CHAPTER 6

IN SACCO DRY MATTER AND CRUDE PROTEIN DEGRADATION OF WOODY PLANT SPECIES IN TSWANA AND BOER GOATS

6.1. Introduction

In desert and tropical environments, feed resources are restricted in quantity and quality (Sheridan *et al*., 2003). Seasonal fluctuations in forage availability and quality are one of the main causes of nutritional stress that limit animal production in these regions (Kawas *et al*., 1999). Kawas *et al*. (2010) states that forage availability may be as limiting as forage quality to goat performance. The intake of animals on the natural vegetation is fairly high during the growing season as the plants produce fresh and lush leaves and stem that could be grazed and utilized accompanied by reasonable body weight gains and general performance. As the plants mature, all their quality indices depreciate rapidly aggravated by the approaching dry season. Animal intake, digestibility and other quality variables also progressively decrease (Anele *et al*., 2009).

Trees and shrubs have been found to play an important role in providing fodder for ruminants in these parts of the world (Fall-Toure *et al*., 1993; Tolera *et al*., 1997; Kawas *et al*., 2010; Camacho *et al*., 2010). Most browse species have an advantage of maintaining their greenness and nutritive value throughout the dry season when grasses dry up and deteriorate both in quality and quantity. Browse is generally richer in protein and minerals (Le Houeron, 1980; Ørskov, 1993; Kadzere, 1995; Owen-Smith, 1997; Alonso-Diaz *et al*., 2010) and thus has the potential to be an inexpensive, locally produced protein supplement that plays an important role in the nutrition of grazing animals (Meuret *et al*., 1990; Salem *et al*., 2006).

The performance of herbivores when grazing, thus depends on forage digestibility and intake (Ramirez *et al*., 2000; Decruyenaere *et al*., 2009; Fraser *et al*., 2009). Moreover, forage intake is related to fibre digestibility because intake is reduced when fibre is increased in the digestive tract (Mertens, 1993). Rate of digestion provides an important measure of forage quality because intake of forages having rapid rates of digestion is greater than that for forages with slower rates of digestion but similar total digestibility (Holechek *et al*., 1982).

Since the rumen is the primary site of digestion of forages, it is important to monitor their degradation kinetics. This can be achieved by using *in sacco* technique which is quicker and cheaper than whole animal studies. Important characteristics of digestion in the rumen with regard to forages are: effective degradability, lag time, rate of digestion and the amount of digestible fibre (Singh *et al*., 1989; Larbi *et al*., 1997). Rumen degradation is thus regarded as a major descriptor of forage quality (Ørskov and McDonald, 1979). It is useful in ranking trees and shrubs in terms of nutritive value (Larbi *et al*., 1994) and for comparing the digestive capabilities of important characteristics of forages (Migongo-Bake, 1992; Singh *et al*., 1989).

The objective of this study was to estimate *in sacco* degradation characteristics of dry matter and crude protein in woody plant species, which were highly preferred and selected by goats during the cold-dry season (*Scutia myrtinus*, *Olea africana*, *Grewia occidentalis*) and the hot-wet season (*Scutia myrtinus*, *Acacia karroo*, *Rhus refracta*), when incubated in the rumen of the Tswana and Boer goats.

6.2. Materials and methods

6.2.1. Experimental goats

Six wethers (3 Tswana and 3 Boer) each ± 2 years old, with mean body weight of (Tswana ± 37 kg; Boer 36 kg) and each permanently fitted with a rumen cannulae were individually housed in metabolic crates. Goats had a 7 day adaptation period to the diet which was made of 50 % lucerne hay and 50 % of the woody plant species under investigation. Two kilograms of the diet was given to each goat at both 0800h and 1600h. Water was available *ad libitum* and goats had free access to a mineralised lick.

6.2.2. Experimental woody plants

The terminal shoot, made up of young leaves and stems < 6mm in diameter of the three most preferred woody plant species in the cold-dry season (*Scutia myrtina, Olea africana, Grewia occidentalis*) and the hot-wet season (*Scutia myrtina, Rhus refracta, Acacia karroo*) were harvested from University of Fort Hare Honeydale Research Farm near Alice, in the Eastern Cape Province of South Africa ($32^0$49′S, $26^0$54′E). Samples were collected from un-browsed bush species (6 trees per species to eliminate variation in the concentration of compounds among individual trees). The harvested bush samples were dried at 60 ^oC for 48 hours to determine DM and milled through a 2 mm sieve. All samples were analysed for nitrogen (N) as outlined by the Kjeldahl method (AOAC, 1990) and crude protein (CP) calculated as N x 6.25. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were analysed using the filter bag technique (ANKOM Technology). Subsamples of the milled bush samples were used to determine rumen degradability.

6.2.3. Experimental procedures

The ruminal degradability of the three most preferred woody plant species by goats, during the cold-dry season (*G. occidentalis, O. africana* and *S. myrtinus*) and the hot-wet season (*A. karroo, R. refracta* and *S. myrtinus),* was measured in situ, using the nylon bag technique described by Ørskov *et al*. (1980). Samples (5 g DM) of each of the most preferred bush species were placed in nylon bags made of a permeable synthetic fabric (size 5 cm x 10 cm and pore size 45 µm). The bags were incubated in the rumen of 3 Tswana and 3 Boer goats for 72, 48, 36, 24, 16, 8, 4, 2 or 0 hours before removal at a common time. Upon removal from the rumen, bags were washed in cold running tap water while rubbing gently between thumb and fingers until the water became clear. Zero time disappearances (washing losses) were obtained by washing un-incubated bags in a similar fashion. Bags were dried in an oven at 60 ^oC for 48 hours and weighed to determine the dry weight of the incubation residues. The residual samples were removed from each bag and analysed for total nitrogen using the Kjeldahl method (AOAC, 1990) and crude protein (CP) calculated as N x 6.25. The percentage disappearance of dry matter and nitrogen was calculated from their respective amounts remaining after incubation in the rumen. Disappearance was assumed to be due to degradation in the rumen.

Dry matter disappearance was calculated using the formula (Jansen *et al*., 2007):

$$\text{DM disappearance (\%)} = \frac{\text{Initial weight} - \text{Final weight}}{\text{Initial weight}} \times 100$$

The three browse species within a season were compared in terms of disappearance of DM and CP from the bags incubated in the rumen of Tswana and Boer goats.

6.3. Statistical analyses

Disappearance data for DM and CP were fitted for each goat to the exponential model of Ørskov & Macdonald, (1979):

$$\mathrm{P} = \mathrm{a} + \mathrm{b}(1 - \mathrm{e}^{-\mathrm{ct}})$$

where: P is the disappearance of nutrients during time *t*;

a the soluble nutrients fraction which is rapidly washed out of the bags and is assumed to be completely degradable or is an intercept representing the portion of DM and CP solubilised at initiation of incubation (time 0);

b the proportion of DM and CP potentially degradable by micro-organisms (slowly degradable fraction);

c is the degradation rate of fraction *b* per hour (% per hour) or rate constant of fraction *b*;

t is the incubation time (h).

The nonlinear parameters *a*, *b* and *c* were estimated using PROC NLIN (SAS 2003). Correlation analyses were used to investigate relationships between dry matter, crude protein degradation, chemical composition and time of incubation of the woody plant species. Differences in significant terms were determined using least significant differences ($LSD_{0.05}$) by SAS (2003) for all analyses.

6.3. Results

6.3.1. Chemical composition of the woody plant species

The chemical composition of the woody plant species used for *in sacco* degradation during the cold-dry season and the hot-wet season is presented in Table 6.1 and Table 6.2 respectively.

Table 6.1. Chemical composition of the woody plant species used for *in sacco* digestion during the cold-dry season (% DM)

Nutrient	Woody plant species		
	Grewia occidentalis	Olea Africana	Scutia myrtina
DM	95.3	95.1	95.6
CP	10.0	7.0	8.0
NDF	59.0	45.0	58.0
ADF	28.0	33.0	54.0
ADL	21.0	20.0	38.0

Dry matter (DM), Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL)

Table 6.2. Chemical composition of the woody plant species used for *in sacco* digestion during the hot-wet season (% DM).

Nutrient	Woody plant species		
	Acacia karroo	Rhus refracta	Scutia. Myrtina
DM	93.8	93.7	94.4
CP	18.0	8.0	10.0
NDF	48.0	46.0	42.0
ADF	31.0	29.0	34.0
ADL	25.0	20.0	25.0

Dry matter (DM), Crude Protein (CP), Neutral Detergent Fibre (NDF), Acid Detergent Fibre (ADF), Acid Detergent Lignin (ADL)

The dry matter content of the same samples taken from woody plant species ranged from 93.7 % in the hot-wet season to 95.6 % in the cold-dry season but did not vary significantly within each season. The crude protein content was significantly different between browse species. During the cold-dry season the crude protein content was lower, ranging from 7 % to10 % and higher in the hot-wet season, ranging from 10 % to 18 %. Across seasons, *Acacia karroo* had the highest crude protein (18%) while *O. africana* had the lowest (7 %). The NDF content of the woody plant species ranged from 42 to 59 % while the ADF content ranged from 29% to 54 %. The lignin content ranged from 20 to 38 %.

6.4.2. Ruminal dry matter degradation during the cold-dry season

Regardless of the breed, the nylon bag incubation revealed large differences in the rumen degradability of DM the three woody plant species during the cold-dry season. The disappearance of DM of woody plant species from the rumen are presented in Figure 6.1. *Olea africana* exhibited rapid rumen degradability of DM, about 63 % of the DM disappearing within 24 hours of incubation. On the other hand only 52 % DM of *G. occidentalis* disappeared within 24 hours of incubation. The disappearance of *S. myrtina* dry matter from the nylon bags was the slowest, with only 30 % disappearing within 24 hours of incubation. After 72 hours of incubation, 75 % DM of *O. africana*, 69 % DMD of *G. occidentalis* and only 37 % DM of *S. myrtina* had disappeared from the nylon bags.

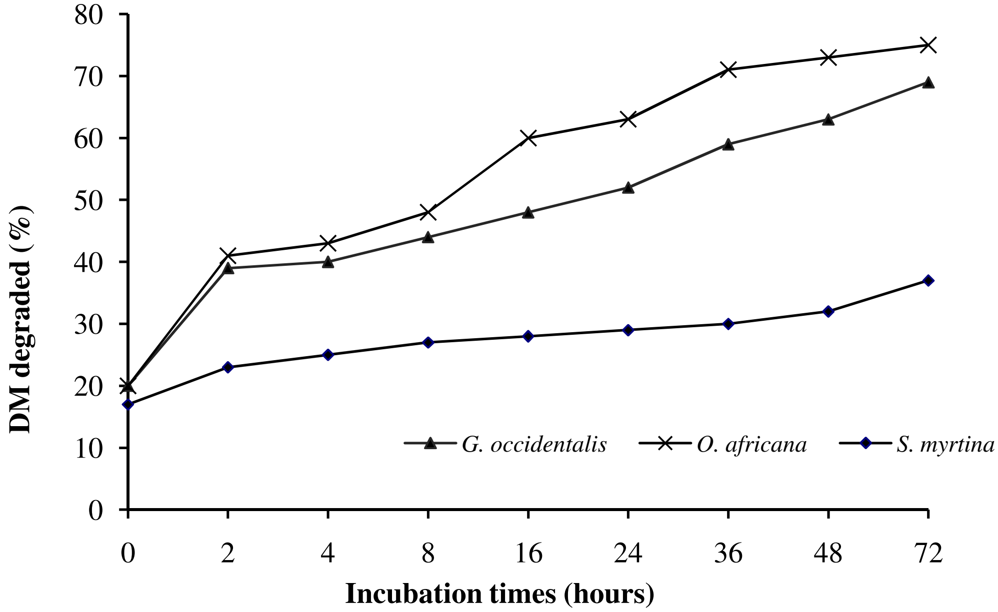

Figure 6.1. *In sacco* dry matter degradation of *G. occidentalis*, *O. africana* and *S. myrtina* during the cold-dry season

A higher percentage of *G. occidentalis* dry matter disappeared from the rumen of Boer goats compared to Tswana goats both at 24 hours (Boer 55 %; Tswana 49 %) and 48 hours (Boer 67 %; Tswana 60 %) of incubation as shown in Table 6.3. *Olea africana* was however degraded to the same extent by both breeds after 24 hours of incubation (Boer 63 %; Tswana 63 %). *Scutia myrtina* was the slowest degrading woody plant species and was also degraded to almost the same extent by both breed after 24 hours (Boer 30 %; Tswana 29 %) and 48 hours (Boer 32 %; Tswana 33 %) of incubation. After 72 hours of incubating *O. africana*, 78 % of it disappeared from the rumen of Tswana goats while 74 % disappeared from the rumen of Boer goats. Boer goats however had a higher DM % disappearance of both *G. occidentalis* (Boer 73 %; Tswana 66 %) and *S. myrtina* (Boer 39 %; Tswana 36 %) after 72 hours of incubation.

Table 6.3. Estimated dry matter degradability parameters of *Grewia occidentalis, Olea africana and Scutia myrtina* during the cold-dry season

Item	**(%) DRY MATTER DISAPPEARANCE**					
	Grewia occidentalis		***Olea africana***		***Scutia myrtina***	
Time (h)of incubation	Tswana	Boer	Tswana	Boer	Tswana	Boer
0	20	20	20	20	17	17
2	36	42	40	43	21	26
4	38	43	42	45	23	27
8	41	47	43	53	26	29
16	44	52	60	61	27	29
24	49	55	63	63	29	30
36	56	63	72	70	30	30
48	60	67	74	71	33	32
72	65	74	78	73	36	38
DEGRADATION RATE CONSTANTS (±SE)						
A	$28.2^{b} \pm 0.01$	$30.9^{a} \pm 0.01$	$27.0^{c} \pm 0.01$	$25.2^{d} \pm 0.01$	$19.4^{f} \pm 0.01$	$22.8^{e} \pm 0.01$
B	$37.3^{d} \pm 0.03$	$41.9^{c} \pm 0.03$	$50.1^{a} \pm 0.03$	$44.16^{b} \pm 0.03$	$16.3^{e} \pm 0.03$	$14.1^{f} \pm 0.03$
a + b	$65.8^{d} \pm 0.07$	$72.8^{b} \pm 0.07$	$77.7^{a} \pm 0.07$	$69.4^{c} \pm 0.07$	$35.7^{f} \pm 0.07$	$39.0^{e} \pm 0.07$
C	$0.04^{b} \pm 0.01$	$0.05^{b} \pm 0.01$	$0.06^{b} \pm 0.01$	$0.14^{a} \pm 0.01$	$0.04^{b} \pm 0.01$	$0.03^{b} \pm 0.01$

a = Fraction of DM (%) lost during washing; *b* = Fraction of DM (%) degraded; *a* + *b* = Fraction of DM (%) potentially degraded; *c* = Rate of degradation of DM (h^{-1}); SE = Standard error, *n* = 3
Means in a row with different superscripts differ significantly (P < 0.05)

Constants for the ruminal degradation of *G. occidentalis* (*a* = 30.9 %; b = 41.9 % and *a+b* = 72.8 %) for Boer goats were significantly higher (P<0.0001) than those for Tswana goats (*a* = 28.2 %; *b* = 37.3 %; *a+b* = 65.8 %). However, the rate of degradation of *G. occidentalis* did not differ significantly (P>0.05) between the Tswana (0.04% h^{-1}) and Boer goats (0.05 % h^{-1}). On the other hand, the ruminal degradation constants (*a*, *b* and *a+b*) for *O. africana* were significantly higher (P<0.0001) for Tswana goats (*a* = 27.0 %; *b* = 50.1 % and *a+b* = 77.7 %) compared to Boer goats (*a* = 25.2 %; *b* = 44.2 % and *a+b* = 69.4 %). However, the rate of degradation, as reflected by the constant (*c*), for *O. africana* and for *S. myrtina* was significantly higher (P<0.0001) for Boer (0.14 % $h^{-1}$and 0.02 % h^{-1}) compared to Tswana (0.06 % $h^{-1}$and 0.01 % h^{-1}) goats. The fraction lost during washing (*a*), and the potentially degraded fraction (*a+b*) of dry matter percentage for *S. myrtina* were significantly higher (P<0.0001) for Boer (*a* = 22.8 %; *a+b* = 39.0 %) compared to Tswana (*a* = 19.4 %; *a+b* = 35.7 %) goats. However, the rate of degradation (*c*) of *S. myrtina* did not differ significantly (P<0.05) between the two breeds.

6.4.3. Ruminal crude protein degradation during the cold-dry season

Across breed, the nylon bag incubation revealed large differences in the rumen degradability of crude protein of the three woody plant species during the cold-dry season (Figure 6.2).

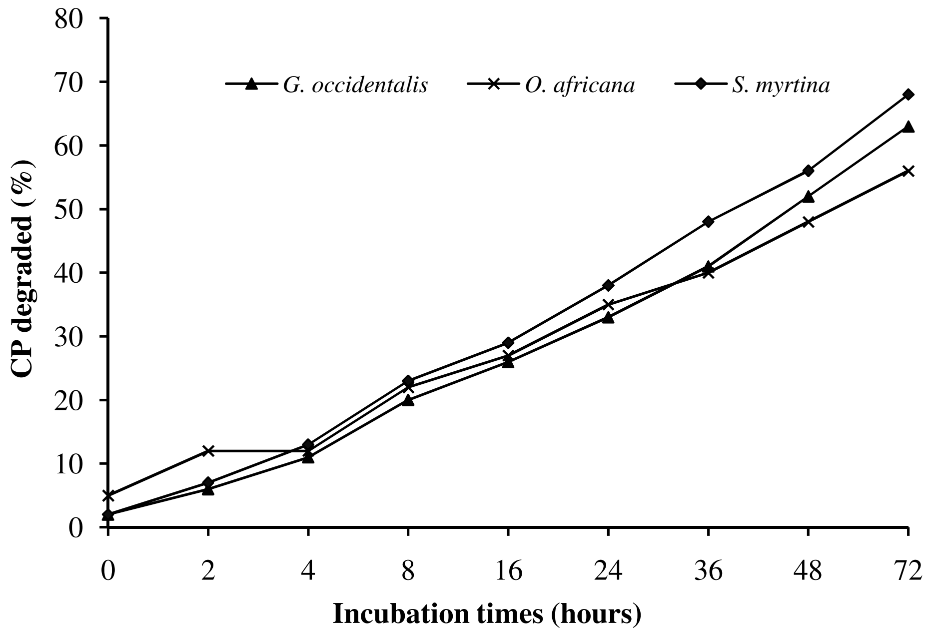

Figure 6.2. *In sacco* crude protein degradation of *G. occidentalis*, *O. africana* and *S. myrtina* during the cold-dry season

Rumen crude protein degradability of *S. myrtina* was greater than that of *G. occidentalis and O. africana*, but all increased with increasing rumen incubation times. *S. myrtina* exhibited rapid rumen degradability of CP, about 38 % of the CP disappearing within 24 hours of incubation compared to *O. africana* (35 %) and *G. occidentalis* (33 %). Crude protein degradability after 48 hours of incubation was still higher for *S. myrtina* (56 %) compared to *G. occidentalis* (52 %) and *O. africana* (48 %).

Boer goats digested more CP from the sample of *O. Africana* during the *in sacco* trial than the Tswana goats, both at 24 hours (Boer 40 %; Tswana 30 %) and 48 hours of incubation (Boer 52 %; Tswana 44 %) as shown in Table 6.4. Both breeds however had similar fractions of CP digested from the *S. myrtina* sample after 24 hours (38 %) of incubation. Similarly the CP content of *G. occidentalis* was degraded to the same extent by both breeds after 24 hours of incubation (33 %). After 48 hours of incubation, the crude protein in the *S. myrtina* sample was degraded more by Tswana goats (58 %) compared to Boer goats (54 %). Crude protein content of *G. occidentalis* was degraded to the same extend by both breeds (52 %) after 48 hours of incubation. Boer goats however, degraded crude protein of *O. africana* to a greater extent than the Tswana goats (44 %) after 48 hours of incubation as shown in Figure 6.3.

Table 6.4. Estimated crude protein degradability parameters for *Grewia occidentalis*, *Olea africana* and *Scutia myrtina* during the cold-dry season

Item	(%) **CRUDE PROTEIN DISAPPEARANCE**					
	Grewia occidentalis		***Olea africana***		***Scutia myrtina***	
Time (h)of Incubation	Tswana	Boer	Tswana	Boer	Tswana	Boer
0	2	2	5	5	2	2
2	7	4	11	12	8	4
4	11	11	11	12	13	13
8	19	22	19	24	25	21
16	30	22	26	28	25	33
24	33	33	30	40	38	38
36	41	41	37	44	50	46
48	52	52	44	52	58	54
72	63	63	52	61	69	67
DEGRADATION RATE CONSTANTS (±SE)						
a	$4.3^{c} \pm 0.011$	$3.8^{d} \pm 0.011$	$7.0^{a} \pm 0.011$	$7.0^{a} \pm 0.011$	$4.9^{b} \pm 0.011$	$3.2^{e} \pm 0.011$
b	$70.5^{c} \pm 0.025$	$77.9^{b} \pm 0.025$	$52.8^{f} \pm 0.025$	$59.5^{e} \pm 0.025$	$78.4^{a} \pm 0.025$	$69.1^{d} \pm 0.025$
a + b	$74.9^{c} \pm 0.004$	$81.7^{b} \pm 0.004$	$59.9^{f} \pm 0.004$	$66.6^{e} \pm 0.004$	$83.3^{a} \pm 0.004$	$72.3^{d} \pm 0.004$
c	$0.02^{a} \pm 0.009$	$0.02^{a} \pm 0.009$	$0.03^{a} \pm 0.009$	$0.03^{a} \pm 0.009$	$0.02^{a} \pm 0.009$	$0.03^{a} \pm 0.009$

a = Fraction of DM (%) lost during washing; *b* = Fraction of DM (%) degraded; *a* + *b* = Fraction of DM (%) potentially degraded; *c* = Rate of degradation of DM (h^{-1}); SE = Standard error, *n* = 3
Means in a row with different superscripts differ significantly (P < 0.05)

The ruminal degradation constant (*a*) for *O. africana* did not differ significantly (P>0.05) between the Tswana (7.0 %) and the Boer (7.0 %) goats. However, the ruminal degradation constant (*a*) differed significantly (P<0.0001) between breeds for *G. occidentalis* (Tswana 4.3 %; Boer 3.8 %) and *S. myrtina* (Tswana 4.9 %; Boer 3.2 %). The fraction of crude protein from *S. myrtina* which was slowly degraded (*b*) was significantly higher (P<0.0001) for Tswana (78.4 %) compared to Boer (69.1 %) goats. The protein degradation constant (*b*) for both *G. occidentalis* and *O. africana* was however significantly higher (P<0.0001) in Boer goats (*G. occidentalis* 77.9 %; *O. africana* 59.5 %) compared to Tswana (*G. occidentalis* 70.5 %; *O. africana* 52.8 %). The rate of degradation (c h^{-1}) of the crude protein fraction for the three woody plant species, by Tswana and Boer goats did not differ significantly (P>0.05). Dry matter and crude protein degradation of *G. occidentalis*, *O. Africana* and *S. myrtina* are graphically illustrated in Figures 5.3, 5.4 and 5.5, respectively.

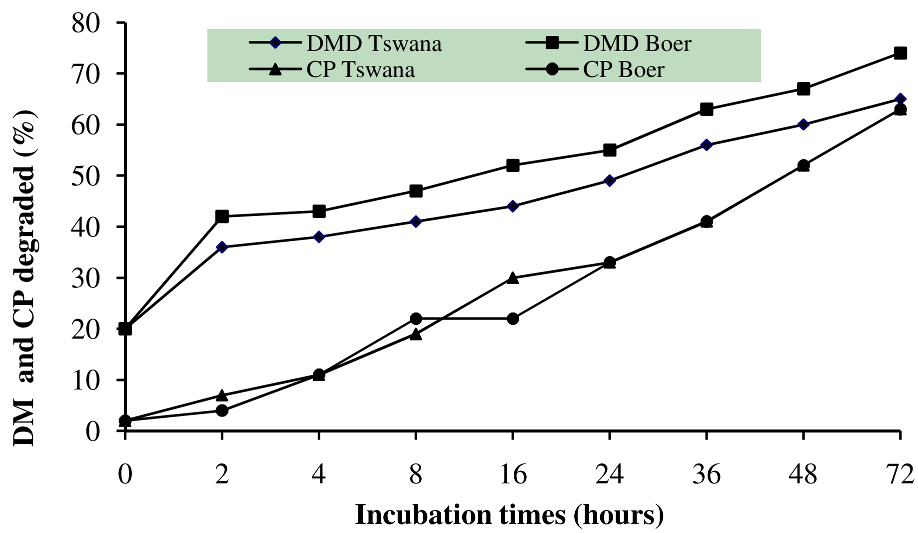

Figure 6.3. *In sacco* DM and CP degradation of *G. occidentalis* by Tswana and Boer goats during the cold-dry season

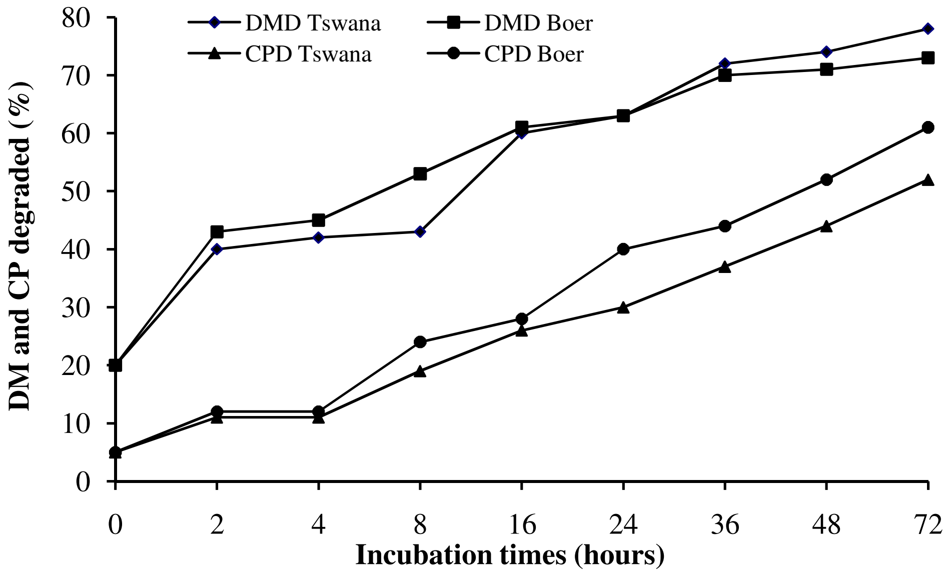

Figure 6.4. *In sacco* dry matter and crude protein degradation of *O. africana* by Tswana and Boer goats during the cold-dry season

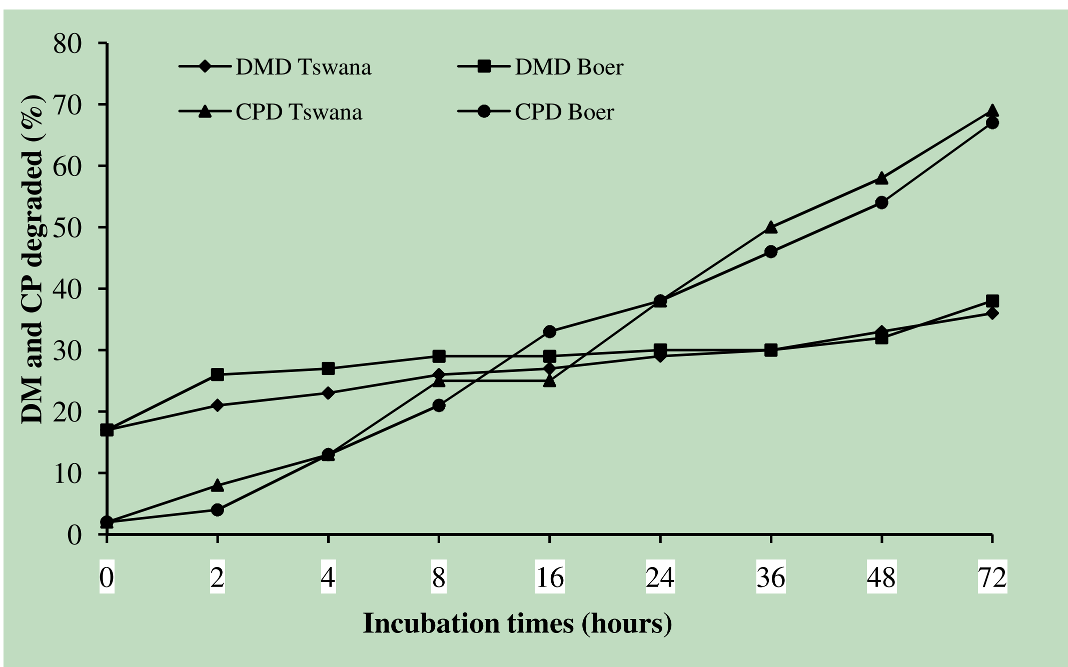

Figure 6.5. *In sacco* DM and CP degradation of *S. myrtina* by Tswana and Boer goats during the cold-dry season

6.4.4. Relationships between DMD, CPD and incubation time in Tswana and Boer goats during the cold-dry season

Dry matter and crude protein degradation for *S. myrtina* were highly correlated with the time of incubation in both Tswana (r^2=0.93; P=0.0003 and r^2=0.97 P<0.0001 respectively) and Boer goats (r^2=0.83; P=0.01; r^2=0.96; P<0.0001, respectively). There was also a strong positive correlation between DMD and CPD (Tswana r^2=0.98; P<0.0001; Boer r^2=0.87; P=0.002). *G. occidentalis* showed strong positive correlation of both DMD (Tswana r^2=0.91 P=0.001; Boer r^2=0.89 P=0.0001) and CPD (Tswana r^2=0.97; P<0.0001; Boer r^2=0.97; P<0.0001) with time of incubation in the rumen. Dry matter degradation strongly correlated with CPD (Tswana r^2=0.96; P<0.001; Boer r^2=0.93; P=0.0003). Similarly for *O. africana*, there was a strong positive correlation of both DMD (Tswana r^2=0.88 P=0.002; Boer r^2=0.80; P=0.01) and CPD (Tswana r^2=0.97; P<0.0001; Boer r^2=0.96; P<0.0001) with time of incubation in the rumen. There was also a strong positive correlation between DMD and CPD (Tswana r^2=0.95; P<0.0001; Boer r^2=0.92; P=0.001). Equations for predicting DMD and CPD of woody plant species in Tswana and Boer goats during the cold-dry season and the hot-wet season are shown in Table 6.5.

Table 6.5. Equations predicting dry matter and crude protein degradabilies during the cold-dry season for Tswana goats and Boer goats

BREED	SPECIES	EQUATION	r^2
Tswana	*Scutia myrtina*	Y = 18.3 - 0.07 TIME + 0.32 CPD	0.96
	Grewia occidentalis	Y = 25.3 - 0.21 TIME + 0.88 CPD	0.93
	Olea africana	Y = 14.9 - 0.64 TIME + 2.09 CPD	0.95
Boer	*Scutia myrtina*	Y = 21.9 - 0.01 TIME + 0.23 CPD	0.76
	Grewia occidentalis	Y = 30.1 - 0.22 TIME + 0.96 CPD	0.87
	Olea africana	Y = 22.3 - 0.59 TIME + 1.52 CPD	0.90
Tswana	*Scutia myrtina*	Y = - 37.9 + 0.42 TIME + 2.24 DMD	0.98
	Grewia occidentalis	Y = - 12.5 + 0.49 TIME + 0.65 DMD	0.98
	Olea africana	Y = - 3.4 + 0.37 TIME + 0.38 DMD	0.99
Boer	*Scutia myrtina*	Y = - 13.7 - 0.70 TIME + 0.98 DMD	0.94
	Grewia occidentalis	Y = - 8.0 + 0.60 TIME + 0.42 DMD	0.97
	Olea african	Y = - 6.9 + 0.49 TIME + 0.47 DMD	0.98

6.4.5. Ruminal dry matter degradation during the hot-wet season

The nylon bag incubation revealed large differences in the rumen degradability of DM of the three browse species (Figure 5.6) regardless of the animal species.

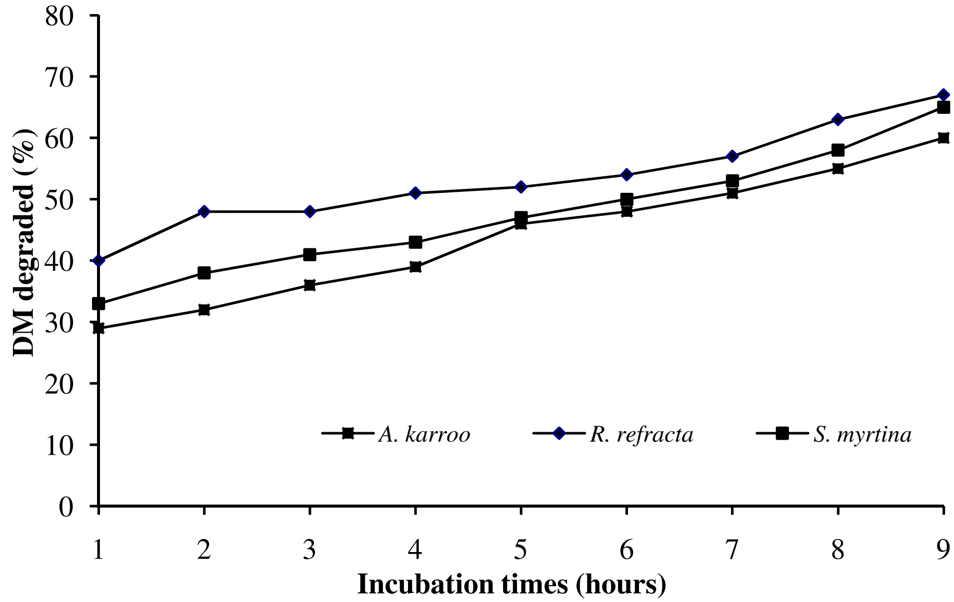

Figure 6.6. *In sacco* dry matter degradation of *A. karroo*, *R. refracta* and *S. myrtina* during the hot-wet season

Rumen dry matter degradabilities of *R. refracta* and *S. myrtina* were greater than that of *A. karroo* and increased with increasing rumen incubation times. *Rhus refracta* exhibited rapid rumen degradability of DM, with about 54 % of the DM disappearing within 24 hours. *Acacia karroo* and *S. myrtina* were degraded to almost the same extend (49 % and 50 % respectively) after 24 hours of incubation. Dry matter degradabilities of *A. karroo* and *S. myrtina* were only 55 % and 58 % respectively after 48 hours of incubation while that of *R. refracta* was 63 %. Though *R. refracta* exhibited rapid rumen degradation initially, its degradability dropped and between 24 and 48 hours of incubation was lower (only 4 % disappearing) compared to *A. karroo* (8 %) and *S. myrtina* (7 %).

A higher fraction of DM of *R. refracta* was degraded by Tswana goats than by the Boer goats, both at 24 hours (Boer 51 %; Tswana 57 %) and 48 hours of incubation (Boer 58 %; Tswana 68 %) as shown in Table 6.9 and graphically illustrated in Figure 6.6. Boer goats however, showed a higher fraction of DM of *S. myrtina* degraded both after 24 hours (Boer 51 %; Tswana 48 %)

and 48 hours of incubation (Boer 61 %; Tswana 55 %). *Acacia karroo* had the lowest fraction of DM degraded after 24 hours of incubation, with only 47 % and 50% degraded by Boer and Tswana goats respectively. After 48 hours of incubation, *A. karroo* was degraded to a greater extent by Boer goats (56 %) compared to Tswana goats (54 %).

Rhus refracta ruminal degradation constants (a = 45.6 %; b = 37.2 % and $a+b$ = 82.8 %) for Boer goats were higher ($P < 0.05$) compared to those for Tswana goats (a = 43.4 %; b = 35.3 %; $a+b$ = 78.7 %) as shown in Table 6.6. However, the rate of degradation of *R. refracta* was higher in Tswana (0.02 % h^{-1}) than Boer goats (0.01 % h^{-1}). Ruminal degradation constants (a, b and $a+b$) of both *S. myrtina* and *A. karroo* were higher for Tswana than for Boer goats. However, the rate of degradation constant (c) for *A. karroo* was similar for both breeds (0.04 % h^{-1}), while for S. myrtina, Boer goats (0.02 % h^{-1}) had a higher rate of degradation compared to Tswana goats (0.01 % h^{-1}).

Table 6.6. Estimated dry matter degradability parameters of *Acacia karroo, Rhus refracta* and *Scutia myrtina* during the hot-wet season

Item	**(%) DRY MATTER DISAPPEARANCE**					
	Grewia occidentalis		***Olea africana***		***Scutia myrtina***	
Time (h)of Incubation	Tswana	Boer	Tswana	Boer	Tswana	Boer
0	29	29	40	40	33	33
2	31	32	47	49	40	37
4	37	35	47	49	41	41
8	41	38	51	51	45	41
16	47	45	55	49	47	46
24	50	47	57	51	48	51
36	52	50	61	54	51	53
48	54	56	68	58	55	61
72	63	57	72	62	66	64
DEGRADATION RATE CONSTANTS (± SE)						
a	$30.4^{e} \pm 0.024$	$29.8^{f} \pm 0.024$	$43.4^{b} \pm 0.024$	$45.6^{a} \pm 0.024$	$38.0^{c} \pm 0.024$	$35.1^{d} \pm 0.024$
b	$31.1^{e} \pm 0.033$	$28.6^{f} \pm 0.033$	$35.3^{d} \pm 0.033$	$37.2^{b} \pm 0.033$	$50.2^{a} \pm 0.033$	$35.6^{c} \pm 0.033$
$a + b$	$61.4^{e} \pm 0.005$	$58.8^{f} \pm 0.005$	$78.7^{c} \pm 0.005$	$82.8^{b} \pm 0.005$	$88.2^{a} \pm 0.005$	$70.7^{d} \pm 0.005$
c	$0.04^{b} \pm 0.004$	$0.04^{b} \pm 0.004$	$0.02^{a} \pm 0.004$	$0.01^{a} \pm 0.004$	$0.01^{a} \pm 0.004$	$0.02^{a} \pm 0.004$

a = Fraction of DM (%) lost during washing; b = Fraction of DM (%) degraded; $a + b$ = Fraction of DM (%) potentially degraded; c = Rate of degradation of DM (h^{-1}); SE = Standard error, $n = 3$
Means in a row with different superscripts differ significantly ($P < 0.05$)

6.4.6. Ruminal crude protein degradation during the hot-wet season

Regardless of the breed of goat, the nylon bag incubation revealed large differences in the rumen degradability of crude protein of the three browse species during the hot-wet season (Figure 6.7). Rumen CP degradabilities of *A. karroo* were greater than that of *R. refracta and S. myrtina* and increased with increasing rumen incubation times. *Acacia karroo* exhibited rapid rumen degradability of CP, about 41 % of the CP disappearing within 24 hours of incubation compared to *S. myrtina* (39 %) and *R. refracta* (31 %). Crude protein degradability after 48 hours of incubation were still higher for *A. karroo* (55 %) compared to *S. myrtina* (51 %) and *R. refracta* (44 %).

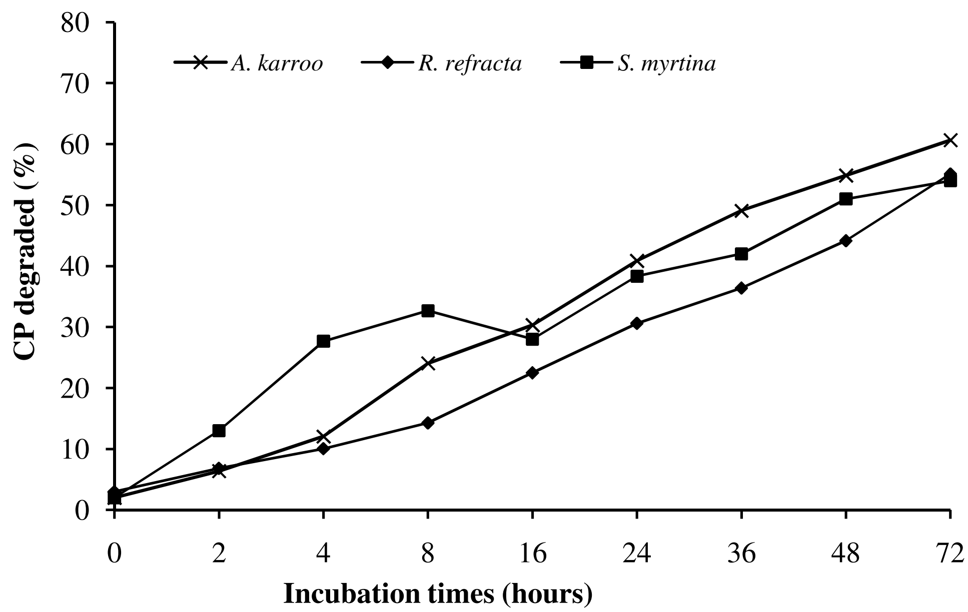

Figure 6.7. *In sacco* crude protein degradation of *A. karroo*, *R. refracta* and *S. myrtina* during the hot-wet season

A higher fraction of CP of both *R. refracta* (Tswana 39 %; Boer 22 %) and *S. myrtina* (Tswana 40 %; Boer 375) was degraded by Tswana goats than the Boer goats, after 24 hours of incubation (Table 6.7). Both breeds, however, showed similar degradation of the CP of *A. karroo* after 24 hours (41 %) of incubation. After 48 hours of incubation, the crude protein of *A. karroo* showed a higher degradability by Tswana goats (56 %) compared to Boer goats (54 %). Similarly the CP degradation of *R. refracta* (Tswana 55; Boer 33 %) and *S. myrtina* (Tswana 52; Boer 30 %), was greater in the Tswana goats than the Boer goats after 48 hours of rumen incubation.

The ruminal degradation constant (*a*) for *A. karroo* differed significantly ($P<0.0001$) between the Tswana (3.4 %) and the Boer (1.4 %) goats. Similarly, for *S. myrtina* the ruminal degradation constant (*a*) differed significantly ($P<0.001$) between breeds (Tswana 10.0 %; Boer 4.2 %). Boer goats, however, had a significantly higher ruminal degradation constant (a) for *R. refracta* compared to Tswana goats (Tswana 2.3 %; Boer 6.4 %). The fraction of crude protein of *R. refracta* percentage slowly degraded (*b*) was significantly higher ($P<0.0001$) for Tswana (81.1 %) compared to Boer (53.3 %) goats. Tswana goats also had a higher ($P<0.0001$) slowly degradable CP fraction (*b*) for *A. karroo* (Tswana 61.1 %; Boer 59.15%) and *S. myrtina* (Tswana 52.3 %; Boer 46.7 %). The rate of degradation (c h^{-1}) of the crude protein fraction of the three woody plant species by Tswana and Boer goats did not differ significantly ($P>0.05$).

Table 6.7. Estimated crude protein degradability parameters of *Acacia karroo, Rhus refracta* and *Scutia myrtina* during hot-wet season

Item	**(%) CRUDE PROTEIN DISAPPEARANCE**					
	Grewia occidentalis		***Olea africana***		***Scutia myrtina***	
Time (h)of Incubation	Tswana	Boer	Tswana	Boer	Tswana	Boer
0	2	2	3	3	2	2
2	9	4	7	7	16	10
4	13	11	9	11	24	13
8	24	24	13	16	24	23
16	31	30	25	20	26	30
24	41	41	39	22	40	37
36	50	48	47	26	44	40
48	56	54	55	33	52	50
72	62	59	67	43	58	50
DEGRADATION RATE CONSTANTS (± SE)						
a	$3.8^{d} \pm 0.024$	$1.4^{f} \pm 0.024$	$2.3^{e} \pm 0.024$	$6.4^{b} \pm 0.024$	$10.0^{a} \pm 0.024$	$4.2^{c} \pm 0.024$
b	$61.1^{b} \pm 0.024$	$59.2^{c} \pm 0.024$	$81.1^{a} \pm 0.024$	$53.3^{d} \pm 0.024$	$52.3^{e} \pm 0.024$	$46.7^{f} \pm 0.024$
a + b	$64.9^{b} \pm 0.005$	$60.7^{d} \pm 0.005$	$83.4^{a} \pm 0.005$	$59.7^{e} \pm 0.005$	$62.3^{c} \pm 0.005$	$50.9^{f} \pm 0.005$
c	$0.04^{a} \pm 0.005$	$0.05^{a} \pm 0.005$	$0.02^{b} \pm 0.005$	$0.02^{b} \pm 0.005$	$0.03^{b} \pm 0.005$	$0.05^{a} \pm 0.005$

a = Fraction of DM (%) lost during washing; *b* = Fraction of DM (%) degraded; *a* + *b* = Fraction of DM (%) potentially degraded; *c* = Rate of degradation of DM (h^{-1}); SE = Standard error, $n = 3$
Means in a row with different superscripts differ significantly ($P < 0.05$)

The percentage of crude protein of *R. refracta* potentially degraded (*a*+*b*) by Tswana goats was high (P<0.0001; 83.4 %) compared to that potentially degraded by Boer goats (59.7 %). Similarly for *A. karroo* and *S. myrtina*, the potentially degraded CP % (*a*+*b*) was higher for Tswana than Boer goats. The rate of degradation (*c*) of *A. karroo* and *R. refracta* did not differ significantly (P>0.05) between the breeds. However, the rate of degradation for *S. myrtina* was significantly higher (P<0.0001) for Boer than Tswana goats.

Dry matter and crude protein degradation of *A. karroo*, *R. refracta* and *S. myrtina* are graphically illustrated in Figures 6.8, 6.9 and 6.10.

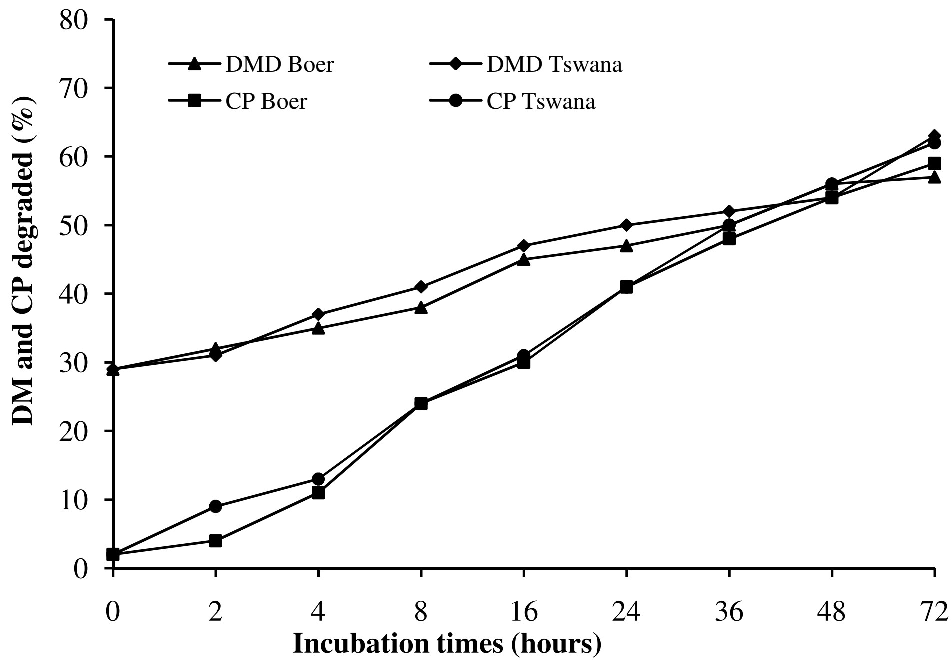

Figure 6.8. *In sacco* DM and CP degradation of *A. karroo* by Tswana and Boer goats during the hot-wet season.

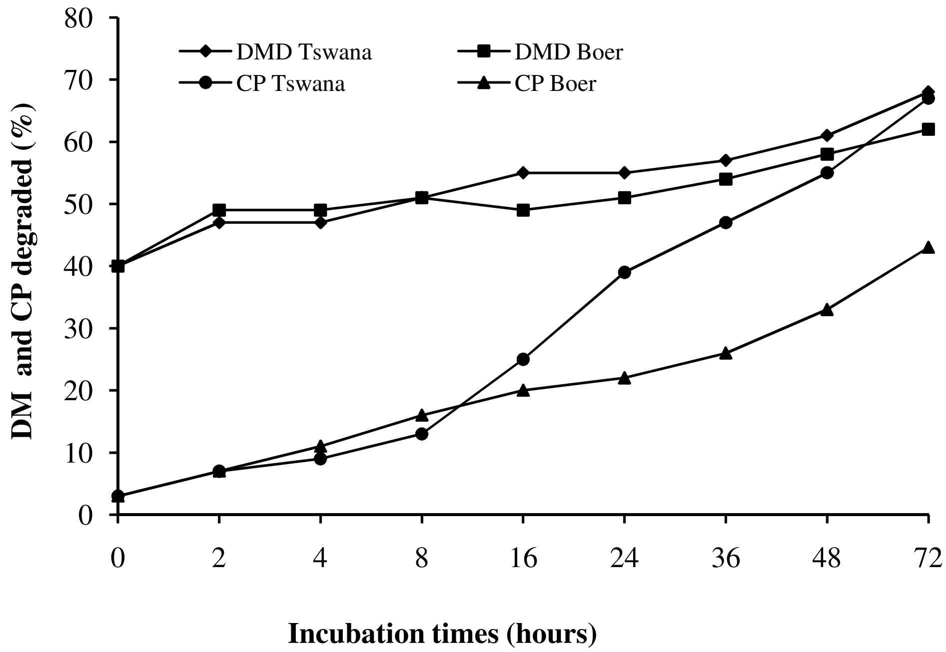

Figure 6.9. *In sacco* DM and CP degradation of *R. refracta* by Tswana and Boer goats during the hot-wet season

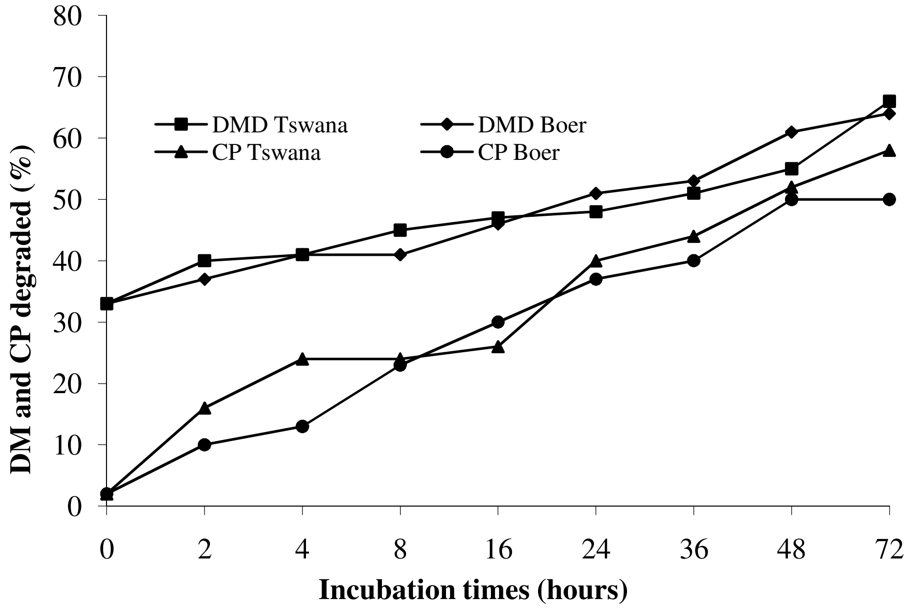

Figure 6.10. *In sacco* DM and CP degradation of *S. myrtina* by Tswana and Boer goats during the hot-wet season

6.4.7. Relationships between DMD, CPD and incubation time in Tswana and Boer goats during the hot-wet season

Dry matter and crude protein degradation for *S. myrtina* were highly correlated with the time of incubation in the rumen in both Tswana (r^2=0.96 P<0.0001 and r^2=0.93 P=0.0003 respectively) and Boer goats (r^2=0.96 P<0.0001; and r^2=0.91 P=0.001 respectively). There was also a strong positive correlation between DMD and CPD (Tswana r^2=0.96 P<0.0001; Boer r^2=0.98 P<0.0001). *Acacia karroo* showed strong positive correlation of both DMD (Tswana r^2=0.93 P=0.0002; Boer r^2=0.93 P=0.0003) and CPD (Tswana r^2=0.94 P=0.0002; Boer r^2=0.92 P=0.0004) with time of incubation in the rumen. Dry matter degradation was strongly correlated with CPD (Tswana r^2=0.98 P<0.0001; Boer r^2=0.99 P<0.0001). Similarly, for *R. refracta*, there was a strong positive correlation of both DMD (Tswana r^2=0.96 P<0.0001; Boer r^2=0.90 P=0.01) and CPD (Tswana r^2=0.97 P<0.0001; Boer r^2=0.97 P<0.0001) with the time of incubation in the rumen. There was also a strong positive correlation between DMD and CPD (Tswana r^2=0.98 P<0.0001; Boer r^2=0.94 P=0.0002). Equations for predicting DMD and CPD of woody plant species, in Tswana and Boer goats, during the hot-wet season are shown in Table 6.8.

Table 6.8. Equations predicting dry matter and protein degradability during the hot-wet season for Tswana goats and Boer goats

BREED	SPECIES	EQUATION	r^2
Tswana	*Scutia myrtina*	Y = 34.7 + 0.19 TIME + 0.28 CPD	0.96
	Acacia karroo	Y = 29.1 + 0.05 TIME + 0.45 CPD	0.96
	Rhus refracter	Y = 43.2 + 0.09 TIME + 0.34 CPD	0.96
Boer	*Scutia myrtina*	Y = 33.1 + 0.19 TIME + 0.35 CPD	0.99
	Acacia karroo	Y = 29.4 + 0.05 TIME + 0.42 CPD	0.98
	Rhus refracter	Y = 41.4 - 0.05 TIME + 0.56 CPD	0.88
Tswana	*Scutia myrtina*	Y = - 53.31 + 0.02 TIME + 1.77 DMD	0.93
	Acacia karroo	Y = - 42.55 + 0.15 TIME + 1.58 DMD	0.97
	Rhus refracter	Y = - 46.99 + 0.44 TIME + 1.19 DMD	0.97
Boer	*Scutia myrtina*	- 72.68 - 0.30 TIME + 2.28 DMD	0.96
	Acacia karroo	-58.32 + 0.02 TIME + 2.04 DMD	0.97
	Rhus refracter	-20.81 + 0.36 TIME + 0.63 DMD	0.97

6.5. Discussion

The ranges of NDF, ADF and ADL found in this study are comparable to earlier reports (Le Houerou, 1980, Onwuka *et al*., 1989; Rittner & Reed, 1992; Topps, 1992; Nsahlai *et al*., 1994; Larbi *et al*., 1997; Mogorosi, 2000; Rogosic *et al*, 2006). 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). The seasonal fluctuations in crude protein content may have been induced by the the hot-wet season (177 mm) precipitations, while low precipitations during the cold-dry season (84 mm) led to a decline in crude protein to levels regarded as being close to being deficient. The higher crude protein levels found in the diet during the hot-wet season are expected, because of the availability of new growth in woody components. Low protein content in the cold-dry season is expected when leaves mature (Owen-Smith, 1988), creating differences in leaf to stem ratio, and this is more pronounced in deciduous, rather than evergreen species. All the woody plant species with the exception of *O. africana* had crude protein levels greater than 7.5%. This is the lowest value for CP which is considered adequate to describe the forage quality, because it falls within the range of values for maintenance of goats (NRC, 1981).

The degraded dry matter and crude protein modeled with the Orskov & McDonald (1977) equation showed significant variability between the woody plant species. Ruminal degradation constants (*a, b* and *a+b*) also varied significantly (P<0.001) between breeds, as well as between goats within a breed. Because of the variation within a breed, no actual signficant breed differences were found in the *in sacco* degradation of DM and CP between Tswana and Boer goats.

The first loss from the bags (hour 0) was caused by the mechanical loss through the nylon bag wall, which means digestion by the animal per se started after hour 0. During the cold-dry season, the quickly degradable fraction (*a*) of DM was significantly higher (P<0.05) for *G. occidentalis* when compared to *O. africana and S. myrtina*. *S. myrtina* had the lowest (*a*) fraction of the three plants studied. However, the quickly degradable fraction (*a*) of CP was significantly higher (P<0.05) for *O. africana* when compared to *G. occidentalis* and *S. myrtina.* The fraction of DM percentage which was slowly degraded (*b*) was higher for *O. africana* and lowest for *S. myrtina.* The fraction of CP percentage slowly degraded (*b*) was significantly higher (P<0.05) for both *G. occidentalis* and *S. myrtina* compared to *O. africana.*

During the hot-wet season, the quickly degradable fraction (*a*) of DM was significantly higher (P<0.05) for *R. refracta* compared to *A. karroo* and *S. myrtina*. However, the quickly degradable fraction (*a*) of CP was significantly higher (P<0.05) for *S. myrtina* compared to *A. karroo* and *R. refracta.* The fraction of DM which was slowly degraded (*b*) was significantly higher (P<0.05) for *S. myrtina* compared to *A. karroo* and *R. refracta.* On the other hand, the fraction of CP percentage slowly degraded (*b*) was significantly higher (P<0.05) for *R. refracta* compared to *A. karroo* and *S. myrtina.* In summary, the DM of *G. occidentalis* would be digested the fastest in the cold-dry season, while in the hot-wet season *R refracta* would digest faster than the other preferred woody species. If the digestibility of CP is examined, *O. africana* and *S. myrtina* would be the fastest of the preferred species.

The degradation rate *in sacco* is a reflection of how fast the particular fraction of the plant will degrade in the rumen after being eaten and can be an indication of the relative importance of the plant in the diet. The potential dry matter degradability (*a*+*b*) is a measure of the proportion of the woody plant species that can be fermented in the rumen if the feed does not pass to the lower digestive tract before maximal degradation occurs (Mupangwa *et al*., 1997). The dry matter degradation rate of *O. africana* was significantly higher than of *G. occdentalis* and *S. myrtina* during the cold-dry season. Similarly, the potential degradability of DM (*a*+*b*) was significantly higher for *O. africana* and *G. occidentalis* when compared to *S. myrtina*. The rate of CP degradation was similar for all the three woody plant species. However, the potential degradability was higher for both G. *occidentalis* and *S. myrtina* compared to *O. africana*. During the hot-wet season, the DM degradation rate of *A. karroo* was significantly higher than that of of *R. refracta* and *S. myrtina*. However the potential degradability (*a*+*b*) of DM was lower for *A. karroo* when compared to *R. refracta* and *S. myrtina*. The rate of CP degradation (*c*) was similar for both *A. karroo* and *S. myrtina* but significantly different (P<0.0001) from *R. refracta*. Potential degradation was higher for *R. refracter* when compared to *A. karroo* and *S. myrtina*.

There was a strong positive correlation between DMD and the time of incubation in the rumen. Crude protein degradation also correlated positively with the time of incubation. The crude protein content of the woody plant species positively influenced the rumen digestion of dry matter because when CP increased DMD also increased.

6.6. Conclusions

The woody plant species showed great variation in chemical composition, dry matter degradation and crude protein degradation. All the browse species contributed substantial amounts of rumen degradable crude protein, dry matter and hence organic matter for microbial utilization, thereby increasing microbial protein synthesis and post ruminal supply of microbial protein. There was no breed difference in *in sacco* degradation of the woody plant species, as rumen degradation characteristics of DM and CP of browse species varied substantially between goats within a breed as well as between breeds from season to season. Rumen degradation characteristics could be used to characterise and detect variations in forage quality in browse species. The results from this research showed no breed difference in nutrient content and ruminal degradation of forages selected by the goats.

CHAPTER 7

CONCLUSIONS AND RECCOMENDATIONS

7.1. Feeding behaviour

The goats in this study did not follow the generally expected trend of being predominantly browsers. Grazing activity was high for both breeds, especially during the hot-wet season. The increased level of grazing is attributed to the high rainfall that was experienced in the hot-wet season. The high rainfall resulted in excessive growth of warm season grasses that were succulent, less coarse and highly digestible. This had a major impact on the dietary preference of goats, leading to high grass consumption.

The hypothesis that the Tswana goats spent more time browsing than the Boer goats was found to be true. Browsing was high for Tswana goats in the cold-dry season and low in the hot-wet season while Boer goats spent time browsing during both seasons which did not differ significantly between seasons. . The high browse consumption by Tswana goats during the cold-dry season can be attributed to the early and fast growth of grasses after the hot-wet season rainfall when legumes are still germinating, thus leaving the legumes fresh, less coarse and more succulent at the onset of the dry season. The breed differences in terms of browse consumption may indicate the adaptability of the Tswana goats to using browse in semi-arid environments.

The hypothesis that time spent browsing will be negatively influenced by the availability of forage turned out as predicted. The goats switched to grazing during the later days of occupation of a camp, when browse got depleted. The observed variation in feeding behaviour was probably a response to the relative availability of various grass and browse species during the period of study. As expected, non-feeding activities were higher during midday compared to morning and afternoon though there were no breed differences during both seasons. This was probably because the goats avoided grazing or browsing during the hotter part of the day.

Results from this study illustrate the complex dynamics of the feeding behaviour of the goats grazing on heterogeneous vegetation with diverse botanical composition**.** This study confirms the modification of feeding behaviour, in terms of grazing, browsing and non-feeding activities, as an efficient tool for goats to adapt to quantity and quality of their ingesta, in order to meet their requirements. The decrease in the most preferred feeds induced goats to diversify their diets. This indicates that the natural seasonal changes modify the feeding pattern of goats affecting proportions of grass or bush consumption according to their availability. A diurnal pattern of foraging observed in this study for both breeds indicates that goats were more selective in the morning than in the afternoon. This was one foraging strategy that goats utilised to select the most nutritious diets in the morning and limit rumen fill in the morning. This allowed for unselective feeding the afternoon to fill up the rumen for the evening. Significant differences that were found between the feeding behaviour of Tswana and Boer goats confirmed findings of several researchers that genotypic variation can also influence the feeding behaviour of goats.

7.2. Woody- plant species selection

The Tswana and Boer goats did not show major differences in diet selection patterns between browse species as expected. The eight most selected woody plant species were similar for both breeds only differing in order of preference. However, Tswana goats selected a higher proportion of woody plant species compared to Boer goats. Woody plant selection for Tswana goats was high in the hot-wet season, while Boer goats maintained the same frequency of selection during both seasons. The reason may be that indigenous Tswana goats are mostly found in semi-arid regions characterised by harsh environmental conditions. Browse plays a major role in the diet of these free ranging animals in these areas when grasses dry out during the cold-dry season.

Diurnal woody plant selection was more pronounced in Tswana goats while Boer goats showed no diurnal pattern in woody plant selection. The diurnal variation in woody plant selection occurred because Tswana goats needed to increase their nutrient intake as their grass consumption was lower than for Boer goats, while on the other hand Boer goats obtained most of their nutrients from the grasses. This demonstrates the importance of woody-plant species for indigenous goats in semi-arid and arid areas, and how these species contribute to the increase in availability of forage resources for free ranging animals.

The measured crude protein content was positively correlated to the ranking of woody palnt species by preference ($r = 1.00$, $P < 0.001$). This is because plants with high ranking based on preference, tend to have a high crude protein content and hence high intake and palatability.

Good grazing management of rangelands implies prior knowledge of the diet selection behaviour, since selection behaviour exerts a major influence on vegetation composition. Feeding practices that permit animals to choose between different plants create the opportunity to reduce costs and enhance performance on rangelands. How individuals learn to mix their diets from an array of diverse plants is likely to influence plant biodiversity because high amounts of nutrients in a plant will increase the probability that it will be grazed. Thus the traditional extensive grazing system is considered to be a useful tool for the conservation of plant biodiversity.

7.3. Nutritive value

Although there were notable difference in the seasonal concentrations of CP, NDF and ADF of diets selected by goats, however, against expectations Tswana and Boer goats selected forages not differing significantly in CP and NDF. The only significant differences were in ADF and ADL. Seasonal fluctuations in nutrient content of diets selected by goats may be attributed to the high rainfall experienced in the hot-wet season and the dry the cold-dry season. Another contributing factor may be the differences in the percentage of grass and browse selected by goats during both seasons. In the hot-wet season goats selected more grass that was fresh, succulent and high in nutrient content. During the cold-dry season, the low crude protein content of selected forages was expected as leaves of browse mature and dry out. Although Tswana goats included more browse in their diets compared to Boer goats, they too were unable to improve the protein content of the diet they selected. This was probably because grass consumption was much higher than browse consumption for both breeds. For goats to derive the maximum benefit of browse available in fodder banks, they should be able to select as much browse as possible, which was not the case in the present study. The low crude protein content was insufficient to meet the maintenance requirements of both breeds and indicates a need for protein supplementation if these two breeds of goats are to be successfully maintained in this area. This also implies that the camps used for the trials are not ideal for foraging goats during the cold-dry season.

Given the reputation of goats as opportunistic yet highly selective feeders, attention should be given to the occurrence and nutritional importance of the diet of free ranging goats in terms of both botanical composition and carrying capacity of the veld. Range management should capitalize upon opportunistic feeding. This means maintaining plant communities that are highly diverse in botanical structure. Species diversity plays an important role in diet selection, as plant species with different types of nutrients may affect forage intake and animal production. This knowledge will help livestock producers to capitalize on nutrient content to enhance intake, optimize forage utilization and ultimately improve performance of free ranging herbivores. Exposure to a variety of plant species may allow herbivores to select mixtures that results in more balanced diets.

7. 4. *In sacco* degradation

Across the breed, the nylon bag incubation revealed large differences in the rumen degradability of dry matter and crude protein of browse species in the cold-dry season and the hot-wet season. Ruminal degradation constants (a, b and $a + b$) varied substantially between breed and between goats within a breed. Therefore no significant breed differences could be identified, in terms of *in sacco* degradability of DM and CP, between the Tswana and the Boer goats. However, dry matter and crude protein degradation were highly correlated with time taken for the incubation. Rumen degradation characteristics could be used to characterise and detect variation in forage quality of the browse.

Results from this study will help to develop strategies to optimise range resources for sustainable animal production. The contribution of goats to the livelihood of farmers is immense. In order to target production improvement, the constraints limiting success should be identified. Tswana goats might be a more favourable breed in semi-arid savannah because of their smaller boy size and, therefore, absolute nutrient requirements as well as better reproductive performance when compared to Boer goats. However, when forage availability is not a limiting factor, Boer goats might yield better returns for the investment since they are superior in meat production.

FUTURE RESEARCH

The results from this research showed no significant breed differences in terms of nutrient content of the selected forages, nor in the ruminal degradation of browse species. Further research needs to be carried out in other areas of the country using the same breeds. This will clarify if any breed differences do exist when other browse species are utilized. Time slots used during the research to observe the feeding behaviour of goats were possibly too short, and it is suggested that a further study be carried out where there is continuous determination of feeding parameters. Included in these parameters should be direct observations on biting, the use of n-alkanes to determine intake and the effect of tannins in digestion. This will provide accurate information on the succession of species consumed and analysis of such data should improve the understanding of diet selection by grazing animals in a heterogenous environment. The study should also be extended further to include other goat breeds.