In sacco dry matter and crude protein degradation of woody plant species in Tswana and Boer goats

Lebopa C. K.[1#]. Boomker E. A.[2] Chimonyo M.[3] & Mokoboki H. K.[1]

[1] Department of Animal Science, Faculty of Agric. Science and Technology, North-West University, Private bag x 2046 Mmabatho, 2735, South Africa

[2] Department of Anatomy and Physiology, Faculty of Veterinary Science, University of Pretoria, Private bag x 04, Onderstepoort, 0110, South Africa

[3]Department of Livestock and Pasture Science, Faculty of Agriculture and Science, University of Fort Hare, Private bag x 04, Alice, South Africa

Abstract: The study was aimed at determining *in sacco* dry matter (DM) and crude protein (CP) degradation of woody plant species incubated in the rumen of Tswana and Boer goats. The ruminal degradability of the three most selected woody plant species by goats during the cold-dry season (*G. occodentalis, O. africana* and *S. myrtina*) and hot-wet season (*A. karroo, R. refracta* and *S. myrtina),* were measured in situ, using *in sacco* digestion techniques. The nylon bag incubation revealed large differences in the rumen degradability of DM of the three woody plant species during both seasons. Ruminal degradation constants (*a, b* and *a*+*b* and *c*) varied significantly (P<0.001) between breeds and between goats within a breed. Thus, no breed difference in *in sacco* degradation of DM and CP was found between Tswana and Boer goats. There was a strong positive correlation between DMD, CPD and time of incubation in the rumen. The crude protein content of the woody plant species positively influenced the rumen digestion of dry matter. Both species preference and degradability of plant species are of importance as they are needed to estimate range suitability for browsing animals.
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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 (Anelea *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; 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. This study intends to contribute towards addressing shortages in quantity and quality of forages in semi-arid regions.

2. Materials And Methods

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.

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 °C 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.

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 °C 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.

Statistical Analyses

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

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

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.

3. Results

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 1.

The dry matter content of woody plant species was high both during the cold-dry season and the hot-wet season. On average the woody plant species had lower crude protein content during the cold-dry season compared to the hot-wet season. However the NDF, ADF and ADL contents of the woody plant species were on average high during the cold-dry season compared to the hot-wet 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. *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. 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 2. *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. Constants for the ruminal degradation of *Grewia 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. Across breed, the nylon bag incubation revealed differences in the rumen degradability of crude protein of the three woody plant species 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 3.

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 (52 %) t than the Tswana goats (44 %) after 48 hours of incubation. 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 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 4.

The nylon bag incubation revealed large differences in the rumen degradability of DM of the three browse species regardless of the animal species. 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. *A*cacia *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 5. 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 5. 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}).

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. 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 %). A higher fraction of CP of both *R. refracta* (Tswana 39 %; Boer 22 %) and *S. myrtina* (Tswana 40 %; Boer 37 %) was degraded by Tswana goats than the Boer goats, after 24 hours of incubation (Table 6). 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 ($P>0.05$).

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 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 7.

4. Discussion

The ranges of NDF, ADF and ADL found in this study are comparable to earlier reports by (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 (1979) 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 and between goats within a breed. Thus, no actual 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.

5. Conclusions

The woody plant species showed great variation in chemical composition, dry matter degradation and crude protein 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 goat production. Further research need to be carried out with a larger sample size as this may produce different results.

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Table 1. Chemical composition of the woody plant species (n=3) used for *in sacco* digestion during the cold-dry season and the hot-wet season (% DM).

Season	***Nutrient***		***Woody plant species***	
Cold-dry season		***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
		Acacia karroo	***Rhus refracta***	***Scutia. Myrtina***
Hot-wet season				
	DM	93.8	93.7	94.4
	CP	18.0	9.0	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)

Table 2. 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 ($P < 0.05$)

Table 3. 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 ($P < 0.05$)

Table 4. Equations predicting dry matter and crude protein degradability 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

Table 5. Estimated dry matter degradability parameters of *Acacia karroo, Rhus refracta* and *Scutia myrtina* during the hot-wet season

Item	**(%) DRY MATTER DISAPPEARANCE**					
	Acacia karroo		***Rhus refracta***		***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 ($P < 0.05$)

Table 6. Estimated crude protein degradability parameters of *Acacia karroo, Rhus refracta* and *Scutia myrtina* during the hot-wet season

	(%) CRUDE PROTEIN DISAPPEARANCE					
	Acacia karroo		***Rhus refracta***		***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)

Table 7. 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

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