CHAPTER 3

FACTORS AFFECTING THE FEEDING BEHAVIOUR OF FREE RANGING TSWANA AND BOER GOATS

3.1. Introduction

The goat's ability to utilize sparse vegetation and survive in stressful nutritional environments better than other ruminant species (Silanikove, 2000; Lachica & Aguilera, 2003; Iniguez, 2004) makes this species an appropriate candidate as a food producing animal in arid environments (Mellado *et al*., 2004). Goats have certain physical characteristics such as narrow muzzle, mobile upper lip, prehensile tongue, bipedal stance, agility in climbing and physical dexterity that provide them with necessary foraging skills to select preferred plant species (Taylor & Kothman, 1990; Ngwa *et al*., 2000; Mellado *et al*., 2004) and adapt to different food resources according to its availability (Orihuela & Solano, 1999).

Goats are mainly raised in rangelands in semi-deserts and sub-tropic conditions (Devendra, 1990; Keskin *et al*., 2005; Tefera *et al*., 2008: Salem *et al*., 2010). Conditions in the rangelands, such as heterogeneity, as well as the seasonal changes of potential feeds and nutritional restrictions, induce range ruminants to exhibit strong food selectivity in order to meet the demands for maintenance and production (Senft *et al*., 1987; Agreil & Meuret, 2004; Morand-Fehr *et al*., 2004). The effect of selection by these grazing herbivores changes the species of plants found in various populations, but the mechanism underlying feeding behaviour and diet selection by goats remains poorly understood (Illius *et al.*, 1999). Interaction between goat choice rules and plant characteristics trigger consistent and dynamic behavioural adjustments (Agreil & Meuret, 2004). Understanding feeding behaviour and diet selection by ruminants is imperative for efficient rangeland management as well as profitable animal production from rangelands because these parameters affect animal performance and hence production (Ungar, 1996; Torrano & Valderrábano, 2005; Sanon *et al*., 2007).

To achieve acceptable levels of goat performance which are compatible with resource preservation, a deep understanding of feeding behaviour and diet selection is needed (Sanon *et*

al., 2007). Efficient utilization of available resources also requires information on plant density, forage species and phytomass at any specific site to define its carrying capacity and strategies of feed supplementation according to desired level of production (Lachica & Aguilera, 2003; Yayota *et al*., 2009).

The objective of the study was to determine how the season, time of the day and period of occupation of a camp influence the feeding behaviour and plant species selection of Tswana and Boer goats.

3.2. Materials and Methods

3.2.1. Study site

The research was conducted at the University of Fort Hare Research Farm near Alice, in the Eastern Cape Province of South Africa ($32^0$49'S, $26^0$54'E). The research farm is situated 80km inland from the Eastern Cape coastline at an altitude of 500-600 m above sea level. This project was part of a collaborative study between the Department of Anatomy and Physiology, University of Pretoria and the Department of Livestock and Pasture Science, University of Fort Hare. All procedures used in experiments received prior approval from the University of Pretoria research committee.

3.2.2. Vegetation

The vegetation is representative of Acocks (1975) "False Thornveld of the Eastern Cape" and ranges from grassland through *Acacia karroo* Savannah to dense, clumped, medium short evergreen thicket. The Savannah consists of subtropical thicket vegetation, mainly dominated by deciduous woody shrubs shorter than 1.5m, although the woody layer reaches 4 to 5m (Scogings *et al*., 1996).

Prior to the start of the experiment in each season (cold-dry season and hot-wet season), a botanical survey was done for each plot according to the method described by Trollope (1986).

In addition, a disc pasture meter (Bransby & Tainton, 1977) was used to estimate the phytomass of grass at the beginning and end of the experiments as shown in Tables 3.1, 3.2, 3.3 and 3.4.

Table 3.1. Veld condition assessment score - Grass component (points 10000 m^2)

GRASS SPECIES	COLD-DRY SEASON	HOT-WET SEASON
	%	%
DECREASERS		
Panicum maximum	5	
Panicum stapfianum		1
Themeda triandra	13	41
INCREASERS		
Aristida congesta	1	
Cymbopogon plurinodis	14	12
Cynodon dactylon	5	
Digitaria eriantha	43	18
Eragrostis chloromelas	3	1
Eragrostis curvula	5	4
Forbs	2	1
Microchlora caffra	1	
Sporobolus africanus	7	5
Sporobolus fimbriatus		17
INVADERS		
Paspalum dilatatum	1	
VELD CONDITION SCORE	452 (63.3%)	676 (94.7%)
GRASS PHYTOMASS	3.6 ton/ha	3.6 ton/ha
GRAZING CAPACITY	4.7 ha/AU	3.2 ha/AU

The vegetation is dominated by four grass species: *Digitaria eriantha* (the cold-dry season 43 %; hot-wet season 18%), *Themeda triandra* (cold-dry season 13 %; the hot-wet season 41 %), *Cymbopogon plurinodis* (cold-dry season 14 %, hot-wet season 12 %) and *Sporobolus fimbriatus* (the hot-wet season 17 %; not available in the cold-dry season). Eight deciduous and semi-

deciduous tree and shrub species that are dominant are *Acacia karroo* (cold-dry season 6 %, hot-wet season 18 %), *Coddia rudis* (cold-dry season 21 %, hot-wet season, 17 %), *Maytenus heterophylla* (cold-dry season 7 %, hot-wet season 12 %), *Olea africana* (cold-dry season 5 %, hot-wet season 8 %), *Rhus refracta* (cold-dry season 7 %; not available in the hot-wet season), *Grewia occidentalis* (cold-dry season 5 %, hot-wet season 7 %), *Scutia myrtina* (cold-dry season 5 %, hot-wet season 7 %) and *Lippia javanica* (cold-dry season 31 %, hot-wet season 25 %). Veld condition assessment was 63.3 % for the cold-dry season and 94.7 % for the hot-wet season. Grass phytomass was similar for both the cold-dry season and the hot-wet season (3.6 ton/ha). Bush phytomass was 1299 TE/ha and 5272 TE/ha for the cold-dry season and the hot-wet season, respectively.

Table 3.2. Percentage available, acceptable and unacceptable bush species

BUSH SPECIES	COLD-DRY SEASON	HOT-WET SEASON
Acceptable species	**(%)**	**(%)**
Acacia karroo	6	18
Coddia rudis	21	17
Cussonia spicata	0.3	
Ehretia rigida	3	1
Grewia occidentalis	5	7
Lippia javanica	31	25
Maytenus heterophylla	7	12
Olea Africana	5	8
Rhus longispina	0.3	
Rhus undulate		1
Rhus lucida	2	1
Rhus macawana	0.3	
Rhus refracta	7	
Scutia myrtina	5	7
Unacceptable species		
Diospyros lyciodes	2	6
Lantana camara	0.3	
Leucas capensis	1	1
Lyceum ferocissimum	1	

Table 3.3. Bush component – Tree Equivalents/ha, browsing units/ha and stocking rate (ha/SSU)

	COLD-DRY SEASON	**HOT-WET SEASON**
Tree equivalent (bush phytomass) **per ha:** current	1299 TE/ha	5273 TE/ha
Browsing units **per ha:** current	1266 BU/ha	525 BU/ha
potential	1291 BU/ha	525 BU/ha
Stocking rate = browsing capacity		
ha/SSU: current	1.6 ha/SSU	3.8 ha/SSU
potential	1.6 ha/SSU	3.8 ha/SSU
ha/AU :	0.3 ha/AU	0.6 ha/AU

AU (animal unit) = a mature livestock unit weighing 450 kg (Danckwerts, 1979)
SSU (small stock unit) = one sixth of an AU
(TE) Tree equivalents = the total phytomass of bush and are expressed as the number of bushes 1.5m high.
Current browsing units = the number of acceptable and available trees and shrubs that are 1.5 m high have browse within the 0-1.5 m stratum
Potential browsing units = acceptable, available and unavailable trees and shrubs where it is assumed that the unavailable bushes are reduced in height to 1.5 m, thus causing them to coppice and shoot before making them available to goats.
Stocking rate is equivalent to the browsing capacity of bush if the utilization of grass is to be kept to a minimum.

Table 3.4. Number and percentage of available bush species that are acceptable and those that are unacceptable

BUSH SPECIES	**COLD-DRY SEASON**	**HOT-WET SEASON**
Available/acceptable		
No :	3987	3500
% :	95.0	92.1
Available/unacceptable		
No :	200	300
% :	5.0	7.9
TOTAL	4187	3800

3.2.3. Soil type

The predominant soil forms in the False Thornveld of the Eastern Cape are Glenrosa and Mispah. These have shallow top soils and hence low plant-available water storage capacities. Since most of the soils are derived from shales and sandstones of the Beaufort and Ecca series, they have high silt and fine sand contents, which result in very poor infiltration capacities thus resulting in low plant available water storage. Although low in phosphates, these soils are moderately fertile (Hensley & Laker, 1979: Teague & Walker, 1988).

3.2.4. Climate and rainfall

The mean daily temperature ranges from 18-21 ^{o}C in the hot-wet season and 10-13 ^{o}C in the cold-dry season (Teague & Walker, 1988). Mean monthly temperatures during the study year ranged from 11.5 to 22.2 ^{o}C. The mean maximum temperatures for the cold-dry season and the hot-wet season (2007) were 21 and 24 ^{o}C, respectively, while the mean minimum temperatures for the cold-dry season and the hot-wet season were 6 and 13 ^{o}C, respectively. Frost is common during July and August. Owing to the frost and low rainfall during the dry season, late cold-dry season and early spring (May-October) may be considered to be the more critical period with regard to foraging. The climate can be regarded as semi-arid with a mean annual rainfall of 574 mm and which varies between 227 mm and 967 mm. The rainfall pattern is bimodial with a distinct peak in March and a lesser one in October. The average annual rainfall during the study year (2007) was 506.4 mm. Most of the rain (79 %) fell during the seven months of the hot-wet season from October to April and the cold-dry season (21 %) was relatively dry. Climatic data were obtained from Honeydale research farm records as obtainable from the South African Weather Bureau. The rainfall and temperature patterns during the research period are shown in Fig. 3.1 and 3.2, respectively.

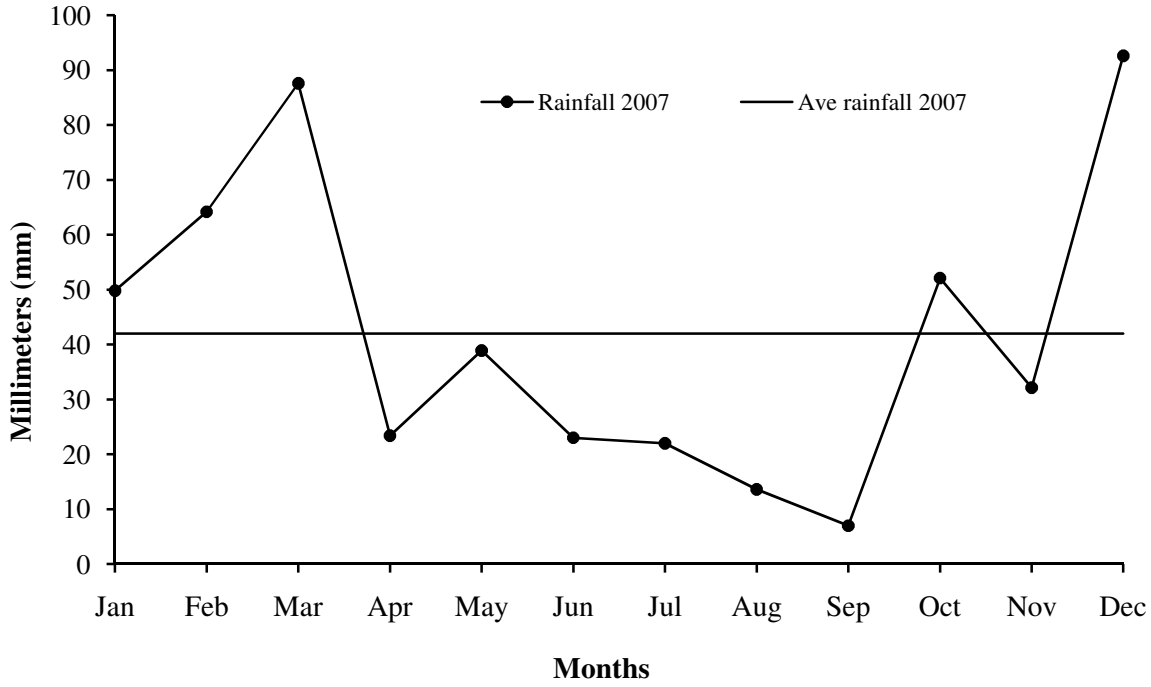

Figure 3.1. Rainfall pattern during the 2007 research period

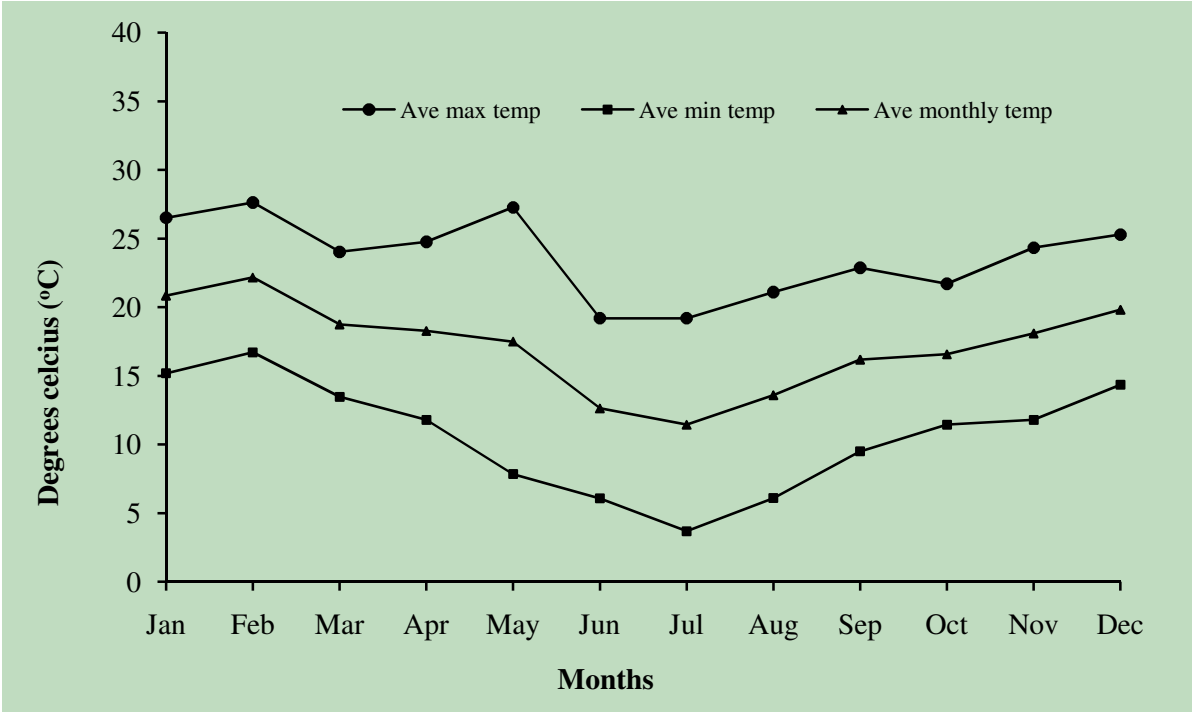

Figure 3.2. Temperature pattern during the 2007 research period

3.2.5. Experimental animals

The sixteen experimental animals (8 Tswana and 8 Boer goat does) were purchased in November 2005 from Mafikeng area in the North West Province, as this is where the drive for the research originated. The Tswana goats were purchased from Kabe village (about 60 km) west of Mafikeng while the Boer goats were purchased from Lehurutshe village (about 70 km) east of Mafikeng. Both breeds were raised extensively.

The Department of Anatomy and Physiology transported the animals from Mafikeng to Pretoria University following proper and recommended regulations on the transportation of animals. Animals were quarantined for a month and subjected to normal health and disease prevention programs as required by the Department of Anatomy and Physiology research management programmes. The 16 goats were kept on conventional grazing, supplemented with Lucerne/tef hay feeding at the Physiology holding pens in University of Pretoria.

Operations to insert oesophageal and rumen fistulae were performed at the Onderstepoort Veterinary Academic Hospital using standard veterinary surgical procedures. The most recent adaptations to the oesophageal fistulae were used during the trials (Booyse *et al*., 2009). The hospital monitored the post-operative recovery and emergency care of the goats. The researcher and technicians from the department of Anatomy and Physiology were responsible for the routine daily care of the animals.

Three months prior to the start of the research, the 16 does (8 Tswana and 8 Boer goats) were classified on the basis of their feeding behaviour. Goats were observed during a three-hour period at five minute intervals for four days. They were classified as browsers, grazers or intermediate feeders according to the times spent on different feeding activities. The browse: graze ratio, hind legs (bi-pedal stance) and consistency during the four observation days were taken into account during the selection process. The five Tswana and five Boer goats selected were all predominately intermediate feeders and were then operated on to place the oesophageal cannulae according to the methods described by Raats *et al*. (1993). The remaining six goats (3 Tswana and 3 Boer) were rumen cannulated and used for *in sacco* digestion.

After recovery from the operations, goats were transported to Fort Hare University following proper and recommended regulations on the transportation of animals. Animals were quarantined for a month and subjected to normal health and disease prevention programs as required by the Department of Livestock and Pasture Science research management programmes.

3.2.6. Experimental area

Two paddocks (8-9 ha in size) which form part of a wagon wheel system, were rested for at least one growing season prior to the start of the experiment. In each paddock an area of 1ha chosen on the basis of a good balance of bush and grass, and judged to be uniform in terms of vegetation was enclosed. A temporary goat proof fence was used to confine goats to a plot during each of the four-week experimental periods. Each plot had its own water trough and a handling kraal for holding the goats at the entrance of each plot. During both the cold-dry season and hot-wet season, a 1ha plot classified as the False Thornveld of the Eastern Cape (Acocks, 1975) was stocked with 8 Tswana and 8 Boer (mean weight of about 37 kg and about 2 years of age) for a period of four weeks. Five Tswana and five Boer goats were oesophageal fistulated while three Tswana and three Boer goats were rumen cannulated.

3.2.7. Management of animals and collection of data

At the start of each trial, there was an adaptation period of two weeks on the veld immediately adjacent to the experimental area. Five days prior to the start of each of the experiments, goats with oesophageal fistulae were trained with harnesses to acquaint the animals with the handling procedures. The fistulated goats were trained with great care, so that they showed no signs of abnormal behaviour, stress or discomfort during sampling and allowed the operators to approach and handle them in the open without resistance. For easier identification from a distance, the six animals to be observed were painted on both flanks with unique identification numbers (± 300 mm in size). During the three-week experimental periods, the goats had access to the experimental plots during the day (0700h to 1600h) only, but were kraaled at night for safety and supplied with a commercial lick (block). Adjacent paddocks with similar vegetation were used for grazing experimental animals during the interim period between experiments.

3.2.8. Experimental procedures

Twice a week (Tuesdays and Thursdays), during each of the two experimental seasons, feeding behaviour of six goats (3 Tswana, three 3 Boer) was observed. Feeding behaviour observations were recorded from 0800h to 0935h (assumed to represent morning), 1100h to 1235h (assumed to represent midday) and 1400h to 1535h (assumed to represent afternoon goat activity). As there were only three observers, only three goats could be observed at a time. Observers were randomly allocated to goat to avoid human bias. Therefore, from 800h to 0815h, the feeding behaviour of three goats (e.g. 3 Tswana) was observed followed by the observations of the 3 Boer goats from 0821h to 0835h. Observations continued at 0900h to 0915h with 3 Boer goats followed by 3 Tswana at (0921h-0935h). On each day of observation, the three goats (representing a particular breed) to start the observation with, were selected randomly. There was a five minutes break in between the observation periods to allow each observer to collect the oesophageal extrusa sample for the determination of the nutrient content of the diet as selected by free ranging goats, from each goat under observation. The same procedure was repeated during midday (1100h-1235h) and afternoon (1400h-1535h) observations. During observations, the following activities of the goats were recorded: browsing, grazing and non-feeding activities (walking, lying, standing and drinking). Browsing activity included bi-pedal stance (recorded separately) and represented the browsing of all woody species. Tree/Bush species browsed at the time of recording were visually identified and recorded separately. Grazing activity represented the grazing of grasses without the identification or recording of species. Non-feeding activities included separate recordings of walking, standing, lying and drinking. Each goat was observed for 30 minutes in the morning, midday and afternoon observation periods.

3.3. Statistical analysis

During the 30 minute observation time, the time spent on different activities (grazing, browsing, walking, drinking, lying and standing) by a goat was recorded in minutes and later converted into percentages. The percentage time was arcsine transformed prior to subjecting the data to analysis of variance. The analysis of data was conducted using Generalized Linear Model Procedure of SAS (SAS, 2003). The significance of a factor on a given feeding behaviour was

tested at P=0.05. The Tukey procedure was used to separate means among levels within a significant factor. The means were back transformed into percentage for the reporting purpose. The factors defined in the analysis model were breed, days in the grazing camp, time of the day, season and two and three way interactions among these factors. In all activities three-way interactions were not significant and not included in the final analysis.

The following statistical model was used on each of the activities:

$$Y = \mu + B_i + T_j + D_k + S_l + (BT)_{ij} + (BD)_{ik} + (BS)_{il} + (TD)_{jk} + (TS)_{jl} + (DS)_{kl} + \text{error}$$

Where

Y = Observation on any of the feeding activities,

μ = Overall mean,

Bi = Breed effect (Indigenous Tswana vs Boar goat),

Tj = Time of the day effect**:** Morning (0800h-0935h), midday (1100h-1235h) and afternoon (1400h-1535h),

Dk = Day in camp effect (1st day to 6th day)

S = Season effect (cold-dry season vs hot-wet season)

(BT)jj to (DS)kl = Two way interaction effects among the factors

e = random error term, assumed to be distributed with mean of 0 and variance, σ^2_e

3.4. Results

Proportions of time spent on feeding and non-feeding activities by goats across seasons are presented in Table 3.5. On average, the goats in this study were observed to spend 21.9 %, 44.7% and 33.3% of their day on browsing, grazing and non-feeding activities (walking, standing, lying, drinking). This implies that goats spent 33 % and 67 % of their active feeding time browsing and grazing respectively.

Table 3.5 Percent of time (least square means) spent on browsing, grazing and non-feeding activity in goats

Behavioral activities	Least square mean (%)
Browsing	21.9 [a]
Grazing	44.7 [b]
NFA	33.3 [c]

Means in the same column with different superscripts are significantly different (P < 0.05). The SE = 0.88

3.4.1. Factors affecting time spent on browsing

The breed, season, time of the day and period of occupation of a camp significantly (P<0.05) influenced the relative time the goats devoted to browsing as shown in Table 3.6. The average percentage time spent on browsing was significantly higher in the cold-dry season (21.7 ± 0.04) compared to the hot-wet season (16.7 ± 0.04).

Table 3.6. Percentage time (least square means) spent browsing as influenced by season, breed, time of the day and period of occupation of a camp by goats

Factors	Browsing time (%)	SE
Season		
The cold-dry season	21.7[a]	0.04
The hot-wet season	16.7[b]	0.04
Breed		
Tswana	23.5[a]	0.04
Boer	15.1[b]	0.04
Time of the day		
(0800h – 0935h)	24.3[a]	0.06
(1100h – 1235h)	15.9[b]	0.06
(1400h – 1535h)	17.6[b]	0.06
Period of occupation		
Day 1	28.5[a]	0.11
Day 2	19.3[ab]	0.11
Day 3	22.6[ab]	0.11
Day 4	16.5[b]	0.11
Day 5	15.4[b]	0.11
Day 6	13.9[b]	0.11

Means in the same column with different superscripts are significantly different (P < 0.05).

Across seasons, Tswana goats allocated more time to browsing (23.5 ± 0.04) than the Boer goats (15.1 ± 0.04). This difference in browsing time was highly significant (P=0.0001). Time spent on browsing by goats changed significantly during the different times of the day (P= 0.005). On average across times of the day, goats spend more time on browsing in the morning (24.3 ± 0.06) compared to midday (15.9 ± 0.06) and afternoon (17.6 ± 0.06). There were significant differences (P=0.002) in time spent on browsing during the period of occupation of the grazing camp.

Tswana goats showed significant seasonal variation in browsing time (30.0 in the cold-dry season vs 17.7 in the hot-wet season – breed by season interaction), while the browsing time of Boer goats did not show this seasonal difference (Table 3.7).

Table 3.7 Percentage time (least square means) spent browsing as influenced by season, breed, time and period of occupation of a camp in Tswana and Boer goats

Factors	**Browsing time (%)**		**SE**
	Breed		
	Tswana	**Boer**	
Season			
The cold-dry season	30.0 [a]	14.4 [b]	0.07
The hot-wet season	17.7[b]	15.7 [b]	0.07
Time of the day			
(0800h – 0935h)	31.4	17.8	0.11
(1100h – 1235h)	17.0	14.8	0.11
(1400h – 1535h)	23.0	12.8	0.11
Period of occupation			
Day 1	33.6	23.5	0.22
Day 2	25.2	14.0	0.22
Day 3	23.3	21.9	0.22
Day 4	22.6	11.1	0.22
Day 5	22.1	9.7	0.22
Day 6	15.6	12.2	0.22

Means in the same row with different superscripts are significantly different (P < 0.05).

Although Tswana goats spent more time browsing both in the morning and afternoon compared to Boer goats, there was no significant differences (P>0.05) between the breeds. The number of days spent occupying a camp did not differ significantly (P>0.05) between the Tswana and the Boer goats but browsing seemed to decrease with advancing period of occupation.

The time the goats spent browsing was not affected by the time of day (Table 3.8) during either the cold-dry season or the hot-wet season. However, the amount of time the goats spent browsing in the camp on progressive days became significantly different (P=0.01) as the period of occupation increased in the cold-dry season.

Goats spent more time browsing during the early days of occupation of a camp. With advancing period of occupation during the cold-dry season, goats decreased their browsing time from 33.3 % on the first day of observations to 11.7 % on the last day of the observations. Similarly during the hot-wet season, browsing decreased with advancing period of occupation of a camp from 23.9 % on the first day of sampling to 16.2 % on the last day of sampling. The decrease in time spent browsing with advancing period of occupation was high during the cold-dry season (21 %) compared to the hot-wet season (8 %).

Table 3.8. Percentage time (least square means) spent browsing during the cold-dry season and the hot-wet season as influenced by time and period of occupation of a camp by goats

Factors	**Browsing time (%)**		**SE**
	Season		
	The cold-dry season	**The hot-wet season**	
Time of the day			
(0800h – 0935h)	25.9	2.7	0.10
(1100h – 1235h)	17.8	14.0	0.10
(1400h – 1535h)	21.6	53.8	0.10
Period of occupation			
Day 1	33.3[a]	23.9[a]	0.21
Day 2	25.0[a]	14.2[a]	0.21
Day 3	31.6[a]	14.7[a]	0.21
Day 4	19.8[a]	13.4[a]	0.21
Day 5	12.5[b]	18.5[a]	0.21
Day 6	11.7[b]	16.2[a]	0.21

Means in the same column with different superscripts are significantly different (P < 0.05).

The time of the day on the consecutive days of observation in the camp showed no significant effect (P>0.05) on the time goats spent browsing. However, results show an interesting trend in time spent browsing during the different time slots (Figure 3.3).

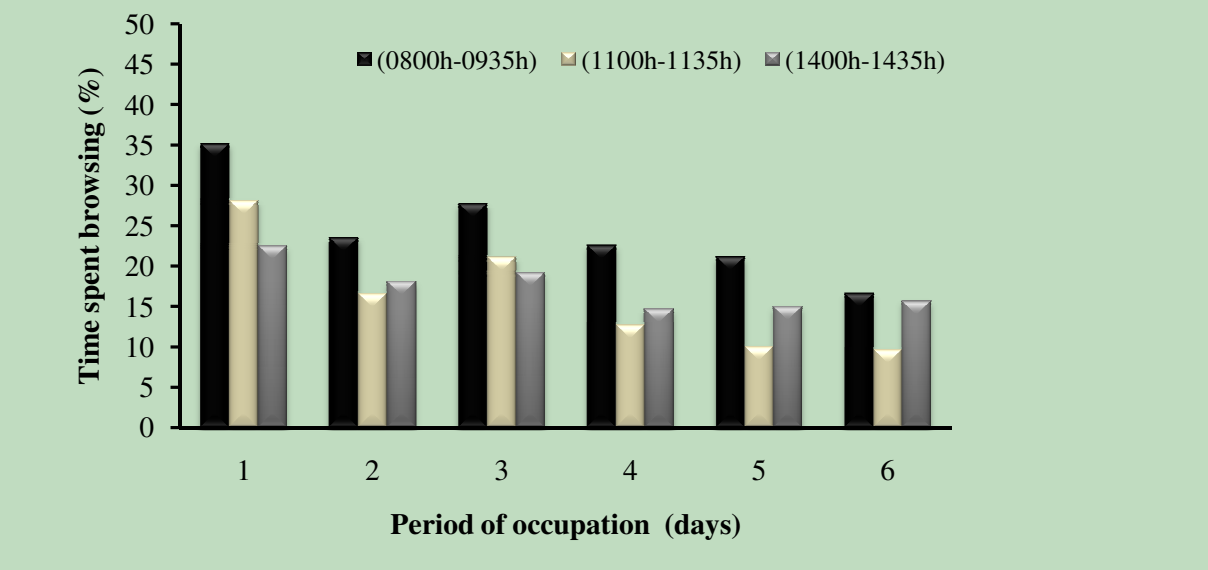

Figure 3.3. The browsing trend of goats as influenced by time of the day and period of occupation

During each of the six observation days, browsing was high in the morning compared to midday and afternoon feeding periods. Browsing showed a decreasing trend with advancing period of occupation in the morning, at midday and in the afternoon.

3.4.2. Factors affecting time spent on grazing

There is a significant difference between seasons ($P<0.0001$) and breeds ($P=0.01$) in terms of the amount of time spent on grazing. However, time of the day and period of occupation of a camp did not significantly ($P>0.05$) influence the amount of time the goats spent grazing. The average time spent on grazing by goats was significantly higher ($P=0.04$) in the hot-wet season (59.3 ± 0.04) compared to the cold-dry season (26.8 ± 0.04) as shown in Table 3.9.

Table 3.9 Percentage time (least square means) spent grazing as influenced by season breed, time and period of occupation of a camp by goats

Factors	Grazing time (%)	SE
Season		
The cold-dry season	26.8[a]	0.04
The hot-wet season	59.1[b]	0.04
Breed		
Tswana	39.0[a]	0.04
Boer	46.3[b]	0.04
Time of the day		
(0800h – 0935h)	41.9	0.07
(1100h – 1235h)	38.9	0.07
(1400h – 1535h)	47.1	0.07
Period of occupation		
Day 1	35.6	0.12
Day 2	45.1	0.12
Day 3	48.2	0.12
Day 4	45.1	0.12
Day 5	41.6	0.12
Day 6	40.3	0.12

Means in the same column with different superscripts are significantly different ($P < 0.05$).

In general, Boer goats allocated more time to grazing (46.3 ± 0.04) compared to Tswana goats (39.0 ± 0.04). This difference in grazing time between the two breeds was highly significant (P=0.01). There was no significant difference (P>0.05) in time goats spent grazing both during the different times of the day and during the period of occupation of a grazing camp (P>0.05).

The Tswana and Boer goats did not differ (P>0.005) in the amount of time spent grazing during either the cold-dry season or the hot-wet season as shown in Table 3.10. The amount of time spent grazing at different times of the day did not differ significantly (P>0.005) between breeds, although goats spent more time grazing during the afternoon (Tswana 42.8: Boer 51.6 ± 0.12) compared to morning (Tswana 37.1: Boer 46.8 ± 0.12) and midday (Tswana 37.2: Boer 40.6 ± 0.12). During the first days of occupying a camp, the Boer goats spent significantly more (P=0.01) time grazing than the Tswana goats.

Table 3.10 Percentage time (least square means) spent grazing as influenced by season time and period of occupation of a camp by Tswana and Boer goats

Factors	Grazing time (%)			
	Tswana	**SE**	**Boer**	**SE**
Season				
The cold-dry season	24.7	0.07	28.9	0.09
The hot-wet season	54.4	0.07	64.1	0.09
Time of the day				
(0800h – 0935h)	37.1	0.12	46.8	0.13
(1100h – 1235h)	37.2	0.12	40.6	0.13
(1400h – 1535h)	42.8	0.12	51.6	0.13
Period of occupation				
Day 1	31.9	0.27	39.4	0.27
Day 2	32.8[a]	0.27	57.8[b]	0.27
Day 3	42.5	0.27	53.8	0.27
Day 4	38.1	0.27	52.1	0.27
Day 5	45.6	0.27	37.6	0.27
Day 6	43.6	0.27	37.1	0.27

Means in the same row with different superscripts are significantly different ($P < 0.05$).

The time goats spent grazing at a particular time of day was not affected ($P>0.05$) by the season when the observations were done (Table 3.11). The highest percentage grazing time was recorded during the hot-wet season in the afternoon (61.8 ± 0.12) while the lowest percentage grazing time was recorded in the cold-dry season during midday (20.1 ± 0.12).

After day 1 the effect of the period of occupation of the camp on the amount of time spent grazing was significantly different ($P=0.04$) between the hot-wet season and the cold-dry season. Goats spent less time grazing during the early days of occupation of a camp during the hot-wet season. With advancing period of occupation, goats increased their grazing time from 43.9 % on the first day of observations to 62.4 % on the last day of the observations. However, during the cold-dry season, grazing decreased with advancing period of occupation of a camp from 27.7 % on the first day of sampling to 20.1 % on the last day of sampling.

Table 3.11. Percentage time (least square means) spent grazing during the cold-dry season and the hot-wet season as influenced by time of the day and period of occupation of a camp by goats

Factors	Grazing time (%)		
	Cold-dry season	**Hot-wet Season**	**SE**
Time of the day			
(0800h – 0935h)	28.0	56.5	0.13
(1100h – 1235h)	20.1	59.5	0.13
(1400h – 1535h)	32.7	61.8	0.13
Period of occupation			
Day 1	27.7	43.9	0.27
Day 2	29.0	61.8	0.27
Day 3	35.8	60.7	0.27
Day 4	28.8	61.9	0.27
Day 5	20.2	64.8	0.27
Day 6	20.1	62.4	0.27

Means in the same column with different superscripts are significantly different ($P < 0.05$).

3.4.3. Factors affecting time spent on non-feeding activities

The breed and period of occupation of a camp did not significantly influence the relative time goats devoted to NFA ($P>0.05$). However, season ($P<0.0001$) and time of the day ($P=0.004$) significantly influenced the time goats spent on NFA as shown in Table 3.12.

Table 3.12 Percentage time (least square means) spent on NFA as influenced by season, breed, time of the day and period of occupation of a camp by goats

Factors	Time spent on NFA (%)	SE
Season		
The cold-dry season	68.8 [a]	0.07
The hot-wet season	31.9 [b]	0.07
Breed		
Tswana	51.9	0.07
Boer	48.9	0.07
Time of the day		
(0800h – 0935h)	45.0 [a]	0.11
(1100h – 1235h)	59.4[b]	0.11
(1400h – 1535h)	46.7[a]	0.11
Period of occupation		
Day 1	50.2	0.22
Day 2	47.9	0.22
Day 3	40.5	0.22
Day 4	51.0	0.22
Day 5	53.0	0.22
Day 6	59.8	0.22

Means in the same column with different superscripts are significantly different ($P < 0.05$).

On average goats spent more time on NFA during the cold-dry season (68.8 ± 0.07) than the hot-wet season (31.9 ± 0.07). This difference in time spent on NFA was highly significant ($P<0.0001$). Throughout the year the Boer and Tswana goats did not differ significantly ($P>0.05$) in the amount of time allocated to NFA (Tswana 51.9 ± 0.07; Boer 48.9 ± 0.07). Time spent by goats on NFA changed significantly during the day ($P=0.004$). On average, the midday period was dominated by NFA (59.4 ± 0.11) compared to morning (45.0 ± 0.11) and afternoon (46.7 ± 0.11) activities. Goats spent less time on NFA (46.2 ± 0.22) during the early days (first 3 days) of occupation of a camp. However, with advancing period of occupation (last 3 days), time spent on NFA increased (54.6 ± 0.22). There was no significant difference ($P>0.05$) in time spent on NFA during the period of occupation of a camp.

Tswana and Boer goats did not differ significantly ($P=0.05$) in the amount of time allocated to NFA during either the cold-dry season or the hot-wet season as shown in Table 3.13.

Table 3.13 Percentage time (least square means) spent on NFA as influenced by season, time of the day and period of occupation of a camp by Tswana and Boer goats

Factors	Grazing time (%)		SE
	Tswana	Boer	
Season			
The cold-dry season	66.7	70.9	0.15
The hot-wet season	37.0	27.0	0.15
Time of the day			
(0800h – 0935h)	43.8	46.2	0.22
(1100h – 1235h)	63.9	54.8	0.22
(1400h – 1535h)	47.9	45.6	0.22
Period of occupation			
Day 1	48.6	51.5	0.44
Day 2	55.4	40.4	0.44
Day 3	48.0	33.3	0.44
Day 4	52.7	49.3	0.44
Day 5	49.3	56.6	0.44
Day 6	57.4	62.2	0.44

Means in the same row with different superscripts are significantly different ($P < 0.05$).

Although Boer goats were observed to spent more time on NFA (70.9 ± 0.15) during the cold-dry season compared to the Tswana goats (66.7 ± 0.15), the difference was not significant ($P>0.05$). In the hot-wet season, time spent on NFA declined for both breeds (Tswana 37.0 ± 0.15; Boer 27.0 ± 0.15) with Tswana goats spending more time on NFA than Boer goats.

Tswana and Boer goats did not differ significantly ($P>0.05$) in the amount of time spent on NFA at different times of the day. Tswana goats spent more time on NFA during midday (63.9 ± 0.22) compared to Boer goats (54.8 ± 0.22). NFA were lower in the morning (Tswana 43.8; Boer goats 46.2 ± 0.22) and afternoon (Tswana 47.9; Boer goats 45.6 ± 0.22) and Tswana goats spent more time on NFA than Boer goats during both these time periods.

The time spent on NFA by the two breeds did not differ significantly ($P>0.05$) over the period of occupation of the camp. It however seems that for both breeds, time spent on NFA increased with advancing period of occupation.

There were no significant differences (P>0.05) between the cold-dry season and the hot-wet season in the time goats spent on NFA during the different times of day, even though it seems more time was allocated to NFA in the cold-dry season compared to the hot-wet season. The highest percentage time spent on NFA was recorded during the cold-dry season at midday (80.3 ± 0.22) while the lowest was recorded in the hot-wet season in the morning (25.3 ± 0.22).

The amount of time the goats spent on NFA during the cold-dry season and the hot-wet season showed significant differences (P<0.0001) the longer the goats were in the camp as shown in Table 3.14. Significant differences were found on days 5 and 6 in both seasons where NFA were very low compared to the other days.

Table 3.14 Percentage time (least square means) spent on NFA during the cold-dry season and the hot-wet season as influenced by time of the day and period of occupation of a camp by goats

Factors	**Time spent on NFA (%)**		**SE**
	Season		
	cold-dry	**hot-wet**	
Time of the day			
(0800h – 0935h)	65.6	25.3	0.22
(1100h – 1235h)	80.3	36.5	0.22
(1400h – 1535h)	59.5	34.2	0.22
Period of occupation			
Day 1	54.1[a]	46.0[a]	0.44
Day 2	59.5[a]	36.4[a]	0.44
Day 3	49.0[a]	32.4[a]	0.44
Day 4	69.4[a]	32.5[a]	0.44
Day 5	2.9[a]	19.7[b]	0.44
Day 6	5.4[a]	26.0[b]	0.44

Means in the same column with different superscripts are significantly different (P < 0.05).

Goats spent more time on NFA during the early days of occupation of a camp. With advancing period of occupation during the hot-wet season, time spent on NFA decreased from 46 % on the first day of observation to 26 % on the last day of observation. During the cold-dry season the amount of time spent on NFA decreased from 54.1 % on the first day of observations to as low as 5.4 % on the last day of observations.

The time goats spent on NFA was not affected by the time of day regardless of the period of time the goats occupied the camp (Figure 3.4)

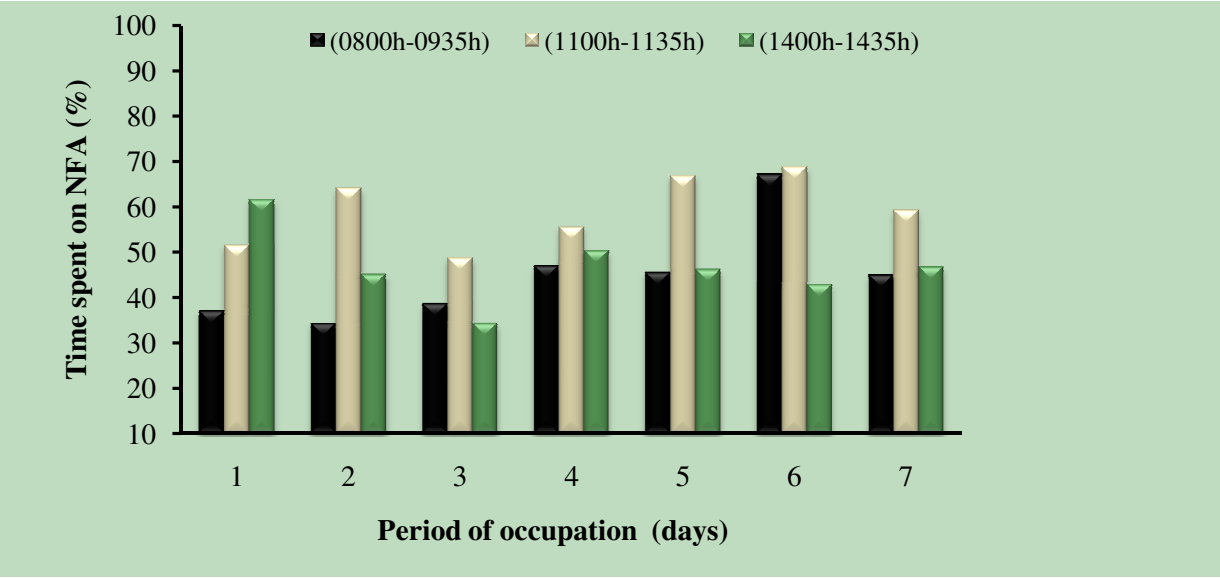

Figure 3.4. Time spent on NFA at different times of the day over the period of occupation

From the graph it seems as though NFA increase with advancing period of occupation in the morning, midday and afternoon.

3.4.4. Factors affecting time spent on walking, standing, lying and drinking by goats

Proportions of time spent by goats on walking, standing, lying and drinking activities across seasons and breeds are presented in Table 3.15. On average, the goats in this study were observed to spend more time walking and standing compared to lying down and drinking.

Table 3.15. Percentage time (least square means) spent walking, standing, lying and drinking by goats

Behavioral activities	Least square mean (%)
Walking	15.6 [a]
Standing	11.6 [b]
Lying	5.8 [c]
Drinking	0.3 [d]

Means in the same column with different superscripts are significantly different ($P < 0.05$). SE = 0.88

The percentage time goats spent walking during the cold-dry season (14.9 %) and the hot-wet season (16.2 %) did not differ significantly (P>0.05). A higher percentage of time (P<0.0001) was spent standing during the cold-dry season (17.6) than the hot-wet season (5.7 %). During the cold-dry season, goats also spent a higher percentage of time (P<0.0001) lying down (10.8 %) compared to the hot-wet season (0.9 %). The percentage time spent drinking was very low (P>0.05) both during the cold-dry season and the hot-wet season (0.5 and 0.1 %) respectively (Table 3.16).

Table 3.16 Percentage time (least square means) spent walking, standing, lying and drinking as influenced by season, breed and time of the day by goats

Factors	Least square mean (%)				SE
	Activity				
	Walking	Standing	Lying	Drinking	
Season					
Cold-dry	14.9[a]	17.6[a]	10.8[a]	0.9[b]	1.24
hot-wet	16.2[a]	5.7[b]	0.9[b]	0.1[a]	1.24
Breed					
Boer	16.4[a]	9.6[a]	7.2[a]	0.3[a]	1.24
Tswana	14.7[a]	13.7[b]	4.5[a]	0.3[a]	1.24
Time of the day					
(0800h–0935h	17.0[a]	9.9[a]	2.5[a]	0.6[a]	1.52
(1100h–1235h)	17.7[a]	9.8[a]	11.3[b]	0.1[a]	1.52
(1400h–1535h)	12.0[b]	15.2[b]	3.7[a]	0.1[a]	1.52

Means in the same column with different superscripts are significantly different (P < 0.05).

The Tswana and Boer goats did not differ significantly (P>0.05) in the time spent walking (Tswana 16.4; Boer 14.7 ± 1.24) or lying down (Tswana 7.2; Boer 4.5 ± 1.24). Boer goats, however, spent a significantly (P=0.02) higher percentage (13.7 ± 1.24) of their feeding time standing compared to Tswana goats (9.6 ± 1.24). The amount of time allocated by goats for drinking was low (0.3 % and 0.3 %) for Tswana and Boer goats respectively (P>0.05). Goats spent more time walking in the morning and midday compared to the afternoon. A significant amount of time was spent standing in the afternoon (15.2 ± 1.52) compared to the morning (9.9 ± 1.52) and midday (9.8 ± 1.52). Time spent lying down was greatest during midday (11.3 ± 1.52) compared to morning (2.5 ± 1.52) and afternoon (3.7 ± 1.52). Time spent drinking was very low during all the different times of the day.

Non-feeding activities of Tswana and Boer goats during the cold-dry season and the hot-wet season are shown in Table 3.17.

Table 3.17 Percent of time (least square means) spent on walking, standing, lying and drinking as influenced by season and breed interaction

Factors	**Least square mean (% ± SE)**			
			Activity	
	Walking	**Standing**	**Lying**	**Drinking**
Cold-dry				
Tswana	12.8 ± 0.03[a]	10.8 ± 0.07[a]	5.6 ± 0.07 [a]	0.03 ± 0.0[a]
Boer	13.6 ± 0.03 [a]	18.6 ± 0.07[b]	2.4 ± 0.07[a]	0.04 ± 0.0 [a]
Hot-wet				
Tswana	16.97 ± 0.03[a]	3.20 ± 0.07[a]	0.18 ± 0.07[a]	0.004 ± 0.01[a]
Boer	13.58 ± 0.03[a]	2.62 ± 0.07[a]	0.004 ± 0.07[a]	0.004 ± 0.01[a]

Means in the same column with different superscripts are significantly different ($P < 0.05$).

When comparing the Tswana and Boer goats during both the cold-dry season and the hot-wet season there was no difference in time spent walking. It does appear that Tswana goats walked more than the Boer goats in the hot-wet season. During the cold-dry season, Boer goats spent a significantly ($P=0.01$) higher percentage (18.6 ± 0.07) of their feeding time standing compared to Tswana goats (10.8 ± 0.07). Percentage time spent walking was low in the hot-wet season for both Tswana and Boer goats ($P>0.05$). Both breeds spent time not differing significantly ($P>0.05$) lying down in the cold-dry season and the hot-wet season. Percentage time spent lying down was higher in the cold-dry season than the hot-wet season for both breeds with Tswana goats spending more time lying down than the Boer goats. The amount of time allocated by Tswana and Boer goats to drinking was very low both during the cold-dry season and the hot-wet season ($P>0.05$).

3.5. Discussion

The feeding behaviour of goats is affected by both environmental and animal related factors (Raats & Tainton, 1992; Agreil & Meuret, 2004; Mellado *et al*., 2004). The present study investigated the effect of breed (Tswana and Boer goats), season (the cold-dry season and the hot-wet season), time of the day (diurnal variation), effect of feed availability (period of occupation of a camp) on the feeding behaviour of goats in the False Thornveld of the Eastern Cape.

The effect of season and period of occupation on the feeding behaviour of goats is well documented. Animut & Goetsch (2008), state that season has profound effects on the grazing behaviour of goats. During a year-long study, goats were found to select about 60 % bush, 30 % grass and 10 % forbs (Malecheck & Provenza, 1981). The ratio is however subject to large changes, depending on the prevailing conditions (Raats and Tainton, 1992). Raats (1996a) obtained similar results in the False Thornveld of the Eastern Cape where Boer goats spent on average 61 % and 39 % of their active feeding time browsing and grazing including forbs respectively. Depending on season however, the same study showed that the percentage browse varied from as low as 27 % in June to as high as 86 % in January.

Although goats prefer browse, a variety in browse selection is characteristic of the feeding behaviour of goats (Devendra & Coop 1982; Ramirez *et al*., 1993; Provenza, 1995; Ramírez-Orduña *et al*., 2008; Kumara Mahipala *et al*, 2009). In the present study the proportion of time spent browsing was lower (33 %), and that spent grazing higher (67 %) than the averages found by Malecheck & Provenza (1981) and Raats (1996a). These results are supported by Orihuela & Solano, (1999) and by Odo *et al*, (2001) where Saanen goats were also found to select more grass (63 %) than bush (32 %). The results of the current study, however, contradict those of several authors (Merrill, 1975; Devendra & McLeroy; 1982; Bjelland & Grøva, 1997; Berhane & Eik, 2006; Aharon *et al*., 2007; Yayneshet *et al.*, 2008) where goats were found to prefer browse to grass. This indicates that shifting between browsing and grazing is largely dependent on prevailing conditions (Lu, 1987) such as the amount and distribution of rainfall and the occurrence of frost. In this regard, Bjelland & Grøva (1997) in a study with Boer goats in the False Thornveld of the Eastern Cape, found that time spent browsing during the cold-dry season

was substantially higher (52 %) than the 27 % recorded by Raats (1996a). In the present study, time spent browsing in the cold-dry season was also higher (46 %) than that recorded by Raats (1996a) and closer to the 52 % recorded by Bjelland & Grøva (1997) and Sanon *et al*. (2007). During the hot-wet season, bush consumption was substantially lower (24 %) than the 86 % recorded by Raats (1996a).

The changes in time spent browsing (cold-dry season 46 %; hot-wet season 24 %) and grazing (cold-dry season 54 %; hot-wet season 76 %) in this study showed that feed availability, as reflected in the number of days in the camp, had a marked influence on feeding behaviour. This is supported by work done by several researchers (Lu, 1987; Raats & Tainton, 1992; Devendra & McLeroy, 1982; Steel, 1996; Taylor & Kothaman, 1990; Merril & Taylor, 1981) who also found that as the availability of feed decreased more time was spent grazing. Steel (1996) found that season influences browse:graze ratio markedly. Omphile *et al*. (2003) found a contribution of about 80 and 50 % browse in the diets of goats during the dry and wet seasons respectively in an Acacia bush savannah in southeast Botswana. Seasonal variations in browse:graze ratio were also found in Spain and Texas (Devendra & McLeroy, 1982). In the present study, grass consumption was higher in the hot-wet season (76 %) than in the cold-dry season (54 %) while browse consumption was higher in the cold-dry season than in the hot-wet season (46 % and 24 % respectively). These results are supported by Taylor & Kothman (1990) and Odo *et al.* (2001) who found goats to select more grass during the hot-wet season than the cold-dry season. Orihuela & Solano, (1999) states that the major growth of warm season grasses occur during the hot-wet season (rainy season). Schwartz & Ellis (1981) found that season has a major impact on the dietary preference of species and grazing tends to increase during the season when the herb layer is actively growing (Migongo-Bake & Hansen, 1987; El Aich *et al*., 2007; Sanon *et al*., 2007). Actively growing grasses have high digestibility (Codron *et al*., 2007), are succulent and less coarse.

The increase in consumption of browse in the cold-dry season compared to in the hot-wet season is supported by Devendra & McLeroy (1982; Sanon *et al*., 2007) who reported that goats tend to prefer the less coarse grass which is found in the hot-wet season. These workers are of the opinion that browse forms the main source of feed for ruminants in the dry season. This could

be attributed to the early and fast growth rate of grasses after the early rain in the hot-wet season, when legumes are still germinating, leaving legumes fresher, less coarse and more succulent at the onset of the dry season. Orihuela & Solano, (1999), state that in early autumn and the cold-dry season, only browse may still be green while the grass dries out. Due to high temperatures and low annual rainfall, lower food availability is a major factor that affects feeding behaviour in dry areas (Abate, 1996). In the present study, goats made a shift in their feeding activity by increasing browse species in their diet when herbaceous species were rare.

Browsing showed a decline with advancing period of occupation both during the cold-dry season and the hot-wet season. Grazing however only showed a decline with advancing period of occupation in the cold-dry season. In the hot-wet season, grazing increased with advancing period of occupation. In this study, the browse:graze ratio showed a clear decline with feed availability both during both the cold-dry season (0.5 to 0.1) and the hot-wet season (0.3 to 0.2). Grass was clearly the preferred feed for goats both in the cold-dry season (54 %) and the hot-wet season (76 %). Browse consumption was higher in the cold-dry season (45 %) and lower in the hot-wet season (24 %). McCammon-Feldman *et al.* (1981), state that the nutritive strategy of goats appears to be to select grass when the protein content and digestibility of the grass is high. However, they switch to browse if the overall nutritive value of browse is high. The initial preference for browse over grass in the cold-dry season during the observation days in this study, suggests the nutritional value of browse was higher than that of grasses, which is expected due to the dormant state of grasses during the cold-dry season. Goats were observed to switch to grazing during the later days of occupation of a camp due to depletion of browse. During the cold-dry season, the decrease in the availability of the most preferred feeds also induced goats to diversify their diets. The botanical composition of the goat's diet varies in accordance with seasonal availability (Animut & Goetsch, 2008) with more species being utilized as the availability decreases. The natural seasonal changes may modify the behaviour patterns of goats (Taylor & Kothman, 1990) affecting proportions of grass or bush consumption according to their availability.

In the present study, the time goats spent walking did not differ significantly between the cold-dry season and the hot-wet season. These results are supported by Ouédraogo-Koné *et al.* (2006)

where goats spent 12.0 % and 10.5 % of their active feeding time walking in the dry and the rainy seasons respectively. The results however do not agree with results from a drier area (Cissé *et al.*, 2002) where animals spent more time walking in the dry season (5 % to 15 %) than in the rainy season (0.6 to 2.6 %). The increased frequency of lying and standing during the dry season was a response to the reduced availability of food items on the range during the dry season. Sharma *et al.* (1998) and Cissé *et al.* (2002) however, found goats to spent more time resting in the hot-wet season than the cold-dry season and speculated that it was probably because of high temperatures that were experienced during the hot-wet season (average 44.5 ^{o}C) compared to the cold-dry season (average 6 ^{o}C). Goats spent a small percentage of time drinking both during the cold-dry season and the hot-wet season. This is probably due to the time slots of the day that were used in this study to determine the feeding behaviour of the goats. Studies have shown that goats consume less water than sheep (Qinisa & Boomker, 1998; Ferreira *et al*., 2002; Keskin *et al*., 2005). During this study it was observed that the goats drank most of their water intake between 1300h–1400h which coincided with the hottest time of the day.

Genotypic variation can also influence preference and selectivity (Warren *et al*., 1984; Ellis *et al*., 2005). Experiments have shown differences among populations of livestock, with population representing the genetic diversity arising from subspecies to breeds and breed crosses (Hohenboken, 1986; Odo *et al*., 2001). In the present study, significant differences were found between the feeding behaviour of the Tswana and the Boer goats. Both breeds devoted the same amount of time (Tswana 66.5 %; Boer 66.2 %) on the range to active foraging. The figures are much higher than that reported by Askin & Turner (1972) for Angora goats (31 %) but are closer to that reported by Mill (1990) for Tunasian goats (77 %) and Aharon *et al*. (2007) on Mamba and Boer goats. In both seasons goats devoted much of the active feeding time to grazing or selection of herbaceous vegetation. The Tswana and Boer goats spent the weighted average of 39.0 % and 46.2 % respectively, of their feeding time grazing. Selection of herbaceous vegetation was also notably higher in the hot-wet season (Tswana 54.4 %; Boer 64.1 %) due to an abundance of lush herbaceous vegetation generally higher in nutritional value. These findings are not consistent with many reports where goats were found to select more browse material than grass (Sidahmed *et al*., 1981; Lu, 1988; Perevolotsky *et al*., 1992; Perevolotsky *et al*., 1998; Berhane & Eik, 2006; Aharon *et al*., 2007; Yayneshet *et al.*, 2008). The difference between

breeds in their time allocations to grazing herbaceous species was notable in the hot-wet season when Boer goats allocated an extra 10 % of their time to grazing compared to Tswana goats, while in the cold-dry season they only allocated an extra 4 % of their time to grazing**.** Both breeds decreased time spent on browsing with advancing period of occupation of a camp. Tswana goats decreased browsing and increased grazing with decline in feed availability compared to Boer goats. This might indicate that Tswana goats have a higher adaptation potential to changes in the vegetation than the Boer goat.

Ruminants display diurnal patterns in time spent grazing and in other activities such as ruminating, being idle and lying down (Sharma *et al*., 1998; Odo *et al.,* 2001; Torrano & Valderrábano, 2005; Schlecht *et al*., 2006). In the present study for both breeds and seasons, a diurnal pattern of foraging was observed. Although goats spent more time grazing than browsing in this study, browsing was significantly high in the morning compared to midday and afternoon while grazing appeared to be high in the afternoon. Dumont *et al*. (1995) in a study on the direct observation of biting for studying grazing behaviour of goats and llamas on garrigue rangelands also observed diurnal variations in diets of both animals where the mornings were spent browsing and afternoons grazing. Torrano & Valderrabano (2005) also observed diurnal pattern of plant utilization where longer time was devoted to browsing earlier in the morning than during the rest of the day. Solanki (1994) on the other hand observed a distinct diurnal pattern for selectivity of forages, with grasses being preferred more in the morning (80 %) followed by bushes (18 %) while in the evening bushes were more preferred (69 %) and grasses (30 %). Diurnal variation feeding behaviour is reported by Steel (1996), stating that when goats are first let out on to pastures in the mornings, they will initially feed unselectively, and later become increasingly selective. In contrast, Benham (1984) cited by Dumont *et al* (1995), states that it is better for ruminants to be selective in the morning than the afternoon. This is supported by results from this study where goats wandered more in the morning (17 %) than the afternoon (12 %), indicating that the level of selection was high in the morning than the afternoon. In the early part of the day, a selective feeding behaviour prevents the rumen from being filled with slowly digestible material that would later limit intake, whereas unselective feeding in the afternoon tops up the rumen ready for the night when little or no feeding is performed (Dumont *et al*, 1995).

It has been reported that diurnal feeding pattern in goats may be modified by factors such as forage availability (Schlecht *et al*., 2006; Sanon *et al*., 2007), environmental stress such as heat and rain (Torrano & Valderrabano, 2005; Sanon *et al*., 2007), frequency of feeding and amount of feeding (Morand-Fehr, 1981; Lu 1988). In the present study, for both breeds and seasons, non-feeding activities were higher during midday compared to morning and afternoon but there were no breed differences. Other studies have also revealed that goats avoid grazing or browsing during the hotter part of the day (Sharma *et al*., 1995).

3.6. Conclusions

The Tswana and Boer goats devoted the same amount of time to active foraging in the False Thornveld of the Eastern Cape. In general grazing was the dominant activity for both breeds and the highest amount of time was spent grazing in the hot-wet season compared to the cold-dry season. When comparisons were made between seasons, Boer goats selected more grass compared to Tswana goats during both seasons. Tswana goats spent more time browsing during the cold-dry season compared to Boer goats, however there was no significant difference between the breeds regarding browsing during the hot-wet season. In general across breeds, a diurnal feeding pattern was observed where browsing was significantly high in the morning compared to midday and afternoon while grazing was high in the afternoon, however, no breed differences were found. Tswana and Boer goats did not differ significantly regarding non-feeding activities. Non-feeding activities were higher for both breeds and seasons during midday compared to the morning and afternoon, but there were no breed differences.

The results suggest that Boer goats spent more time grazing and their diets contained less browse and more grass in both the cold-dry and hot-wet seasons. On the other hand Tswana goats spent more time browsing in the cold-dry season compared to Boer goats and their diets contained less grass and more woody-plant species showing that they exhibit more diversity in their eating choice.

These results have two practical implications for resource partitioning and fire prevention. In areas exploited by cattle, where mixed grazing is practiced, Tswana goats may compete to a lesser extent with cattle than Boer goats and may be more desirable for mixed grazing systems.

Tswana goats may also be more desirable for the control of bush encroachment due to their feeding behaviour which will also deplete combustible mass of herbaceous vegetation and as a result lower fire hazards. Both breeds showed the potential to serve as a management tool in mixed grazing systems.

The variation in preference for grass and browse with different seasons, breeds, the time of the day and period of occupation of a camp, should be taken into account when designing management practices in range areas. Knowledge of feed availability, feeding behaviour and feed preference of free ranging Tswana and Boer goats is fundamental for small scale farmers to develop management strategies aimed at optimum sustained use of the natural vegetation and for the survival of these breeds in the semi arid environment.

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CHAPTER 4

FACTORS AFFECTING WOODY PLANT SPECIES SELECTION OF FREE RANGING TSWANA AND BOER GOATS

4.1. Introduction

Range goats are known to utilize a variety of native browse and herbaceous vegetation (Ramirez *et al*., 1993; Provenza, 1995; Ammar *et al*., 2008; Ramírez-Orduña *et al*., 2008; Kumara Mahipala *et al*, 2009). The contribution made by shrubs and trees to livestock nutrition is considered to be the most important in semi-arid and arid areas (Devendra, 1990; Bhatta *et al*., 2004; Ventura *et al*., 2004; Kamalak, 2006; Tefera *et al*., 2008; Noumi *et al*., 2010; Camacho *et al*., 2010), where extensive livestock production systems are practised (Berhane & Eik, 2006; Gasmi-Boubaker *et al*., 2006). Diet selection is influenced by a complex mix of intrinsic and external factors (Glasser *et al*., 2009). Intrinsic factors include the animal species (le Houeron, 1980; Odo *et al*., 2001) and breed (Celaya *et al*., 2003; Ellis *et al*., 2005); health (Villalba *et al*, 2005); physiological state of the animal (le Houeron, 1980; Barroso *et al*., 1995); and hunger and other physiological feedbacks or control mechanisms (Launchbaugh *et al*., 1999; Jansen *et al*., 2007). External factors include plant availability and accessibility (le Houeron, 1980; Murden & Risenhoover, 1993; Barroso *et al*., 1995; Schlecht *et al*., 2006; Sanon *et al*., 2007); variations in phenology stages and seasons (Illius & Gordon, 1993; Odo *et al*, 2001; Dziba *et al*., 2003; Torrano & Valderrábano, 2005; Schlecht *et al*., 2006; Sanon *et al*., 2007 ; Fraser *et al*., 2009; Glasser *et al*., 2009); plant quality (Ngwa *et al*., 2000; Rafferty & Lamont, 2007; Alonso Diaz *et al*., 2008; Fraser *et al*., 2009; Stolter *et al*., 2009); plant toxicity (Provenza & Malecheck 1984; Glasser *et al*., 2009) and social relations (Provenza & Burrit, 1991: Glasser *et al*., 2009).

It is well known that animals choose different plant species to meet their nutritional requirements, unless limited by forage availability (Sanon *et al*., 2007). Goats exhibit a marked flexibility in diet selection when confronted with seasonal changes in the availability, and nutritional quality (Alonso-Díaz *et al*., 2008), of various constituent plant species on the range

(Yayneshet *et al*., 2008). The selective grazing behaviour of goats buffers the annual variation in the chemical composition of the pastures (Fajemisin *et al*., 1996).

Diet selectivity by herbivores shapes diversity, structure and dynamics of the plant populations (Hodgson & Illius, 1996; Duncan *et al*., 2006). Understanding the reasons why animals prefer some shrubs and not others is important in managing livestock and wildlife with regard to sustaining the shrubland they occupy (Barroso *et al*., 1995). Identification of diet preferences of herbivores can lead to better understanding of the succession development of native rangeland vegetation and help to improve management strategies (Yayneshet *et al*., 2008). The assessment of forage preference could enhance the fodder production in order to improve goat production systems in regions where goat milk and meat contribute to the food needs of the human population (Berhane & Eik, 2006). Yet, the factors that affect diet selection by goats are poorly understood (Torrano & Valderrábano 2005; Fraser *et al*., 2009).

The feeding behaviour of the Tswana and Boer goats in first experiment of the current study, varied between seasons, time of the day and period of occupation of a camp. Tswana and Boer goats, spent less time browsing than grazing and the time spent browsing declined with advancing period of occupation of a camp. It was therefore important to determine if feeding behaviour influenced woody plant species selection of goats and to also determine the roles played by the season, time of the day and period of occupation.

4.2. Materials and methods

4.2.1. Study area, experimental animals and procedures

The study area, experimental animals and procedures have been described in chapter 3. The same procedure for recording the observed browsing activities was used to determine the woody plant species selection pattern of Tswana and Boer goats.

4.3. Statistical analyses

Data was statistically analysed for frequency of utilization using Chi-square test.

4.4. Results

From a wide spectrum of plant species found in the camp used during this trial, the goats encountered and selected a total of thirteen woody plant species. However, five of the thirteen selected woody plant species were utilised in small amounts ranging from 0.1 to 1.2 %. These include *Diospyros lyciodes*, *Dovyalis caffra*, *Lippia javanica*, *Rhus andulata* and forbs. The eight most preferred woody-plant species are listed in Table 4.1. *Scutia myrtina* was the most frequently (29.9 %) consumed woody plant species in the camp followed by *Rhus refracta* (16.3 %), *Grewia occidentalis* (14.0 %), and *Olea africana* (10.8 %). These four woody-plant species accounted for 71 % of the woody plants selected by goats. The remaining four species, A*cacia karroo* (8.7 %), *Coddia rudis* (6.9 %), *Maytenus heterophylla* (6.9 %) and *Ehretia rigida* (6.6 %), accounted for 29 % of the total woody plants selected by goats. Significant differences ($P<0.001$) were found in the percentage time spent selecting the different woody plant species by goats.

Table 4.1. The eight most preferred woody plant species selected by goats listed in order of preference, and indicating their presence in the camp as percentages

Woody-plant Species	**Frequency**	**Percent**	**Percent in the camp**	
			cold-dry season	**hot-wet season**
Scutia myrtina	392	29.9	5	7
Rhus refracta	214	16.3	4	2
Grewia occidentalis	184	14.0	5	7
Olea africana	141	10.8	5	8
Acacia karroo	114	8.7	6	18
Coddia rudis	91	6.9	21	17
Maytenus heterophylla	90	6.9	7	12
Ehretia rigida	86	6.6	3	1

4.4.1. Factors affecting the selection pattern of woody-plant species by goats

4.4.1.1. Season

In general, goats spent more time selecting woody-plant species ($P<0.001$) in the cold-dry season (56.9 %) than the hot-wet season (43.1 %). Goats also showed a preference for different woody-plant species during the cold-dry season and hot-wet season (Table 4.2). *Scutia myrtina* was the most frequently browsed woody-plant species and time spent browsing this species peaked in the cold-dry season (22.5 %) and decreased in the hot-wet season (7.4 %). On the other hand *R. refracta* was the most preferred woody-plant species selected in the hot-wet season (10.4%) while its selection was low in the cold-dry season (6.0 %).

Table 4.2. Woody plant species selected by goats as influenced by season listed in order of preference for each season

Season			
Cold-dry season		**Hot-wet season**	
Woody-plant Species	Frequency & Percent	Woody-plant Species	Frequency & Percent
Scutia myrtina	295 (22.5)	*Rhus refrater*	136 (10.4)
Grewia occidentalis	97 (7.4)	*Scutia myrtina*	97 (7.4)
Olea Africana	87 (6.6)	*Acacia karroo*	97 (7.4)
Rhus refrater	78 (6.0)	*Grewia occidentalis*	87 (6.6)
Maytenus heterophylla	78 (6.0)	*Olea Africana*	54 (4.1)
Coddia rudis	60 (4.6)	*Ehretia rigida*	52 (4.0)
Ehretia rigida	34 (2.6)	*Coddia rudis*	31 (2.4)
Acacia karroo	17 (1.3)	*Maytenus heterophylla*	12 (0.9)

Grewia occidentalis was the second most preferred woody-plant species in the cold-dry season followed by *O. Africana, R. refracta M. heterophylla, C. rudis, E. rigida* and *A. karroo.* In the

hot-wet season the order of preference was different, with *S. myrtina* being the second most preferred species followed by *A. Karroo, G. occidentalis, O. africana, E. rigida, C. rudis* and *M. heterophylla.*

4.4.1.2. Breed

In general, Tswana goats spent more time selecting the woody-plant species than the Boer goats (P<0.001). It was seen that the Tswana goats spent 58.1 % of their selection time collecting woody plants while the Boer goats spent 41.9 % of their selection time using woody palnts.

The differences between Tswana and Boer goats with regard to the frequency of selection of woody-plant species is shown in Table 4.3.

Table 4.3. The effect of breed (Tswana or Boer goat) on the selection of preferred woody plant species by goats

	Tswana		Boer		
Woody-plant Species	**Frequency**	**Percent**	**Frequency**	**Percent**	**Level of Significance**
Scutia myrtina	246	13.1	146	18.8	***
Rhus refracta	112	8.5	102	7.8	NS
Grewia occidentalis	92	7.1	92	7.1	NS
Olea Africana	72	5.5	69	5.3	NS
Acacia karroo	61	4.7	53	4.0	NS
Coddia rudis	63	4.8	28	2.1	***
Martens heterophylla	60	4.6	30	2.3	**
Ehretia rigida	56	4.3	30	2.3	**

NS = not significant * = P < 0.05 ** = P < 0.01 *** P < 0.001

The two breeds showed many similarities as well as minor differences in their preference for woody-plant species. Boer goats showed a higher preference for *S. myrtina* (18.8 %) compared to Tswana goats (13.1 %). Tswana goats, however, preferred *R. refracta* (8.5 %) compared to Boer goats (7.8 %). Preference for *G. occidentalis* was similar for both Tswana (7.0 %) and Boer goats (7.1 %). Similar preferences were also observed in the selection of *O. africana* (Tswana 5.5 %; Boer 5.3 %) and *A. karroo* (Tswana 4.7 %; Boer 4.0 %). Woody-plant species preferred by Tswana goats in comparison to Boer goats included *C. rudis* (Tswana 4.8 %; Boer 2.1 %), *M. heterophylla* (Tswana 4.57 %; Boer 2.3 %) and *E. rigida* (Tswana 4.3 %; Boer 2.3 %)

4.4.1.3. Time of the day

Woody-plant selection varied significantly ($P<0.001$) during the day. The selection was higher in the morning followed by the afternoon. Selection was lower during midday (28.7 %) when compared to the morning (39 %) and afternoon (32.2 %). In general the goats displayed a definite diurnal variation ($P<0.05$) in woody-plant species selection as shown in Table 4.4.

Table 4.4. The effect of time of the day on the selection of preferred woody plant species by goats

	Time of the day		
	(0800h-0935h)	**(1100h-1235h)**	**(1400h-1535h)**
Woody-plant Species	Frequency & Percent	Frequency & Percent	Frequency & Percent
Scutia myrtina	129 (9.8)	130 (9.9)	133 (10.1)
Rhus refrater	94 (7.2)	56 (4.3)	64 (4.9)
Grewia occidentalis	71 (5.4)	52 (3.4)	61 (4.7)
Olea Africana	47 (3.6)	37 (2.8)	57 (4.3)
Acacia karroo	51 (3.9)	31 (2.4)	32 (2.4)
Coddia rudis	42 (3.2)	20 (1.5)	29 (2.2)
Maytenus heterophylla	43 (3.3)	23 (1.8)	24 (1.8)
Ehretia rigida	35 (2.7)	28 (2.1)	23 (1.8)

The selection pattern for *S. myrtina*, was the same during the different times of the day (Morning 9.8 %; midday 9.9 %; afternoon 10.1 %). However, *Rhus refracta* and *G. occidentalis* were browsed more in the morning (7.2 % and 5.4 % respectively) followed by afternoon (4.9 % and 4.7 %) and midday (4.3 % and 3.4 % respectively). Selection of *O. africana* was higher in both the afternoon (4.3 %) and morning (3.6 %) compared to midday (2.8 %). A*cacia karroo, C. rudis* and *M. heterophylla* were selected more in the morning (3.9 %, 3.2 % and 3.3 % respectively) followed by the afternoon (2.4 %, 2.2 % and 1.8 % respectively) and midday (2.4 %, 1.5 % and 1.8 % respectively). The selection of *E. rigida* was higher in the morning (2.7 %) compared to at midday (2.1 %) and in the afternoon (1.8 %).

4.4.1.4. Period of occupation

The percentage time spent selecting woody plant species by goats decreased with the advancing period of occupation ($P<0.001$) of a grazing or browsing camp (22.6 % on the first day to 2.3 % on the last day of occupation) as shown in Table 4.5.

Table 4.5. The effect of period of occupation of a camp on the selection of woody plant species by goats

Period of occupation	Frequency	Percentage
Day 1	297	22.6
Day 2	235	17.9
Day 3	236	18.0
Day 4	196	15.0
Day 5	182	13.9
Day 6	166	12.7

The frequency of woody plant species selection varied during the different observation days as shown in Table 4.6. It appears as though the frequency of browsing decreases the longer the goats stay in the camp.

Table 4.6. The effect of period of occupation of a grazing or browsing camp on the selection of preferred woody plant species by goats

	Period of occupation of a grazing/browsing camp					
	Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**
Woody-plant Species	**Freq & %**	**Freq & %**	**Freq & %**	**Freq & %**	**Freq & %**	**Freq & %**
Scutia myrtina	75 (5.7)	84 (6.4)	46 (3.5)	84(6.7)	41 (3.1)	58 (4.4)
Rhus refrater	41 (3.1)	36 (2.7)	43 (3.2)	16 (1.2)	29 (2.2)	49 (3.7)
Grewia occidentalis	41 (3.1)	33 (2.5)	35 (2.7)	36 (2.7)	25 (1.9)	14 (1.1)
Olea africana	38 (2.9)	28 (2.1)	44 (3.4)	4 (0.3)	14 (1.1)	13 (1.0)
Acacia karroo	40 (3.1)	18 (1.4)	17 (1.3)	11 (0.8)	22 (1.7)	6 (0.5)
Coddia rudis	14 (1.1)	15 (1.1)	16 (1.3)	21 (1.6)	18 (1.4)	7 (0.5)
Maytenus heterophylla	29 (2.2)	11 (0.8)	24 (1.8)	8 (0.6)	11 (0.8)	7 (0.5)
Ehretia rigida	19 (1.5	10 (0.8)	11 (0.8)	12 (0.9)	12 (0.7)	12 (0.9)
Total Frequency	**297**	**235**	**236**	**196**	**182**	**166**
Total Percent	**22.6**	**17.9**	**18.0**	**14.9**	**13.9**	**12.7**

Definite diurnal patterns in woody plant selection were observed in both the Tswana and Boer goats during the cold-dry season and the hot-wet season (Table 4.7). Tswana goats had a higher frequency of woody plant selection in the cold-dry season than in the hot-wet season. The Boer goats, on the other hand, maintained the same frequency of woody plant selection in both the cold-dry season and the hot-wet season. During both seasons, Tswana goats had a higher frequency of woody plant selection compared to Boer goats.

Table 4.7. The effect of season and time of the day on the preference for woody plants (n=1312) by Tswana and Boer goats

Factor	Breed				
	Tswana		Boer		
	Frequency	Percent	Frequency	Percent	Significance level
Season					
Cold-dry	474	36.1	272	20.7	***
Hot-wet	288	22.0	278	21.2	NS
Time					
(0800h-0935h)	320	24.4	192	14.6	***
(1100h-1235h)	193	14.7	184	14.0	NS
(1400h-1535h)	249	18.9	174	13.3	***

NS = not significant * = P < 0.05 ** = P < 0.01 *** P < 0.001

Tswana goats selected more woody-plant species in the morning followed by the afternoon and midday. Boer goats on the other hand did not vary their frequency of woody plant selection much throughout the day.

4.4.1.5. Woody plant species selected by Tswana and Boer goats during the cold-dry season and the hot-wet season at different times of the day

Woody plant selection by Tswana and Boer goats varied during the different seasons and times of the day as shown in Table 4.8.

4.4.1.5. (a) *Scutia myrtina*

Tswana goats spent the same amount of time in the morning, midday and afternoon (18.2 %) selecting *S. myrtina* during the cold-dry season. Boer goats also spent the same amount of time selecting *S. myrtina* both in the morning and midday (16.7 %), but increased their selection in the afternoon (20 %). During the hot-wet season, the selection of *S. myrtina* by both breeds

increased compared to the cold-dry season. Tswana goats had a higher preference for *S. myrtina* in the afternoon (26.3 %) and a similar preference in the morning and midday (21.1 %). Boer goats however showed a higher preference for *S. myrtina* during midday (37.5 %) followed by morning (31.3 %) and afternoon (25.0 %).

Table 4.8. The effect of the season and time of the day on the browsing percentage of specific woody plants by Tswana and Boer goats

Woody-plant species	Season	Breed	Time (08:00-09:35)	(11:00-12:35)	(14:00-15:35)
Scutia myrtina	Cold-dry season	Tswana	18.2	18.2	18.2
		Boer	16.7	16.7	20.0
	Hot-wet season	Tswana	21.1	21.1	26.3
		Boer	31.3	37.5	25.0
Rhus refracta	Cold-dry season	Tswana	18.5	11.1	11.1
		Boer	12.5	8.3	16.7
	Hot-wet season	Tswana	18.5	22.2	18.5
		Boer	20.8	25.0	16.7
Grewia occidentalis	Cold-dry season	Tswana	14.3	17.9	21.4
		Boer	15.4	11.5	11.5
	Hot-wet season	Tswana	21.4	17.9	7.1
		Boer	23.1	23.1	15.4
Olea Africana	Cold-dry season	Tswana	26.3	5.3	21.1
		Boer	9.1	9.1	22.7
	Hot-wet season	Tswana	10.5	15.8	21.1
		Boer	18.2	22.7	18.2
Acacia karroo	Cold-dry season	Tswana	15.8	5.3	10.5
		Boer	6.3	0.0	0.0
	Hot-wet season	Tswana	21.1	21.1	26.3
		Boer	31.3	37.5	25.0
Coddia rudis	Cold-dry season	Tswana	31.6	15.8	15.8
		Boer	12.5	12.5	18.8
	Hot-wet season	Tswana	21.1	5.3	10.5
		Boer	18.8	25.0	12.5
Maytenus heterophylla	Cold-dry season	Tswana	29.4	17.7	29.4
		Boer	23.1	7.69	23.1
	Hot-wet season	Tswana	17.7	0.0	5.9
		Boer	23.1	7.7	15.4
Ehretia rigida	Cold-dry season	Tswana	14.3	9.5	14.3
		Boer	21.1	10.5	5.3
	Hot-wet season	Tswana	28.6	19.1	14.3
		Boer	31.6	21.1	10.5

4.4.1.5. (b) *Rhus refracta*

During the cold-dry season, Tswana goats selected more *R. refracta* in the morning (18.5 %) compared to midday and the afternoon (11.1 %) when a similar percentage was selected. Boer goats however showed a higher preference for *R. refracta* in the afternoon (16.7 %) compared to morning (12.5 %) and midday (8.3 %). During the hot-wet season the selection pattern of Tswana goats changed with a higher preference occurring at midday (22.2 %) than in either the morning (18.5 %) or the afternoon (18.5 %). Boer goats also showed the same pattern of

preference for *R. refracta* with a higher selection at midday (25.0 %) compared to the morning (20.8 %) and afternoon (16.7 %).

4.4.1.5. (c) *Grewia occidentalis*

Grewia occidentalis was better utilized in the afternoon (21.4 %) by Tswana goats, followed by midday (17.9 %) and morning (14.29%) browsing during the cold-dry season. Boer goats however preferred utilizing *G. occidentalis* in the morning (15.38%) compared to both midday and afternoon (11.5 %). In the hot-wet season, Tswana goats had a higher preference for *G. occidentalis* in the morning (21.5 %) followed by the afternoon (17.9 %). The lowest selection of *G. occidentalis* by Tswana goats was in the afternoon (7.1 %). Boer goats selected the same percentage (23.1) of *G. occidentalis* both in the morning and midday compared to the afternoon (15.4%).

4.4.1.5. (d) *Olea africana*

In the cold-dry season, the selection of *O. africana* by Tswana goats was higher in the morning (26.3 %) and afternoon (21.1 %) and low at midday (5.3 %). Boer goats however showed high preference for *O. africana* in the afternoon (22.7 %) and low preference both in morning and midday (9.1 %). During the hot-wet season, preference for *O. africana* by Tswana goats was high in the afternoon (21.1 %) followed by midday (15.8 %) and low in the morning (10.5 %). Boer goats on the other hand preferred *O. africana* more during midday (22.7 %) compared to both morning and afternoon (18.2 %).

4.4.1.5. (e) *Acacia karroo*

A high selection of *A. karroo* by Tswana goats occurred in the morning (15.8 %) followed by the afternoon (10.5 %) and midday (5.3 %). Boer goats also selected *A. karroo* in the morning (6.3 %) while none was selected during midday and the afternoon. During the hot-wet season, Tswana goats selected more *A. karroo* in the afternoon (26.3 %) while selection in the morning

and midday was the same (21.1 %). Boer goats however selected more *A. karroo* during midday (37.5 %) followed by the morning (31.3 %) and afternoon (25.0 %).

4.4.1.5. (f) *Coddia rudis*

During the cold-dry season, Tswana goats preferred *C. rudis* in the morning (31.6 %) when compared to midday (15. 8%) and afternoon (15.9 %). Boer goats, however, selected *C. rudis* more in the afternoon (18.8 %), and a similar preference was shown in the morning and midday 12.5 %). In the hot-wet season, Tswana goats preferred browsing *C. rudis* in the morning (21.1 %) followed by the afternoon (10.5 %) and midday (5.3 %). Boer goats however preferred browsing *C. rudis* more at midday (25 %) followed by morning (18.8 %) and afternoon (12.5 %).

4.4.1.5. (g) *Maytenus heterophylla*

Tswana goats selected similar percentages of *M. heterophylla* both in the morning and afternoon (29.4 %) compared to midday (17.7 %). The same trend was also observed with Boer goats where their preference for *M. heterophylla* was similar in the morning and afternoon (23.1 %) and low during midday (1.7 %). During the hot-wet season, Tswana goats selected more *M. heterophylla* in the morning (23.1 %) than in the afternoon (15.4 %), but none during midday. Boer goats also selected more *M. heterophylla* in the morning (23.1 %) followed by afternoon (15.4 %) and less at midday (7.7 %).

4.4.1.5. (h) *Ehretia rigida*

During the cold-dry season, Tswana goats showed similar preference for *E. rigida* both in the morning and afternoon (14.3 %) when compared to midday (9.5 %). Boer goats, however, showed a high preference for the same plant in the morning but this declined by midday (10.5 %) and afternoon (5.3 %). In the hot-wet season both Tswana and Boer goats selected more *E. rigida* in the morning (28.6 % and 31.6 respectively) than at midday (19.1% and 21.1 % respectively) and in the afternoon (14.3 % and 10.5 % respectively)

4.5. Discussion

Goats exhibit marked flexibility in diet selection when confronted with seasonal changes in availability and nutritional changes of various constituent plant species (Morand-Fehr, 1981; Yayneshet *et al*. 2008). Negi *et al*. (1993) point out that goats should be regarded as highly selective in its foraging behaviour. Jones (1953) states that in some plant species, the differences in preference are not only due to their chemical makeup but to their morphological features as well. Degree of selection by goats depends on plant species offered and stage of growth of forage (Morand-Fehr *et al*., 1980). The Tswana and Boer goats foraged upon diverse woody-plant species. Both breeds selected similar types of woody plant species. The eight most preferred woody-plant species were similar for both breeds, however, the frequency of selection and order of preference were different. Across treatments, Tswana goats exhibited a higher frequency of woody plant selection compared to Boer goats. The difference between breeds in their time allocations to woody plant species selection was notable in the cold-dry season when Tswana goats allocated an extra 15 % of their time to woody-plant selection compared to Boer goats. In the hot-wet season Tswana goats decreased their frequency of woody plant section. Boer goats maintained the same frequency of woody plant selection in both the cold-dry season and the hot-wet season. Boer goats showed a higher preference for *S. myrtina* while Tswana goats showed a higher preference for *R. refracta.* Both breeds showed similar preferences for *G. occidentalis*, *O. africana* and *A. karroo*. Tswana goats however showed a greater preference for *C. rudis*, *M. heterophylla* and *E. rigida* than the Boer goats did.

In a study by Bjelland and Grøva (1997) on woody-plant preference by indigenous Ciskeian goats and improved Boer goats, both breeds selected in a similar fashion six preferred woody-plant species (*Acacia karroo*, *Rhus lucida*, *Grewia occidentalis*, *Scutia myrtina*, *Ehretia rigida* and *Maytenus heterophylla*) though the order of preference was different.

Differences in the frequency of woody plants selected by goats were observed during the different seasons. This is in agreement with results from studies by Torrano & Valderrabano (2005) and Yayneshet *et al*. (2008) where goats exhibited a seasonal and diurnal pattern of plant utilization. In general, the frequency of woody-plant species selection was higher in the cold-

dry season than the hot-wet season. *Scutia myrtina* was the most preferred woody-plant species during the cold-dry season followed by *G. occidentalis, O. africana, R. refracta, M. heterophylla, C. rudis, E. rigida,* and *A. karroo.* During the hot-wet season *R. refracta* was the most preferred followed by *S. myrtina*, *A. karroo, G. occidentalis, O. africana, E. rigida, C. rudis* and *M. heterophylla.*

Woody-plant species selection pattern changed during the course of the day. A higher percentage of woody-plants were selected during the morning. Selection was lower during midday but increased again slightly during the afternoon. Regardless of the breed of goat or the season, only *G occidentalis* and *O. Africana* were the most preferred woody-plant species in the afternoon, while all the other woody-plant species were selected with the highest frequency in the morning. During the cold-dry season, the following woody-plant species were preferred by Tswana goats in the morning*: S. myrtina, R. refracta, O. africana, A. karroo, C. rudis, M. heterophylla and E. rigida.* Boer goats on the other hand preferred *G. occidentalis, A. Karroo, M. heterophylla* and *E. rigida.*

During midday, both breeds showed no particular preference for specific species. In the afternoon however, Tswana goats showed higher preference for *G. occidentalis* and *M. heterophylla* while Boer goats preferred *S. myrtina, R. refracta, O. africana, C. rudis* and *M. heterophylla.* During the hot-wet season, woody-plant species most preferred by Tswana goats in the morning were *G. occidentalis, C. rudis, M. heterophylla and E. rigida.* Boer goats showed a higher preference for *G. occidentalis, M. heterophylla* and *E. rigida.* During midday, Tswana goats showed a higher preference for only *R. refracta* while Boer goats showed a higher preference for *G. occidentalis, M. heterophylla* and *E. rigida.* In the afternoon Tswana goats preferred browsing *S. myrtina, O. africana* and *A. karroo* while Boer goats did not show a higher preference for any particular woody-plant species.

During both seasons and for both breeds of goat, the frequency of woody-plant selection decreased with advancing period of occupation. Browse was the preferred feed when feed availability was high, supporting the findings of Bjelland & Grova (1997) and Mogorosi *et al.* (1996). When feed availability declined, goats decreased their frequency of woody-plant

selection as they were forced to eat more grass (Gøthasen, 1997; Dziba & Raats, 1998). Negi *et al*., 1993) observed that when food resources are diversified, a goat's feeding behaviour is highly selective and when plant diversity narrows down, it resorts to generalist behaviour.

Both deciduous and evergreen plant species were among the more preferred species. Deciduous woody plant species are usually preferred above evergreen species (Papachristou & Nastis, 1996) as they are easily available and highly nutritious. They are also more preferred in the hot-wet season than evergreen species (Gennin & Pijoan, 1993). The botanical survey showed that during the cold-dry season goats foraged in a range that had a total of 59 % of the eight most preferred woody plant species (Table 4.1). In the hot-wet season the percentage of the woody plant species was higher, constituting about 72 % of the total plants in the range. Woody plant species that each constituted less than 10 % of the plants in the camp during both seasons were amongst the top four most preferred plants. Ngwa *et al*. (2000), states that plant species that constitute a small proportion of the entire range make a large part of the diet of animals. Barroso *et al*. (1995) also found a trend of higher selectivity for species with a lower availability. It could be argued that certain plant types are relatively rare because they are the plant types the goats select. On the other hand, there may be an inherent tendency by the generalist forager towards selective grazing of relatively rare plant types which are rare for reasons other than herbivory.

Grewia occidentalis, *A. karroo and E. rigida* are deciduous, so have less available browse in the cold-dry season than the hot-wet season, while *S. myrtina* is evergreen thus their browse availability does not change with season. *G. occidentalis* is regarded as very palatable and highly preferred (Gøthasen, 1997; Haschick & Kerly, 1997) and has been ranked as the second most preferred woody-plant species after *S. myrtina* (Dziba, 2000; Dziba *et al*., 2003). This supports the finding of the current study where *G. occidentalis,* was the second most preferred woody-plant species after *S.* myrtina, during the cold-dry season; but the fourth most preferred in the hot-wet season. *Scutia myrtina* is regarded as palatable during the dry season (Raats *et al*., 1996b) when deciduous species have shed their leaves. A*cacia. karroo and E. rigida* are also palatable but preference for these species declines as the period of occupation increases (Mogorosi *et al.*, 1996). Studies have shown that goats show a particular preference for *A. karroo* (Mapuma *et al*., 1996; Mogorosi *et al*., 1996; Raats *et al*., 1996b). Although results from

the current study show *A. karroo* to be the 8th in order of preference during the cold-dry season, it was still high in preference during the hot-wet season following *R. refracta* and *S. myrtina*. This is mainly a function of the high occurrence of *A. karroo* (Table 4.1) in the study area and the subsequent high encounter rate of goats with *A. karroo* in the range (Raats *et al*., 1996b; Gøthasen, 1997). The proportion of deciduous trees in the range might determine productivity of goats in semi-arid savannas since they lose their leaves in the dry season (Dziba *et al*., 2003).

4.6. Conclusions

Goats foraged upon a wide spectrum of woody-plant species found in the camp. This demonstrates the importance of woody-plant species in semi-arid and arid areas, contributing to the increase in availability of forage resources to free ranging animals. It is however important to highlight that the type of vegetation, availability of woody plant species and phenological stage of the plant influence the woody plant selection by goats. Variations in woody-plant species proportions as well as changes in their quality may modify intake levels and therefore the variation in preference for some plant species with grazing season and time of day should be taken into account when designing management practices in forestry areas. An understanding of plant species selection by free ranging Tswana and Boer goats is important for management strategy and profitable animal production. This information could allow for optimal forage allocation to different types of ruminants, selecting species for re-seeding deteriorated ranges, predicting the outcome of overgrazing by different animals and to identify new species on which to base the management. In the present study, plants that contributed a small proportion of the entire range made a large part of the diet of Tswana and Boer goats. This suggests that careful monitoring of the vegetative community will be required in the light of the different foraging pressures on scarce plant types. Goats may be an important inclusion in multi-herbivore ranging systems in communal ranges of semi-arid areas.

In this experiment, differences in the frequency of woody plants selected by goats were observed during the different seasons and times of the day. During both seasons and for both breeds of goat, the frequency of woody-plant selection decreased with advancing period of occupation. It was therefore of importance to determine if the plant selection pattern is influenced by the nutrient content of the selected forage.

CHAPTER 5

NUTRITIVE VALUE OF FORAGES SELECTED BY FREE RANGING TSWANA AND BOER GOATS

5.1. Introduction

The majority of goats in the world exist on rangelands (Mellado *et al*., 2004; Schlecht *et al*., 2006) where seasonal shortages and low quality of available feed resources are considered the most widespread technical constraints to small-stock production systems in many parts of the developing world (Osuji & Odenyo, 1997; Ouedraogo-Kone *et al*., 2006; Kawas *et al*., 2010). In South Africa, approximately 80% (68.4 million ha) of land available for agricultural purposes can only be utilised effectively by free ranging herbivores (de Waal, 1990). Although the natural vegetation provides the bulk of the nutrients for domestic livestock and all the nutrients for wild herbivores (Harris *et al*., 1967), its ability to sustain animal production varies substantially according to climate (Sanon *et al*., 2007), geography, plant community, bush encroachment and range deterioration (Keskin *et al*., 2005). In arid and semi arid areas, the environment is characterised by chronic deficiencies in certain nutrients and periodic intervals of harsh climate and food shortages (Ramirez *et al*, 2004). Nevertheless these areas offer an important potential for goat production (Ramirez *et al*., 1990) which in most cases represent the sole source of income to farmers (Morand-Fehr *et al*., 2004). The survival of grazing animals is thus, among other factors dependent on the ability to digest low quality roughages, store fat, withstand heat and cold, and recycle deficient nutrients (Raats, 1993). The grazing ruminant therefore exists in a highly dynamic situation where its productivity is primarily dependent on the net nutrient intake, which exceeds maintenance requirements (Laredo *et al*., 1991), and which in turn relies directly on the quantity and quality of food intake. In range animals, this process commences with the ability of the animal to select large quantities of nutritious forage components (Raats, 1993; Sun *et al*., 2008).

The need to evaluate the nutritional characteristics of diets consumed by range ruminants is well recognised (Cerrillo *et al*., 2006). Knowledge of the nutritive value of the diet as selected by grazing or browsing animals is of primary importance in estimating the productivity of the range

(Harris *et al*., 1967; France *et al*., 2000; Sun *et al*., 2008). Any assessment of the nutritional value of the range using goats may lead to the identification of the nutritional constraints that affect efficient rangeland production of livestock (Allison, 1985; Ramirez, 1999; Cerrillo *et al*., 2006). Sub-optimal animal production on rangeland is the result of several factors of which nutrient intake is probably the most common (Allison, 1985). However, not much is known about the nutritive value of the diet selected by free ranging goats (Fraser *et al*., 2009), especially the Tswana goat. Tswana and Boer goats from the experiment on species selection in the current research varied their plant species selection during the different seasons, time of the day and period of occupation of a camp. It was therefore of importance to determine if nutrient content of the diet was also influenced by seasons, time of the day and period of occupation of a camp. The objective of the current study was to compare the nutritive values of diets selected by free ranging Tswana and Boer goats during the cold-dry season and the hot-wet season in the False Thornveld of the Eastern Cape.

5.2. Materials and Methods

5.2.1. Study area and experimental animals

The study area and experimental animals are described in Chapter 3.

5.2.2. Experimental procedures

At 0700h on Tuesdays and Thursdays during the study period, the six goats (3 Tswana and 3 Boer) which had oesophageal fistulae were equipped with remote controlled fistula valves and allowed into the plots to graze/browse. These valves allow the collection of samples without the observer distracting the goat during the selection of plant material. Fistula valve samples were collected from the same six fistulated goats during the rest of the day (until 1535h) at the following hours (8, 9, 11, 12, 14, 15) while the animals were actively grazing/browsing. During collection, the valve remained open until sufficient extrusa had been collected (15 minutes) and then closed when the oesophagus was clear of plant material. Samples were allowed to drop to the ground where they were collected. Any debris adhering to these samples was removed and the clean sample kept in labelled plastic bags on ice in a cooler box. All extrusa samples were

returned to the laboratory and stored in a deep freeze prior to drying and milling. Each sample was freeze-dried and hand separated into bush (woody species) and grass components (including forbs), which were then weighed separately. The bush and grass components were recombined and the sample milled through a 1mm sieve. These oesophageal valve samples were analysed for nitrogen by the Kjeldhal method (AOAC, 1990) and crude protein was calculated as 6.25 x N. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed using the filter bag technique (ANKOM Technology). All results were then calculated and expressed on a dry matter basis.

5.3. Statistical analyses

Data were analysed using Generalised Linear Model Procedures (GLM) of SAS (2003) with breed, season, time of the day and period of occupation and their interactions as the main factors in the model.

5.4. Results

The season, breed, time of the day and period of occupation of a grazing/browsing camp significantly influenced the nutrient content of forages selected by free ranging goats as shown in Table 5.1.

Table 5.1. The effect of season, breed of goat, time of day and the period of occupation of camp on the nutritive value of diets selected by free ranging goats (mean ± SE)

FACTOR	CP	NDF	ADF	ADL
Season				
Cold-dry season	5.4 ± 0.15^{a}	48.2 ± 1.02^{a}	34.3 ± 0.72^{b}	18.0 ± 0.52^{a}
Hot-wet season	9.5 ± 0.15^{b}	53.8 ± 1.02^{b}	37.5 ± 0.72^{a}	19.5 ± 0.52^{a}
Breed				
Tswana	7.7 ± 0.15^{a}	52.4 ± 1.02^{a}	37.0 ± 1.25^{a}	20.0 ± 0.52^{a}
Boer	7.2 ± 0.15^{a}	49.5 ± 1.02^{a}	34.8 ± 1.25^{b}	17.5 ± 0.52^{b}
Time				
(0800h-0935h)	7.7 ± 0.18^{a}	52.0 ± 1.25^{a}	36.8 ± 0.89^{a}	20.4 ± 0.64^{a}
(1100h-1235h)	7.1 ± 0.18^{a}	48.3 ± 1.25^{b}	33.8 ± 0.89^{b}	17.6 ± 0.64^{b}
(1400h-1535h)	7.5 ± 0.18^{a}	52.4 ± 1.25^{a}	37.1 ± 0.89^{a}	18.3 ± 0.64^{b}
Day				
1	8.1 ± 0.26^{a}	52.4 ± 1.77^{a}	40.9 ± 1.25^{a}	23.0 ± 0.90^{a}
2	6.8 ± 0.26^{b}	54.0 ± 1.77^{a}	37.1 ± 1.25^{b}	20.3 ± 0.90^{b}
3	7.7 ± 0.26^{a}	53.6 ± 1.77^{a}	363 ± 1.25^{b}	18.7 ± 0.90^{bc}
4	7.6 ± 0.26^{a}	52.1 ± 1.77^{a}	34.6 ± 1.25^{bc}	17.1 ± 0.90^{c}
5	7.7 ± 0.26^{a}	46.8 ± 1.77^{b}	32.0 ± 1.25^{c}	17.2 ± 0.90^{c}
6	6.7± 0.26^{b}	47.1 ± 1.77^{b}	34.6 ± 1.25^{c}	16.2 ± 0.90^{c}

Means in the same column with different superscripts are significantly different (P<0.05)

5.4.1. Effect of season, breed, time of the day and period of occupation on the crude protein (CP) content of forages selected by goats

There were notable differences (P<0.001) in the seasonal concentrations of crude protein in diets selected by free ranging goats (Table 5.1). On average the crude protein content of the selected diets pooled over treatments varied significantly (P<0.0001) between seasons (cold-dry: 5.4 % SE = 0.15 and hot-wet 9.5 % SE = 0.15). No breed difference (P>0.05) was found between Tswana and Boer goats in the crude protein content of selected forages. Similarly, there were no diurnal variations in crude protein content of forages selected by goats. There were however

significant differences (P=0.001) in the CP content of forages selected on different observation days. The crude protein content of forages selected by Tswana and Boer goats did not differ significantly within each season as shown in Table 5.2.

Table 5.2. The effect of season on the nutritive value of diets selected by Tswana and Boer goats (Percent least square means)

SEASON	BREED	CP	NDF	ADF	ADL
Cold-dry season	Tswana	5.8[a]	50.0[a]	35.9[a]	20.2[a]
	Boer	5.0[a]	46.2[a]	32.7[b]	15.9[b]
Hot-wet season	Tswana	9.5[a]	54.8[a]	38.2[a]	19.9[a]
	Boer	9.4[a]	52.7[a]	36.8[a]	19.1[a]
	SE	0.21	1.45	1.02	0.74

Means in the same column with different superscripts are significantly different (P<0.05)
Crude protein (CP), Neutral Detergent fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL)

However, when comparisons were based on breed, by day and season interaction, there were significant differences (P<0.0001) in CP content of selected forages both during cold-dry season and hot-wet season as shown in Tables 5.3 and Table 5.4 respectively.

Table 5.3. Effect of breed and period of occupation on the nutritive value of forages selected by free ranging Tswana and Boer goats during the cold-dry season

BREED	DAY	CP (%)	NDF (%)	ADF (%)	ADL (%)
Tswana	1	6.9^{a}	56.7^{a}	40.2^{a}	21.8
Tswana	2	5.8^{abc}	47.4^{ab}	34.1^{ab}	22.7
Tswana	3	5.9^{abc}	47.2^{ab}	34.3^{ab}	19.7
Tswana	4	6.0^{abc}	48.7^{ab}	33.0^{ab}	19.8
Tswana	5	5.7^{abcd}	56.1^{ab}	39.4^{a}	19.2
Tswana	6	4.1^{cd}	43.6^{bc}	34.4^{ab}	17.7
Boer	1	6.1^{abc}	52.6^{ab}	35.8^{ab}	20.3
Boer	2	5.7^{abc}	58.7^{a}	40.4^{a}	16.6
Boer	3	6.5^{a}	55.6^{ab}	38.3^{ab}	19.3
Boer	4	4.2^{cd}	49.2^{ab}	29.8^{b}	12.4
Boer	5	3.1^{d}	27.8^{d}	17.7^{c}	8.3
Boer	6	4.7^{bc}	33.4^{cd}	34.4^{ab}	18.2
SE		0.50	4.47	3.21	2.18

Means in the same column with different superscripts are significantly different ($P < 0.05$).
Crude protein (CP), Neutral Detergent fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL)

Significant differences ($P<0.0001$) were found in the crude protein content of selected forages during the cold-dry season.

Table 5.4. Effect of breed and period of occupation on the nutritive value of forages selected by free ranging Tswana and Boer goats during hot-wet season.

BREED	DAY	CP (%)	NDF (%)	ADF (%)	ADL (%)
Tswana	1	10.3^{bc}	50.2	43.9	24.3^{ab}
Tswana	2	8.1^{d}	55.6	36.2	21.1^{b}
Tswana	3	8.9^{bcd}	56.7	36.9	16.6^{cd}
Tswana	4	10.0^{bc}	55.8	39.4	21.2^{b}
Tswana	5	10.1^{bc}	52.6	36.6	21.4^{b}
Tswana	6	9.7^{bc}	57.9	35.6	14.9^{d}
Boer	1	9.1^{bcd}	48.7	43.8	25.4^{a}
Boer	2	7.7^{d}	54.2	37.1	20.8^{b}
Boer	3	9.3^{bc}	54.9	35.4	19.1^{bc}
Boer	4	10.2^{bc}	54.7	36.4	15.1^{d}
Boer	5	11.9^{a}	50.5	34.2	19.9^{bc}
Boer	6	8.3^{bcd}	53.4	34.1	14.1^{d}
SE		0.52	1.29	1.09	1.25

Means in the same column with different superscripts are significantly different ($P < 0.05$).
Crude protein (CP), Neutral Detergent fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL)

Graphical illustrations of the effect of season and period of occupation on the crude protein content of forages selected by goats during cold-dry season and hot-wet season are presented in Figure 5.1 and Figure 5.2 respectively.

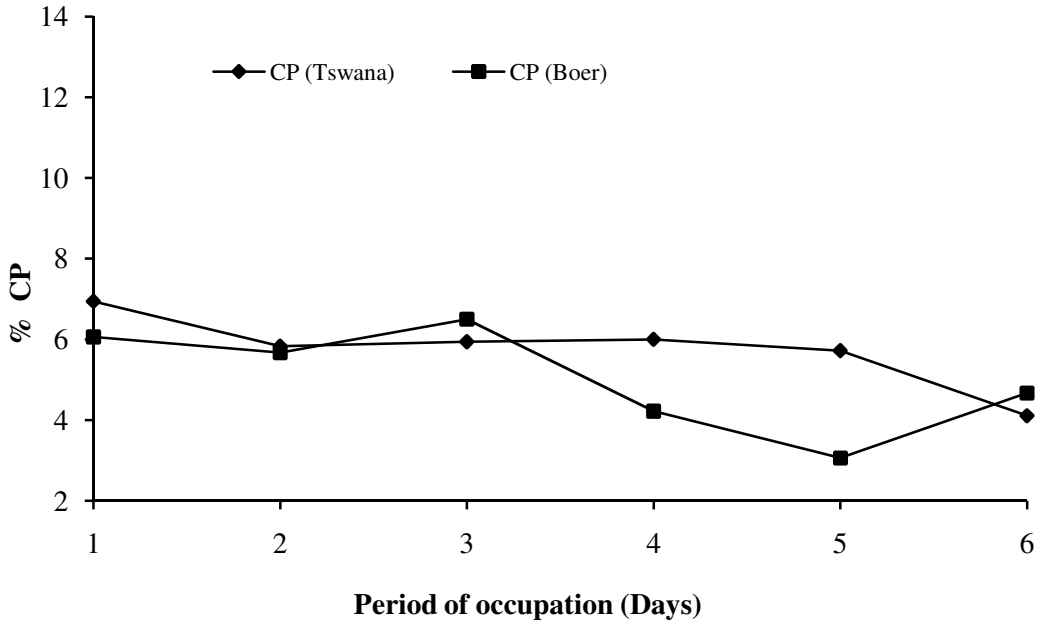

Figure 5.1. Crude protein content of diets selected by free ranging Tswana and Boer goats during the cold-dry season.

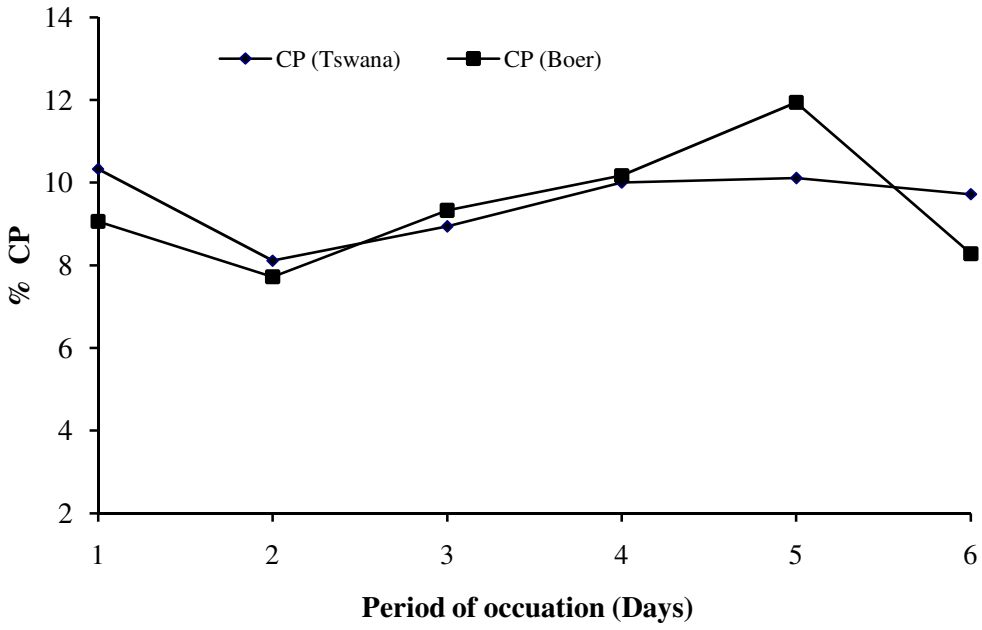

Figure 5.2. Crude protein content of diets selected by free ranging Tswana and Boer goats during the hot-wet season.

5.4.2. Effect of season, breed, time of the day and period of occupation on the neutral detergent fibre (NDF) content of forages selected by goats

There were notable differences (P<0.001) in the seasonal concentrations of NDF in diets selected by free ranging goats (Table 5.1). On average the NDF content of the selected diets varied significantly (P=0.001) between seasons (cold-dry season 48.1 % SE = 1.02; and hot wet season 53.8 % SE = 1.02). There was no difference (P>0.05) found between Tswana and Boer goats in the NDF content of selected forages (52.4 % and 49.5 % SE = 1.02). Regardless of breed and season, there were diurnal variations (P=0.04) in the NDF content of forages selected by goats. There were also significant differences (P=0.01) in the NDF content of forages selected by goats on different observation days. The NDF content of forages selected by Tswana and Boer goats during the period of occupation of a grazing/browsing camp differed significantly (P<0.05) during cold-dry season as shown in Table 5.3 and graphically illustrated in Figure 5.3. However, during the hot-wet season there was no significant difference (P>0.05) in NDF content of selected forages with advancing period of occupation of a grazing/browsing camp as shown in Table 5.4 and graphically illustrated in Figure 5.4.

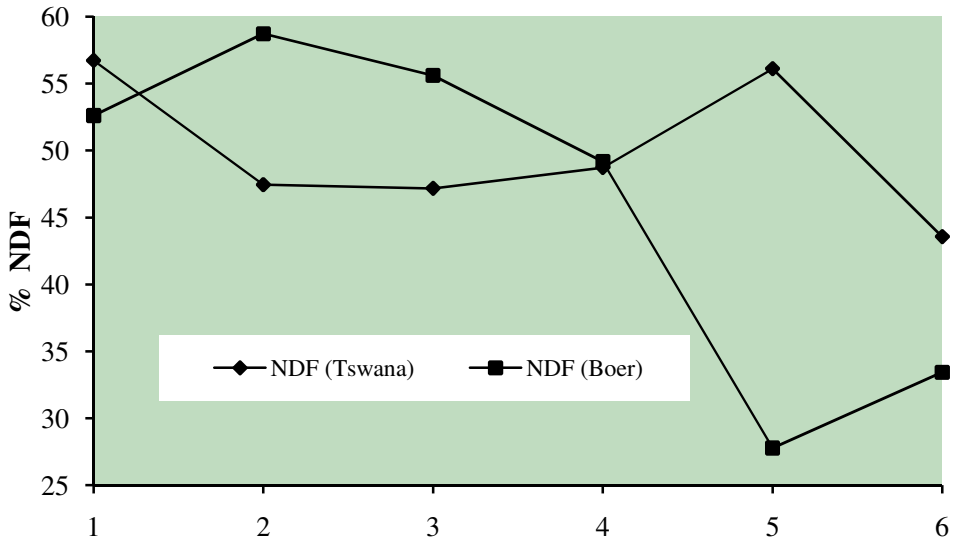

Figure 5.3. The NDF content of diets selected by free ranging Tswana and Boer goats during the cold-dry season

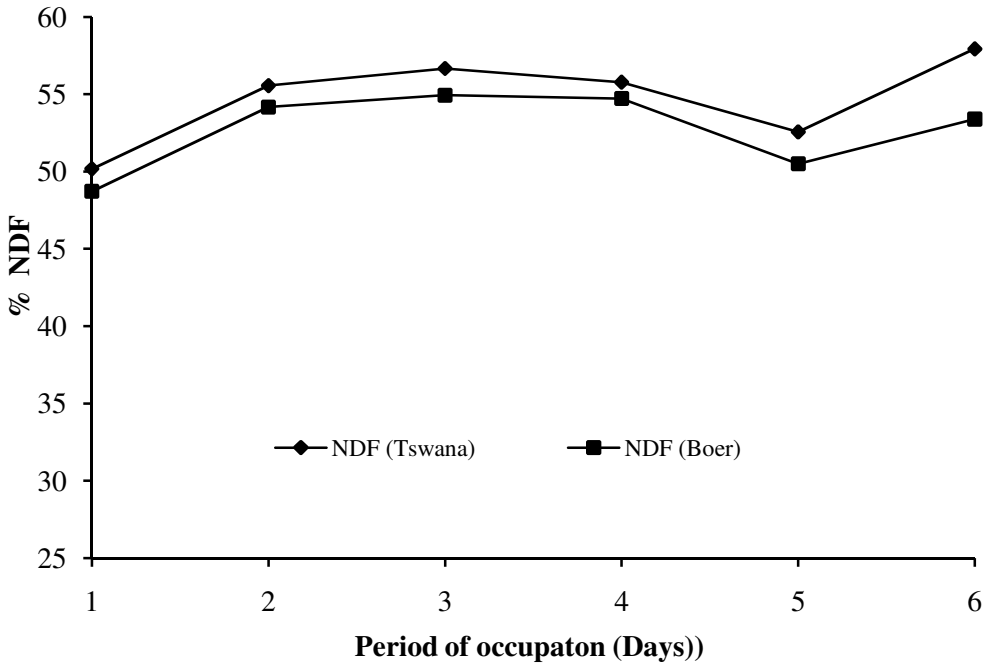

Figure 5.4. NDF content of diets selected by free ranging Tswana and Boer goats during the hot-wet season

5.4.3. Effect of season, breed, time of the day and period of occupation on the acid detergent fibre (ADF) content of forages selected by goats

There were notable differences (P=0.002) in the seasonal concentrations of ADF in diets selected by free ranging goats (Table 5.1). The average ADF content of diets selected by goats, varied significantly (P=0.002) between the cold-dry season (34.3 % SE = 0.72) and the hot-wet season (37.5 % SE = 0.72). There was a breed difference (P=0.03) found between Tswana and Boer goats in the ADF content of selected forages (37.0 % and 34.8 % SE = 1.25 respectively). Regardless of breed and season, there were diurnal variations (P=0.02) in the ADF content of forages selected by goats. Goats selected forages with higher ADF content both in the mornings and afternoons and those with lower ADF during midday. There were also significant differences (P<0.001) in the ADF content of forages selected by goats on different observation days. The ADF content of forages selected by Tswana and Boer goats during the period of occupation of a grazing/browsing camp differed significantly (P=0.003) during the cold-dry season as shown in Table 5.3 and graphically illustrated in Figure 5.5. However, during the hot-wet season there was no significant difference (P>0.05) in ADF content of selected forages with advancing period

of occupation of a grazing/browsing camp as shown in Table 5.4 and illustrated in Figure 5.6. This followed the same trend as found for the NDF content of the selected diets.

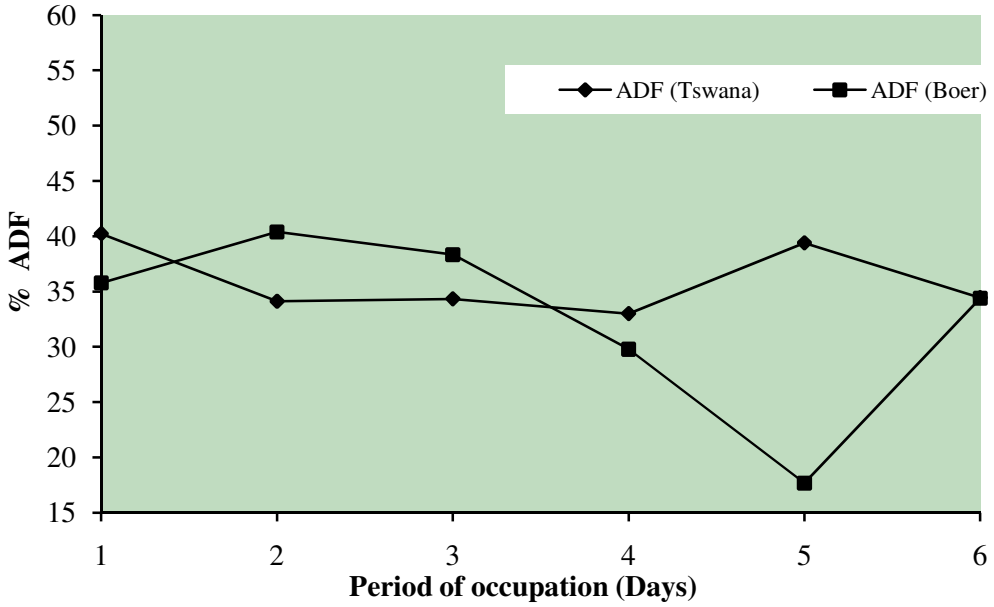

Figure 5.5. ADF content of diets selected by free ranging Tswana and Boer goats during the cold-dry season

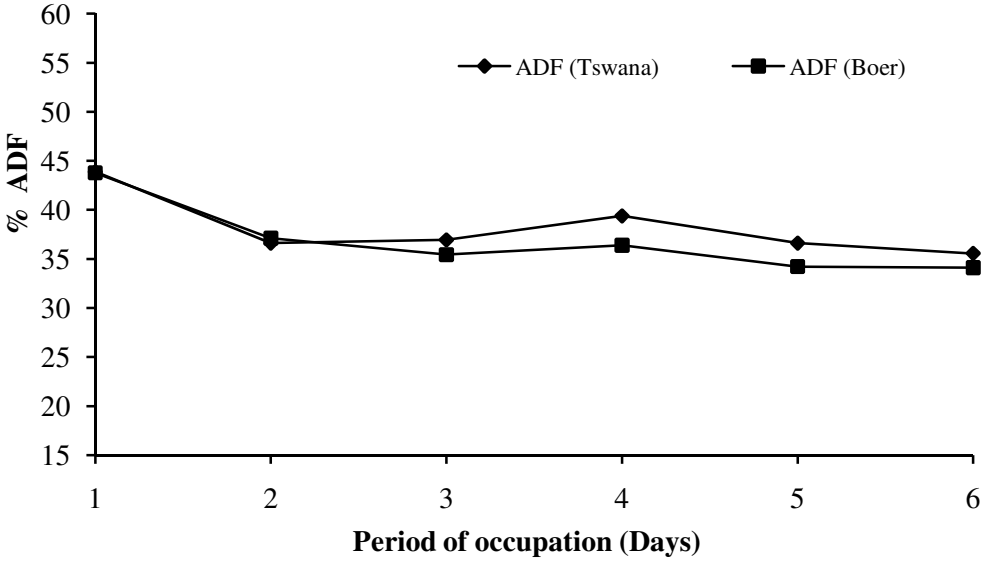

Figure 5.6. ADF content of diets selected by free ranging Tswana and Boer goats during the hot-wet season

5.4.4. Effect of season, breed, time of the day and period of occupation on the acid detergent lignin (ADL) content of forages selected by goats

The average ADL content of diets selected by goats, pooled over treatments did not differ significantly (P>0.05) between the cold-dry season (18.0 % SE = 0.52) and the hot-wet season (19.5 % SE = 0.52) as shown in Table 5.1. There was a significant difference (P=0.001) found between Tswana and Boer goats regarding the ADL content of selected forages (20.0 % and 17.5 % SE = 0.52 respectively). Regardless of breed and season, there were diurnal variations (P=0.01) in the ADL content of forages selected by goats. Goats selected forages with a lower ADL content both during midday and the afternoon while forages with higher ADL content were selected in the morning. There were also significant differences (P<0.0001) in the ADL content of forages selected by goats on different observation days. The ADL content of forages selected by Tswana and Boer goats during the period of occupation of a grazing/browsing camp did not differ significantly (P>0.05) during the cold-dry season as shown in Table 5.3 and graphically illustrated in Figure 5.7. However, during the hot-wet season there was a significant difference (P=0.004) in ADL content of forages selected by goats with advancing period of occupation of a grazing/browsing camp as shown in Table 5.4 and graphically illustrated in Figure 5.8.

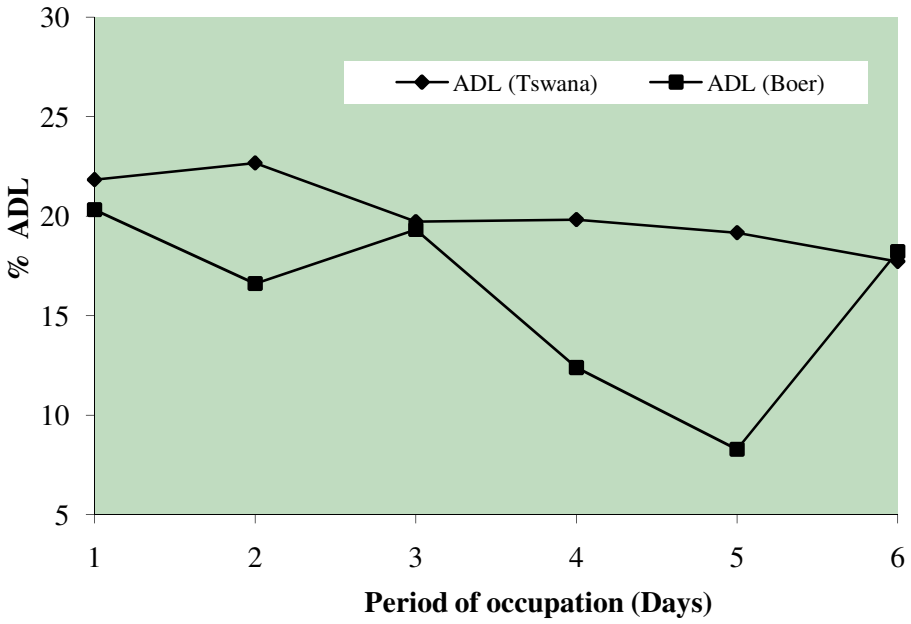

Figure 5.7. ADL content of diets selected by free ranging Tswana and Boer goats during the cold-dry season

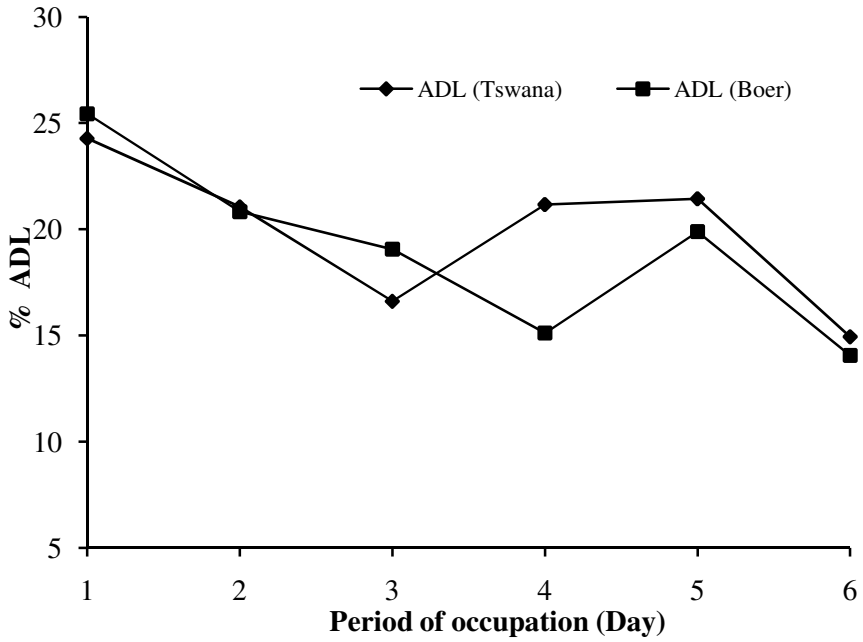

Figure 5.8. ADL content of diets selected by free ranging Tswana and Boer goats during the hot-wet season

5.5. Discussion

The nutrient content of the diet selected by free ranging Tswana and Boer goats varied substantially over seasons. The variation occurred in spite of the large seasonal differences in percentage grass and bush selected by goats. With the wide range of forage plants available to goats, including evergreen species, it is expected that these animals should be able to compensate to a very large degree for seasonal changes in the chemical composition of plants; especially as camps were stocked according to their carrying capacities. During most of the year the foliage of many woody plants has a protein content which is appreciably higher than that of the grasses, even after senescence and death. Otsyina & McKell (1985) showed browse to be richer in protein and certain minerals in the dry season. This is when browse species are the most valuable feed used by livestock. The ranges of NDF, ADF and ADL were comparable to earlier reports by Mogorosi (2000) who found goats to select diets with 45.8-51.1 % NDF, 30.4-31.4 % ADF and 12.5-21.6 % ADL. Seasonal variations in these constituents probably occurred as a result of differences in environmental conditions such as rainfall, temperature and relative humidity (Akkasaeng *et al*, 1989). Ott *et al*. (2004) found a decline in rainfall led to a decline in browse foliage production, which can also be a reason for the decline found in this study.

Crude protein levels reported in this study (5-9 %) were lower than those reported by Mogorosi (2000) in diets of free ranging Boer goats (12-17 %) but comparable to those obtained by Njwe *et al*., (1995) in a study on nutritive value of diets selected by West African dwarf goats (11-12 %) in central Nigeria. The seasonal fluctuations in crude protein contents may have been induced by the the hot-wet season (177 mm) precipitations and also by the high percentage grass (67 %) and low percent bush (37 %) in forages goats selected. Low precipitations during the cold-dry season (84 mm) led to a decline in crude protein resulting in levels that can be regarded as a protein deficiency. Normally the dietary crude protein is greater in the wet versus the dry season (Kronberg & Malecheck, 1997: Kawas *et al*., 2010). The higher crude protein of the diet during the hot-wet season is an expected phenomenon due to the availability of new growth in both the grass and woody components. Low protein contents in the cold-dry season are expected when leaves mature (Owen-Smith, 1988) and this is more pronounced in deciduous, rather than evergreen species. Experiments from the Eastern Cape Province indicate a seasonal tendency of crude protein to increase during spring, decrease in autumn and reach a minimum during the cold-dry season (Trollope, 1981). The 7.5 % CP level is considered as an adequate forage quality threshold, because it falls within the range of values for maintenance of goats (NRC, 1981). Therefore during the cold-dry season, both Tswana and Boer goats selected diets with insufficient crude protein to meet their maintenance requirements, indicating that protein supplementation is required. With the availability of evergreen bush, it is surprising that goats allocated a maximum of only 54 % of their feeding time to browsing activities during the cold-dry season. For goats to derive maximum nutritional benefit of browse available in the fodder banks, they should be able to select as much of browse as possible (Njwe *et al*, 1995). During both seasons, camps had stocking rates of 16 goats ha^{-1}, since any increase in the number of goats ha^{-1} beyond this capacity would have resulted in a decline in the proportion of browse in the diet. It is however evident that during the cold-dry season as the feed supply declined in quality and quantity, the stocking density should have been adjusted, particularly during the study period because the the cold-dry season was very dry.

In the cold-dry season when the quality of the grass is expected to deteriorate, it is surprising that the grass consumption (54 %) was higher than the browse consumption (46 %). This is probably due to the availability of large amounts of browse (evergreen and deciduous bush species) during

the hot-wet season, but the supply was limited to only the evergreen species during the cold-dry season. The other reason may be that as feed supply was depleted in the cold-dry season, goats supplemented their diet with grasses to obtain enough dry matter. The high grass consumption during the cold-dry season resulted in a low crude protein content of the diet selected by goats, as crude protein in grasses reaches a minimum during the cold-dry season. Therefore, during the cold-dry season the use of forages from woody-plant species as a protein supplement can be an alternative strategy that perhaps has not been given adequate research and development attention (Ramirez, 1999).

Higher concentrations of CP were also observed during the early days of sampling in this study, followed by a decrease in CP during the later observation days but only during the cold-dry season. The reason for this is that goats consumed more bush when they first entered the camp and with advancing period of occupation switched to grazing. The significant decrease in CP content of diets selected by goats over time is evidence of the gradual fall in the quality of the foliage available to animals. Grazing animals tend to select the most digestible and nutritious species first before turning to less desirable species or plant parts (Njwe *et al.*, 1995). It has been demonstrated that diet selection is affected by protein levels in available plants (Nyamangara & Ndlovu, 1995; Dziba *et al*., 2003). Studies have already shown that browse generally has higher protein (Taylor & Kothman, 1990; Kadzere, 1995; Owen-Smith, 1997) and mineral contents (Otsyina & McKell 1985; Kadzere, 1995) compared to tropical grasses. During the hot-wet season the CP levels did not follow the trend found by Raats (1997), and this is probably because bush consumption was constantly high throughout the period of stay in the camp. Higher bush consumption resulted in higher CP levels in diets selected by both Tswana and Boer goats during the hot-wet season.

The NDF content ranged from 48.2 % in the cold-dry season to 53.8 % in the hot-wet season compared to a range of (57-59 %) in a study by Njwe *et al*., (1995) with African dwarf goats in Nigeria. The NDF (49.6 %) values obtained in a study by Cerrillo *et al*., (2006) with Spanish goats browsing a thorn shrubland in North Mexico are also comparable to the results of this study. Diets with a cell wall content of 45-55 % are acceptable source of energy for range ruminants (Johnson & de Oliveira, 1989). Thus, values obtained in this study (mean = 51 %)

may indicate an adequate source of energy to sustain productivity of goats. Crude protein and NDF concentrations of the diet were found to be affected by season, stocking rate and period of occupation (Webber *et al*., 1996; Raats, 1997). These researchers found CP in the diet to be significantly higher and NDF significantly lower during the initial days of occupation of a camp compared to the subsequent period of occupation. This corresponds with lower levels of NDF during the first day of sampling in the present study, followed by an increase in NDF during the later observation days, but only during the hot-wet season. The probable reason for this is an increase in the amount of bush consumed with advancing period of occupation during the hot-wet season. During the cold-dry season the NDF levels did not follow the trend found by Raats (1997). This is probably because the amount of bush consumed decreased with advancing period of occupation. The NDF content of selected diets seems to be positively correlated to browse consumption.

Against expectations, the ADF content of the diet was higher in the hot-wet season than in the cold-dry season. This may be due to the higher browse component in the diet during the hot-wet season. High temperatures and solar radiation during the hot-wet season increase fibre fractions of plants because of thickened cell walls (Wilson *et al*., 1991) and enhanced lignin synthesis (Buxton & Fales, 1994; Ngwa *et al*., 2000). The ADF (37.5 %) value obtained in a study by Cerrillo *et al*., (2006) with Spanish goats browsing a thorn shrubland in North Mexico are comparable to the results of this study.

Dietary lignin (mean = 19 %) did not vary between seasons but goats selected forages higher in lignin content in the morning than midday and afternoon. This was probably because forages selected in the morning had higher browse content than those selected at midday and in the afternoon. It is known that twigs from browse contain a high level of lignin.

5.6. Conclusions

In diets selected by goats CP, NDF and ADF were all affected by climatic conditions with the exception of ADL. Goats selected diets higher in CP, NDF and ADF during the hot-wet season compared to the cold-dry season. However, the type of breed did not have any effect on the

nutrient content of diets selected as Tswana and Boer goats selected diets not differing significantly in nutrient content within a season. Period of occupation of a camp had an effect on the nutrient content of diets selected by free ranging Tswana and Boer goats. Nutrient content of selected diets decreased in quality with advancing period of occupation of a camp. Dietary CP was adequate to meet goat requirements only in the hot-wet season. During the cold-dry season, both Tswana and Boer goats selected diets with insufficient crude protein to meet their maintenance requirements. A regime of CP supplementation must be considered during the cold-dry season.