Knight *et al.*, 1988). Holmes (1980) attributed the embryonic death in cows fed high levels of *Leucaena* to abortion and resorption of embryos, while Jones *et al.* (1989) attributed the poor reproductive performance to a transient effect on embryonic death.

The inconsistent and inaccuracy of the scanner technique imposed a great limitation in its use. It is thus difficult to ascribe the 25% reduction in fertility of goats fed *Leucaena* in this trial during Year 2, to either the transient effect on embryonic death postulated by Jones *et al.* (1989), or abortion and resorption as described by Holmes (1980) and Holmes *et al.* (1981). The poor results obtained via the scanner can be ascribed to varying presentations (positioning) of the foetus during scanning. Ruminants used by Jones *et al.* (1989), Holmes (1980) and Holmes *et al.* (1981) were not DHP inoculated, which possibly accounts for the poor reproductive performance observed and reported in their studies.

The changes in the live weight during gestation are often assumed to be indicative of prenatal development of the foetus(es) (Amoah *et al.*, 1996). Isaacs *et al.* (1991) likewise acknowledged that the live weight of pregnant goats during gestation affects the amount of energy available for foetal growth. Therefore, changes in the weight of the pregnant doe can be used to monitor foetal development- which could be a better alternative in overcoming the inconsistencies and inaccuracies associated with the scanner.

Leucaena species possess a high nutritive value as animal feed, with the crude protein content ranging between 19 and 30% (Chapter 2; Akingbade *et al.*, 2001b) and a high total digestible nutrient (54-70%), phosphorus, calcium and carotene (Machado *et al.*, 1978). The improved average daily gain (ADG) associated with the LGP during gestation could be attributed to the higher crude protein, less crude fibre content and high mineral element contents, compared to the NP. This confirms the nutritive potential of *Leucaena* as regards growth (Hernandez *et al.* 1986; Wildin, 1986; Bonsi *et al.*, 1994, 1995; Adejumo, 1995).

The higher nitrogen content of *Leucaena* could have provided digestible protein at levels above that required for maintenance (Akyeampong and Dzowela, 1996). This concurs with the reports of Akbar and Gupta (1985a), Gupta and Atreja (1999) and Srivastava and Sharma (1998) who claimed that mimosine-adapted goats fed *Leucaena* forage were in a positive nitrogen, calcium and phosphorus balance. Muir and Massaete (1997) demonstrated that goats supplemented with *Leucaena* gained 168% of their body weight (BW), compared to non-supplemented goats. Morris and Du Toit (1998) recently reported a weight gain benefit for *Leucaena* in DHP-inoculated SABG maintained on LGP at the location of this study.

5.4.3. Effects of LGP on gestation and reproductive performance

The prolificacy of goats on LGP treatment in both years of study were within the range for litter size observed under experimental conditions (Henniawati and Fletcher, 1986) and even exceeded the performance reported by Wilson (1976) and Manjeli *et al.* (1996) for West African dwarf goats. The higher birth weight of kids whose dams were maintained on LGP treatment could be linked to adequate nourishment (high crude protein and mineral elements and low crude fibre contents) obtained from the *Leucaena* component of the pastures This is in agreement with Peart (1967) who claimed that dam weight during gestation had an influence on kid birth weight. Bindon and Lammond (1966), in contrast, reported low kid birth weights in ewes fed *Leucaena* from 30 to 90 days post-mating. The denial of *Leucaena* to ewes within 30 days of ram introduction, coupled with the absence of *S. jonesii* bacteria in the ewes' rumen capable of breaking down mimosine and its toxic metabolites (2,3-DHP and 3,4-DHP), might have accounted for the low birth weights in the study reported by Bindon and Lammond (1966).

In un-inoculated ruminants, circulating DHP's impairs thyroid function (Megarrity and Jones, 1983; Quirk *et al.*, 1988) by reducing circulating thyroid hormone (Elliott *et al.*, 1985; Hammond, 1995) and voluntary feed intake. Previous studies (Jones and Hegarty, 1984) have shown that supplementation of ruminants fed *Leucaena* with thyroxine to have little effect on alleviating the depression in voluntary feed intake. The positive net growth of gravid goats and the higher kid birth weights on LGP could suggest that the pastures enhanced placenta development.

The high incidence of multiple births in goats on LGP treatment can be ascribed to the diet, which is in line with previous reports (Gunn, 1983; Rhind 1992) that nutrition influenced ovulation rate. Within treatment, male kids were heavier than female kids. Overall kids birth weights for the two year period within treatment decreased, as the litter size increased. These observations are in agreement with Husain *et al.* (1997) and Mia and Bhuiyan (1997). Pre-weaning kid mortality rate in the *Leucaena* treatment during Year 1 was mainly from the twin litter. Though twins from *Leucaena*-fed dams in Year 1 were heavier at birth than their counterparts on the same treatment in Year 2, the latter still had a low pre-weaning kid mortality rate.

The high pre-weaning kid mortality in the *Leucaena* treatment in Year 1 with a higher kids birth weight seems to suggest that the pre-weaning kid mortality on the treatment was not due to birth weight. This confirms the reports of Knight *et al.* (1988), that birth weight difference does not account for all pre-weaning kid mortalities. Previous studies (Alexander, 1964; Dalton *et al.*, 1980) attributed pre-weaning kid mortality rate to season, diet, dam parity, maternal nourishment and management.

Kidding on both treatments occurred during the same season in both years of study. However, kidding was more dispersed in Year 1 than Year 2, due to lack of oestrus synchronisation in Year 1. The significant ($p < 0.01$) higher pre-weaning kid mortality cannot be ascribed to seasonal variation, but may probably due to a problem associated with multiple births (Wilson, 1976; Manjeli *et al.*, 1996). Twins and multiple birth types (≥ 3 kids) are more prone to death from mis-mothering (Wilson *et al.*, 1985; Ademosun, 1992), poor maternal milk supply (Adu *et al.*, 1979), physiological starvation (Smith, 1977) or inappropriate management practices at kidding (Husain *et al.*, 1997).

Sufficient quantities of colostrum intake by the kids positively influence their survival rate (Altmann and Mukkur, 1983; Mellor and Murray, 1986). Colostrum production is influenced by the diet fed during gestation(Barnicoat *et al.*, 1949). However, the availability of large quantities of standing *Leucaena* on the LGP plot at the end of each year study suggests that poor colostrum supplies of the *Leucaena*-reared goats was not due to a nutritional constraint, but probably due to poor rate of colostrum secretion. The intense pressure applied during hand milking of the does fed LGP in Year 2 may have affected subsequent milk let down and possibly offers an explanation for the reduction in pre-weaning kid mortality during Year 2.

Does on LGP were associated with a higher incidence of multiple births, relative to does on NP. Kids in multiple birth type were light and too weak to suckle efficiently. The high pre-weaning kid mortality rate in goats maintained on LGP during Year 1, when natural suckling was not disturbed, was probably due to the kids' inability to obtain enough colostrum. The inadequate intake of colostrum by kids in multiple litters probably resulted in a low intake of antibodies (serum immunoglobulin) in the colostrum and subjected kids to death from opportunistic infections (Khalaf *et al.*, 1979; Calavas *et al.*, 1995). Report of Goyena *et al.* (1997) revealed that adequate consumption of colostrum by kids effectively prevents infections.

5.5. **Conclusions**

The *Leucaena leucocephala*-grass pastures favoured growth performance of pregnant goats during gestation and high kids' birth weight. *Leucaena leucocephala*-grass pastures favoured ovulation and resulted in a higher incidence of multiple birth type compared to their counterparts maintained on NP. This study demonstrated that LGP as gestation feed resource to SAING has a greater potential than NP.

The absence of any deleterious effects of mimosine in SAING maintained on LGP treatment showed that the pastures can be safely fed to SAING without restriction once the goats have been innoculated or transferred *S. jonesii* bacteria. The poor conception previously associated with SAING does on LGP treatment at the location of this study cannot be attributed to the *Leucaena* component of pastures- as the conception rates of does on both LGP and NP treatments in this study were not significantly different.

CHAPTER 6

Post-kidding productive and reproductive performance of mimosine-adapted South African indigenous *Nguni* goats grazed on *Leucaena leucocephala*-grass pasture or natural pastures during gestation[1]

Abstract

The main objective of the study was to examine the effect of feeding *Leucaena leucocephala*-grass pasture (LGP) or natural pasture (NP) as gestation feed resource on post-kidding reproductive performance of South African indigenous *Nguni* goats (SAING). Twenty lactating SAING (LGP: n = 8; NP: n = 12) that received dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) via animal-to animal transfer were used in the study. The goats were maintained on LGP or NP during gestation and on 0% or 10 % Molasses (M) concentrate diet during lactation that lasted 10 weeks. Records kept were does and kids live weight at kidding, pre-weaning weekly live weight of kids, weekly milk yield and return to first postpartum oestrus. Average kidding weight of does on LGP was significantly (p = 0.05) higher than that on NP group (40.0 ±1.3 vs 36.4 ±1.1 kg). Birth weight and pre-weaning kid average daily gains of kids on LGP group were greater than on NP. Milk yield of does on LGP was higher than that on NP (81.8 ±7.4 vs 66.6 ±6.1 kg). Return to first postpartum oestrus occurred earlier (24.1 ±7.6 days vs 44.2 ±6.3 days postpartum) and among larger proportion of does in LGP group than in NP group (6 out of 8 7 out of 10 does on LGP and NP does, respectively). The higher values of pre-weaning average daily live weight gains of kids, milk yield and first postpartum oestrus on LGP when compared with data on NP group, were indications that quantities of mimosine and its toxic metabolites that escaped degradation and detoxification of the *S. jonesii* bacteria were insufficient to have any detrimental carry-over effect on post-kidding reproductive performance. This implies that the *Leucaena* component of LGP cannot be attributed to the poor conception that can be linked to a delay in the return to postpartum oestrus in SAING possessing *S. jonesii* and maintained on LGP during gestation. *Leucaena leucocephala*-grass pastures had no detrimental effects on the post kidding reproductive performance of SAING possessing *S. jonesii*.

[1]Part of this study has been published in: South African Journal of Animal Science 2000, 30 (Suppl. 1): 4-5.
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6.1. Introduction

Productivity from native tropical pastures is hampered by, amongst other factors, poor soil fertility (Cocks and Thomson, 1988). Fertilizing or incorporation of some leguminous plants such as the *Leucaena* species, can partly alleviate this problem. *Leucaena* species flourish well in the absence of expensive nitrogenous fertilizer and rejuvenate soil fertility through nitrogen fixation (Webb, 1988). The poor soils and lack of capital to procure inorganic fertilizers by the resource poor farmers that constitute the bulk of the agricultural sector in developing countries have led to the incorporation of *Leucaena* species into the farming systems (Wildin, 1983). *Leucaena* species provide a nutritious fodder with considerable potential towards meeting the protein needs of ruminants, especially in developing countries where the majority of the livestock operators cannot afford expensive cereal-based protein concentrates.

The main constraint in the use of *Leucaena* species as a feed resource prior to the discovery of DHP-degrading rumen bacteria (*Synergistes jonesii*) has been its high foliage content (3-5%) of mimosine (Gupta *et al.*, 1983). Mimosine is rapidly hydrolysed to 2,3 and 3,4-dihydroxypyridones (DHPs) in the rumen (Gupta and Atreja, 1998a) and this mimosine is anti-mitotic (Boehme and Lenardo, 1993) and goitrogenic (Jones and Megarrity, 1986).

The metal-chelating ability of the 3-hydroxy-4-oxo functional group of the pyridone ring in mimosine {β-N (3-hydroxy-4-pyridone)-α-amino propionic acid} has been implicated in promoting deficiencies of mineral elements such as zinc (Sethi and Kulkarni, 1995) and phosphorous (Girdhar *et al.*, 1991) and impairs the activity of metal-containing enzymes.

Ruminants in some regions, notably Central America, Hawaii and Indonesia, where *Leucaena* is indigenous, are naturally endowed with the bacterium *S. jonesii* in their rumen (Allison *et al.*, 1992). The geographical variations in rumen microbial ecology probably explain the absence of *S. jonesii* bacteria in SAING and their susceptibility to mimosine toxicity. Results in Chapters 3 (Akingbade *et al.* in press a) and 4 (Akingbade *et al.*, 2002) have shown that the poor conception in does on *Leucaena leucocephala*-grass pastures (LGP) was neither due to the detrimental effects of the mimosine constituent of the *Leucaena* species on semen quality, nor the chelating tendency of mimosine on blood mineral elements and protein metabolites of does (mature female goats) maintained on LGP.

An advanced stage of pregnancy has been associated with an increased outflow rate of rumen digesta (Weston *et al.*, 1988a; 1988b), in order to reduce the intake from a decreased rumen volume (Graham and Williams, 1962 cited by Sibanda, 1984). There is therefore the likelihood that some mimosine and its metabolites (2,3 and 3,4-dihydroxypyridones (DHP)) contained in the *Leucaena* forage ingested by the pregnant goats might escape rumen degradation and detoxification by the *S. jonesii* bacteria.

The mimosine escaping rumen degradation and detoxification towards term probably delayed the return to oestrus- which resulted in the poor conception observed by Morris and Du Toit (unpublished) among South African indigenous *Nguni* goats (SAING) on LGP. Furthermore the bypass mimosine and its metabolites probably affected milk yield and milk quality that resulted in the high pre-weaning kid mortality rate, among kids nursed by the does on the LGP.

This study was aimed at examining the post kidding reproductive performance of mimosine-susceptible SAING transferred *S. jonesii* bacteria and grazed on LGP or natural pastures (NP) during gestation. This study of post-kidding reproductive performance of does maintained on LGP during gestation will facilitate in determining the following:

i. Whether the poor conception and high pre-weaning kid mortality rate previously associated with the LGP treatment were related to the carryover effects of *Leucaena* component of the LGP fed as a gestation diet;

ii. Whether the quantity of mimosine and its metabolites that escaped rumen degradation and detoxification towards term, in response to the increased outflow rate was sufficient to exert any detrimental effect on the post-kidding reproductive traits of does fed LGP during gestation.

6.2. **Materials and methods**

6.2.1. Site

Location of the study site has been reported in subsection 2.2.1 of Chapter 2.

6.2.2. Animals and experimental design

A total of 20 lactating female SAING were used for the study. Eight and 12 does were maintained on LGP and NP, respectively. The lactating does were in good condition and acceptable health status. The does on both treatments were sub-divided into two equal groups. The two sub-groups of each treatment were assigned to a different dietary treatment (0 or 10% molassed concentrate diet) and were maintained on their respective diets for a period of ten weeks. Kidding weights of the does on the LGP and NP sub-groups were 40.0 ±1.3 and 36.4 ±1.1 kg, respectively.

6.2.3. Dietary treatments and experimental design

The goats were maintained solely on LGP or NP during gestation. Details of the forage species on both LGP and NP plots had been previously reported in subsection 3.2.7 (Chapter 3). Lactation or experimental diets were 0 and 10% molassed cereal-based concentrate diets.

6.2.4. Measurements

Live body weights of does and kids: Does and kids were weighed within 24 hours of kidding and subsequently weekly for a period of ten weeks, using an electronic weighing apparatus described under live weight component of the subsection 3.2.9 in Chapter 3.

Return to first postpartum oestrus: Return to oestrus was determined using two vasectomised bucks and commenced 48 h post kidding. The bucks were fitted with a marking harness on the brisket and assigned to the does on a 0 or 10% molassed concentrate diet to detect oestrus. A doe was said to be in oestrus if she allowed mounting and was marked by the vasectomised buck (Mbayahaga *et al.*, 1998). The mounting records were corroborated with daily observations between 08:00 and 09:00 hour daily for overt signs of oestrus (restlessness, homosexuality, enlarged vulva and cervico-vaginal mucus discharge). Dams, kids and vasectomised bucks were allowed un-restricted access to the experimental diets and drinking water.

Milk yield determination: The milk production of the lactating does was determined using a combination of weighed-suckled-weighed and hand milking methods (Aboul-Naga *et al.*, 1981) weekly for ten weeks, commencing during the second week of lactation. At 18:00 h of the day preceding the milk evaluation, the kids were separated from the dams and the udder was completely drained by hand. At 08:00, 13:00 and 17:00 h on the day of sampling, kids were weighed, returned to their respective dams and allowed to suckle for 30 minutes. Kids were then removed from their dams and weighed again and separated from the dams until the next sampling period. Following each suckling period, the remaining milk in the udder was drained by hand and weighed. The daily total milk yield was taken as the difference in weight of kids before and after suckling plus the respective weights of residual milk obtained during hand milking from the udder of the respective dams. The weekly milk yield of each doe was calculated by extrapolating the total milk yield on the day of sampling for seven days.

6.2.5. Chemical analysis

The lactation diets were analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ether extract (EE), ash and mineral elements (Ca, P, Mg, Zn, Fe and Cu), using the procedures described in the forage study component of subsection 2.2.3 (Chapter 2).

6.2.6. Statistical analysis

Data were subjected to analysis of variance (ANOVA) using General Linear Models (GLM) of Minitab statistical package (Minitab, 1998).

(i) The statistical model used for birth weight of kids was: $Y_{ijkl} = \mu + GD_i + L_j + S_k + D_l + e_{ijkl}$, where Y_{ijkl} = individual observations, μ = overall mean, GD_i = effect of gestation diet; L_j = effect of litter size; S_k = effect of gender, D_l = effect of dam weight at mating and e_{ijkm} = unexplained variation assumed to be randomly and independently distributed.

(ii) The following statistical model was used for determination of pre-weaning live weight change of kids: $Y_{ijklmn} = \mu + GD_i + LD_j + (GD*LD)_k + S_l + D_m + B_n + e_{ijklmn}$; where Y_{ijklmn} = individual observations, LD_j = effect of gestation diet, $(GD*LD)_k$ = effect of interaction between gestation and lactation diets, S_l = effect of gender D_m = effect of dam weight at kidding, B_n = effect of kid birth weight and e_{ijklmn} = unexplained variation assumed to be randomly and independently distributed.

(iii) Live weights of does at kidding were analysed using the model: $Y_{ijl} = \mu + GD_i + L_j + D_l + e_{ijl}$, where Y_{ijl} = individual observations and e_{ijl} = unexplained variation assumed to be randomly and independently distributed.

(iv) Model used for lactation live weight of does, days return to first postpartum oestrus and milk yield was: $Y_{ijklm} = \mu + GD_i + LD_j + (GD*LD)_k + L_l + D_m + e_{ijklm;}$ where Y_{ijklm} = individual observations, L_l = effect of litter size and e_{ijklm} = unexplained variation assumed to be randomly and independently distributed.

Treatment means were compared using standard error of the difference between means (s.e.) and assumed to be significant at $p < 0.05$.

6.3. **Results**

6.3.1. Animal health and reproductive record

Eight and 12 lactating does in the LGP and NP sub-groups nursed 15 and 23 kids, respectively (Table 6.1). Three kids and three does died during lactation. Two of the dead does were from NP treatment group while the other was a LGP doe. Post mortem result revealed that death of the first doe on the NP resulted from intestinal verminosis and fatty hepatosis, while the second doe died from internal bleeding sustained during assertion of social order (head butting). The death of the LGP doe was ascribed to severe diarrhoea. Two of the dead kids were kids of the dead doe on LGP sub-groups, while the third was from a doe in the NP sub-groups. The health of does and kids with complete records in both treatments was good and the experimental measurements represented the real treatment effects. Pre-weaning kid mortalities on LGP and NP sub-groups were 13.3% and 4.3%, respectively, the difference was significant ($p< 0.01$). Kidding rates on LGP and NP sub-groups 187.5 and 191.7%, respectively, but the difference was not significant. Data of dead animals and those of animals with incomplete records due to illness were excluded during statistical analysis.

6.3.2. Diet

The chemical composition and mineral element content of forage species on the LGP and NP on which the lactating SAING were maintained during gestation had been reported in Chapter 5 (Table 5.1; Akingbade *et al.*, 2001a and 2002). The use of molassed (10% M) and un-molased (0% M) concentrate diets as lactation diets, was implemented to evaluate the effect of molasses on voluntary feed intake in lactating SAING. However, the incessant feed spoiling by kids and uncontrollable feed spillage by does made it impossible to keep an accurate record of the daily feed intake.

The proximate composition and mineral element content of the lactation diets are presented in Table 6.2. Differences in the nutritive value (CP, NDF, ADF, fat, ash and mineral elements) of both diets were marginal. The effects of lactation diets and interaction of gestation and lactation diets on pre-weaning average daily gains of kids, return to first postpartum oestrus and milk yield of does were not significant.

6.3.3. Kids birth weight and pre-weaning growth

Overall mean birth weight of kids on LGP was slightly higher (2.5 kg vs 2.3 kg) than that of their counterparts on NP. The weekly live weights of kids of the LGP does were also consistently heavier than those of kids in the NP sub-groups, throughout the pre-weaning period (Figure 6.1).

Birth weight of kids was significantly affected by litter size ($p < 0.001$) and gender ($p = 0.051$). Male kids were heavier than female kids. Kids from single litters were heavier than kids from larger litters (≥ 2 kids). The mean birth weight of kids on LGP sub-groups (LGP 0%M and LGP 10%M) was 2.7 ± 0.2 kg for males and 2.3 ± 0.2 kg for females. On the NP sub-groups (NP 0%M and NP 10%M) male and female kids weighed 2.4 ± 0.1 kg and 2.1 ± 0.2 kg, respectively.

Pre-weaning average daily live weight gain of kids was significantly influenced by the weight of the does at kidding, litter size and gender ($p < 0.001$). Mean average daily live weight gain of kids of does on LGP sub-groups, between birth and weaning was significantly higher (147 gd^{-1} vs 120 gd^{-1}; $p = 0.002$) than that of their counterparts on the NP sub-groups. Between birth and weaning, the averages of daily body weight gains of single, twin and multiple kids on LGP sub-groups were 199 gd^{-1}, 137 gd^{-1} and 92 gd^{-1}, respectively, while in the NP sub-groups single, twin and multiple kids gained 155 gd^{-1}, 130 gd^{-1} and 70 gd^{-1} body weight, respectively. The mean live weight gain of LGP does between gestation and kidding was significantly higher than that of does on NP (4.0 ±1.3 vs 0.4 ±l.1 kg; $p = 0.047$). The mean body weight of the does on LGP at kidding was significantly (40.0 vs 36.4; $p = 0.047$) higher than that of does on NP..

Returns to first postpartum oestrus occurred 20.1 days earlier (24.1 ±7.6 vs 44.2 ±6.3 days; $p = 0.08$) and in a larger proportion of does in the LGP sub-groups (six out of eight and seven out of ten does on LGP and NP sub-groups, respectively) than does in the NP subgroups. Milk yield of does maintained on LGP sub-groups during each week of lactation was consistently higher ($p > 0.05$) than that of their counterparts on NP sub-groups (Figure 6.2). However, does on both LGP and NP sub-groups attained peak milk yield during the fourth week of lactation.

Table 6.1. Kidding and post-kidding reproductive performance of South African indigenous *Nguni* goats grazed on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) during gestation and concentrate diets during lactation

	LGP-SG[a]	**NP-SG**[b]	χ^{2e}
No. of does at kidding	8	12	
No. of live kids at birth (%)	187.5	191.7	
No. of still birth (%)	6.6	0	
No. of dead kids	2	1	
No. of kids with incomplete records	1	5	
No. of dead does	1	2	
Pre-weaning kid mortality (%)	13.3	4.3	9.3[c]
Pre-weaning doe mortality (%)	12.5	16.7	0.7[d]

[a]two sub-groups of does previously grazed on LGP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation.
[b]two sub-groups of does previously grazed on NP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation.
[e]Chi-square: [c]$P < 0.01$ and [d]$P > 0.05$

Table 6.2. Proximate composition and mineral element content of lactation diets fed to South African indigenous *Nguni* goats during lactation

	0% Molassed concentrate	**10% Molassed concentrate**
Composition (%)		
Crude protein	14.8	13.9
Neutral detergent fibre	35.9	36.8
Acid detergent fibre	16.7	18.7
Fat	2.5	2.6
Ash	6.4	6.7
Major elements (gkg^{-1})		
Calcium	48	49
Phosphorous	80	72
Magnesium	26	29
Trace elements ($mgkg^{-1}$)		
Copper	16	14
Zinc	107	121
Iron	256	268

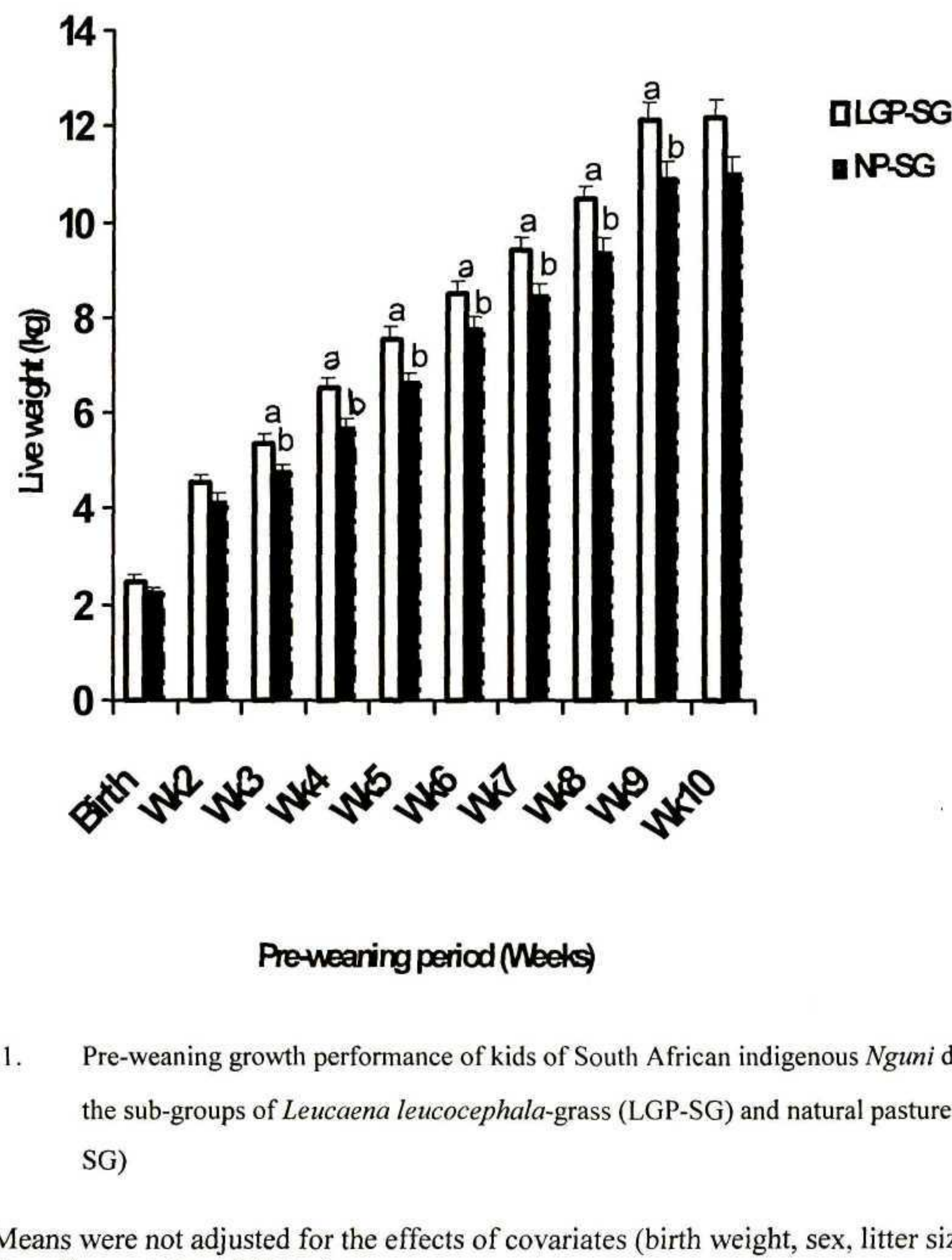

Figure 6.1. Pre-weaning growth performance of kids of South African indigenous *Nguni* does in the sub-groups of *Leucaena leucocephala*-grass (LGP-SG) and natural pastures (NP-SG)

Nb: Means were not adjusted for the effects of covariates (birth weight, sex, litter size and dams live weight at kidding);

$^{LGP\text{-}SG}$Two sub-groups of does previously grazed on LGP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation;

$^{NP\text{-}SG}$Two sub-groups of does previously grazed on NP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation.

Different superscripts in a pair of bars imply a significant difference ($p < 0.05$)

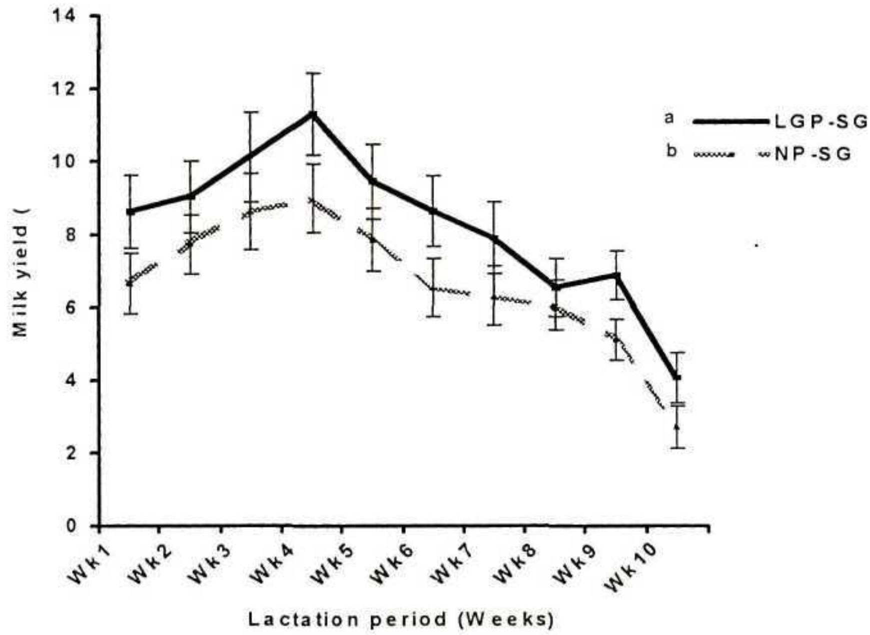

Figure 6.2. Milk yield of South African indigenous *Nguni* does in the sub-groups of *Leucaena leucocephala*-grass (LGP-SG) and natural pastures (NP-SG)

Nb: Means were not adjusted for the effects of covariates (litter size and does live weights at kidding).

[a]Two sub-groups of does previously grazed on LGP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation.

[b]Two sub-groups of does previously grazed on NP during gestation but maintained on 0 or 10% molassed concentrate diet during lactation.

6.4. **Discussion**

Foliage from *Leucaena* species possesses a high nutritive value as animal feed, with a crude protein (CP) ranging from 18 to 32% (Chapter 2; Akingbade *et al.*, 2001b) of dry matter (DM), a high total digestible nutrients (TDN) content of between 54-70% of DM and high in phosphorous, calcium and carotene (Machado *et al.*, 1978). The significantly higher gestation weight gain of the LGP does, when compared to does that were maintained on NP, could be attributed to the higher CP, lower crude fibre (ADF and NDF) and high mineral element contents of *Leucaena leucocephala* on the LGP plots, relative to the accessible forage species on NP plot (Chapters 4 and 5; Akingbade *et al.*, 2001a and 2002).

Although the NP plot had more browse species, compared to the only *Leucaena* species on the LGP plot, the height (> 1.5 m) of most of the browse species on NP plot limited it for browsing by the goats on the treatment during gestation (Chapter 4, Akingbade *et al.*, 2002). The inability of the lactation diets to significantly influence all post-kidding traits evaluated in this study, was possibly due to the marginal differences in the proximate composition and mineral element constituents as revealed in the proximate and mineral element chemical composition of the diets.

The extent of degradation and detoxification of mimosine and its metabolites (2,3 and 3,4-dihydroxypyridones) depends largely on the action of DHP-degrading rumen bacteria (*Synergistes jonesii*; D'Mello, 1992) in the rumen (Dominguez-Bello and Stewart, 1990). The increased outflow rate of rumen digesta associated with an advanced stage of pregnancy (Weston *et al.*, 1988a and 1988b), was expected to increase the escape of mimosine and its metabolites from rumen degradation and detoxification. This escaped mimosine and its metabolites could be absorbed into the blood stream of the pregnant SAING on LGP and pose a problem on the goats post kidding traits. However, no adverse effects on the post kidding traits of lactating does, previously maintained on LGP, during gestation was recorded.

Post weaning kid growth performance, milk yield and return to first postpartum oestrus of dams previously maintained on LGP were higher than from the NP does. The absence of any detrimental effect on post-kidding traits (i.e. milk yield and return to oestrus, pre-weaning live weight change) among does and kids on the LGP sub-groups was an indication that the mimosine and its metabolites that escaped rumen degradation and detoxification of the *S. jonesii* bacteria as a result of increased outflow rate of rumen digesta during late gestation, were insufficient to exert any detrimental effect.

The significant influence of gender on birth weight confirms other findings (Belay *et al.*, 1993). Similar to other studies (Amoah *et al.*, 1996), birth weight of the kids in both treatment groups decreased as the litter size increased. The consistently higher pre-weaning live weight gain of kids on LGP relative to NP kids, can be attributed to the effect of birth weight as reported by Ehoche and Buvanendran (1983) that kid birth weight positively influenced pre-weaning growth.

During the first four weeks of life, the digestive system of the kid is less developed and unable to handle forage. Kids are therefore solely dependent on maternal colostrum and milk for immunity (Rattray, 1992) and nutrients (Geenty and Dyson, 1986), respectively. Apart from the influence of birth weight on pre-weaning growth performance, the better growth performance of kids in the LGP sub-groups relative to kids in the NP sub-groups, may be due to the higher milk yield of the LGP dams. This is in harmony with reports by Gibb and Treacher (1980) and Mbayahaga *et al.* (1994) that differences in growth rates among offspring are a reflection of varying milk yield of the dams.

As live weight of does at kidding significantly influenced total milk yield in this study, and does on LGP sub-groups were significantly heavier ($p < 0.05$) at kidding than their counterparts on NP, the high milk yield associated with LGP sub-groups may be ascribed to the use of LGP as gestation feed. This is in consistent with report by Treacher (1970) that nutrition during gestation influences the performance during lactation via accumulation of body reserves for milk synthesis. The higher body weight gain of the LGP goats at kidding relative to that of their counterparts on the NP treatment, possibly increased body energy reserves of LGP goats, for mobilisation to milk synthesis (Mukasa-Mugerwa *et al.*, 1997). Milk yield in this study was found to increase with litter size, and agrees with the findings of Zygoyiannis (1994) that milk yield increases with litter size.

6.5. **Conclusions**

The quantities of mimosine and its metabolites that escape rumen degradation and detoxification as a result of the increase in outflow rate associated with the late gestation stage, were not enough to cause any detrimental effects on post kidding traits of the SAING possessing *S.jonesii* and maintained on LGP. The differences in milk yield and return to first postpartum oestrus on both treatments were not statistically significant. The higher milk yield and earlier return to oestrus in a larger proportion of does in the LGP sub-groups were indications that the feeding LGP to pregnant SAING does possessing *S. jonesii* bacteria was not detrimental to the post kidding reproductive traits of the does.

CHAPTER 7

Reproductive performance, colostrum and milk constituents of mimosine-adapted South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass or natural pastures[1]

Abstract

The aim of the study was to evaluate the reproductive performance, colostrum and milk constituents of South African indigenous *Nguni* goat (SAING) does over a 2-year period. Fifty and thirty eight multiparous SAING were for the study in Years 1 and 2, respectively. Eight mature intact SAING bucks (mature male goats) were used for mating during both years. The does were maintained on *Leucaena leucocephala*-grass (LGP) or natural pastures (NP) during gestation and lactation and were also offered a concentrate diet (20.5 % crude protein) as a supplementary diet in Year 2. Does on LGP treatment possessed dihydroxy pyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*), while those on NP lacked the bacteria. Records kept were gestation live weight, chemical composition of diets, birth type, kids and does live weight at kidding (recorded within 24h of birth), pre-weaning kid mortality, return to oestrus, weekly milk yield, colostrum and milk constituents. The lactation period in both years lasted 10 weeks. Colostrum and milk were analysed for total solids (TS), solids-not fat (SNF), fat, protein, ash, lactose and energy. Does on LGP gained 2.87 kg ($p = 0.02$) and 5.20 kg ($p < 0.01$) more body weight between gestation and kidding and were 4.66 kg ($p = 0.02$) and 5.2 kg ($p < 0.01$) heavier than NP does during Years 1 and 2, respectively. In Year 1: number of does that kidded on LGP treatment was significantly ($p = 0.025$) higher than on NP treatment; incidence of multiple births ($\geq$ 2 kids) on LGP was significantly ($p < 0.05$) higher than on NP; pre-weaning kid mortality on NP was 30.56 % higher (55.56 vs 25.00%; $p > 0.05$) than on LGP treatment. In Year 2, the proportion of multiple births on LGP treatment was also significantly ($p < 0.05$) higher than on NP group. In both years, kidding rates and prolificacy on LGP treatment were better than on NP treatment. Differences between colostrum constituents on both treatments were not significant. However, TS ($p = 0.035$), SNF ($p = 0.01$), protein ($p = 0.042$) and lactose ($p = 0.018$) contents in milk, and return to first postpartum oestrus ($p = 0.001$) were significantly influenced by diet. Conception and pre-weaning kid mortality were higher in years with high precipitation. The benefits of *Leucaena* species in increasing ovulation and high incidence of multiple births can be fully exploited if appropriate kidding management practices that ensure adequate consumption of colostrum and milk are put in place. The kidding management practice should also be such that would ensure adequate nutrition to lactating does so as to enhance high milk yield and availability for kids consumption.

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7.1. **Introduction**

Increased conception rates and normal pregnancies are pre-requisites for elevating goat productivity. Proper nutrition, especially the provision of a diet rich in protein content prior and during gestation, enhances the attainment of multiple births (Isaacs *et al.*, 1991). However, twin and multiple births are associated with low kid birth weights and increased pre-weaning kid mortalities.

Protein content of the diet during gestation also influences the colostrum and milk yield (Sibanda *et al.*, 1997; Etter *et al.*, 2000). Colostrum provides the critical initial nourishment and immunity needed against infections in the kid (Geenty and Dyson, 1986). Smith (1977) linked multiple births with delayed lactogenesis which makes newborns susceptible to death from starvation and opportunistic infections (Dalton *et al.*, 1980). Variation in growth rates of kids prior to weaning has been attributed to the differences in milk intake (Gibb and Treacher, 1980).

Pre-weaning kid mortalities among South African indigenous *Nguni* goat (SAING) kids of dams maintained on *Leucaena leucocephala*-grass pasture (LGP) was found to be significantly higher than that for kids of dams maintained on natural pastures (NP) in previous study (Chapter 6; Akingbade *et al.*, 2001a). From the results from studies reported in Chapters 5 and 6 (Akingbade *et al.*, 2000 and 2001a), it is evident that mimosine toxicity is unlikely to be the cause of the poor conception among does maintained on LGP as their reproductive performances pre and post kidding were better than those of does maintained on NP. Based on the report by Gupta and Atreja (1999), a barrier exists between the blood and udder, and according to Alvarez *et al.* (1978), no sign of mimosine toxicity was recorded from mimosine in goat kids maintained on milk of dams maintained on *Leucaena* species. Therefore, milk poisoning was unlikely to be the cause of the high pre-weaning kid mortalities that were experienced in Year 1 of the study reported in Chapter 5 (Akingbade *et al.*, 2001a).

However, there have been no reports on colostrum and milk constituents of SAING possessing *Synergistes jonesii* bacteria and maintained on LGP or NP. In the further pursuit of the cause of high pre-weaning kid mortalities on LGP obtained in Year 1 of the study reported in Chapter 5 (Akingbade *et al.*, 2001a). This study was aimed at evaluating further the:

i. Potential of LGP and NP in increasing the productivity of SAING;

ii. Effects LGP and NP as gestation and lactation diets on reproductive performance of SAING;

iii. Effects of diets on colostrum constituents, milk constituents and milk yield of SAING.

7.2. **Materials and methods**

7.2.1. Site

The study site was the same as that reported in subsection 2.2.1, Chapter 2. Total precipitations in Years 1 and 2 of the study were 785 mm and 581.5 mm, respectively. Averages of the mean ambient temperatures during lactation (May and June) in Years 1 and 2 were 16 °C and 18 °C, respectively.

7.2.2. Animals and experimental procedure

Fifty and 38 multiparous South African indigenous *Nguni* goats (SAING) were used in Years 1 and 2 study, respectively. Eight mature intact bucks were used to breed in both years. The does and bucks were in good condition and acceptable health status. The averages of body weights of does at mating were 33.81 ±2.78 kg (LGP); 38.64 ±4.20 kg (NP) and 38.35 ±2.06 kg (LGP); 37.27 ±2.19 kg (NP) in Years 1 and 2, respectively.

7.2.3. Diet and grazing management practices

In both studies, gestation diets (*Leucaena leucocephala*-grass pasture: LGP; or natural pasture: NP) were retained as lactation diets. Based on the poor quality of vegetation on NP plot and unavailability of *Leucaena* component of the LGP (Akingbade *et al.*, 2001b), a concentrate diet was offered as supplementary diet in Year 2. The concentrate contained 20.5 % crude protein (CP) and was served in the night camps between 15.00 and 07.00 h. Details of forage species on the LGP and NP plots, daily grazing management and procedures for sampling forage for analysis have been reported in subsections 3.2.7, 3.2.8 (Chapter 3) and 4.2.6 (Chapter 4), respectively. Grazing management on the NP was continuous grazing, while rotational grazing was adopted on the LGP-with an average grazing interval of 7 days. The animals on the LGP plot were removed when the grass on the plot had been grazed to approximately 20 cm above the ground level. Kids remained in the night camps and were not herded with their dams to the pastures during lactation.

7.2.4. Reproductive management practices

The does used in both studies were mated in late spring season (mid November) and their oestrus cycles were synchronized as described in Chapter 3 (subsection 3.2.6). The eight bucks were randomly divided into two equal groups (n = 4) and each group was assigned to a treatment (LGP or NP treatment) 48 h after cessation of oestrus synchronisation, and were made to remain with the does for 21 days.

7.2.5. Kidding management practices

In Year 2, the weak kids on both treatments were assisted to nurse colostrum, by restraining the dams and allowing the kids to suckle from the udder. Colostrum and milk were hand milked into a feeding bottle from dams having enough colostrum and milk and used in feeding kids of dams with insufficient colostrum or milk or used in feeding kids in twin and multiple litters.

7.2.6. Measurements

Body weight: Body weights of the pregnant does were measured at buck introduction and subsequent weights were taken fortnightly throughout the gestation period using an electronic weighing apparatus (subsection 3.2.9, Chapter 3). Does and kids were weighed and ear-tagged within 24 hours of kidding. Does and kids were weighed once a week throughout the ten week period of lactation.

Reproductive traits: Breeding and lactation records were used to determine pre-weaning kid mortality, prolificacy, conception (fertility rate) and kidding rate using the expressions as reported in subsection 5.2.6 of Chapter 5.

Colostrum sampling and milk yield determination: Due to a small sample size that resulted from poor conception rate on the NP treatment in Year 1, milk yield, colostrum and milk analysis were only determined in Year 2. Approximately 60 ml colostrum was hand milked from each doe on both treatments (LGP: n = 14 does; NP: n = 13 does). Colostrum was sampled between 12 and 18 hours of kidding, while milk yield was determined using the methods as set out in subsection 6.2.4 (Chapter 6). The colostrum and milk samples were preserved by refrigerating at -20 °C and analysed for total solids (TS), solids-not-fat (SNF), lactose and energy using the following expressions:

(i) Colostrum or milk total solids (TS) = Colostrum or milk dry matter (DM)

(ii) Colostrum or milk SNF = Colostrum or milk DM - Colostrum or milk fat content

(iii) Colostrum or milk lactose = Colostrum or milk SNF - (% Colostrum or milk protein + % Colostrum or milk ash).

(iv) Colostrum or milk energy values (MJ/kg) = 1.64 + 0.42 (Colostrum fat or milk fat content in %) (Economides, 1986).

Return to first postpartum oestrus: Return to first postpartum oestrus was monitored during both studies from 48 hours post-kidding using two vasectomised SAING bucks. Details of the method employed in oestrus detection has been reported under return to first postpartum oestrus, in subsection 6.2.4 (Chapter 6).

7.2.7. Laboratory analyses

Forage species on both LGP and NP plots and the concentrate diet were separately analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), ether extract (EE), ash and mineral elements (Ca, P, Mg, Zn, Fe and Cu), using the procedures previously reported in subsection 2.2.3 (Chapter 2).

Total solids in the colostrum and milk samples were determined by freeze-drying (Holst *et al.*, 1996). Protein content of colostrum and milk and amino acid profiles of the colostrum were determined by means of a highly sensitive protein hydrolysate analysis, using a Beckman 6300 (Beckman Inc. Spinco Division, Palo Alto, California). Milk protein was calculated as N x 6.38 (Nutrition Chemistry Laboratory Manual, 1992). The fat contents of the colostrum and milk samples were determined as described by Gerber method (BSI 1969), while the ash content was determined according to AOAC (1990), by igniting a known weight of freeze-dried samples in a Wild Barfield furnace at 550 °C for 16 h.

7.2.8. Statistical analysis

Data from both years of the study were separately subjected to analysis of variance (ANOVA), using the following General Linear Models (GLM) in the Minitab statistical package (Minitab, 1998) for:

(i) Kids birth weight: $Y_{ijkm} = a + T_i + L_j + S_k + D_m + e_{ijkm}$

Where Y_{ijkm} = individual observations, a = overall mean, T_i = effect of treatment; L_j = effect of litter size; S_k = effect of gender, D_m = effect of dam weight at mating and e_{ijkm} = unexplained variation assumed to be randomly and independently distributed;

(ii) Pre-weaning live weight change of kids: $Y_{ijkpw} = a + T_i + L_j + S_k + D_p + B_w + e_{ijkpw}$, Where Y_{ijkpw} = individual observations, D_p = effect of dam weight at parturition, B_w = effect of birth weight and e_{ijkpw} = unexplained variation assumed to be randomly and independently distributed;

(iii) Does live change during gestation and live weight at kidding: $Y_{ijm} = a + T_i + L_j + D_m + e_{ijm}$ where Y_{ijm} = individual observations and e_{ijm} = unexplained variation assumed to be randomly and independently distributed and

(iv) Return to oestrus, does live weight change during lactation, milk yield, colostrum and milk constituents: $Y_{ijp} = a + T_i + L_j + D_p + e_{ijp}$

Where Y_{ijp} = individual observations and e_{ijp} = unexplained variation assumed to be randomly and independently distributed.

7.3. **Results**

7.3.1. Seasons, precipitation and temperature at the study site

Seasonal demarcation, mean monthly precipitation and ambient temperatures during each year of the study at the location are presented in Table 7.1. Does were mated in late spring/early summer and kidded in early winter season. Precipitation in Year 1 was 203.5 mm more than that recorded in Year 2, while mean monthly ambient temperatures during lactation (May and June) in Year 1 was 2 °C colder than in Year 2.

7.3.2. Diets

The feed ingredients, proximate and mineral composition of the concentrate diet fed as supplementary diet during lactation in Year 2 study are presented in Table 7.2. The proximate and mineral elements composition of the forage species on LGP and NP plots are presented in Table 7.3. Forage species on the LGP treatment contained more than twice the quantity of CP content of herbage on NP treatment (Table 7.3). Except for iron, values of other mineral elements of forage resource on LGP plot were higher than those of vegetation on NP plot. Crude protein content of the concentrate diet was 10.3 % greater than that of forage resource on NP plot, but was 5.2 % less than that of vegetation on LGP plot. Of all the diets (LGP, NP and concentrate diet), the concentrate diet and vegetation on NP plot had the lowest and highest crude fibre contents (NDF + ADF), respectively.

7.3.3. Mortalities during gestation and occurrence of stillbirths

All dead goats were forwarded to the Allerton Provincial Veterinary Laboratory for postmortem examination. During gestation in Year 1, there were more deaths on the NP treatment than on the LGP treatment (Table 7.4). Postmortem results attributed deaths on the NP treatment to anaemia from severe infestation of wireworm, round worm, nodular worm and flea (*Dermatophilus congolensis*) bites.

The only dead doe on the LGP treatment was carrying twins and died of heart water. In the Year 2 gestation, the only death was a barren doe on the NP treatment that died of anaemia due to infestation of round and nodular worms. Many still births were recorded on both treatments in Year 1, but only one was recorded in Year 2 and was from a doe on LGP that kidded triplets. All stillborn weighed $\leq$ 1.2 kg and were either from twin or multiple ($\geq$ 3 kids) litters. Data of dead animals and animals with incomplete records were excluded during statistical analysis. The health of animals with a complete record on both treatments was good and the experimental measurements represented the real treatment effects. There were no signs of *Leucaena* toxicosis in does and kids during both Years.

7.3.4. Reproductive performance of does

The number of does that kidded on LGP in Year 1 was significantly ($p < 0.05$) higher than that on NP (Table 7.4). In Year 1, conception rate, kidding rate and prolificacy of SAING on LGP treatment were 36.0%, 56.0% and 21.4%, respectively, higher than values recorded for their counterparts on NP treatment. Similarly, conception rate, kidding rate and prolificacy of does maintained on LGP were 10.5%, 68.4% and 54.1%, respectively, higher than those of their counterparts on NP treatment in Year 2. The incidence of multiple birth ($\geq$ 3 kids) was higher on LGP treatment than on NP treatment. The proportion of birth types (single, twins and multiples ($\geq$ 3 kids)) on both treatments over the entire study was significant ($p < 0.05$).

7.3.5. Live weight change of does and kids

Does maintained on the LGP plot gained 2.87 ($p = 0.02$) and 5.20 ($p < 0.01$) kg more in body weight between gestation and kidding in Years 1 and 2, respectively, than the body weight gains of their counterparts on NP (Table 7.5). At kidding, does on the LGP treatment were 4.66 ($p = 0.02$) and 5.2 ($p < 0.01$) kg heavier than does on the NP treatment (Years 1 and 2, respectively). The differences in weight loss of lactating does on both treatments during both studies were not significant. Kids from the LGP treatment in Year 1 were 510 g ($p = 0.02$) and 900 g heavier at birth and at day 28, respectively, than kids on the NP treatment. The difference between average daily body weight gain of kids between kidding (birth) and day 28 post kidding in Year 1 was significant ($p = 0.02$), with the LGP kids gaining 30 gd^{-1} more than the NP kids.

7.3.6. Milk yield, colostrum and milk constituents

Means of weekly milk yield of does on the LGP and NP treatments were 33.80 ±2.74 and 29.02 ±2.85 kg, respectively. Throughout the four weeks of milk yield determination, weekly milk production on LGP treatment was consistently higher than that of NP treatment (Fig. 7.1). The weekly differences in milk yield were not significant. The differences between colostrum' constituents of does on both treatments were also not significant (Table 7.6). However, total solids ($p = 0.035$), solids-not-fat ($p = 0.010$), protein ($p = 0.042$) and lactose ($p = 0.018$) contents of the milk of NP does were significantly greater than values recorded for LGP does. With the exception of leucine, threonine, valine (essential amino acids), proline, serine and tyrosine (non-essential amino acids), the colostrum of the LGP does had a marginally higher concentration of all amino acids analysed (Table 7.7).

Table 7.1. Seasons, mean monthly precipitation and mean ambient temperatures at the experimental site over the entire study

		Precipitation (mm)		Ambient temperatures (°C)	
Months	**Seasons**	**2000 (Year 1)**	**2001 (Year 2)**	**2000 (Year 1)**	**2001 (Year 2)**
January	**Summer**	124.5	50.5	20.6	21.1
February	,,	57.5	77	22.8	22
March	,,	72.5	29	22.3	22.3
April	**Autumn**	45.5	86.5	18.5	20.2
May	**Winter**	23	42	15.6	17.9
June	,,	1.5	5	16.4	18.2
July	,,	0	0	15.4	17.5
August	,,	0	0	17.9	19.2
September	**Spring**	21.5	50	17.3	----
October	,,	72.5	48.5	18	----
November	,,	60.5	97.5	18.8	----
December	**Summer**	306	95.5	21.3	----
Total rainfall		785	581.5		

Precipitation data supplied by Grassland Science unit, Ukulinga Research and Training Farm, University of Natal, Pietermaritzburg. RSA. Temperature data supplied by Institute for soil climate and water, Agromet Section, Pretoria. Republic of South Africa (RSA).

Table 7.2 Ingredients, proximate and mineral elements composition of concentrate diet fed as supplementary diet during lactation of the Year 2 study

	Concentrate diet
Ingredients[a]	
Yellow maize	53.97
Cotton seed cake	8.87
Sunflower meal	25.41
Lucerne hay	10
Limestone	1
Vit + min premix	0.25
NaCl	0.5
Proximate composition (gkg^{-1})	
Crude protein	205
Neutral detergent fibre	356
Acid detergent fibre	143
Fat	36
Ash	48.3
Major mineral (gkg^{-1})	
Calcium	86
Phosphorous	54
Magnesium	26.8
Trace mineral (mgkg^{-1})	
Zinc	59.2
Iron	154.6
Copper	15.8

Table 7.3 Proximate composition and mineral elements of forage species on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) fed to South African indigenous *Nguni* goats during gestation and lactation

	LGP	NP
Proximate composition (gkg^{-1})		
Crude protein	258	103
Neutral detergent fibre	292	614
Acid detergent fibre	190	349
Fat	30	21
Ash	94	96
Major minerals (gkg^{-1})		
Calcium	98	124
Phosphorous	38	11
Magnesium	39.3	32.8
Trace minerals ($mgkg^{-1}$)		
Zinc	40.8	29.8
Iron	412.8	487.9
Copper	14	8.2

7.3.7. Return to first postpartum oestrus

In Year 1, none of the does on both treatments returned to oestrus during lactation. However, in Year 2, twelve and eight does on LGP and NP, respectively, exhibited postpartum oestrus. Does on the LGP returned to oestrus 15.8 days earlier (41 vs 56.8 days; $p = 0.001$) to oestrus than does on the NP treatment. Return to oestrus postpartum was not influenced by the live weight of the does at kidding and litter size.

Table 7.4 Summary of the reproductive performance of South African indigenous *Nguni* does maintained on *Leucaena leucocephala*-grass pasture (LGP), natural pastures (NP) and a concentrate diet

	Year 1			Year 2		
	LGP	NP	χ^2	LGPC	NPC	χ^2
Dams' reproductive record						
No. of does mated	25	25		19	19	
Mortalities during gestation	1	5		0	1	
No. of does that kidded	16	7	6.52^b	17	15	1.34^{ns}
No. of live kids at birth	24	9		33	21	
No. of still birth	4	5		1	0	
No. of dead kids (wk 1- 10 post kidding)	6	5		1	1	
Reproductive parameters (%)						
Conception rate	64	28	6.52^b	89.47	78.94	1.34^{ns}
Kidding rate	112	56		179	110.5	
Prolificacy	150	128.57		194.1	140	
Kid mortality (wk 1-10)	25	55.56	2.75^{ns}	3	4.76	0.11^{ns}
Birth type (%)						
Singles	56.2	-		23.5	60	
Twins	12.5	100	6.47^b	58.8	40	4.40^a
Multiples (≥ 3 kids)	31.2	-		17.6	-	

LGPC : does grazed on *Leucaena leucocephala*-grass pasture and fed a concentrate diet.
NPC: does grazed on natural pasture and fed a concentrate diet.
χ^2: Chi-square; $^a p < 0.05$; $^b p < 0.025$ and $^{ns} p > 0.05$

Table 7.5 Summary of mean (±s.e.) live weight changes in South African indigenous *Nguni* does and kids on *Leucaena leucocephala*-grass pasture (LGP), natural pastures (NP) and a concentrate diet over a two year study period

	Year 1			Year 2		
	LGP	**NP**	**s.e.**	**LGPC**	**NPC**	**s.e.**
Does mated						
Number of does (kg)	16	7		17	15	
Wt. at mating (kg)	33.81	38.64	5.04	38.35	37.27	3.01
Wt. at kidding (kg)	39.05^{a}	34.39^{b}	1.81*	44.06^{a}	38.86^{b}	1.44**
Total gestation wt. gain (kg)	3.76^{a}	0.89^{b}	1.81*	6.22^{a}	1.02^{b}	1.44**
Does kidding						
Number of does	15	5		17	15	
Wt. at kidding (kg)	39.05^{a}	34.39^{b}	1.81*	44.06^{a}	38.86^{b}	1.44**
Wt. wk 4 post-kidding (kg)	36.21	33.97	4.82	40.18	41.12	1.39
Av. daily wt. loss (kg d^{-1}; birth - wk 4)	-0.12	-0.07	0.1	-0.05	0.02	0.05
Number of does	11	2		16	14	
Wt. wk. 4 post-kidding (kg)	38.47	40.93	3	39.97	41.75	1.32
Wt. at weaning (kg)	36.36	44.75	3.46	38.77	39.83	1.62
Av. daily wt. gain/loss (kg d^{-1}; wk 4-10)	-0.05	0.1	0.1	-0.03	-0.05	0.03
Kids						
Number of kids	21	9		26	17	
Birth wt. (kg)	2.51^{a}	2.00^{b}	0.21*	2.39	2.54	0.1
Wt. wk 4 post-birth (kg)	4.65^{a}	3.75^{b}	0.33	6.03	5.73	0.24
Av. daily wt. gain (kg d^{-1}; birth - wk 4)	0.08^{a}	0.05^{b}	0.01*	0.13	0.12	0.01
Number of kids	15	4		26	17	
Wt. at 4 wks old (kg)	5.14^{a}	3.82^{b}	0.48*	6.03	5.73	0.24
Wt. at weaning (kg)	8.43	7.28	1.11	10.01	8.88	0.6
Av. daily wt. gain (kg d^{-1}; wk 4-10)	0.07	0.07	0.01	0.1	0.08	0.01

LGPC : does grazed on *Leucaena leucocephala*-grass pasture and fed a concentrate diet.

NPC: does grazed on natural pasture and fed a concentrate diet.

Means were not adjusted for the effects of covariates; Means with different superscripts within a row and within a year are significantly different (*$P < 0.05$; **$P < 0.01$).

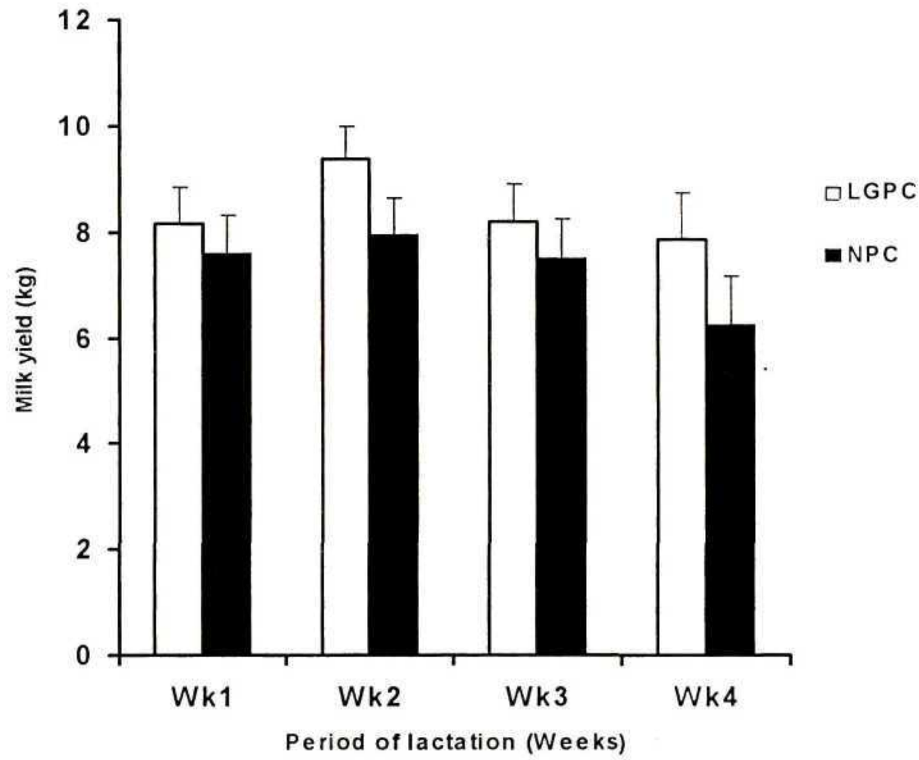

Figure 7.1 Weekly milk production (kg) of South African indigenous *Nguni* does maintained on *Leucaena leucocephala*-grass pasture and concentrate (LGPC) or natural pastures and concentrate (NPC) during the first four weeks of lactation

Nb: Means were not adjusted for the effects of covariates.
Bars are standard deviations of the means.

Table 7.6 Means (±s.e,) of colostrum and milk constituents (%) of South African indigenous *Nguni* does maintained on *Leucaena leucocephala*-grass pasture and concentrate (LGPC) or natural pastures and concentrate (NPC) during the first four weeks of lactation

	LGPC	NPC	s.e.
Number of sample	14	13	
Colostrum' constituents			
Total solids (TS)	56.43	52.59	2.88
Solids-not fat (SNF)	46.1	45.94	2.32
Fat	7.93	6.91	0.75
Protein	13.91	14.4	2.24
Ash	4.12	4.22	0.36
Lactose	27.6	27.82	1.8
Energy (MJ kg^{-1})	4.97	4.55	0.32
Milk' constituents (wk 1-10)			
Number of sample	140	130	
Total solids (TS)	41.54^{a}	42.91^{b}	0.58*
Solids-Not-Fat (SNF)	38.53^{a}	39.93^{b}	0.48**
Fat	3.01	2.98	0.24
Protein	5.71^{a}	6.05^{b}	0.17*
Ash	6.27	6.29	0.12
Lactose	26.56^{a}	27.56^{b}	0.47*
Energy (MJ kg^{-1})	2.9	2. 89	0.1

Means were not adjusted for the effects of covariates. Means with different superscripts within a row are significantly different (*$p <= 0.05$; **$p < 0.01$).

Table 7.7 Means (±s.e.) of anmino acid profiles of colostrumof South African indigenous *Nguni* does grazed on *Leucaena leucocephala*-grass pasture (LGP) or natural pastures (NP) during gestation

	LGP	NP	s.e.
Indispensable Amino acids (%)			
Number of does	6	6	
Arginine	2.69	2.65	0.62
Histidine	1.37	1.21	0.16
Isoleucine	2.36	2.04	0.25
Leucine	4.57	5.26	0.72
Lysine	4.43	3.90	0.50
Methionine	1.04	0.56	0.14*
Phenylalanine	2.42	2.20	0.26
Threonine	2.97	3.08	0.40
Valine	4.10	4.25	0.56
Dispensable Amino acids (%)			
Alanine	2.44	1.66	0.34
Aspartate	5.10	3.64	0.46
Glycine	2.22	1.42	0.34
Proline	4.09	4.79	0.64
Serine	3.00	3.02	0.46
Tyrosine	2.14	2.36	0.38

Means were not adjusted for the effects of covariates; *Probability tended towards significance ($p = 0.055$).

7.4. **Discussion**

7.4.1. General health of animals and occurrence of stillborns

The absence of any visual evidence of mimosine or DHP toxicity during gestation confirms the previous findings at the same location (Chapter 5; Akingbade *et al.*, 2001a and 2002), and has been attributed to the presence of *S. jonesii* bacteria. Previous workers (Jones and Megarrity, 1986; Hammond *et al.*, 1989b; Morris and Du Toit, 1998) have reported the presence of *S. jonesii* bacteria to prevent *Leucaena* toxicosis. Stillborns were lighter in body weight than the live kids and were from twin or multiple litters. This is also in line with previous studies (Notter and Copenhaver, 1980). Engeland *et al.* (1997) attributed the low body weight of stillborn kids to nutritional deficiencies that resulted in imbalances in cotyledonary distributions to the foetuses during gestation.

7.4.2. Live weight change of does during gestation

The height of the grazing strata influences feed intake (Orihuela and Solano, 1999) of ruminants on natural vegetation. Walk energy in goats accounts for a substantial part of their total daily energy requirements (Sharma *et al.*, 1998) and walking drains their energy reserves (Masika *et al.*, 1998). The height (>1.5 m tall) of most browse plants on the NP plot were beyond the reach of the goats for consumption (Chapter 4; Akingbade *et al.*, 2002). This problem of accessibility to browse on the NP plot probably imposed nutritional a constraint which compelled the goats to walk further in search for accessible browse species. The low body weight gain on the NP during gestation can be attributed to the drain in energy resulting from long distance walking in search of forage. The better weight gains of the LGP does, compared with their counterparts on NP treatment, can be ascribed to less energy dissipated on walking and also to the high protein content of the accessible *Leucaena* component of the LGP. This agrees with reports of Muinga *et al.* (1993), Morris and Du Toit (1998) and Akingbade *et al.* (2001a) that the feeding of *Leucaena* species improves growth performance.

7.4.3. Reproductive performance of does

Apart from nutrition, parasites and diseases are impediments to conception (Mascarenhas *et al.*, 1995). Parasites cause anemia and reduce body condition and lower conception rates (Saad, 1977). Frequent precipitation favour parasite proliferation and disease (Maqbool *et al.*, 1997). Morris and Du Toit (1998), found that rainfall favoured bushy growth that serves as a protective cover for parasites. The poor conception rate in Year 1 could possibly be due to a high parasitic challenge, resulting from the high annual rainfall. The severe infestation with wireworm, round worm and nodular worm and fleas' (*Dermatophilus congolensis*) bites revealed in autopsy reports of dead does on the NP treatment corroborates reports of Mascarenhas *et al.* (1995) and Saad (1977) that parasites and disease lower conception rate.

The increased protein content of forage enhances conception (Davis *et al.*, 1976) and favours the occurrence of multiple births (Wheeler and Land, 1977). The higher protein content of forage resource on LGP relative to that on NP (revealed in the diets' chemical composition table) probably explains the higher conception rate and multiple births of goats on LGP treatment relative to values recorded on NP treatment. Conception rates on both treatments in Year 2 were higher than those of does in Year 1- probably due to the lower annual rainfall in Year 2 that resulted in less parasitic challenge.

7.4.4. Birth weight, pre-weaning kid growth and mortality

Foetal development depends on the gestation diet (Muir and Massaete, 1997; Srivastava and Sharma, 1998). The significantly higher birth weight of kids on LGP treatment relative to NP treatment can be ascribed to the better nutritive value of the accessible forage species on LGP plot. During the first four weeks of life, goat kids are solely dependent on colostrum and milk for immunity (Rattray, 1992) and nutrients (Geenty and Dyson, 1986). Pre-weaning growth rates of newborns reflect varying milk yields of their dams and milk intake by the newborns (Gibb and Treacher, 1980; Mbayahaga *et al.*,1994). The high milk yield on LGP relative to NP agrees with that reported in a recent study of Akingbade *et al.* (2000) (Chapter 6) and in a previous findings of Garcia *et al.* (1994), who reported a high milk yield in lactating ruminants maintained on *Leucaena* pasture.

The protein content of the diet fed during gestation has been reported to influence colostrum and milk yield (Sibanda *et al.*, 1997; Etter *et al.*, 2000). Colostrum and milk provide nutrients and immunity against infections to the offspring (Geenty and Dyson, 1986). The high pre-weaning kid mortality rate on NP treatment in Year 1 was probably due to poor immunity and starvation that resulted from low colostrum and milk yield consumption of the NP kids (Altman and Mukkur, 1983; Mellor and Murray, 1986).

Mean ambient temperature during kidding and early lactation in (May/June) Year 1 was slightly lower (2 °C) than that in Year 2. Thompson (1983) stated that cold reduces milk yield and increases pre-weaning kid mortalities from cold stress. The high pre-weaning death during the colder year (Year 1) on both treatments presumably resulted from cold stress or starvation due to the effect of cold on milk production of the dam. Supplementary feeding during lactation was reported by Crosse *et al.* (1998) to increase milk yield. Feeding of concentrates in addition to grazing during the lactation of Year 2 may have enhanced milk yield of does and increased milk available to kids for consumption. This consequently prevented kids death from starvation. This kidding management practice adopted in Year 2 whereby assistance was offered to the weaker kids in a multiple litter (kids in twin and multiple litters were nursed with milk obtained from does nursing singles with excess milk) could partly have markedly reduced the pre-weaning kid mortality rate.

7.4.5. Return to postpartum oestrus

The lactation period coincided with the winter season and the two cultivars of *Leucaena* species at the site of the study are susceptible to cold and frost (Chapter 2; Akingbade *et al.*, 2001b). The cold temperature and frost in winter results in a low quantity and poor quality of grass (Zacharias, 1990) and the partial or complete leaf loss of foliage most leguminous browses on NP plot (Kirkman, 1988). Failure of lactating does to return to oestrus during the postpartum period in Year 1 was perhaps due to nutritional stress as reported by Folch *et al.* (1988) and Mukassa-Mugerwa *et al.* (1991). The delayed postpartum ovarian activity could be due to the extra nutritional demands of lactation.

The return to postpartum oestrus displayed by does on both treatments in Year 2 when concentrates were supplemented to pastures, was similar to that obtained in Chapter 6 (Akingbade *et al.*, 2000). Zerbini *et al.* (1993) indicated that lactation diets influence the return to first postpartum oestrus. The results in this study also confirm that reported by Eduvie (1985), who claimed that feeding concentrates during lactation enhances the return to oestrus post-kidding. A recent study (Eloy *et al.*, 1999) has also shown that a satisfactory level of feeding postpartum ensures an early return to first postpartum oestrus. Return to oestrus was not influenced by the live weight of does at kidding and litter size. This differs from the claim of Mukass-Mugerwa *et al.* (1991) that both parameters influence return to first postpartum oestrus; the trend in this study is physiologically difficult to explain.

7.4.6. Milk yield, colostrum and milk composition

The higher milk yield of does on LGP in this study is similar to that observed in previous study (Chapter 6; Akingbade *et al.*, 2000) and is in agreement with report of other workers (Saucedo *et al.*, 1980; Saada, 1993) that *Leucaena* species increase milk yield than grass species. The higher values of protein and fat contents of colostrum observed in this study were higher than those of normal milk (Protein: 3.83%, 4.46%, 5%; Fat: 6.8%, 5%) and these observations are in line with the findings of earlier workers in cow, sheep and other goat breeds (Treacher, 1970; Migdal and Kaczmarczyk, 1992). Milk TS, SNF, protein and lactose were significantly influenced by dietary treatments, unlike Goromela *et al.* (1997) who claimed that milk constituents were independent of diets.

The daily milk yield on LGP and NP in this study exceeded 545 gd^{-1} reported by Ehoche and Buvanendran (1983) in their studies using Red Sokoto goats. However, milk fat contents on both treatments were lower than values reported by AFRC (1998) for Anglo-Nubian, Saanen and Toggenburg goats. The milk protein content of *Nguni* goats exceeds that of Red Sokoto (3.83%; Ehoche and Buvernendran, 1983) and Toggenburg goats (2.72%; Muggli, 1978). The variations in milk yield and milk protein content could be ascribed to differences in breed, experimental diets, environment, duration of sampling and methods of milk yield determination and processing (AFRC, 1998).

7.5. **Conclusions**

Similar to the study reported in Chapter 5, productivity and reproductive performance of SAING over the two year period of this study were better on LGP than on NP. Conception rate on LGP treatment was higher than on NP treatment in both years. This indicates that the poor conception of SAING does and high pre-weaning mortality of SAING kids previously ascribed to the LGP were not due to the *Leucaena* component of the pastures.

The high pre-weaning kid survival rate achieved in Year 2 when a sound kidding management practice was incorporated and adequate nutrition provided to lactating does indicated that previous kids death were presumably due to nutritional inadequacies to does and kids and also due to managerial shortcomings or lapses during parturition and lactation.

The possible benefits of *Leucaena* species in increasing the ovulation rate and enhancing high incidence of twins and multiple births could be fully exploited if:

i. The does are adequately fed during lactation in order to enhance high milk yield for kids consumption;

ii. The weaker kids in twins and multiple litters are assisted to nurse colostrum in order to prevent death from opportunistic infections;

iii. The kids in multiple litters are supplementary fed milk from dams with excess milk so as to prevent death from starvation.

CHAPTER 8

Pre-weaning growth performance and blood profile of unweaned South African indigenous *Nguni* goat kids grazing with dams possessing *Synergistes jonesii* on *Leucaena leucocephala*-grass or natural pastures[1]

Abstract

The objectives of the study were to examine the safety of exposing 70 day old unweaned South African indigenous *Nguni* goat (SAING) kids to *Leucaena leucocephala*-grass pasture (LGP) and also to evaluate the potential of LGP and natural pastures (NP) regarding growth performance and blood profiles of growing kids. Sixteen kids (8 on each treatment) were used in the study that lasted 13 wks (including one week of acclimatization). The kids were not weaned from their dams and were maintained on the same pastures with their respective dams. Lactating SAING does on LGP treatment possessed dihydroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) while those on NP lacked the bacteria. Body weight and heart girth measurements were taken every week and fortnight, respectively. Blood samples were taken on day one of acclimatization and also once during weeks 6 and 12 of the study and analysed for mineral elements (Ca, P, Mg, Fe, Cu and Zn), packed cell volume (PCV) and protein metabolites (serum protein, albumin and globulin). Averages of daily live weight gains of kids on LGP and NP treatments over the entire study were 73 g d^{-1} and 25 gd^{-1}, respectively. Means of daily weight gains of male and female kids on LGP treatment were 84 ± 0.02 gd^{-1} and 54 ± 0.01 gd^{-1}, respectively. Mean daily weight gain of female kids on NP was 25 ± 0.02 gd^{-1}. Heart girth of kids can be used to predict their body weight with 59.7% ($p < 0.001$) of accuracy. Values of blood mineral elements on both treatments were within the normal range for goats in the tropics and subtropics. The poor nutritive value of accessible forage resource on NP treatment was reflected in the form of low values for blood mineral and protein metabolites of the kids on the treatment. The values of blood mineral and protein metabolites of the NP kids were below the normal range for goats in the tropics and subtropics. However, there were no symptoms of mineral or nutrient deficiency. The absence of deficiency symptoms probably indicates that the values were still above critical values for *Nguni* kids. Blood mineral and protein metabolite contents of LGP kids compared favourably with those reported for goats in the tropics and subtropics. The LGP kids also showed no symptoms of mimosine toxicity-an indication that the kids had acquired the *S. jonesii* bacteria. Exposure of kids of SAING dams possessing *S. jonesii* to LGP in company of their dams was safe as the kids were able to acquire the bacteria from the dams via animal-to-animal transfer.

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[1]Part of this chapter has been submitted for publication in: Small Ruminant Research
Co-authors: Nsahlai, I.V and Morris, C.D.

8.1. Introduction

The blood profile technique has been employed in determining nutrient, mineral element and vitamin status of animals (Cronje and Gollah, 1996) and also in diagnosing metabolic and production disorders. Blood constituents depend on nutrition (Saba *et al.*, 1995), environmental temperature (Hassan and Roussel, 1975) and physiological state of the animal (Cozler *et al.*, 1999; Chapter 4; Akingbade *et al.* 2002).

The incessant increase in the price of conventional protein diets has led to the use of leguminous trees and shrubs such as *Leucaena* species in the feeding of ruminants. *Leucaena* species are a good source of protein (Machado *et al.*, 1978) and also improve intake of roughage diets and soil nitrogen status (Minson, 1982). Recent studies (Akingbade *et al.*, 2001a; Chapters 5 and 7) have shown that presence of *S. jonesii* (DHP-degrading rumen bacteria) in the rumen of adult South African indigenous *Nguni* goats (SAING) assists in overcoming mimosine toxicity and also frees the goats from mineral chelating tendency of mimosine (Chapter 4; Akingbade *et al.* 2002).

However, no study has investigated whether kids of dams that possessed *S. jonesii* can acquire the bacteria when grazed together with their dams on *Leucaena leucocephala*-grass pasture (LGP). This study was aimed at examining the following:

i. Safety of exposing ten week old SAING kids of dams that possessed *S. jonesii* bacteria to LGP;

ii. Potential of LGP and natural pastures (NP) regarding growth performance, blood protein and mineral element status of growing SAING kids;

iii. Relationship between heart girth and live weight of SAING kids.

8.2. **Materials and methods**

8.2.1. Site.

The location of the study has been previously stated in subsection 2.2.1 (Chapter 2). The study was carried out between mid winter (mid July) and mid spring (mid October) seasons.

8.2.2. Animals and dietary treatments

Sixteen, 70 days old unweaned SAING kids were used for the study that lasted for a period of 13 weeks. Dietary treatments comprised LGP (n = 8) and NP (n = 8). The SAING kids on LGP comprised three females and five males while all the eight kids on the NP plot were females. The kids on both treatments had unrestricted access to their respective dams throughout the study. Forage species composition on both pastures and daily grazing management practices were similar to that reported in subsections 3.2.7 and 3.2.8, respectively. Nutritional/mineral supplements were not offered to the animals (kids and dams) during the study.

8.2.3. Housing and health management practices

The kids on both treatments were confined daily in a separate night camps between 15:30 and 07:30 h. Each night camp was an open paddock with water troughs and Kikuyu grass (*Pennisetum clandestinum*). Kids on both treatments were allowed a week of acclimatization to the pasture and their new environment, followed by a 12 week period of data collection. On day one of adaptation period, kids were treated for endo- and ectoparasites using Ex-A-Lint and tritick, respectively.

8.2.4. Measurements

Body weight: Body weights of kids were measured weekly throughout the study using an electronic weighing apparatus as reported under subsection 3.2.9 (Chapter 3).

Heart girth: Heart girths of kids were measured using a measuring tape. The measurement was carried out once every two weeks throughout the study.

Blood sampling: Blood sampling procedures were similar to that described in subsection 4.2.7 of Chapter 4. Blood was sampled on day one of acclimatization and also once during weeks 6 and 12 of the study. The blood was analysed for mineral elements (Ca, P, Mg, Cu, Zn and Fe), packed cell volume (PCV) and protein metabolites (serum protein, globulin and albumin)

Sampling of forage species: The forage sampling technique was similar to that reported in subsection 4.2.6 (Chapter 4). Forage sampling was carried out every fortnight. About 200 g of each forage species grazed or browsed by the kids was harvested and air-dried. Fifty grams of each air-dried forage species on each treatment for every fortnight were pooled and used for the laboratory analysis.

8.2.5. Laboratory analysis

Forage species on each treatment and blood samples of the kids were analysed as reported under forage and blood analysis in subsection 4.2.8 of Chapter 4.

8.2.6. Statistical analysis

All data were analysed using the General Linear Model (GLM) of Minitab statistical package (Minitab, 1998), but the regression analysis of live weight and heart girth were carried out using SAS (SAS, 1987).

(i) The model for analysing live weight and weekly weight gain was :

$Y_{ijkl} = \mu + T_i + W_j + L_k + S_l + e_{ijkl}$, where Y_{ijkl} = individual observations, μ = overall mean, Ti = effect of treatment, W_i = effect of live weight at the start of the study, L_j = effect of litter history, Sj = effect of gender and e_{ijkl} = unexplained variation assumed randomly and independently distributed..

(ii) The heart girth was analysed using the model: $Y_{ijkl} = \mu + T_i + HG_j + L_k + S_l + e_{ijkl,}$ where HG_j = effect of heart girth at the start of the study. Weekly live weight was regressed on weekly heart girth, while mean daily weight gain was regressed on mean daily heart girth gain.

(iii) The model used for the haematological parameters was:

$Y_{iskl} = \mu + T_i + W_s + L_k + S_l + e_{iskl}$, where Y_{iskl} = individual observations, W_s = effect live weight during week of blood sampling and e_{iskl} = unexplained variation assumed randomly and independently distributed.

8.3. **Results**

8.3.1. Animal health

One kid died on the NP treatment during the study and was forwarded to Allerton Provincial Veterinary Laboratory, for an autopsy. Postmortem results attributed the death to anaemia that resulted from a severe infestation of intestinal parasites (wireworm, round and nodular worms) on the NP plot. The health of kids with complete records on both treatments was good and the experimental measurements represented the real treatment effects. Apart from the poor growth performance displayed by kids on the NP treatment, there were no visible external symptoms of nutrient or mineral deficiency symptoms during the study. Kids on the LGP treatment did not show any visible external symptoms of mimosine toxicity, mineral or nutrient deficiencies.

8.3.2. Diet nutrient content

The proximate and mineral element composition of the forage species on LGP and NP plots are presented in Table 8.1. Crude protein (CP) content on the NP treatment was 18.07% lower than that of the LGP, but crude fibre (ADF and NDF) on NP was 34.19% higher than that of LGP treatment. Except for Fe and Ca, concentrations of the other mineral elements on LGP treatment were higher than values recorded for NP.

8.3.3. Growth performance

Kids on LGP treatment were consistently heavier than those on NP treatment (Table 8.2). Between weeks 1 and 12, kids on LGP treatment gained 325 gwk^{-1} and 0.8 $cmwk^{-1}$ ($p < 0.05$) more in body weight and heart girth than their counterparts on NP treatment. Over the entire study, means of daily body weight gains of the kids on LGP and NP treatments were 73 gd^{-1} and 25 gd^{-1}, respectively. The averages of daily body weight gains of male and female kids on LGP were

84 ±0.02 gd $^{-1}$ and 54 ±0.01 gd $^{-1}$, respectively. The mean of daily body weight gains of female kids on NP was 25 ±0.02 gd $^{-1}$.

The means of all the fortnight heart girth measurements showed heart girths of LGP kids to be consistently higher than those of their counterparts on NP treatment. The variation accounted for by the relationship between weekly live weight and weekly heart girth was positive and significant (R^2-sq adj = 0.597; $p < 0.001$; Figure 8.1). The regression equation of the relationship between weekly live weight (LW) and weekly heart girth (HG) was: LW = -9.21 + 0.413HG (n = 90; RMSE = 3.43).

8.3.4. Blood profiles

Effect of period of sampling: Blood P, Mg, Cu, and Zn concentrations on both treatments decreased between the first and last sampling. Iron, serum protein and globulin concentrations increased between the period interval (Table 8.3), while other haematological parameters (i.e. Ca, PCV and albumin) did not follow a definite pattern.

Effect of dietary treatment: Beside the blood Cu and Zn levels of kids on the LGP treatment that were consistently higher than those of the kids on the NP treatment, the trend of other blood constituents on both treatments failed to follow a definite trend (Table 8.3). Throughout the period of sampling, the values of PCV and blood protein metabolites (except serum albumin) of LGP kids were consistently higher than those of their counterparts on the NP treatment.

Table 8.1. Proximate and mineral element composition of *Leucaena leucocephala*-grass (LGP) and natural pasture (NP) fed to unweaned South African indigenous *Nguni* goat (SAING) kids

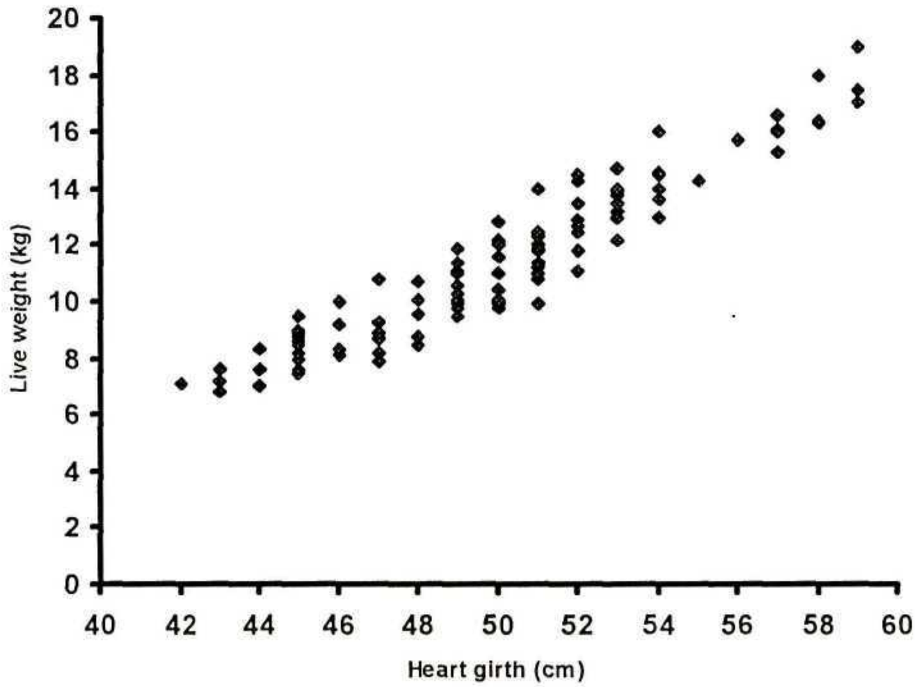
	LGP	NP
Proximate composition (%)		
Crude protein	29.32	11.25
Neutral detergent fibre	31.28	50.36
Acid detergent fibre	17.85	32.96
Fat	1.49	1.88
Ash	7.62	9.4
Minerals ($mgkg^{-1}$)		
Calcium	9800	12400
Phosphorous	3800	1100
Magnesium	3933	3277
Zinc	40.8	29.84
Iron	412.77	487.86
Copper	13.97	8.2

Table 8.2. Live weight and heart girth changes of South African indigenous *Nguni* goat kids maintained on *Leucaena leucocephala*-grass (LGP) or natural pastures (NP)

Period	LGP	NP	s.e.	P-values
Live weight (kg)				
Wk 1	10.4^{a}	8.8^{b}	0.61	0.02
Wk 3	11.4^{a}	9.2^{b}	0.86	0.02
Wk 6	12.8^{a}	9.7^{b}	0.92	0.005
Wk 9	14.3^{a}	10.5^{b}	1.1	0.004
Wk 12	16.0^{a}	10.8^{b}	1.23	0.001
Wt gain/wk (kg wk^{-1})	0.555^{a}	0.186^{b}	0.079	0.001
Heart girth (cm)				
Wk 2	49.8^{a}	46.7^{b}	1.32	0.04
Wk 4	51.5^{a}	47.4^{b}	1.25	0.006
Wk 6	51.4^{a}	47.0^{b}	1.38	0.007
Wk 8	53.2^{a}	47.7^{b}	1.76	0.008
Wk 10	55.4^{a}	49.1^{b}	1.89	0.006
Wk 12	59.9^{a}	48.7^{b}	4.08	0.02
Heart girth gain/wk ($cmwk^{-1}$)	1.0^{a}	0.2^{b}	0.31	0.05

Means were not adjusted for the effects of covariates; s.e. implies standard error of the difference between means. Means with different superscripts in a row differ significantly.

Figure 8.1. Relationship between weekly live weight and weekly heart girth measurements of South African indigenous *Nguni* goat kids



NB: r = 59.7%; $p < 0.001$

Table 8.3. Mean (±s.e.) concentration of mineral elements, packed cell volume (PCV) and protein metabolites in the blood of unweaned South African indigenous *Nguni* goats kids grazed on *Leucaena leucocephala*-grass pasture (LGP) and natural pasture (NP)

	Period of acclimatization				Week 6				Week 12			
	LGP	**NP**	**s.e.**	**P-value**	**LGP**	**NP**	**s.e.**	**P-value**	**LGP**	**NP**	**s.e.**	**P-value**
No. of animals	8	7			8	7			8	7		
Macro elements (mmol/l)												
Calcium	1.9	1.98	0.129	0.539	2.18	2.15	0.079	0.756	2.26	1.93	0.056	0.001
Phosphorous	3.58	3.53	0.176	0.804	2.73	2.22	0.142	0.003	2.3	2.57	0.22	0.181
Magnesium	1.07	0.91	0.096	0.118	0.88	0.95	0.03	0.036	0.86	0.85	0.04	0.815
Trace elements (µmol/l)												
Copper	19.41	20.64	1.456	0.413	13.06	11.74	0.773	0.11	13.01	12.79	1.393	0.876
Zinc	16.74	14.84	1.393	0.195	12.93	9.31	0.898	0.001	12.88	12.76	0.895	0.885
Iron	15.04	10.31	1.338	0.004	7.58	10.24	1.553	0.11	15.83	17.99	3.257	0.518
PCV (%) & Protein metabolites (g/l)												
Packed cell volume	31.5	30.43	1.248	0.407	32.25	28.43	1.5	0.024	29.5	27.42	1.755	0.259
Serum protein	55.96	52.41	2.504	0.18	53.22	45.58	1.628	0.001	62.59	57.14	4.574	0.255
Serum albumin	25.31	25.84	1.318	0.694	27.99	23.44	1.716	0.02	26.92	25.43	1.43	0.315
Serum globulin	30.65	26.57	2.877	0.18	25.24	22.11	2.582	0.248	35.68	31.7	4.006	0.339

s.e. implies standard error of the difference between means.

8.4. **Discussion**

8.4.1. Growth performance

The growth performance of the kids on both pasture treatments was similar to previous studies at the same location (Morris and Du Toit, 1998; Akingbade *et al.*, 2001a). The poor growth performance of the NP kids relative to the LGP kids can be attributed to a variation in available and accessible browse species on both treatment plots. Akingbade *et al.* (2002) did show that most leguminous browse species on the NP plot were tall trees (> 1.5 m) and beyond the reach of adults SAING for browsing. The inaccessibility of the NP kids to the more nutritious leguminous browse species can be attributed to their poor growth performance.

The crude protein (CP) content of the *Leucaena* component of LGP ranged between 18.6 and 32.1% (Chapter 2; Akingbade *et al.*, 2001b). The high protein content of the *Leucaena* component of LGP improves rumen environment, enhances degradation rate of roughage diet (Bonsi and Osuji, 1997) and improves dry matter intake (Bonsi *et al.*, 1995; Tudsri *et al.*, 1998). McDonald *et al.* (1990) has also shown that feed intake influences growth performance.

The significant differences in weekly heart girth measurements throughout the study was expected, as differences in weekly live weight between treatments were also significant. Varade *et al.* (1997), reported that both parameters (heart girth and body weight) are highly correlated. The significant correlation between the two parameters in this current study is in harmony with the report by Poonia and Rao (1999) who claimed that heart girth may be used to predict body weight in the absence of an electronic weighing scale, especially in the rural areas.

8.4.2. Blood profiles

Effect of period of sampling: The rise in the values of globulin levels between first and last sampling agrees with reports of Rowlands and Manston (1976) that globulin concentration increases as animals become older. The increases observed in blood Fe, serum protein and globulin concentration, and decreases in blood P, Mg, Cu, Zn and PCV contents of the kids may also have been influenced by the age of kids at sampling.

Effect of dietary treatment: Blood chemistry is influenced by diet, infection/disease, season and physiological state of the animal (Chapter 2; Akingbade *et al.*, 2002; Rowlands and Manston, 1976). *Leucaena* is rich in protein (Machado *et al.*, 1978). Protein intake is reflected in the blood albumin and globulin concentrations (Manston *et al.*, 1975). Wolf *et al.* (1972), has also shown blood albumin concentration to increase with an increase in diet protein content. Blood albumin concentration is thus a useful tool in diagnosing protein deficiency (Cronje and Gollah, 1996).

The proximate composition of the accessible forage resource on both treatments in this study has shown the LGP to be nutritively better (in term of high crude protein and less fibre content) than NP. The low protein content of accessible forage resource on the NP might have accounted for the albumin and globulin concentrations of the NP kids falling below the normal range reported by Puls (1994).

In spite of the low serum albumin and globulin concentration in the NP kids, they did not show any visible symptoms of nutritional deficiency. The absence of nutrient deficiency symptoms in NP kids was probably either an indication that the levels of the deficient protein metabolites were still above the critical values for the *Nguni* breed, or perhaps due to the short duration of the study.

8.4.3. Dams-to-kids transfer of *Synergistes jonesii* bacteria

Previous workers (Wahvuni *et al.*, 1982; Ahn *et al.*, 1989) have shown that mimosine and its metabolites (2,3 and 3,4-dihydroxypyridones (DHPs)) retard the growth performance in unadapted ruminants fed *Leucaena* species over a long period of time. Other symptoms of mimosine or DHP toxicity include low feed intake (Puchala *et al.*, 1996), loss of body weight (Ahn *et al.*, 1989) and hair loss (Hegarty *et al.*, 1964).

There was, however, no incidence of loss of body weight or hair loss (alopecia) among the kids on LGP treatment in this study. This is similar to the findings of Morris and Du Toit (1998) in SABG and Akingbade *et al.* (2001a), in SAING at the same location. They attributed the absence of symptoms of mimosine toxicity in SABG and SAING exposed to LGP to the presence of *S jonesii* bacteria in the rumen of the goats. Absence of any symptoms of mimosine or DHP toxicity among LGP exposed to *Leucaena* from 70 days of age, was an indication that the kids had acquired the *S. jonesii* bacteria from the dams possessing the bacteria.

The metal-chelating ability of mimosine has been implicated in promoting deficiencies of mineral elements such as Zn (Sethi and Kulkarni, 1995), P (Girdhar *et al.*, 1991), Cu (Apgar, 1992; Graham *et al.*, 1994), and Fe (Acamovic and D'Mello, 1981). The fact that the levels of blood mineral and protein metabolites of the LGP kids were within the normal physiological range for goats in the tropics and subtropics, suggests that the kids had acquired *S. jonesii* bacteria. This confirms the findings of Hammond (1995), that *S. jonesii* bacteria are easily spread among animals which are maintained on *Leucaena* pastures in close proximity.

8.5. Conclusions

Similar to the previous studies on adult SAING, the better live weight and heart girth gains of kids on the LGP treatment relative to their counterparts on NP confirmed the better potential of LGP as feed resource. The heart girth of SAING kids can be used to estimate live weight in the absence of an electronic weighing apparatus.

The levels of blood constituents of LGP kids were within the normal physiological range and higher than values recorded for NP kids. Also NP kids displayed no visible symptoms of mineral deficiency or mimosine toxicity-an indication that the kids had acquired *S. jonesii* bacteria from their dams.

Exposing the kids of SAING dams possessing *S. jonesii* bacteria to LGP was found to be safe as long as they are reared in a close proximity with their dams, as the kids can acquire the *S. jonesii* bacteria from the dams via animal-to animal-transfer.

CHAPTER 9

Effects of dietary protein content on feed intake, apparent digestibility, microbial nitrogen supply and blood profile of South African indigenous *Nguni* goat kids[1]

Abstract

This study was aimed at examining the post weaning growth performance, blood profiles, protein and energy requirements of early weaned South African indigenous *Nguni* goat (SAING) kids. Fifty two, 70 day old weaned SAING kids were used for the study over a two winter season. The kids were randomly divided into four groups and each group assigned to a different concentrate diet. The diets contained 13% (Diet 1), 15% (Diet 2), 17.5% (Diet 3) and 20.5% (Diet 4) crude protein (CP) content. Feed intake was measured daily, while body weight and heart girth measurements were carried out every week and fortnight, respectively, during the 13 weeks (including one week of adaptation) of intake and growth trials. Blood sampling was carried out on day one of adaptation and once in weeks 6 and 12, and analysed for mineral elements (Ca, P, Mg, Fe, Cu and Zn), packed cell volume (PCV) and protein metabolites (serum protein, albumin and globulin). A two week metabolic study was carried out immediately after the intake and growth trials. Feed intake, body weight gain, heart girth gain and feed efficiency were 2.57, 3.60, 4.00 and 4.24 kg wk^{-1}; 326, 608, 820 and 783 g wk^{-1}, 46, 75, 87 and 86 cm wk^{-1} and 12.6, 15.5, 19.8 and 18.2%, on Diets 1, 2, 3 and 4, respectively. The correlation coefficient of the relationship between weekly live weight and weekly heart girth was 0.917 ($p < 0.01$). Concentrate diet containing 15 to 17.5% CP content appears to be adequate for weaning 70 day old SAING kids. Dry matter digestibility, total nitrogen retention and total purine derivatives were 83.5, 80.7, 78.9 and 77.6%; 1.7, 2.0, 6.9 and 7.1 g d^{-1} and 16.4, 13.2, 15.2, 16 $mmold^{-1}$ for Diets 1,2, 3 and 4, respectively. Microbial nitrogen supply, protein efficiency and efficiency of microbial nitrogen supply were unaffected by diets. Most hematological constituents of kids on Diet 1 were below the normal physiological range for tropical and subtropical goats. However, apart from the poor growth rate displayed by kids on Diet 1, there were no symptoms of mineral deficiency. The absence of deficiency symptoms on Diet 1 was probably an indication that the concentrations of the deficient blood constituents were still above the critical levels for the breed or due to the short duration of the study. The overall estimated averages metabolisable energies for maintenance (ME*m*; ME MJ/kg $W^{0.75}$) and gain (MEg) of the SAING kids were 19.7 kJ/g ADG (se = 2.25; $p < 0.001$) and 0.538 MJ/kg $W^{0.75}$, respectively. The high ME*m* could be attributed to either the high metabolic active tissues of the kids or the winter period during which the study was conducted which probably necessitated the high ME*m* requirement for high body heat production.

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[1]Part of this chapter has been submitted for publication in: South African Journal of Animal Science
Co-authors: Nsahlai, I.V.and Morris, C.D.

9.1. **Introduction**

The polyestrous nature of female South African indigenous *Nguni* goats (SAING) permits year-round mating, but the peak of sexual activity of does in Pietermaritzburg has been found to be late spring (late November)/early summer (early December) (Akingbade *et. al.*, 2001b). During this period, the high nutritional value of the pastures improves body condition of does and enhances conceptions (Narasimha *et al.*, 1992). The *Nguni* does that are bred in late spring kid and lactate in winter.

Winter season is characterised by cold ambient temperatures and occasional frost. During winter, quantity and quality of grass species are at their lowest (Zacharias, 1990) and most tropical leguminous browse species loose some or all of their leaves (Kirkman, 1988). Therefore, the winter season at the site of the study is associated with under-nutrition of the lactating does. *Leucaena* stands are virtually unavailable for grazing between late winter and early spring (August and September; Chapter 2; Akingbade *et al.*, 2001b) at the site of the study, and available grass species are also of poor nutritive quality.

Early weaning has been reported (Fluharty *et al.*, 2000) to be beneficial to does when pastures are inadequate in quantity and limited in quality. Due to the low quantity and poor quality of feed the resources in peak winter, kids can be weaned on concentrate diets to prevent competition between the dams and kids for the limited available feed on pastures. Early weaning of kids will give dams time to recover from lactation stress, in preparation for the following breeding season. However, there are no reported studies on growth performance, blood profiles, protein and energy requirements of early weaned SAING kids.

The objectives of this study were to:

i. Examine post weaning the growth performance of SAING kids on concentrate diets;

ii. Examine the blood profiles of SAING kids on concentrate diets;

iii. Determining protein and energy requirements of early weaned SAING kids.

9.2. **Material and methods**

9.2.1. Site

The location of the study site has been reported in subsection 2.2.1 (Chapter 2). The studies were carried out over a two winter season (2000 and 2001).

9.2.2. Animals and dietary treatments

Sixteen and 36, 70 day old early weaned SAING kids comprising males and females were used in this study during Years 1 and 2, respectively, for a 15 week period. The kids in both years were randomly divided into four equal groups and each group assigned to a different dietary treatment. The dietary treatments consisted of concentrate diets that contained varying levels of crude protein (CP): 13% (Diet 1), 15% (Diet 2), 17.5% (Diet 3) and 20.5% (Diet 4) CP content. The means of the kid weight at the start of the study were 9.68 ±1.58 kg (Diet 1), 9.71 ±1.71 kg (Diet 2), 9.74 ±3.98 kg (Diet 3) and 10.20 ±3.56 kg (Diet 4), respectively.

9.2.3. Feed intake and growth trials

Kids were kept in a roofed house and individually penned in pens fitted with water and feed troughs and served a known quantity of their respective diets daily between 07.30 and 08.00 h. The diet was sufficient to last 24 hours so as to ensure *ad libitum* feed intake. Feed refused was emptied from the feed troughs between 07:00 and 0:7.30 h and weighed before the daily diets were served. Daily refusals (left over feed) were also regularly sampled and oven dried on a weekly basis at 60 ^{0}C for 48 h for laboratory analysis.

Kids on all dietary treatments were allowed a week of acclimatization to the diet and the new environment, followed by 12 weeks of data collection. Kids were weighed weekly throughout the study. On day one of acclimatization, kids were treated for endo and ecto-parasites using Ex-A-Lint and tritick, respectively. Kids on all the dietary treatments were not provided nutritional or mineral supplements during the study. Feed efficiency (FE) and protein efficiency (PE) were deduced using the following expressions:

FE = Live weight gain (kg)/ Feed intake (kg) (Lin, 1980)

PE = Live weight gain (kg)/(Feed intake (kg) x Diet protein content (%)).

9.2.4. Blood sampling

Blood sampling was carried out as described in subsection section 4.2.7 (Chapter 4). Sampling occurred on day 1 of acclimatization and also once during weeks 6 and 12 of the study.

9.2.5. Metabolic trial

At the end of the intake and growth trials, a metabolic study was conducted using four male kids on each of the concentrate treatments. The kids were transferred to metabolic crates and maintained on their previous diet. Kids were allowed a week of acclimatization, after which urine and faeces were collected once a day over a seven day period. The averages of body weights of kids on each treatment at the start of the metabolic study were: 15.8 ±0.8 kg (Diet 1), 19.8 ±1.4 kg (Diet 2), 25.2 ±4.9 kg (Diet 3) and 21.1 ±5.5 kg (Diet 4).

Daily feed intake during the metabolic trial was recorded. Refusals were regularly sampled and preserved by oven drying at 60 ^{0}C for 48 h. The daily urine output of each animal was collected into a plastic container containing 100 ml of 10% sulphuric acid (H_2SO_4) to prevent ammonia-nitrogen loss (Chen *et al.*, 1992).

Refusals, urine and faeces were recorded. A constant proportion of the daily urinary and faecal output (10% urine and 20% faeces) of each kid was sampled and preserved in a refrigerator. On the last day of the study, faecal dry matter was determined by oven drying at 60 °C for 48 h. Equal samples (250 g) of the refusal of each diet during the intake and metabolic trials were pooled for laboratory analysis.

9.2.6. Laboratory analysis

The offered diets, feed refused and faeces were analysed as reported in subsection 4.2.8 (Chapter 4). Urine samples were analysed for nitrogen and uric acid using the modified Berthelot reaction, and read at a wavelength of 660 nm on the spectrophotometer (Hitachi Model, Tokyo, Japan), as described by Chen *et al.* (1990b). Xanthine and hypoxanthine in the urine were measured together as uric acid after urine treatment with xanthine oxidase (Chen *et al.*, 1992). The allantoin was determined as described by Borchers (1977). Haematological parameters were analysed by the Allerton Provincial Veterinary Laboratory, Pietermaritzburg, South Africa as described by Wolf *et al.* (1972).

9.2.7. Statistical analysis

Feed intake, live weight, heart girth and haematological data were analysed using the General Linear Model (GLM) of Minitab (Minitab, 1998).

(i) Feed intake, feed efficiency, protein and live weight were analysed using the following statistical model: $Y_{ijkl} = \mu + T_i + W_j + L_k + S_l + e_{ijkl}$, where Y_{ijkl} = individual observations, μ = overall mean, Ti = effect of treatment, W_i = effect of live weight at the start of the study, L_j = effect of litter size, S_l = effect of gender and e_{ijkl} = unexplained variation assumed randomly and independently distributed.

(ii) Using the General Linear Model (GLM) of SAS (1987), the mean daily live weight gain (ADG) was obtained by regressing live weight (W) on time, in days. Efficiencies of crude protein (CP) and metabolisable energy (ME) utilisation were determined by regressing weekly live weights on cumulative intake of dry matter (cDMI), protein (cCPI), and metabolizable energy (cMEI). Metabolizable energy (ME, MJ/kg $W^{0.75}$/d) requirement was the intercept of the ME intake against average daily gain (g/kg $W^{0.75}$).

(iii) The statistical model for the heart girth analysis was: $Y_{ijkl} = \mu + T_i + HG_j + L_k + S_l + e_{ijkl}$, Where HG_j = effect of live heart girth at the start of the study.

The weekly live weight vs Weekly heart girth; and average daily live weight gain vs average daily heart girth gain were subjected to a regression analysis.

(iv) Haematological parameters were analysed using the model:

$Y_{iskl} = \mu + T_i + W_s + L_k + S_l + e_{iskl}$, where Y_{iskl} = individual observations, W_s = effect of live weight during week of blood sampling and e_{iskl} = unexplained variation assumed randomly and independently distributed.

(v) The daily purine derivatives of microbial origin (X; mmol) was estimated according to Chen *et al.* (1990a): Purine derivatives (PD) = $0.84X + Ce^{-0.25x}$, where $C = 0.150\ BW^{0.75}$, PD (mmol) = total urinary PD and BW = body weight of the goat at the start of the metabolic study. The use of litter size as a covariate was eliminated from the model in the analysis of microbial nitrogen supply and efficiency of microbial nitrogen supply. The treatment effects on parameters considered during metabolic studies were analysed using the General Linear Model (GLM) of SAS (1987).

The statistical model for all analysing all metabolic parameters was:

$Y_{imk} = \mu + T_i + W_m + L_k + e_{imk}$, where Y_{imk} = individual observations, W_m = effect of initial live weight during metabolic trial and e_{imk} = unexplained variation assumed randomly and independently distributed.

9.3. **Results**

9.3.1. Animal health

Four kids died during the study, two of the kids were from Diet 4 and one each from Diets 1 and 2. The dead kids were autopsied at Allerton Provincial Veterinary Laboratory. All deaths were attributed to phosphatic urinary calculi (uroliathiasis). The health of kids with complete records on all treatments was good and the experimental measurements represented the real treatment effects. Apart from the poor growth performance displayed by kids on the crude low protein diet (Diet 1), there were no visible symptoms of nutrient or mineral deficiency.

9.3.2. Diet nutrient content

The proximate and mineral element composition of the diets are presented in Table 9.1, while those of feed refused (refusals) are presented in Table 9.2. The diets and refusals were not tested statistically.

9.3.3. Intake, growth performance and nutritional requirements

Between weeks 1 and 12 of the intake and growth trials, weekly mean dry matter intake, live weight gain and feed efficiency of kids on Diet 1 were significantly ($p < 0.05$) lower than those of Diets 3 and 4 (Table 9.3). Mean weekly feed intake, live weight gain and feed efficiency on Diet 2 were not significantly different from those on Diets 1, 3 and 4. Differences between dietary treatments in efficiency of protein utilisation were not significant. The weekly mean heart girth gain on Diet 1 was significantly ($p < 0.05$) lower than those of kids on the other dietary treatments. The proportions of variation (R^2) accounted for by the relationship between weekly live weight and weekly heart girth (Figure 9.1) and that between average daily live weight gain and average daily heart girth gain were 91.7% (SE = 1.43; $p < 0.001$) and 24.8% (SE = 0.072; $p < 0.001$), respectively. Regression equation of the relationship between weekly live weight (LW) and weekly heart girth (HG) was: LW = -25.3 + 0.740HG (n = 224, RMSE = 2.0), while that of mean daily live weight gain (ADG) and mean daily heart girth gain (HGG) was:

ADG = -0.0440 + 0.361 HGG (n = 192, RMSE = 0.005).

The proportions of variation explained by the relationship between body weight (BW) vs cDMI or cCPI or cMEI were 62, 63 and 62%, respectively. The efficiencies were: 265 g ADG/ kg of DMI ($P < 0.001$), 1.45 kg ADG/kg of CPI ($P < 0.001$) and 22.4 g ADG/MJ ME ($P < 0.001$). The requirements of metabolisable energy for maintenance (ME*m*; MJ/kg $W^{0.75}$) were 0.578 (SE = 0.108), 0.518 (SE = 0.059), 0.625 (SE = 0.083) and 0.518 (SE = 0.113) for kids on diets 1, 2, 3 and 4, respectively, with 0.538 (SE = 0.033) as the overall mean for all dietary treatments. Requirements of metabolisable energy for gain (ME*g*; kJ/g ADG; deduced from the regression coefficients of the above relationships) on diets 1, 2, 3 and 4 were 13.5 (SE = 12.3, P = 0.299), 26.1 (SE = 3.8, $P < 0.001$), 15.4 (SE = 4.9, $P < 0.01$) and 19.9 (SE = 7.1, $P < 0.05$), respectively, with 19.7 (SE = 2.25, $P < 0.001$) as the overall average of treatments.

9.3.4. Apparent dry matter digestibility, urinary products and microbial nitrogen supply

Apparent dry matter digestibility of kids on Diet 1 was significantly ($p < 0.05$) higher than those on Diets 3 and 4, but that on Diet 2 were not significantly different from those on the other Diets (Table 9.4). Digestible dry matter intake and nitrogen retention of kids on Diets 1 and 2 were significantly ($p < 0.05$) lower than those of their counterparts on Diets 3 and 4. Urinary purine derivatives on Diet 1 was significantly ($p <0.001$) higher than those of other concentrate diets. Daily supply of microbial nitrogen and efficiency of microbial nitrogen supply were independent of the dietary treatments.

9.3.5. Blood profiles

Effect of period of sampling: Between the first and last blood samples, Diet 1 had the highest Mg, Cu, Zn, serum protein, globulin, albumin and packed cell volume (Table 9.5). Serum protein, globulin and packed cell volume on all dietary treatments (except Diet 3) increased while albumin recorded a decrease between the first and last blood sampling periods. Irrespective of treatments, blood Fe concentration decreased, while serum protein and globulin concentration increased as kids became older.

Effect of diet: Within each period of sampling, most blood protein metabolites and mineral elements on all dietary treatments did not follow a specific pattern (Table 9.5). However, during acclimatization, serum protein and Mg concentration increased with increased protein level in the diet. In week six, P and Fe concentration decreased and increased, respectively, with increased in diet protein content, while in week 12, Mg concentration decreased but Fe and albumin concentration increased with increased dietary protein level. The differences in concentrations between treatments varied from marginal to significant.

Table 9.1. Proximate and mineral element composition of concentrate diets fed intensively to weaned South African indigenous *Nguni* goat kids over a twelve week period

	Diet 1	Diet 2	Diet 3	Diet 4
Proximate composition (%)				
Crude protein	13	15	17.5	20.5
Neutral detergent fibre	26.72	34.28	27.3	35.6
Acid detergent fibre	8.34	11.71	11.7	14.27
Fat	4.23	4.02	3.52	3.6
Ash	3.55	4.6	4.66	4.83
Minerals ($mgkg^{-1}$)				
Calcium	4600	6800	7500	8600
Phosphorous	3400	4500	4700	5400
Magnesium	1761	2334	2373	2685
Zinc	37.97	56.22	54.92	59.12
Iron	135.67	170.53	161.49	154.65
Copper	5.9	11.71	9.69	15.83

Table 9.2. Proximate and mineral element composition of refusals of concentrate diets fed intensively to weaned South African indigenous *Nguni* goat kids

	Diet 1	Diet 2	Diet 3	Diet 4
Proximate composition (%)				
Crude protein	12.5	16	17.5	20
Neutral detergent fibre	31.54	34.18	27.92	35.48
Acid detergent fibre	7.41	10.68	11.15	12.62
Fat	3.81	3.82	3.45	3.54
Ash	3.53	5.3	5.13	4.95
Minerals (mgkg^{-1})				
Calcium	6700	8200	7700	9500
Phosphorous	3500	4400	4800	5300
Magnesium	1514	1920	1963	2091
Zinc	47.69	58.2	56.74	60.4
Iron	181.63	256.9	272.81	356.49
Copper	5.77	11.36	13.27	16.34

Nb: refusals are left over feed emptied from the feed troughs each day before serving fresh diet.

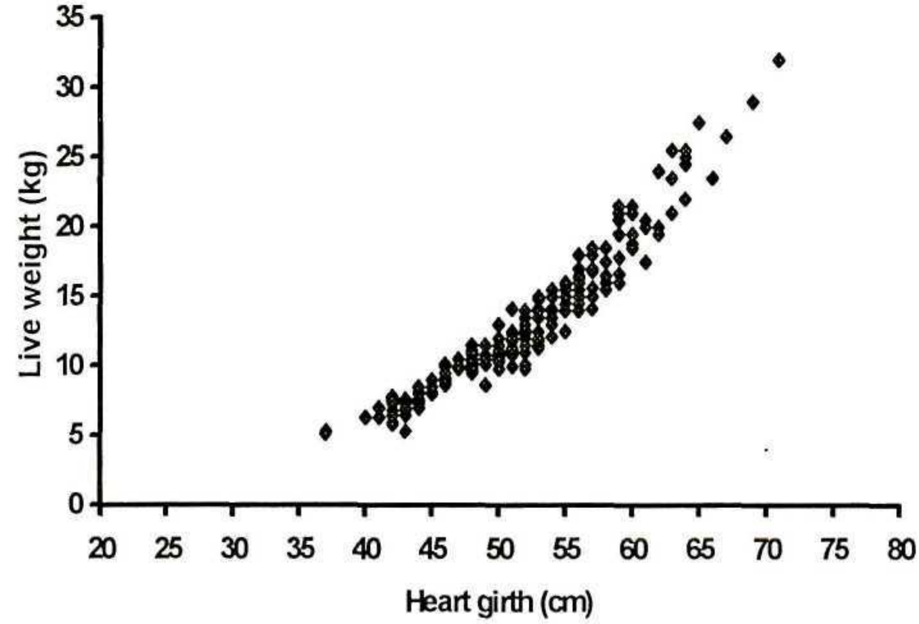
Table 9.3. Mean (±s.e.) weekly feed intake, live weight and hearth girth gains and feed efficiency of growing South African indigenous *Nguni* goat kids maintained intensively onconcentrate diets

Period	Diet 1	Diet 2	Diet 3	Diet 4	s.e.	P-values
No. of animals	8	8	9	7	-	-
Mean feed intake ($kgwk^{-1}$)	2.57^{b}	3.60^{ab}	4.00^{a}	4.24^{a}	0.768	0.024
Mean weight gain ($kgwk^{-1}$)	0.326^{b}	0.608^{ab}	0.820^{a}	0.783^{a}	0.214	0.01
Mean heart girth gain ($cmwk^{-1}$)	0.46^{a}	0.75^{b}	0.87^{b}	0.86^{b}	0.214	0.022
Mean feed efficiency (%)	12.64^{b}	15.49^{ab}	19.75^{a}	18.22^{a}	0.031	0.014
Protein efficiency (coefficient)	0.97	1.03	1.13	0.89	0.207	0.427

Crude protein contents: Diet 1 - 13.0%; Diet 2 - 15.0%; Diet 3 - 17.5% and Diet 4 - 20.5%.

Means were not adjusted for the effects of covariates; Means with different superscripts within a row differ significantly ($P < 0.05$).

Figure 9.1. Relationship between weekly live weight and weekly heart girth measurements of growing South African indigenous *Nguni* goat kids weaned on concentrate diets



Nb r = 0.92%, $p < 0.01$

Table 9.4. Digestibility, nitrogen output and urinary purine derivatives of weaned South African indigenous *Nguni* goat kids maintained on concentrate diets varying in crude protein content

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	s.e.	P-values
Daily feed intake (gd^{-1})	378.7[b]	393.3[b]	644.5[a]	574.1[a]	42.71	0.001
Daily faecal excretion (gd^{-1})	62.59[b]	70.40[b]	132.79[a]	127.58[a]	9.632	0.001
Dry matter digestibility (%)	83.47[a]	80.71[ab]	78.86[b]	77.63[b]	0.156	0.002
Digestible dry matter intake (gd^{-1})	316.1[b]	322.9[b]	511.7[a]	446.5[a]	36.24	0.001
Nitrogen determination (gd^{-1})						
Nitrogen intake	7.88[b]	9.44[b]	18.04[a]	18.83[a]	1.278	0.001
Faecal nitrogen	3.70[a]	3.47[b]	3.31[c]	3.12[d]	0.054	0.001
Urinary nitrogen	2.48[c]	3.98[b]	7.79[a]	8.60[a]	0.649	0.001
Total nitrogen excretion	6.18[c]	7.45[b]	11.11[a]	11.72[a]	0.63	0.001
Total nitrogen retention	1.70[b]	2.00[b]	6.94[a]	7.11[a]	1.038	0.001
Urinary products ($mmold^{-1}$)						
Total allantoin	15.41[a]	12.25[b]	14.25[a]	15.00[a]	0.827	0.001
[a]Total uric acid	1.02[a]	0.99[b]	0.99[b]	0.99[b]	0.004	0.001
Total purine derivatives	16.42[a]	13.24[b]	15.23[a]	15.99[a]	0.828	0.001
Microbial nitrogen supply (mns)	13.62	11.33	13.74	13.91	1.111	0.708
Efficiency of mns (gkg^{-1} OMADR)	39.33	35.77	31.12	34.46	3.744	0.157

Crude protein contents: Diet 1 - 13.0%; Diet 2 - 15.0%; Diet 3 - 17.5% and Diet 4 - 20.5%. Means were not adjusted for the effects of covariates; Means with different superscripts within a row differ significantly ($P < 0.05$). OMADR implies organic matter apparently digested in the rumen. OMADR was assumed to be 0.75 (Osuji *et al.*, 1993). [a]Xanthine and hypoxanthine in the urine were determined together as uric acid after urine treatment with xanthine oxidase (Chen *et al.*, 1992).

Table 9.5. Mean (±s.e.) concentration of mineral elements, protein metabolites and packed cell volume (PCV) in the blood of weaned South African indigenous *Nguni* goats kids maintained on four concentrate diets containing different protein content over a twelve week period

	Period of acclimatization						**Week 6**						**Week 12**					
	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**	**s.e.**	**P-value**	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**s.e.**	**P-value**	**Diet 1**	**Diet 2**	**Diet 3**	**Diet 4**	**s.e.**	**P-value**
No. of animals	8	8	9	7	-	-	8	8	9	7	-	-	8	8	9	7	-	-
$mmol l^{-1}$																		
Ca	2.22^{b}	2.49^{a}	2.30^{ab}	2.10^{b}	0.169	0.03	2.07	2.23	2.12	2.28	0.182	0.39	1.97^{b}	2.13^{ab}	2.05^{ab}	2.18^{a}	0.112	0.07
P	2.92	2.96	3.01	3.47	0.378	0.197	3.55	3.47	3.46	3.21	0.294	0.435	3.24	3.29	3.81	3.34	0.409	0.17
Mg	0.89^{b}	0.97^{ab}	0.98^{ab}	1.14^{a}	0.117	0.05	1.98^{a}	1.52^{b}	1.44^{b}	1.58^{b}	0.209	0.01	1.94^{a}	1.65^{b}	1.54^{b}	1.39^{b}	0.202	0
$\mu mol l^{-1}$																		
Cu	15.44	14.77	15.64	15.52	1.707	0.886	16.62^{a}	13.61^{b}	14.53^{b}	14.63^{b}	1.297	0.02	17.35^{a}	14.98^{ab}	13.49^{bc}	11.46^{c}	2.168	0
Zn	19.19^{a}	16.51^{b}	21.45^{a}	18.22^{a}	3.214	0.178	22.19	17.56	19.8	18.6	3.606	0.322	16.37	15.66	16.05	15.17	2.5	0.921
Fe	22.06	23.14	34.97	21.7	13.526	0.427	13.83	14.81	18.49	20.07	5.944	0.424	10.32	12.36	14.05	16.08	5.867	0.58
$g l^{-1}$																		
Serum protein	55.68	58.71	61.08	61.34	3.965	0.177	54.9	54.49	53.22	57.04	4.078	0.626	64.46^{a}	60.52^{ab}	58.44^{b}	61.86^{ab}	3.375	0.09
Serum albumin	30.16^{b}	31.75^{ab}	32.32^{ab}	34.50^{a}	1.926	0.04	25.51^{a}	24.01^{b}	24.70^{ab}	28.14^{a}	1.948	0.038	29.22^{b}	30.65^{ab}	31.12^{ab}	32.03^{a}	1.778	0.197
Serum globulin	25.51	26.96	28.73	26.84	3.709	0.654	29.64	30.45	28.54	28.9	3.314	0.847	35.24^{a}	31.12^{ab}	27.32^{b}	29.83^{b}	3.5	0.02
PCV (%)	27.38	27.38	27.33	26.57	2.51	0.964	31.5	29	31.89	31.71	2.106	0.191	36.62^{a}	32.00^{b}	32.22^{b}	33.29^{ab}	2.51	0.05

s.e. implies standard error of the difference between means. Means were not adjusted for the effects of covariates. Means with different superscripts within a row differ significantly ($P < 0.05$).

Discussion

9.4.1. Health of animals

The normal range of phosphorus in the blood of goats in the tropics and sub-tropics was reported (Puls, 1994) to be between 1.4-2.6 mmol/l. Goats are highly selective feeders (Owen-Smith and Cooper, 1987), and the selective feeding trait of goats has been reported (Huston, 1998) to result in mineral imbalances. Such imbalances could be responsible for the high blood phosphorous in all dietary treatments that caused phosphatic urinary calculi (Schultz *et al.*, 1988). Kids on Diet 3 were unaffected by phosphatic urinary calculi despite the diet having a higher phosphorous content relative to Diets 1 and 2. Individual animal differences in the levels of phosphorous tolerance could be the reason..

9.4.2. Nutritive value of diet and refusal

Goats are very versatile in diet selection. The better nutritive value (higher values of crude protein and most mineral elements) of refusals relative to fresh feeds can be attributed to the selective habit of goat. This trend is in harmony with the report by Huston (1998) that goats carried out selection to their disadvantage- resulting in crude protein content of refusals being higher than that of fresh diet served. Sixty to eighty percent of saliva nitrogen is urea nitrogen (Church, 1988). The effect of salivation during feeding could partly account for the higher protein contents of refusals compared to the fresh diets. The financial implication of loss of goats to death from urinary calculi that resulted from selective habit of goats, emphasised the need to develop a feeding strategy that will minimise selection of goats. This strategy can be in the form of processing goat diets into a pellet form.

9.4.3. Feed intake, apparent digestibility and growth performance

Increased intake in response to increased protein content could be attributed to the improvement in rumen environment and an increase in microbial population associated with increased protein intake. Increased microbial populations haa been reported (Bonsi and Osuji, 1997) to improve dry matter intake. The poor growth performance of kids on Diet 1 seemed to indicate a low protein intake. The significantly higher weekly body weight and heart girth gains of kids on Diets 3 and 4 relative to those on Diet 1 was expected as intake and feed efficiency of kids on Diets 3 and 4 were significantly higher than those on Diet 1. This confirms the report of McDonald *et al.* (1990) that intake influences growth performance.

The significant correlations between mean weekly live weight vs mean weekly heart girth and average daily live weight gain vs average daily heart girth gain were indications that heart girth can be used to predict live weight in the absence of an electronic scale, especially in the rural areas. The relationship between live weight and heart girth in this study is in harmony with previous studies (Varade *et al.*, 1997; Poonia and Rao, 1999).

Apparent dry matter digestibility decreased with increased intake, similar to the trend reported by Woods *et al.* (1999) for cattle and by Murphy *et al.* (1994) for sheep, where increased intake was associated with decreased digestibility. To the contrary, Bines *et al.* (1988) reported that digestibility was independent of intake of concentrate diets. Decreased digestibility that accompanied increased intake in this study was probably due to the increased rumen outflow rate (Owen and Goetsch, 1986; Mulligan *et al.*, 2001) or decreased residence time which shortened extent of microbial degradation (Pond *et al.*, 1980).

9.4.4. Urinary products and microbial nitrogen supply

Excess ammonia is absorbed from the rumen, converted into urea and excreted in the urine (Colin-Schoellen *et al.*, 2000). The lower growth performance and higher urinary products (total nitrogen excretion, allantoin, purine derivatives) and microbial nitrogen supply of kids on Diet 4 relative to Diet 3 can be ascribed to high loss of ammonia nitrogen in the rumen as revealed in the total nitrogen excretion data. The high quantity of allantoin, compared with other constituents of purine derivatives is in agreement with the values reported by other workers (Merchen, 1988; Nsahlai *et al.*, 2000).

The relationship between intake and purine derivatives in this study differs from reports of Owen and Goetsch (1986) and Nsahlai *et al.* (2000b) that increasing the dry matter intake, increases digesta flow and microbial yield. The difference between reports is difficult to explain. The disparity was presumably due to animal differences- as most studies on purine derivatives were conducted with sheep and cattle, while goats are known to be more selective than cattle and sheep (AFRC, 1998; Huston, 1998)

9.4.5. Feed and protein efficiencies and nutritional requirements

Protein efficiency which is a measure of nutritive value of dietary proteins (McDonald *et al.*, 1990) was independent of the dietary treatments imposed in this study. Although protein efficiency was independent of the diets, Diet 3 had the highest protein efficiency value. The choice of diet to feed to early weaned kids should depend on the efficiency of protein utilisation for growth.

Although Diet 2 had a marginally higher protein efficiency than Diet 4, growth performance of the kids on Diet 4 was marginally better than on Diet 2. Diet 3 was marginally better than Diet 4 in terms of growth performance (live weight and heart girth), protein and feed efficiency. Based on the growth performances (live weight and heart girth) of weaned SAING kids obtained in this study, Diet 3 tended to be the best of all the Diets fed Thus concentrate diet containing between 15% (Diet 2) and 17.5% CP (Diet 3) content can be recommended for feeding early weaned SAING kids.

The estimated metabolisable energy requirements for maintenance and gains of the kids did not follow a definite trend between dietary treatments, probably due to the selective habit of goats (Hafez, 1975). Huston (1998) did show that selective habit of goats, resulted in a better nutritive value of the refusals relative to fresh diet in a stall feeding study. The higher values of metabolisable energy for maintenance (ME*m)* in this study relative to the 438kJME/kg $W^{0.75}$ values recommended by AFRC (1998), was a reflection of the metabolic active tissue in kids or it can be due to the effect of season (winter) during which the study was conducted. The latter reason agrees with the report by McDonald *et al.* (1990), that animals in cold environment, eat more and generate more body heat so as to keep warm.

9.4.6. Blood profiles

Effect of period of sampling: Effects of dietary protein on most haematological parameters considered did not follow a specific trend during the three periods of sampling. The highly selective nature of goats might be responsible for this lack of definite pattern between sampling periods. However, the increase in globulin concentration between the first and last sampling concurs with the reports by Rowlands and Manston (1976), which they attributed to an increase in age. The higher serum protein and decrease in blood Fe concentration between the first and last blood sampling was perhaps also an indication that the constituents were influenced by age.

Effect of dietary treatments: Nutrition is one of the factors known to influence blood chemistry (Rowlands and Manston, 1976). The effects of diet protein content on blood chemistry in this study failed to follow a definite trend for most haematological parameters considered. The highly selective habit of goats can be ascribed to lack of definite pattern between diets. However, values of blood PCV, protein metabolites (except serum protein on Diet 3 during week 6 sampling) and mineral elements were within the normal physiological range (Puls, 1994).

The highest values for PCV of kids on Diet 1 (lowest protein diet) at the end of the study (week 12) was expected. Previous reports of Martin *et al.* (1969) cited by Miller *et al.* (1969) did show that low protein diets are associated with increased PCV. Possible malnutrition on Diet 1 is suggested by the poor growth performance of kids fed the diet. This is in line with the McDonald *et al.* (1990) that intake influences growth performance.

The low albumin content of kids fed Diet 1 relative to their counterparts on other diets can be attributed to the difference in diets protein content. This corroborates the research findings of Wolf *et al.* (1972), that blood albumin concentration increases with protein content of diet. The decrease in albumin concentration associated with an increased globulin concentration is consistent with the reports of Srivastava and Sharma (1990) that albumin decreases with an increase in globulin concentration.

Apart from the poor growth performance displayed by kids on Diet 1, there were no visible symptoms of a mineral deficiency. Absence of signs of a mineral deficiency was an indication that the concentrations of all relative deficient blood constituents were still above the critical levels of this breed of goats, below which deficiency symptoms would manifest. The short duration of the experimental period may also be responsible for the absence of mineral or protein metabolite deficiency symptoms.

9.5. Conclusions

Concentrate diet containing between 15% (Diet 2) and 17.5% CP (Diet 3) content can adequately meet protein requirements of early weaned SAING kids. However, the use of concentrate diets in this study was found to be associated with better nutritive value of refusals relative to fresh diets and kids death from urinary calculi. This constrain, emphasised the need to develop a feeding strategy that will make it difficult for goats to be offered concentrates to carry out feed selection. The strategy can be in form of processing the concentrate diets to be offered into a pellet form. Similar to results obtained in previous studies with unweaned kids in Chapter 8, the heart girth in this study was found to be reliable in predicting live weight.

The failure of some haematological parameters of the kids to follow a definite pattern between diets or between sampling periods, was an indication that blood profile of SAING kids cannot be used with a reasonable degree of accuracy in assessing nutritional status of the growing SAING kids. The highly selective nature of goats might be responsible for this lack of definite pattern between diets and sampling periods.

The higher energy requirements of SAING kids obtained in this study compared to other studies can be attributed to the difference in age and breeds of goat used in various studies. The difference between studies can also be due to the period (climatic season) of the study. The high MEm can also be due to the metabolically active tissues of the SAING kids used in the study. Suffice to say that the energy requirements recommended by previous researchers were derived from studies conducted using mature animals.

CHAPTER 10

General discussion, summary and conclusion

10.1 General discussion

Animal performance is dependent on the nutritive value of available forage resources and the extent to which the resources meet their nutritional requirements for energy, protein, minerals and vitamins (Kaitho, 1997). In the tropics and sub-tropics, forage species mature and become fibrous rapidly, resulting in poor quality forage (Payne, 1990). The use of chemical and enzyme treatments to improve forage quality has been advocated (Adebowale *et al.*, 1989; Goodchild, 1990; Al-Saghier and Campling, 1991; Aletor and Omodara, 1994), but were found to be laborious, expensive and too technical for resource poor livestock farmers to adopt (Mero and Uden, 1990). The feeding of leguminous species, notably *Leucaena* species with grass (*Leucaena*-grass pastures) was deemed an affordable alternative (Bonsi *et al.*, 1994).

However, feeding excess *Leucaena* forage (> 30% of the total basal diet) to unadapted ruminants is detrimental to their growth and reproductive performance due to the mimosine content of the forage (Holmes, 1980; Jones and Megarrity, 1986; Lohan *et al.*, 1988; Ahn *et al.*, 1989; Puchala *et al.*, 1996). In the search to overcome problems associated with mimosine and its metabolites (2,3 and 3,4-dihyroxypyridones (DHPs)), Dihyroxypyridone (DHP)-degrading rumen bacteria (*Synergistes jonesii*) were discovered in the rumen of *Leucaena*-adapted ruminants. *Leucaena*-adapted ruminants are able to consume large quantities of *Leucaena species* without any ill effects in Central America, Hawaii and Indonesia (Jones and Megarrity, 1986) where *Leucaena* species originate. The *S. jonesii* bacteria were then transferred to mimosine-susceptible ruminants via inoculation or animal-to-animal transfer and the mimosine-susceptible ruminants became mimosine-adapted/mimosine-tolerant and were able to consume excessive quantities of *Leucaena* (30% above total basal diet) with impunity (Jones and Megarrity, 1986).

Similar successes of transfer or inoculation of *S. jonesii* bacteria were reported in the United States of America (Hammond *et al.*, 1989b) and in the Republic of South Africa (Morris and Du Toit, 1998). However, after some years of exposing South African indigenous *Nguni* goats (SAING) that possessed *S. jonesii* bacteria to *Leucaena leucocephala*-grass pasture (LGP), their reproductive performance (i.e. poor conception and high pre-weaning kid mortality) was reported to decline, despite the absence of any visible external symptoms of mimosine toxicity (Morris and Du Toit personal communication, 1999).

The experiments reported in this thesis were designed to:

i. Examine the causes of poor conception and high pre-weaning kid mortality rate in SAING possessing *S. jonesii* and maintained on *Leucaena leucocephala*-grass pasture (LGP);

ii. Evaluate the potential of LGP and natural pasture (NP) as feed resources for the productivity of SAING.

10.1.1 **Seasonal changes on forage composition**

The proximate composition, mineral and mimosine contents of cultivars Cunningham and Spectra varied with season (Akingbade *et al.*, 2001b). Cultivar Cunningham was more available over a longer period (10 vs 6 months) of the year than cv. Spectra. The period of availability of both cultivars in this study was not in agreement with that reported by Morris and Du Toit (1998). They found no difference between availability periods of the two cultivars at the same location. The difference in reports possibly can be attributed to the yearly variation in rainfall. Based on seasonal rainfall pattern obtained during this study, and the period of forage availability of both cultivars, cv. Cunningham appeared to be better suited as a feed resource than cv. Spectra at the location of the study. The availability of cv. Cunningham in the month of October would be valuable in flushing breeding males and females SAING prior to breeding in late spring or early summer. Adequate nutrition prior to mating and during mating has been reported to increase ovulation and kidding rates (Henniawati and Fletcher, 1986), and also improves semen quality and enhances conception (Chapters 3, 5 and 7; Akingbade *et al.*, 2001a; in press a).

10.1.2 Detection of *Synergistes jonesii* bacteria

Direct analysis of rumen fluid from goats on both LGP and NP treatments indicated that DHP-degrading rumen bacteria (*Synergistes jonesii*) were present only in the LGP goat. The presence of *S. jonesii* bacteria in the LGP goat reported in Chapter 2 confirmed that the bacteria is present in other goats on LGP treatment. This confirmation is valid because previous researchers (Hammond *et al.*, 1989a; 1989b; Pratchett *et al.*, 1991) have reported that the bacteria are easily spread (via animal-to-animal transfer) among animals grazed together in close proximity.

The presence of *S. jonesii* bacteria in the goats on LGP demonstrates that the poor reproductive performance (i.e. poor conception and high pre-weaning kid mortality rate) associated with the goats on LGP were not due to the absence of the bacteria in their rumen. Since the *S. jonesii* bacteria are easily spread among animals kept in close proximity, the detection of the bacteria in the rumen of the LGP goat indicates the presence of the bacteria in the rumen of other LGP goats used for the entire study.

Although previous workers (Hammond *et al.*, 1989a; 1989b; Pratchett *et al.*, 1991) reported that *S. jonesii* bacteria easily spread among animals grazed in close proximity, the bacteria were not detected in the rumen samples of NP goat used in the *S. jonesii* detection study, despite the goat close contact with the LGP goats during weighing and other occasional management practices such as medication, dipping, deworming, etc. The absence of the bacteria in the NP goat, indicates that *Leucaena* forage has to be a component of goat diet for the bacteria transferred to survive and thrive (Hammond, 1995).

Hammond (1989a), reported that prolonged absence of *Leucaena* from the diet of ruminants possessing *S. jonesii* bacteria results in dwindling of the bacteria population in the rumen. Frost and cold temperatures during winter adversely affect *Leucaena* species at the location of the study (Isarasenee *et al.*, 1984; Jurado et al., 1998; Akingbade *et al.*, 2001b). There is usually a gradual reduction in the quantity of *Leucaena* foliage available on *Leucaena* plant with the advent of frost and winter (month of May).

By mid-winter (Middle of July) there is virtually no foliage on the standing *Leucaena* plants at the location of the study (Akingbade *et al.*, 2001b). However, cv. Cunningham recovers from winter stress faster than cv. Spectra, and as from the month of October, cv. Cunningham is usually available for browsing. Based on cv. Cunningham faster recovery after winter at the site, and the need for *Leucaena* forage to be a constituent of the diet for sustaining adequate rumen population of *S. jonesii* bacteria (Hammond, 1995), cv. Cunningham is better suited as a feed resource than cv. Spectra.

10.1.3 **The effect of *Leucaena leucocephala* on semen quality and fertility**

Low reproduction rate is the most important constraint to goat production in the tropics (Chifamba *et al.*, 1995). Successful conception depends on both male and female fertility. Semen quality improved over the entire period of feeding SAING bucks on *Leucaena leucocephala* forage in this study (Akingbade *et al.*, in press a). This improvement can be ascribed to the high protein content of *Leucaena* forage in line with the report by Rekwot *et al.* (1988 that protein content influences semen quality. However, the improvement in the semen quality obtained in this study contradicts the findings of Lohan *et al.* (1988). They (Lohan *et al.*, 1988) reported that feeding *Leucaena* forage was detrimental to the semen quality in bulls. The absence of any detrimental effects and improvement in the semen quality and fertility of SAING bucks maintained on *leucocephala* foliage in this study can be attributed to the presence of *S. jonesii* bacteria in the rumen of the bucks.

The higher conception rate, reproductive output and higher incidence of multiple births on LGP treatment relative to those on NP treatment indicate the greater potential of LGP over NP as a forage for enhancing reproduction and productivity. The reproductive performance of LGP goats relative to that of NP goats demonstrates that available nutrition at conception to both genders influences reproductive output. This is in harmony with the report by Rodriguez *et al.* (1998) that incorporating leguminous browse complementary to grass species improves male fertility and female fecundity through improved nutrition.

The better semen quality of bucks fed *Leucaena* foliage and appreciable conception rate among does serviced by these bucks, compared to bucks maintained on a concentrate diet, showed that the poor conception previously recorded on the LGP treatment (Morris and Du Toit, unpublished) that necessitated this study, was not due to the detrimental effects of *Leucaena* component of LGP on semen quality and fertility of SAING bucks that were used for mating the SAING does (Akingbade *et al.*, in press a).

10.1.4 **Foraging activities and blood profiles of pregnant SAING during the 2nd and 3rd trimesters of pregnancy**

Pregnant goats on NP treatment spent more time grazing than browsing, while those on the LGP treatment spent more time browsing than grazing. This difference in time spent on these two activities can be attributed to the influence of height of grazing strata (Orihuela and Solano, 1999). Most leguminous trees and shrubs on the NP treatment were tall (> 1.5 m; Figure 10.1) with their foliage and succulent twigs beyond the reach of the goats assigned the treatment (Akingbade *et al.* 2002). Therefore, the marked difference in the time spent grazing and browsing on both treatments was an indication that accessibility to available forage can influence the time field goats allot to grazing and browsing activities.

The higher time spent browsing, relative to grazing, by the pregnant goats on LGP plot despite their easy reach (accessibility) to both grass and *Leucaena* species on the plot is consistent with the findings of other workers (Poppi and Norton, 1995; Erasmus and Fahmy, 2000) that goats are predominantly browsers. This browsing preference of goats has resulted in their beneficial use as a biological control tool in preventing bush encroachment (Huston, 1998; Greyling, 2000).

Wolf *et al.* (1972), reported that blood albumin concentration increases with an increase in dietary protein content. The higher serum albumin content of pregnant goats on LGP treatment, relative to that on NP, can be attributed to the higher protein content of available and accessible forage species on LGP treatment compared to the NP treatment. This is revealed in the proximate composition and mineral contents of the forage species on both treatments (Chapters 3, 4, 5, 7 and 8; Akingbade *et al.*, 2001a; 2002). However, there were no visible symptoms of protein and mineral deficiencies among pregnant goats on both treatments.

The absence of mineral deficiency symptoms among pregnant goats on both treatments can be attributed to the values of most of their haematological parameters falling within the values reported by Puls (1994) for goats in the tropics and subtropics. The results from this study reveal that the feeding of LGP as a gestation diet to the SAING had no detrimental effect on the packed cell volume, blood mineral elements and protein metabolites status of the goats.

Mimosine is an antinutrient in *Leucaena* species that can chelate mineral elements (Girdhar *et al.*, 1991) and causes mineral deficiencies (Sethi and Kulkarni, 1995). The values of haematological parameters in pregnant goats (Akingbade *et al.*, 2002) and kids (Chapter 7; Akingbade *et al.*, in press b) maintained on LGP throughout the study were within the range of values reported by Puls (1994) for goats in the tropics and subtropics. The absence of any external symptoms of mimosine toxicity and mineral elements/nutrient deficiency among goats and kids maintained on LGP could be attributed to the presence of *S. jonesii* bacteria in their rumen (Akingbade *et al.*, 2002; in press b).

The results from this study indicate that the poor conception associated with the LGP treatment which necessitated this research was not due to the deficiencies of blood mineral elements and protein metabolites that are associated with enhancing conception. The values of most haematological constituents of the pregnant goats on the LGP treatment fall within values reported for goats in the tropics and sub-tropics. This indicates that there was no chelating tendency of mimosine and its metabolites on the blood mineral elements and protein metabolites (Akingbade *et al.*, 2001a; 2002).

10.1.5 **Conception, prolificacy and kidding rate of SAING**

A summary of reproductive performance over the entire study is presented in Table 10.1. Similar to the report of Engeland *et al.* (1997), still births on both treatments were from multiple or twin birth types. Mimosine contained in the *Leucaena* species has been reported to cause poor conception (Holmes *et al.*, 1981), decrease and increase calving rate and incidence of still birth, respectively, in cows lacking *S. jonesii* bacteria (Jones *et al.*, 1976 and 1989). Differences in conception rate, prolificacy, kidding rate and still births recorded on LGP and NP treatments in this study were not significant (Table 10.2). The marginally higher conception rate, prolificacy and kidding rate on LGP treatment relative to NP treatment could be attributed to the higher nutritive value of the forage resource on LGP plot and the presence of *S. jonesii* bacteria in the rumen of LGP goats. The *S. jonesii* bacteria seemed to have assisted in overcoming the negative effect of *Leucaena* component of the LGP.

The foliage of *Leucaena* species is high in protein content (Machado *et al.*, 1978). The CP content of the two cultivars at the location of the study ranged between 18.1 and 32.1% (Akingbade *et al.*, 2001b). The marginally higher prolificacy and kidding rate recorded on LGP, compared to values for NP treatment, can be attributed to the high protein content of the *Leucaena* component of LGP. This is in harmony with the previous reports (Wheeler and Land, 1977; Rattray, 1986; Isaacs *et al.*, 1991; Rhind, 1992) that a high protein diet increases ovulation rate and incidence of twin and multiple birth (≥ 3 kids) types.

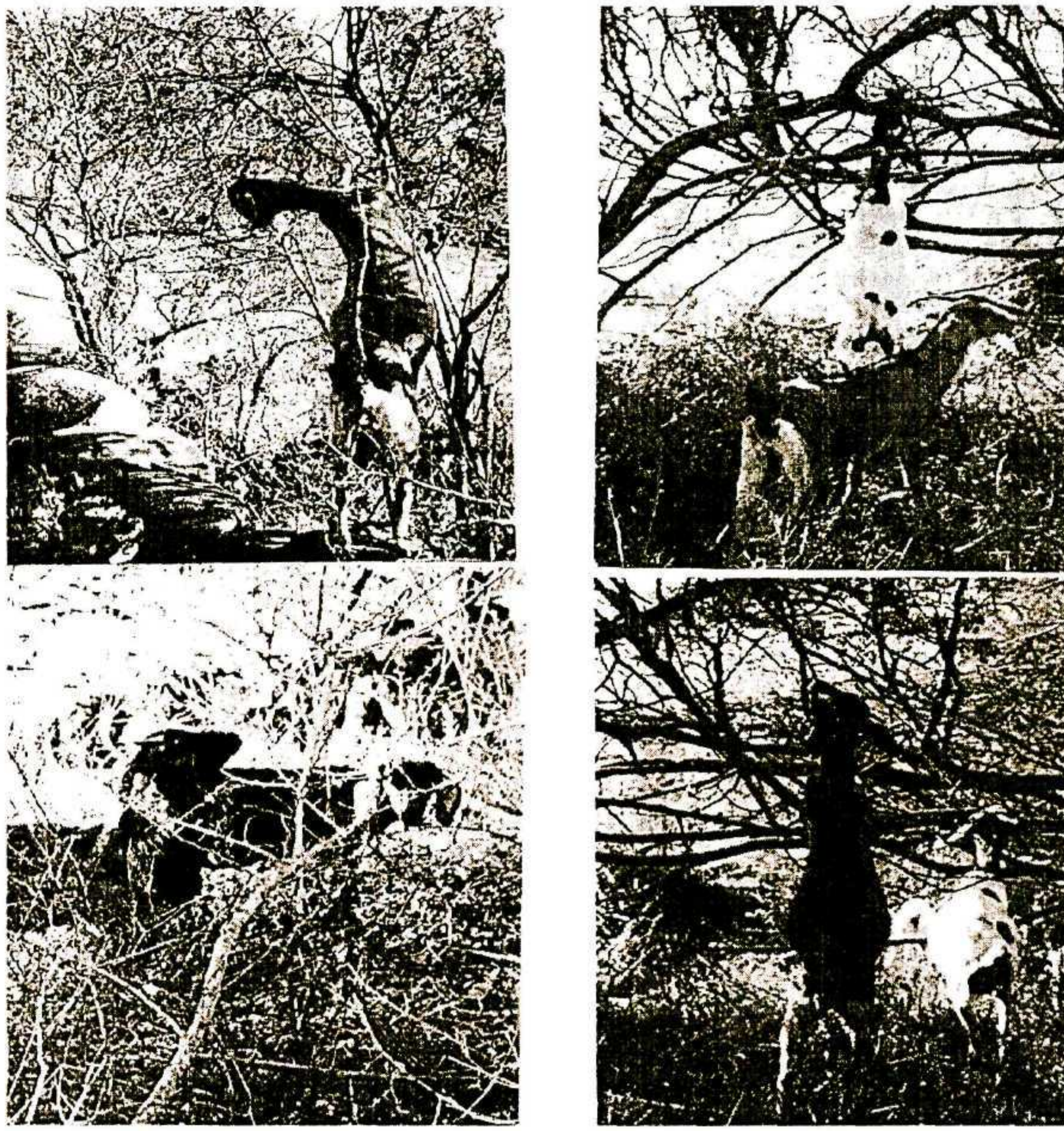


Figure 10.1 South African indigenous *Nguni* goats on natural pasture plot characterised by tall trees and shrubs (> 1.5 m) beyond the easy reach of the goats for browsing

The fact that conception rate on LGP treatment compared favourably with that on NP was an indication that, *Leucaena* component of LGP was not responsible for the poor conception recorded among SAING on LGP (Morris and Du Toit, unpublished) that necessitated this study.

Conception among goats on the NP plot over the entire study compared favourably with those of LGP goats, despite the poor nutritive value of the accessible forage on the plot. This indicates the resilience of SAING breed to nutritional stress in their indigenous environment. A similar adaptation was also reported in Matabele goats in Zimbabwe, where Sibanda *et al.* (1999) argued that the adaption of Matabele goats to nutritional constraints was responsible for their survival in the semi-arid regions.

Conception and pre-weaning kid mortality rates were low and high, respectively (Table 10.1), on both treatments in years with high precipitation (rainfall). The trend agrees with the findings in Angora goats (Van der Westhuysen, 1980) and Boer goats (Morris and du Toit, 1998) at the location of this study. Years of high rainfall are associated with maximum growth of vegetation, which serves as adequate cover for parasites (Morris and Du Toit, 1998). High precipitation is also associated with high parasitic infestation (Arthur and Ahunu, 1992; Kusina *et al.*, 1999). Parasite causes anaemia, lower conception rates and reproductive performance in goats (Saad, 1977; Howlader *et al.*, 1996); this could explain the poor conception rates and high pre-weaning kid mortalities in years with high rainfall (Akingbade *et al.*, 2001a).

However, in Year 1 of the study only does and kids on LGP treatment were affected and not those on NP treatment, this is difficult to explain. In Year 4 only does and kids on NP treatment were affected and not those on LGP treatment. This can be attributed to the bushy nature of the vegetation on natural pasture with abundant browse species that served as cover for parasites compared to *Leucaena* as the only browse species on the LGP treatment.

Table 10.1. Reproduction performance of South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) over a four year period

Years	Total annual rainfall (mm)	Treatments	Conception rate (%)	Prolificacy (%)	Kidding rate (%)	No. of live kids at birth	Still births (%)	Pre-weaning kid mortality (%)
Year 1	748.5	LGP	60	167	107	15	6.2	46.7
Year 1	748.5	NP	73.3	182	133	20	0	5
Year 2	543	LGP	75	188	125	15	6.2	13.3
Year 2	543	NP	100	192	192	23	4.2	4.3
Year 3	785	LGP	64	150	112	24	1.4	25
Year 3	785	NP	28	129	56	9	35.7	55.6
Year 4	581.5	LGP	89.5	194	179	33	2.9	3
Year 4	581.5	NP	78.9	140	111	21	0	4.8

LGP = *Leucaena leucocephala*-grass pasture treatment; NP = natural pasture treatment.

10.1.6 **Live weight performance, foetal development and kid birth weights of SAING**

Means of gestation weight gains, foetal development and kidding weights of SAING does (Akingbade *et al.*, 2001a) and averages of birth weights and pre-weaning weight gains of SAING kids (Akingbade *et al.*, 2001a; in press b) maintained on LGP were significantly higher than their respective counterparts on NP.

Table 10.2. Mean conception rate, prolificacy, kidding rate, still birth and pre-weaning kid mortality of South African indigenous *Nguni* goats grazed on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) over a four year period

Reproductive parameters (%)	**LGP**	**NP**	**Chi-square (χ^2)**
Conception rate	70.2	70	0.63
Prolificacy	175	160.8	0.09
Kidding rate	130.8	123	0.51
Still births	5.7	6.8	1.11

Differences between means were not significant ($p > 0.05$).

The performance of SAING does and kids on LGP plot confirms the better nutritive quality of LGP as reflected in the proximate and mineral chemical composition of forage on both treatments throughout the study (Akingbade *et al.*, 2001a and 2002; in press b). This agrees with reports that legume-grass mixture improves live weight gains (Hernandez *et al.*, 1986; Bonsi *et al.*, 1994; 1995; Morris and Du Toit, 1998; Tudsri *et al.*, 1998). Intake of forage high in protein content improves rumen environment and increase microbial synthesis, (Bonsi and Osuji, 1997), nitrogen retention, feed intake, and growth performance (Bonsi *et al.*, 1994 and 1995; Kaitho *et al.*, 1998).

The problem of accessibility to available forage species on NP treatment which probably limited intake was responsible for the lower live weight gains of goats (does and kids) on the treatment throughout the study (Chapters 5, 7 and 8; Akingbade *et al.*, 2001a; 2002; in press b). The is in harmony with the report by Mc Donald *et al.* (1990). They claimed that voluntary feed intake influences growth performance.

Masika *et al.* (1998) also claimed that walking during foraging drains energy reserves, while (Sharma *et al.* (1998) reported that energy expended by goats on walking during foraging accounts for a substantial part of the goats' total energy requirements. Goats are known to prefer browse to grass (AFRC, 1998; Huston, 1998) when accessibility to both species is not the constraining factor. However, the problem of inaccessible browse species on NP plot revealed during field observation may have necessitated more walking in search of forage resource. This probably resulted in greater energy expenditure by the goats maintained on NP. The low live weight gain of the pregnant SAING goats (Chapters 5 and 7; Akingbade *et al.*, 2001a) and kids (Chapter 8; Akingbade *et al.*, in press b) on NP treatment can therefore be partly attributed to the energy expended on walking in search of accessible forage resource.

10.1.7 Colostrum and milk constituents of dams, pre-weaning kid growth and mortality rates in SAING

Milk yield of SAING maintained on LGP during gestation was higher than that of their counterparts on the NP, despite feeding of the same diets during lactation (Chapters 6 and 7; Akingbade *et al.*, 2000). This corroborates the findings of Kassem (1988) that nutrition during gestation influences milk production. Other studies (Saucedo *et al.*, 1980; Maasdorp *et al.*, 1999) also demonstrated that maintaining cows on *Leucaena* forage increased milk yield than on grass species. The higher milk yield of does on LGP treatment, relative to NP does can be attributed to the higher gestation weight gains of LGP goats (Akingbade *et al.*, 2001a). The better weight gains of LGP goats could have increased the goats' body reserves, which were eventually mobilised for milk production during lactation (Spedding, 1962; Mukasa-Mugerwa *et al.*, 1997).

Pre-weaning growth performance of kids of does maintained on LGP during gestation, was significantly ($p < 0.05$) higher than their counterparts born to does that were maintained on NP during gestation, despite feeding of the same lactation diet (Chapters 6 and 7; Akingbade *et al.*, 2000). The better growth performance of LGP kids can be attributed to the higher milk yield of their dams compared to milk yield of NP dams. This concurs with the reports of other researchers (Gibb and Treacher, 1980; Mbayahaga *et al.*, 1994) who claimed that, the differences in growth rates amongst pre-weaned offsprings reflect varying milk yield of dams and milk intake of offsprings.

The higher values of protein and fat contents of colostrum observed in this study were higher than those of normal milk (Protein: 3.83%, 4.46%, 5%; Fat: 6.8%, 5%) (Chapter 7; Akingbade *et al.*, in press c) and these observations are in line with the findings of earlier workers in cow, sheep and other goat breeds (Treacher, 1970; Migdal and Kaczmarczyk, 1992; Akingbade *et al.*, in press c). However, there are many contradictory reports on the effects of diet on milk composition. Some workers claimed that diets influence milk constituents (Pond and Wallace, 1988; Bass, 1989; Economides *et al.*, 1989), while others reported no effect (Mayes and Colgrove, 1983; Florris *et al.*, 1988; Pailan and Kaur, 1996). The difference in results could be ascribed to the various factors involved and interactions between factors responsible for changes in milk constituents. In this study, colostrum constituents, milk fat, ash and energy contents were independent of dietary treatments, while milk solids, solids-not-fat, protein and lactose contents were influenced by the lactation diets.

Over the entire study, total pre-weaning kid mortality on LGP treatment was higher ($p > 0.05$) than on NP treatment (Table 10.1). Starvation has been one of the main factors implicated in pre-weaning lamb losses (Hinch *et al.*, 1986). Colostrum serves as the first source of nourishment for newly born kids and provides immunity against opportunistic infections (Khalaf *et al.*, 1979).

The viscosity of colostrum influences its flow from the udder during suckling (Lan *et al.*, 2000). Colostrum from goats browsing on pastures contains a certain factor that increases viscosity (Gatenby, 1986; Klobasa, 1988; Merin, 2000); this explains the thicker colostrum of LGP goats reported in previous study (Chapter 5; Akingbade *et al.*, 2001a). The highly viscous colostrum on LGP treatment could have impeded the suckling by the kids, similar to that reported in lambs by Holst *et al.* (1996). This phenomena seem to explain the high pre-weaning kid mortality recorded on LGP treatment in previous study (Table 10.1; Chapter 5; Akingbade *et al.*, 2001a).

Ambient temperature at kidding could also have influenced pre-weaning kid survival on both treatments during the study. During the entire study, kidding and lactation took place in winter season, and newborn kids are known to be susceptible to cold stress (Mellado *et al.*, 2000). Therefore, the pre-weaning kid death may be cold related. Apart from increasing death from cold stress, Thompson (1983) also reported that a low ambient temperature reduces milk yield. The effect of cold temperatures during winter on milk yield probably subjected the kids to starvation death from low milk yield consumption that resulted from low milk yield of dams. The inadequate milk yield of dams and milk consumption of kids may have aggravated the effects of cold stress on pre-weaning kid survival.

The high incidence of multiple births on LGP was due to the high protein content of forage on LGP treatment, in line with reports of other workers that high protein diet increases ovulation

(Wheeler and Land, 1977; Machado *et al.*, 1978; Rattray, 1986; Isaacs *et al.*, 1991; Rhind, 1992). Over the entire study, LGP treatment recorded a higher number of multiple births than NP treatment, and most pre-weaning kid mortalities on both treatments were from twin and multiple birth types (≥ 3 kids). Therefore, it is also possible that LGP kids experienced a higher pre-weaning death than their counterparts on the NP treatment because of the significant ($p < 0.05$) difference in birth types on both treatments (Table 10.3).

Multiple and twin birth types are associated with delayed lactogenesis, lighter kids and weaker kids at birth, when compared to singletons (McCance and Alexander, 1959; Smith, 1977). Weak or light kids are more susceptible to cold stress than heavier kids in single litters (Rattray, 1992) and also lack the ability to effectively suckle enough colostrum. The cold stress and inadequate strength of kids to suckle enough colostrum may have exposed the kids in such birth types to pre-weaning death (Mellor and Murray, 1985) from starvation and opportunistic infections (Khalaf *et al.*, 1979). Reports of Ehoche and Buvanendran (1983) and Malik *et al.* (1998) did show that poor maternal supply of colostrum or milk and inadequate consumption of colostrum or milk by weak kids were responsible for the high pre-weaning kid mortality rate in twin and multiple birth types.

An inadequate number of functional teats to match the number of kids in multiple litters is another cause of pre-weaning kid death from starvation (Erasmus *et al.*, 1985). Though some workers acknowledged (Raats *et al.* 1983) that milk yield increases with increased litter size, report by El-Feel *et al.* (1998) revealed that the additional milk produced in response to the increased litter size was inadequate for the needs of all the kids in large litters. Donald and Purser (1956) attributed the short-fall in milk yield of dams nursing larger litter size (> 2 kids) to the drainage of maternal resources by the foetuses in such litters during gestation.

Lactations occurred during winter season, which is characterised by inadequate quality and quantity of grass species (Zacharias, 1990; Akingbade *et al.*, 2001b), most leguminous browse loose most of their leaves (Kirkman, 1988) and Leucaena on the LGP plot are unavailable as from mid winter (Akingbade *et al.*, 2001b). The nutritional constraint is known to reduce milk yield (Adu *et al.*, 1979; Thompson, 1983). The high pre-weaning kid mortality rate recorded on LGP can be attributed to the adverse effects of the nutritional constraint during winter season on milk yield of the lactating does. The kids on the LGP treatment were more affected than their counterparts on the NP treatment either because of the total absence of the *Leucaena* component of the LGP during winter (Chapter 2; Akingbade *et al.*, 2001b) or possibly because of the higher proportion of multiple birth type on the LGP treatment (Table 10.3).

Similar to the report by Tegegne *et al.* (1992) in small East African Zebu cows, pre-weaning kid mortalities on LGP and NP treatments were markedly reduced during studies (Chapters 6 and 7) in which the lactating does were offered concentrates. Pre-weaning deaths were also stemmed when the following kidding management practices were implemented (Chapter 7):

i. Immediate transfer of dams and kids to a warm environment to alleviate the effect of cold stress on the newborn;

ii. Restraining dams and aiding weak and light kids in multiple and twin litters to suckle colostrum or normal milk directly from the dams or from dams nursing single litters having excess milk;

iii. Feeding of lactating dams solely on a high concentrate diet (20.5% CP) during the first seven days of kidding;

iv, Supplementary feeding of lactating dams on a high concentrate diet (20.5% CP) as a supplementary diet, throughout the 10 weeks of lactation.

The kidding management practices could be said to have reduced: cold stress, starvation and dam rejection (Chapter 7). The supplementary concentrate diet enhanced milk yield of does resulting in more milk available to the kids and accounted for the high pre-weaning kid survival in the study reported in Chapter 7. This is consistent with the report that adequate level of nutrition during lactation increased milk production and survival of offspring (Penning *et al.*, 1988; Sheehan and Hanrahan, 1989).

These results also confirm the findings of Manjeli *et al.* (1996) that mortality can be fully controlled, if proper management practices are put in place. It can therefore be deduced from the results that the previous higher pre-weaning kid mortalities on LGP treatment in previous studies (Chapters 5 and 7; Akingbade *et al.*, 2001a) were due to inadequate nutrition to lactating does and inadequate kidding management practices.

Table 10.3 Birth type proportion (%) of South African indigenous *Nguni* goats maintained on *Leucaena leucocephala*-grass (LGP) and natural pastures (NP) during gestation over a four year period

	LGP	**NP**	**Chi-square**
Single	36	31.1	
Twin	42	64.4	
Multiple ($\geq$ 3 kids)	22	4.4	
Total number of kids	50	45	7.77 ($p < 0.001$)

10.1.8 **Post-kidding reproductive performances of does**

Late gestation is known to be associated with increased outflow rate of rumen digesta (Graham and Williams, 1962 cited by Sibanda, 1984; Weston *et al.*, 1988a, 1988b). There is therefore a likelihood that some mimosine and its metabolites might escape degradation and detoxification by *S. jonesii* bacteria in the rumen of pregnant SAING maintained on LGP during gestation. The escaped mimosine and its metabolites can then manifest its adverse effects on post kidding traits.

However, SAING on LGP during gestation had higher milk yield, returned to first postpartum oestrus earlier, and their kids gained more live weight during pre-weaning period than on values obtained on the NP treatment (Chapters 6 and 7; Akingbade *et al.*, 2000). These good attributes were indications that the quantities of mimosine that escaped rumen degradation and detoxification during gestation were insufficient to cause any detrimental carry-over effect on post-kidding reproductive performance of pregnant SAING maintained on LGP (Chapter 6; Akingbade *et al.*, 2000). The results could be attributed to the presence of *S. jonesii* bacteria in the rumen of LGP goats.

Nutrition during lactation was found to influence return to first postpartum oestrus in this study (Chapters 6 and 7; Akingbade *et al.*, 2000). This is in agreement with the findings of other workers (Peters, 1984; Folch *et al.*, 1988; Dunn and Moss, 1992; Robinson, 1996; Eloy *et al.*, 1999) that nutritional constraints delay return to post partum oestrus. The quick return to first postpartum anoestrus during lactation in years when concentrates were fed (Chapters 6 and 7; Akingbade *et al.*, 2000) agrees with the reports of Eduvie (1985), who claimed that feeding of concentrates during lactation shortens postpartum anoestrus period.

10.1.9 **Blood profiles and Dams-to-kids transfer of *Synergistes jonesii* bacteria**

Blood albumin concentration has been used to determine blood protein status (Cronje and Gollah, 1996). The low blood albumin levels of NP kids was an indication of the low protein content of accessible forage species on NP plot (Chapter 8; Akingbade *et al*., 2002; in press b). This is corroborated by the low CP content of accessible forage resource on the NP treatment (Chapters 4, 5, 6 and 7; Akingbade *et al.*, 2001a; 2002; in press b). Blood albumin concentration of kids in this study increased with an increased dietary protein, similar to that reported by Wolf et al. (1972), while blood globulin concentration increases with age of kids as reported by Rowlands and Manston (1976).

Foliage of *Leucaena* species are rich in protein (Machado *et al.*, 1978; Akingbade *et al.*, 2001b). Forage intake is reflected in blood concentrations of protein metabolites, notably albumin and globulin of LGP kids (Manston *et al.*, 1975). The higher concentration of blood protein in LGP kids, relative to their counterparts on the NP treatment was expected as the proximate and mineral composition of accessible forage resources on LGP were better (e.g. high CP content) than values obtained for forage resource on NP. However, despite the low blood albumin and globulin concentrations in NP kids, the kids did not show any visible protein metabolites deficiency symptoms. The absence of symptoms was an indication that the concentrations of the NP kids protein metabolites were still above a critical level or it may be due to the short duration of the study which was not long enough for the adverse effects of the inadequate nutrition to manifest (Chapter 8; Akingbade *et al.*, in press b).

The kids also showed no symptoms of mineral deficiency or mimosine toxicity; this can be attributed to the presence of *S. jonesii* bacteria in the dams. The bacteria which are known to assist in overcoming the adverse effects of mimosine contained in *Leucaena* species (Jones and Megarrity, 1986; Hammond *et al.*, 1989b; Morris and Du Toit, 1998; Akingbade *et al.*, 2000;

2001a; 2002). The bacteria have also been reported to be easily transferred via animal-to-animal transfer (Hammond 1995). Exposing un-weaned kids of dams possessing *S. jonesii* bacteria to a diet high in *Leucaena* was safe as long as they are grazed in the company of adults possessing the bacteria.

10.1.10 **Growth performance, blood profiles, protein and energy requirements of weaned *Nguni* kids**

Early weaning of kids on a concentrate diet during winter season allows dams the adequate time for recovery from lactation stress. Early weaning also enhances the use of few available feed resource in winter for preparing dams for the next breeding season (Ayantunde *et al.*, 2000). However, selective feeding of goats on concentrates always results in mineral imbalance (Schultz *et al.*, 1988; Huston, 1998). This explains the high blood phosphorous that results in phosphatic urinary calculi recorded in this study (Chapter 8). However, there was no incidence of urinary calculi on Diet 3 (17.5%CP), in spite of the diet mineral composition showing higher phosphorous content than those of Diets 1 and 2. The absence of any urinary calculi in kids on Diet 3 was probably due to the individual differences in the selectivity or differences in the levels of phosphorous tolerance.

The financial implication of loss of goats to death from urinary calculi and the feed wastage from their selective habit, emphasises the need to develop a feeding strategy that will make it more difficult for goats to carry out feed selection (sorting). This strategy can be in the form of processing concentrates into a pellet form.

Intake of concentrate diet increases with an increase protein content in line with the report by Bonsi and Osuji (1997). The higher weekly weight gains of kids on Diets 3 and 4 (20.5%CP) relative to Diets 1 (13%CP) and 2 (15%CP), agrees with the findings of McDonald *et al.* (1990).

They claimed that feed intake influences growth performance. The apparent decreased dry matter digestibility that accompanied the increased feed intake is consistent with the findings of other workers (Pond *et al.*, 1980; Owen and Goetsch, 1986; Murphy *et al.*, 1994; Woods *et al.*, 1999; Mulligan *et al.*, 2001). They attributed the trend to an increased rumen outflow rate and reduced residence time.

The poor growth performance of kids on Diet 4, despite the diet having a high protein content, was an indication of a protein waste in the form of ammonia nitrogen. The protein waste was reflected in the high quantities of excreted urinary products (total nitrogen excretion, allantoin and purine derivatives). Contrary to other reports (Owens and Goetsch, 1986; Nsahlai *et al.*, 2000b), Diet 1 with the lowest protein content had the highest microbial nitrogen supply compared to other diets. The difference between reports was difficult to explain.

The choice of concentrate diet to feed to early weaned SAING kids depends on efficiency of protein utilisation for growth. Diet 2 had a marginally higher protein utilisation efficiency than Diet 4 (20.5%CP), but growth performance of kids on Diet 4 was marginally better than that on Diet 2 (15%CP). Diet 3 was found to be marginally better than Diet 4 in terms of growth performance (live weight and heart girth), protein and feed efficiencies. Based on body weight and heart girth gain of the kids on all dietary treatments, diet containing 15% - 17.5% CP appears to be suitable for weaning 70 day old SAING kids.

The energy requirements for maintenance and gains of early weaned kids in this study were slightly higher than the values recommended by the AFRC (1998). The difference may due to the age and breed difference between studies or effect of season (winter) during which the study was conducted.

Nutrition influences blood chemistry (Rowlands and Manston, 1976). The high values of PCV recorded for kids on Diet 1 agrees with the findings that low protein diets are associated with high packed cell volume (Martin *et al.*, 1969 as cited by Miller *et al.* (1969). The high PCV in the blood of kids on Diet 1 confirms the low protein content of the diet revealed in the diet proximate and mineral composition. However, the kids failed to display any protein deficiency symptoms. The absence of protein deficiency symptoms either indicates that the blood protein metabolites were still above critical levels below which deficiency symptoms would manifest or it signifies the resilience nature of indigenous breeds to nutritional constraints. The short duration of the study may also have been responsible for the non-manifestation of protein deficiency symptoms.

10.2 **Summary**

Cultivar Cunningham was better suited for the location of the study than cv. Spectra as it was available during the 10 months of the year, compared to 6 months for cv. Spectra. South African indigenous *Nguni* goats on NP lacked *S. jonesii* bacteria in their rumen, while those on LGP possessed the bacteria. The absence of the bacteria in the NP goat was an indication that *Leucaena* has to be a component of the diet for the bacteria to survive.

Growth performance of adults and kids of SAING on LGP was better than on NP. Further, the reproductive performance and overall productivity of SAING on LGP were higher than on NP. Over the entire study, conception on LGP treatment was marginally better that on NP. Feeding *Leucaena* foliage to SAING bucks did not have any detrimental effect on semen quality and fertility, instead the foliage was found to improve semen quality and fertility.

Maintaining pregnant SAING does possessing *S. jonesii* bacteria on LGP during gestation had no adverse effect on the does' pre- and postpartum reproductive performance, but beneficial effects were recorded during gestation and lactation. Gestation period benefits of feeding LGP include gestation weight gain, kidding weight, high birth weight of kids and high incidence of twin multiple births, while high milk yield, early return to postpartum oestrus and better pre-weaning growth of the kids were the benefits of feeding LGP during lactation period.

The concentration of blood minerals and protein metabolites of SAING (adults and kids) on LGP plot were within the normal physiological range for goats in the tropics and sub-tropics. There were also no visible signs of mineral deficiency or mimosine toxicity symptoms in the goats maintained on LGP. This confirms the ability of the *S. jonesii* bacteria to overcome mineral-chelating tendency of mimosine and its metabolites. It also implies that SAING kids of dams possessing *S. jonesii* bacteria were able to acquire the bacteria from the dams. Early weaned SAING kids can be weaned on a concentrate diet containing CP content ranging between 15% and 17.5%. Their metabolisable energy requirements of early weaned SAING kids for gain (ME*g*) and maintenance (MEm) were found to be 19.7 kJ/g ADG and 0.538 MJ/kg $W^{0.75}$, respectively.

10.3 **Conclusions**

The findings from the study revealed that *Leucaena* component of the LGP had no detrimental effect on conception and pre-weaning survival of SAING does and kids, respectively. The results also showed that overall productivity and reproductive performance of SAING maintained on LGP were higher than on NP. The fact that high pre-weaning survival rate was attained in years when adequate nutrition was fed to lactating does and when better kidding management practices were implemented suggest that nutrition and appropriate management practice are indispensable for improving the reproductive performance and overall productivity of South African indigenous *Nguni* goats on *Leucaena leucocephala*-grass pasture.

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