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# Effects of season and species on *in sacco* degradability of forages in the sub-humid subtropical savannah

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**Effect of season and plant species on *in sacco* dry matter (DM) and crude protein (CP) degradability of five plant species were investigated. Plant species were *Acacia natalitia*, *Acacia nilotica*, *Dichrostachys cinerea*, *Scutia myrtina* and *Chromolaena odorata*. Leaves were harvested during dry, early wet and late wet seasons, subjected to degradation in cows' rumen using nylon bags technique. Season affected potential DM degradability and effective degradation of DM and CP. Species affected all parameters except slowly degradable fraction of CP. Interaction between season and species affected the parameters except potential and slowly degradable fraction of CP. *Chromolaena odorata* had highest estimated parameters of degradation among seasons compared to others. Based on potential and effective degradation, plants followed this decreasing order: *C. odorata*, *A. nilotica*, *A. natalitia*, *S. myrtina* and *D. cinerea*. These plants have a potential as feed supplements. *C. odorata* has the highest potential as feed protein source in ruminants. It concluded that season and species affected *in sacco* degradability of DM and CP of browse species.**

**Key words:** Dry matter, crude protein, *Chromolaena odorata*, ruminants, nutritive value.

## INTRODUCTION

Smallholder farmers in subtropical savannah of Africa keep different ruminant species, most of which survive on natural pastures (Ugwu, 2007). The productivity of these ruminant species depends on quantity and quality of feeds (forage), which is affected by seasonal fluctuations (Abusuwar and Ahmed, 2010). The lowest quantity of forage occurs during dry season and may limit feeding and production of livestock. One strategy to increase value is the use of trees and shrubs as a sufficient source of food for ruminants. Some of forages are legumes, and legumes offer important sources of protein to maintain ruminant production in tropical savannah (Belachew et al., 2013; Gusha et al., 2013). Browse and shrub fodders are essential because they reduce seasonal limitation in ruminant feed (Balgees et al., 2013; Belachew et al., 2013). However, the distribution of tannins and other phenolic compounds in shrubs and tree leaves limits their utilization as animal feed (Belachew et al., 2013). Hence,

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**Table 1.** Chemical compositions (g $kg^{-1}$ DM) of five main browse species selected by goats sampled in three seasons at Zululand Thornveld.

| Season | Species | Parameters | | | | |
|---|---|---|---|---|---|---|
| | | **CP** | **NDF** | **ADF** | **ADL** | **CT** |
| | *A natalitia*[a] | 121.9 | 405.8 | 275.9 | 200.0 | 117.7 |
| | *A. nilotica* | 115.7 | 228.1 | 130.6 | 79.5 | 3.8 |
| Dry | *D. cinerea* | 109.1 | 452.7 | 330.5 | 207.0 | 45.8 |
| | *S. myrtina* | 105.0 | 429.4 | 291.6 | 199.7 | 32.2 |
| | *C. odorata*[b] | 185.8 | 360.0 | 218.6 | 97.5 | 0.5 |
| | *A. natalitia* | 140.7 | 380.6 | 259.7 | 203.6 | 211.7 |
| | *A. nilotica* | 136.1 | 242.9 | 120.5 | 90.2 | 16.5 |
| Early wet | *D. cinerea* | 172.8 | 427.3 | 243.3 | 161.2 | 59.0 |
| | *S. myrtina* | 122.8 | 452.0 | 247.8 | 181.7 | 207.6 |
| | *C. odorata* | 215.7 | 212.9 | 130.2 | 56.4 | 0.5 |
| | *A. natalitia* | 132.7 | 497.6 | 401.3 | 324.0 | 97.0 |
| | *A. nilotica* | 137.7 | 272.4 | 180.6 | 119.5 | 2.6 |
| Late wet | *D. cinerea* | 169.9 | 585.6 | 511.6 | 337.0 | 33.8 |
| | *S. myrtina* | 128.9 | 471.2 | 400.0 | 277.9 | 133.4 |
| | *C. odorata* | 226.4 | 336.6 | 297.9 | 204.7 | 0.5 |
| | RMSE | 2.0 | 8.4 | 32.2 | 18.1 | 5.1 |
| **Sources of variation effects** | | | | | | |
| Season | | *** | *** | *** | *** | *** |
| Species | | *** | *** | *** | *** | *** |
| Season × Species | | *** | *** | * | *** | *** |

[a]Formerly part of *Acacia karroo* (Coates Palgrave, 2002); [b] invasive non-native species; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; CP, crude protein; CT, condensed tannin; RMSE = root mean square error; ns (P > 0.05); * (P < 0.05); *** (P<0.0001).

evaluation of nutritive value of browse trees becomes important only when browse species is used as ruminant feeds.

*In sacco* degradability is a main evaluation technique of nutritive value of forages (Ørskov and McDonald, 1979). It is a useful method for ranking browse trees in terms of quality (Mehrez and Ørskov, 1977), and for evaluating the digestive abilities of ruminant species (Migongo-Bake, 1992). *In sacco* estimation has a benefit of estimating the degradation of particular constituent of feed such as dry matter (DM), crude protein (CP). *In sacco* technique also does not only determine the extent of degradation, but the part that degrades fast and its rate (Ørskov and McDonald, 1979). Moreover, estimation of soluble and slowly degradable fractions is necessary for dietary protein, thus estimating dietary protein used by rumen microbes, and that which bypass the rumen and become available for digestion in the small intestine.

The objective of this study was to determine the effect of season and plant species on *in sacco* degradation characteristics of dry matter and nitrogen on edible forage of browse species in sub-humid subtropical savannah.

## MATERIALS AND METHODS

### Plant samples and their collecting area

Leaves of five plant species (main in the field and goat's diet) selected by goats were sampled during dry (June/July 2008), early (November/December 2008) and late wet (February/March 2009) seasons at the Owen Sitole College of Agriculture (OSCA), Empangeni, South Africa (Basha et al., 2012). The mean annual rainfall of OSCA is 1022 mm and temperature is 26°C, and the type of soil is Mayo/Tambankulu. The early and late wet seasons are each part of the wet (rainy) season. January is the middle of the wet season. Plant species were *Acacia natalitia* (Mely), *Acacia nilotica* (L. Willd ex Del), *Dichrostachys cinerea* (L.Wight Arn), *Scutia myrtina* (Burm. f.) and *Chromolaena odorata* (King and Robinson). Browse samples were randomly sampled by collecting leaves 1.0 to 1.5 m above ground from three non-browsed trees per species per season. Once collected, leaf samples were kept in paper bags and air dried prior to oven drying at 60°C for 48 h. Part of dried samples was ground through 1-mm mesh sieve (Retsch GmbH & Co. KG 5657 HANN 1, West-Germany) for chemical analysis (Table 1). Other part of dried samples was milled through a 2-mm mesh sieve for *in sacco* purpose. All ground samples were stored in sealed plastic bottles until used.

Samples were analysed for chemical composition on dry matter basis using pseudo replicates (3 replicates). Nitrogen (N) concentration was determined based on AOAC (Wendt, 2003) using a LECO, FP2000, nitrogen analyser. Crude protein (CP) was calculated as 6.25 × N concentration. Neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) were determined according to Van Soest et al. (1991) using ANKOM Technology Technique. The NDF was determined with α-amylase. The acid-butanol proanthocyanidin assay (Porter et al., 1985) was used to determine condensed tannin (CT) (Makkar, 1995). Cellulose was calculated as the difference between ADF and ADL, while hemicellulose was derived from the difference between NDF and ADF.

### *In sacco* degradability

The experiment was conducted at the Livestock Section of the University of KwaZulu-Natal Research Farm (Ukulinga), South Africa. Three rumen-fistulated cows (average weight: 350± 45 kg LW) were used. Cows were each fed 2 kg of Lucerne hay per day, with *ad libitum* access to hay, water and a mineral lick. Cows were adapted to the diet for one week before being used in the experiment. The experiment followed the nylon bag technique described by Mehrez and Ørskov (1977).

Three grams of each dry sample per incubation period replicated thrice (three nylon bags) were incubated for 0, 3, 6, 9, 12, 24, 48 and 72 h in three fistulated cows (one bag/cow). The whole bag size was 18×8 cm with pore size of 40 to 60 µm. Samples were incubated in four batches; all samples within a batch were withdrawn simultaneously. Withdrawn samples were cleaned with water and kept in a refrigerator till washing date, when all samples were washed together including zero hour ones. Washing occurred in a semi–automatic washing machine (Hoovermatic model T4350, South Africa) in 6 cycles of 5 min each. The washed bags were dried in an oven (LABCO, model 5SOE1B, P.O. Box 155, Maraisburg 1700) at 60˚C for 48 h, cooled in a desiccator and weighed. Residues were analysed for nitrogen using a LECO, FP2000, nitrogen analyzer. The DM and CP degradation data were fitted to the exponential equation (McDonald, 1981):

$$Y = a + b\,(1 - e^{-c(t-lt)})$$

where, $Y$ is the degradability of DM and CP at time ($t$), $a$ is the soluble fraction which is rapidly washed out the bags, $b$ is the insoluble fraction which is potentially degradable by micro-organisms, $c$ is the degradation rate of fraction b per hour and $lt$ is the lag time.

The effective degradability (ED) of DM and CP were calculated at a rumen out flow rate ($r$) of 0.03 $h^{-1}$ using the following equation:

$$ED = a + b{*}c/(c+r).$$

### Statistical analysis

All degradation variables are followed by subscript 'dm' or 'n' to indicate the nutrient being degraded (dry matter or nitrogen). Data were subjected to analysis of variance (ANOVA) using the general linear models (GLM) procedure of SAS (2002) in a 3 seasons ×5 feeds factorial design with three replicates. The model used was:

$$Y_{ijk} = \mu + s_i + p_j + (sp)_{ij} + \varepsilon_{ijk};$$

where, $Y_{ijk}$ is the observation, µ is the population mean, $s_i$ is the season effect ($i$ = 1–3), $p_j$ is the plant species effect ($j$ = 1–5), $(sp)_{ij}$ is the interaction between season and plant pecies and $\varepsilon ijk$ is the residual error. Statistical significance was declared at P<0.05. Means were compared by least significant difference (LSD). Correlation was used to test the relationships between *in sacco* degradability and chemical variables of browse species.

## RESULTS

### Effects of season and plant species on *in sacco* dry matter degradation

Table 2 shows the effect of season and plant species on *in sacco* dry matter degradation. Season affected (P<0.001) the soluble fraction ($a_{dm}$), potential degradability ($PD_{dm}$), effective dry matter degradability ($ED_{dm}$) and lag time ($lt_{dm}$). Browse species and its interaction with season affected (P<0.001) all variables ($a_{dm}$, $b_{dm}$, $c_{dm}$, $PD_{dm}$, $ED_{dm}$ and $lt_{dm}$). Among the three seasons, the soluble fraction was higher in the dry season than in the early wet and the late wet seasons. The $PD_{dm}$ and $ED_{dm}$ were higher in the dry season than in the early wet and late wet seasons. The $lt_{dm}$ was longest in the late wet season and shortest in the dry season.

Among five plant species, *A. natalitia* had the highest soluble fraction ($a_{dm}$) and *C. odorata* had moderate $a_{dm}$, while *A. nilotica.*, *D. cinerea* and *S. myrtina* had similar $a_{dm}$. *C. odorata* had highest insoluble degradability ($b_{dm}$), while *A. natalitia* and *S. myrtina* had similar and moderate $b_{dm}$, and *A. nilotica* and *D. cinerea* had lowest $b_{dm}$. *C. odorata* had the fastest degradation rate, followed by *A. natalitia*, *A. nilotica*, *D. cinerea* and *S. myrtina* in this order. The $PD_{dm}$ and $ED_{dm}$ showed similar trend among the species, *C. odorata* had highest values followed by *A. nilotica*, *A. natalitia*, *S. myrtina* and *D. cinerea* in this order. *Acacia natalitia* had the longest $lt_{dm}$, whilst *S. myrtina* had the shortest $lt_{dm}$.

Interaction between season and browse species showed different trends for these variables. For the five species, except *D. cinerea*, soluble fraction decreased from the dry to the early wet seasons then decreased in the late wet season (*A. natalitia*, *A. nilotica* and *C. odorata*) or increased in the late wet season (*S. myrtina*), while the soluble fraction of *D. cinerea* increased from the dry to the early wet seasons from where it decreased in the late wet season. The degradation rate ($c_{dm}$) of all five species except *C. odorata* were low and did not change throughout the three seasons, while degradation rates of *C. odorata* decreased from the dry to the early wet and late wet seasons in this order.

The $PD_{dm}$ for *A. natalitia* decreased from the dry season to the early wet and late wet seasons in this order. For *A. nilotica*, the $PD_{dm}$ was similar between the dry and the early wet seasons but decreased in the late wet season. The $PD_{dm}$ of *D. cinerea* did not change during the three seasons. For *S. myrtina* and *C. odorata*, the $PD_{dm}$ decreased (*S. myrtina*) or increased (*C. odorata*) from the dry to the early wet and late wet seasons which were similar.

The $ED_{dm}$ for *A. natalitia*, *A. nilotica* and *S. myrtina* decreased from the dry to the early wet and late wet seasons in this order. For *D. cinerea* and *C. odorata* the

**Table 2.** *In sacco* dry matter degradation constants of plant species harvested at different three seasons from sub-humid subtropical savanna.

| Season | Species | $a_{dm}$ | $b_{dm}$ | $c_{dm}$ | $PD_{dm}$ | $ED_{dm}$ | $lt_{dm}$ |
|---|---|---|---|---|---|---|---|
| Dry | *A natalitia*[a] | 308.5 | 520.6 | 0.032 | 829.0 | 576.1 | -1.256 |
| | *A. nilotica* | 527.6 | 359.6 | 0.066 | 887.2 | 773.7 | 0.847 |
| | *D. cinerea* | 307.2 | 289.3 | 0.026 | 596.5 | 429.5 | -0.377 |
| | *S. myrtina* | 292.3 | 519.4 | 0.022 | 811.7 | 492.8 | -2.102 |
| | *C. odorata*[b] | 352.7 | 484.3 | 0.341 | 837.1 | 795.9 | -0.064 |
| Early wet | *A. natalitia* | 267.8 | 451.0 | 0.035 | 718.8 | 510.7 | -0.241 |
| | *A. nilotica* | 500.1 | 357.4 | 0.066 | 857.5 | 745.1 | 1.001 |
| | *D. cinerea* | 331.3 | 227.3 | 0.040 | 558.6 | 458.4 | 1.052 |
| | *S. myrtina* | 241.7 | 448.8 | 0.020 | 690.5 | 422.6 | -0.568 |
| | *C. odorata* | 328.9 | 609.4 | 0.280 | 938.2 | 879.1 | 0.056 |
| Late wet | *A. natalitia* | 207.8 | 390.5 | 0.042 | 598.3 | 433.5 | 0.235 |
| | *A. nilotica* | 327.4 | 443.2 | 0.088 | 770.7 | 657.8 | -0.262 |
| | *D. cinerea* | 221.5 | 324.4 | 0.039 | 545.9 | 394.0 | 0.545 |
| | *S. myrtina* | 255.2 | 398.7 | 0.021 | 654.0 | 408.8 | 0.833 |
| | *C. odorata* | 316.8 | 632.2 | 0.229 | 949.0 | 875.7 | -0.030 |
| | RMSE | 7.1 | 50.9 | 0.029 | 50.2 | 10.6 | 0.648 |
| **Sources of variation effects** | | | | | | | |
| Season | | *** | ns | ns | *** | *** | ** |
| Species | | *** | *** | *** | *** | *** | ** |
| Season x Species | | *** | *** | * | *** | *** | ** |

[a] Formerly part of *Acacia karroo* (Coates Palgrave, 2002); [b] invasive none-native species; $a_{dm}$, the soluble nutrient fraction which is rapidly washed out of the bags and is assumed to be completely degradable; $b_{dm}$, the proportion of insoluble nutrient which is potentially degradable by micro-organisms; $c_{dm}$, the degradation rate of fraction $b_{dm}$ per hour; $PD_{dm}$, the potential degradability; $ED_{dm}$, effective dry matter degradability; $lt_{dm}$, lag time; RMSE, root mean square error; ns (P>0.05); **(P<0.01); * (P<05); *** (P<0.001).

$ED_{dm}$ increased from the dry to the early wet seasons then decreased in the late wet season (*D. cinerea*) or remained similar between the early wet and the late wet season (*C. odorata*).

The lag time ($lt_{dm}$) for *A. natalitia* and *S. myrtina* increased from the dry to the early wet and late wet seasons in this order. For *A. natalitia*, *D. cinerea* and *C. odorata* the $lt_{dm}$ increased from the dry to the early wet seasons from where it decreased in the late wet season.

## Effects of season and plant species on *in sacco* nitrogen degradation

Table 3 shows the effect of season and plant species on *in sacco* nitrogen degradation. Season affected (P<0.001) only the soluble fraction ($a_n$) and $ED_n$. Species strongly affected (P<0.001) $a_n$, $c_n$, $PD_n$ and $ED_n$, weakly affected (P<0.05) the $lt_n$. Interaction between season and species affected (P<0.001) $a_n$, $c_n$ and $ED_n$. Among these three seasons, $a_n$ and $ED_n$ were higher in the early wet season than in the dry and the late wet seasons.

Among the five plant species, *C. odorata* had the highest soluble fraction ($a_n$), while *A. nilotica* and *S. myrtina* had moderate ($a_n$), and *A. natalitia* and *D. cinerea* had similar and low $a_n$. *C. odorata* had the fastest degradation rate ($c_n$) followed by *A. nilotica*, *A. natalitia*, *D. cinerea* and *S. myrtina* in this order. *C. odorata* had the highest $PD_n$ and $ED_n$ followed by *A. nilotica*, *A. natalitia*, *S. myrtina* and *D. cinerea* in this order. *A. nilotica* had the longest $lt_n$, whilst *S. myrtina* had the shortest $lt_n$.

According to interaction between season and browse species, the $a_n$ fraction in *A. natalitia*, *S. myrtina* and *C. odorata* decreased from the dry to the early wet seasons which was either similar to the late wet season (*A. natalitia* and *S. myrtina*) or lower than in the late wet season (*C. odorata*). For *A. natalitia* and *D. cinerea, $a_n$* increased from the dry to the early wet seasons then either decreased in the late wet season (*A. natalitia)* or remained similar to the late wet seasons (*D. cinerea*).

During the dry season, the degradation rate ($c_n$) was slowest with *D. cinerea*, *A. natalitia* and *S. myrtina;* intermediate with *A. nilotica* and fastest with *C. odorata.* During the early wet season, the degradation rate was slowest for *A. natalitia* and *S. myrtina*; intermediate for *A. nilotica* and *D. cinerea*; and fastest for *C. odorata.* For the late wet season, the degradation rate was fastest for *C. odorata followed by A. nilotica*, *A. natalitia, D. cinerea*, and *S. myrtina* in this order. Among seasons, *A. nilotica*

**Table 3.** *In sacco* nitrogen degradation constants of plant species harvested at three seasons harvested at different three seasons from sub-humid subtropical savanna.

| Season | Species | $a_n$ | $b_n$ | $c_n$ | $PD_n$ | $ED_n$ | $lt_n$ |
|---|---|---|---|---|---|---|---|
| Dry | *A. natalitia*[a] | 267.8 | 646.2 | 0.030 | 914.1 | 569.5 | 0.534 |
| | *A. nilotica* | 351.2 | 522.0 | 0.057 | 873.2 | 692.3 | 1.649 |
| | *D. cinerea* | 171.7 | 543.2 | 0.014 | 714.9 | 337.7 | 0.712 |
| | *S. myrtina* | 336.3 | 449.9 | 0.033 | 786.2 | 535.7 | -0.088 |
| | *C. odorata*[b] | 433.7 | 480.6 | 0.282 | 914.3 | 867.9 | -0.069 |
| Early wet | *A. natalitia* | 231.5 | 545.0 | 0.036 | 776.5 | 526.1 | -0.747 |
| | *A. nilotica* | 432.3 | 452.2 | 0.054 | 884.5 | 722.4 | 1.694 |
| | *D. cinerea* | 276.2 | 2558 | 0.056 | 532.1 | 442.7 | -0.893 |
| | *S. myrtina* | 286.8 | 432.1 | 0.026 | 718.9 | 464.3 | -0.619 |
| | *C. odorata* | 407.3 | 566.6 | 0.265 | 973.9 | 916.0 | 0.108 |
| Late wet | *A. natalitia* | 242.0 | 404.1 | 0.037 | 646.1 | 464.1 | 0.298 |
| | *A. nilotica* | 298.6 | 466.6 | 0.077 | 765.2 | 631.9 | 0.836 |
| | *D. cinerea* | 261.0 | 433.8 | 0.037 | 694.8 | 453.9 | -0.756 |
| | *S. myrtina* | 279.1 | 507.3 | 0.024 | 786.5 | 461.9 | -1.001 |
| | *C. odorata* | 388.1 | 580.5 | 0.209 | 968.6 | 895.7 | 0.036 |
| | RMSE | 20.0 | 106.2 | 0.014 | 103.7 | 15.6 | 1.199 |
| **Sources of variation effects** | | | | | | | |
| Season | | *** | ns | ns | ns | *** | ns |
| Species | | *** | ns | *** | *** | *** | * |
| Season x Species | | *** | ns | *** | ns | *** | ns |

[a] Formerly part of *Acacia karroo* (Coates Palgrave, 2002); [b] invasive none-native species; $a_n$, the soluble nutrient fraction which is rapidly washed out of the bags and is assumed to be completely degradable; $b_n$, the proportion of insoluble nutrient which is potentially degradable by micro-organisms; $c_n$, the degradation rate of fraction $b_n$ per hour; $PD_n$, potential degradable; $ED_n$, effective nitrogen degradability; $lt_n$, lag time; RMSE, root mean square error; ns (P>0.05); * (P<05); *** (P<0.001).

for which the degradation rates were similar between the dry and the early wet seasons but higher during the late wet season. The degradation rate of *D. cinerea* was fastest during the early wet season and slowest during the dry season. For *C. odorata,* the degradation rate was fastest, moderate and low during the dry, early wet and late wet seasons, respectively.

The effective nitrogen degradability ($ED_n$) for *A. natalitia* and *S. myrtina* decreased from the dry to the early wet seasons from where it remained similar (*A. natalitia*) or decreased in the late wet season (*S. myrtina*). For *A. nilotica*, *D. cinerea* and *C. odorata* the $ED_n$ increased from the dry to the early wet seasons then decreased in the late wet season (*A. nilotica* and *C. odorata*) or remained similar between the early wet and the late wet seasons (*D. cinerea*).

## Correlation between chemical composition and *in sacco* degradability

Table 4 presents the correlations between the CP, NDF, ADF, ADL, CT, cellulose (Cell) and hemicellulose (Hcell), and DM and nitrogen degradation parameters. Crude protein was strongly and positively correlated (P<0.001) with degradation rate of $b_{dm}$ and $b_n$, and negatively correlated (P<0.05) to CT. Crude protein was strongly and positively correlated (P<0.001) with $ED_n$ and moderately and positively correlated (P<0.01) with $ED_{dm}$ and $a_n$. Crude protein was weakly and positively correlated (P<0.05) with $b_{dm}$, $PD_{dm}$ and $PD_n$. The soluble fraction ($a_{dm}$) was strongly and negatively correlated (P<0.001) to fibre fractions (NDF, ADF and ADL) while $a_n$ was moderately and negatively correlated (P<0.01) to NDF and ADL as well as $a_n$ was weakly correlated (P<0.05) to ADF. Neutral detergent fibre was strongly and negatively correlated (P<0.001) with $PD_{dm}$ and $ED_{dm}$ which were moderately correlated (P<0.01) with ADF and ADL. Effective N degradation ($ED_n$) and $lt_n$ had negative correlations (P<0.01) with NDF; and weak negative correlations (P<0.05) with ADF, ADL and CT. The $PD_n$ was negative correlated (P<0.05) to NDF. Condensed tannins had negative correlation (P<0.05) with $a_{dm}$, $a_n$ and $ED_{dm}$. Cellulose negatively correlated (P<0.05) with $a_{dm}$ and $lt_n$.

## DISCUSSION

Seasonality was hypothesized to affect rumen

**Table 4.** Correlation coefficient between chemical composition, and *in sacco* dry matter and nitrogen degradation and estimated parameters.

| Parameters | Chemical constituents | | | | | | |
|---|---|---|---|---|---|---|---|
| | **CP** | **NDF** | **ADF** | **ADL** | **CT** | **Cell** | **Hcell** |
| $a_{dm}$ | $0.13^{ns}$ | -0.78*** | -0.77*** | -0.77*** | -0.52* | -0.55* | $-0.02^{ns}$ |
| $b_{dm}$ | 0.57* | $-0.36^{ns}$ | $-0.22^{ns}$ | $-0.21^{ns}$ | $-0.08^{ns}$ | $-0.18^{ns}$ | $-0.33^{ns}$ |
| $c_{dm}$ | 0.83*** | $-0.47^{ns}$ | $-0.35^{ns}$ | $-0.48^{ns}$ | -0.53* | $0.06^{ns}$ | $-0.30^{ns}$ |
| $PD_{dm}$ | 0.55* | -0.81*** | -0.69** | -0.68** | $-0.41^{ns}$ | $-0.51^{ns}$ | $-0.29^{ns}$ |
| $ED_{dm}$ | 0.76** | -0.86*** | -0.70** | -0.74** | -0.62* | $-0.41^{ns}$ | $-0.38^{ns}$ |
| $lt_{dm}$ | $0.22^{ns}$ | $-0.14^{ns}$ | $-0.05^{ns}$ | $-0.08^{ns}$ | $-0.17^{ns}$ | $0.04^{ns}$ | $-0.22^{ns}$ |
| $a_n$ | 0.65** | -0.66** | -0.59* | -0.65** | -0.56* | $-0.27^{ns}$ | $-0.17^{ns}$ |
| $b_n$ | $0.22^{ns}$ | $-0.31^{ns}$ | $-0.12^{ns}$ | $-0.13^{ns}$ | $0.01^{ns}$ | $-0.07^{ns}$ | $-0.46^{ns}$ |
| $c_n$ | 0.84*** | $-0.48^{ns}$ | $-0.36^{ns}$ | $-0.49^{ns}$ | -0.52* | $0.04^{ns}$ | $-0.29^{ns}$ |
| $PD_n$ | 0.56* | -0.63* | $-0.45^{ns}$ | $-0.50^{ns}$ | $-0.34^{ns}$ | $-0.22^{ns}$ | $-0.44^{ns}$ |
| $ED_n$ | 0.82*** | -0.74** | $-0.58^{*}$ | -0.64* | $-0.55^{*}$ | $-0.28^{ns}$ | $-0.39^{ns}$ |
| $lt_n$ | $0.05^{ns}$ | -0.65** | -0.58* | -0.52* | -0.51* | -0.57* | $-0.17^{ns}$ |

CP, crude protein; NDF, neutral detergent fibre; ADF, acid detergent fibre; ADL, acid detergent lignin; CT, condensed tannin; Cell, cellulose; Hcell, hemicellulose; $a_{dm}$, the soluble fraction of dry matter which is rapidly washed out of the bags and is assumed to be completely degradable; $b_{dm}$, the proportion of insoluble nutrient which is potentially degradable by micro-organisms; $c_{dm}$, the degradation rate of fraction $b_{dm}$ per hour; $PD_{dm}$, the potential degradability; $ED_{dm}$, effective dry matter degradability; $lt_{dm}$, lag time of dry matter; $a_n$, the soluble nitrogen fraction which is rapidly washed out of the bags and is assumed to be completely degradable; $b_n$, the proportion of insoluble nitrogen which is potentially degradable by micro-organisms; $c_n$, the degradation rate of $b_n$ per hour; $PD_n$, potential degradable; $ED_n$, effective nitrogen degradability; $lt_n$, lag time of nitrogen; $^{ns}$ (P>0.05); * (P<0.05); ** (P<0.01); *** (P<0.001)

degradability due to variation in forage quality among seasons. Results supported the hypothesis. The *in sacco* degradability ($a_{dm}$, $PD_{dm}$ and $ED_{dm}$) of browse species was lower during the wet season than the dry season in agreement with a previous finding (Camacho et al., 2010). This decrease in DM degradability can be attributed to the effects of CT on accessible N, which can decrease ammonia concentrations and microbial growth in the rumen (Salem et al., 2007). Van Soest (1994) suggested that lignin and its cross-linkage to hemicellulose, polysaccharides and proteins could also depress digestibility. High $a_n$ and $ED_n$ of browse species during the early wet season is partly in agreement with Ramírez-Orduña (2003) who reported high $ED_n$ of browse plants during autumn and winter at Baja California Sur, Mexico. There may be variation in climate factors between the locations of two studies. Ramírez et al. (2000b) suggest that plants may response to produce new foliage with highly soluble CP due to warm temperatures and wet climate that arise sometime at the end of winter at Northeastern Mexico.

Rumen degradability was hypothesized to vary among plant species due to their variation in chemical composition and results supported the hypothesis. Consistent with our results, Melaku et al. (2003), Anele et al. (2009) and Balgees et al. (2013) reported significant variations in DM and CP degradation parameters of multipurpose trees. The DM and CP potential degradability in the current study overlapped the range of 720 - 914 and 546 – 949 g/kg, respectively, reported by Melaku et al. (2003). The current study had values that are higher than the range of 362 - 673 for the $PD_{dm}$ reported by Anele et al. (2009). Based on potential and effective degradation of both DM and CP, the plant species followed this order: *C*. *odorata*, *A*. *nilotica*, *A*. *natalitia*, *S*. *myrtina* and *D*. *cinerea*. These differences in degradation may be associated to the structural and non-structural protein and carbohydrate fractions (Belachew et al., 2013). Previous reports suggested that the variation in the degradation parameters of the browse species may be due to the variation in chemical composition (Kamalak, 2006; Belachew et al., 2013; Gusha et al., 2013). Furthermore, the variations in chemical composition between seasons or among plant species have been reported (Gusha et al., 2013) which indicate the variation in degradation material of browse species. These variations in $PD_{dm}$ and $PD_n$ in the rumen have been reported as a result of variations in fibre content and tannins levels (Gusha et al., 2013) or due to other factors such as ash (Benjamin et al., 1995) or maturity (Kamalak, 2006; Gusha et al., 2013) . Moreover, $PD_{dm}$ and $PD_n$ were negatively correlated with NDF, ADF and CT (Kamalak, 2006). Acid detergent fibre (ADF) and tannins were negatively correlated with $PD_{dm}$ (Vadiveloo and Fadel, 1992). With regards to *C. odorata*, there has not been any previous report on the $PD_{dm}$ and $PD_n$.

The soluble fraction of DM ($a_{dm}$) and CP ($a_n$) varied within and among plant species, the highest $a_{dm}$ in *A. nilotica* during the three seasons while the highest $a_n$ values recorded in *C. odorata* in the dry and the late wet seasons and *A. nilotica* in the early wet season. Comparable to the others, differences among these species may be because of variation in the type of carbohydrates (in term of structure and content). The $a_{dm}$ and $a_n$ were negative correlated with ADF, NDL and CT of browse species (Ramírez et al., 2000a).

Melaku et al. (2003) also reported that $a_{dm}$ and NDF were negatively correlated, and agree with the negative correlation in this study between $a_{dm}$ and $a_n$, and fibre fractions and CT. In addition, these results are consistent with the lowest values of $a_{dm}$ and $a_n$ in *A. natalitia* in the late wet season and in the two wet seasons, respectively, and *D. cinerea* in the late wet season and in the dry season. These species had higher fibre fractions in these seasons.

The greatest value of the slowly degradable fraction of DM ($b_{dm}$) and CP ($b_n$) in *A. natalitia* in the dry season and *C. odorata* during the two wet seasons and the lowest values of $b_{dm}$ and $b_n$ recorded in *D. cinerea* in the three seasons and in the early wet season, respectively. These parameters were not related to any measured chemicals in this study except $b_{dm}$ was positive correlated to CP. On the other hand, Ramírez et al. (2000a) reported that the slowly degradable fraction of plant cell wall was limited by ADL and tannins and by other factors not measured in the current study such as organic matter, ash and insoluble ash. Many studies reported that the extent of degradation of DM or CP was negatively correlated with NDF, ADF, ADL and CT (Melaku et al., 2003).

Markedly higher degradation rate of DM ($c_{dm}$) and protein ($c_n$) in *C. odorata* and the slowest rates ($c_{dm}$ and $c_n$) observed with *S. mytrina* in the three seasons; reflect differences in chemical composition between the plant species. For instance, *C. odorata* had higher CP and lower CT contents in the three seasons whilst *S. mytrina* had lower CP and higher CT. Results showed $c_{dm}$ and $c_n$ are positively correlated with CP but negatively correlated with CT and is consistent with findings of Kamalak (2006). Balgees et al. (2013) reported that the rate of degradation of protein ($c_n$) was negatively correlated to NDF and ADF concentrations. Melaku et al. (2003) found negative relationship between $c_n$ and CT, and between $c_{dm}$ and neutral detergent fibre bound nitrogen (NDF-N) and ADL, and positive relationship between $c_n$ and NDF-N.

The effective degradability of DM ($ED_{dm}$) and CP ($ED_n$) were positive correlated with CP, but negatively related with fibre fractions and CT. This is in agreement with results of previous studies (Kamalak, 2006; Gusha et al., 2013) reporting that $ED_{dm}$ and $ED_n$ were negatively correlated with NDF and ADF concentrations and $ED_{dm}$ was positive correlation to CP concentration. Melaku et al. (2003) found negative relationship between $ED_n$ and ADL. The differences in $ED_{dm}$ and $ED_n$ may be attributed to structural and non-structural CP and carbohydrate fractions, which affect protein solubility and bio-availability (Belachew et al., 2013).

## Conclusion

A significant variation in *in sacco* degradability parameters were reported among seasons and different browse species harvested from sub-humid subtropical savannah of South Africa, during dry, early, and late wet seasons. These variations were more related with fibre fractions than with tannins content. Fibre concentration appears to be the main factor limiting *in sacco* degradability. It is suggested that the dilution rate and other factors in the rumen may limit tannin effects on degradability. Based on potential and effective degradability, the plant species can be placed in the following decreasing order: *C*. *odorata*, *A*. *nilotica*, *A*. *natalitia*, *S*. *myrtina* and *D*. *cinerea*. Consequently, *C. odorata* is the best supplementary protein source like high-quality leguminous forages.

## Conflict of Interest

The authors have not declared any conflict of interest.

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### REFERENCES

Abusuwar AO, Ahmed EO (2010). Seasonal variability in nutritive value of ruminant diets under open grazing system in the semi-arid rangeland of Sudan (South Darfur State). Agric. Biol. J. N. Am. 1:243-249.

Anele UY, Arigbede OM, Sudekum KH, Oni AO, Jolaosho AO, Olanite JA, Adeosun AI, Dele PA, Ike KA, Akinola OB (2009). Seasonal chemical composition, in vitro fermentation and in sacco dry matter degradation of four indigenous multipurpose tree species in Nigeria. Anim. Feed Sci. Technol. 154:47-57.

Balgees A, Elmnan A, Elseed AF, Mahala A, Amasiab E (2013). In-situ degradability and in vitro gas production of selected multipurpose tree leaves and alfalfa as ruminant feeds. World's Vet. J. 3:46-50.

Basha NAD, Scogings PF, Dziba LE, Nsahlai IV (2012). Diet selection of Nguni goats in relation to season, chemistry and physical properties of browse in sub-humid subtropical savannah. Small Rumin. Res. 102:163-171.

Belachew Z, Yisehak K, Taye T, Janssens G (2013). Chemical composition and in sacco ruminal degradation of tropical trees rich in condensed tannins. Czech J. Anim. Sci. 58:176-192.

Benjamin RW, Lavie Y, Forti M, Barkai D, Yonatan R, Hefetz Y (1995). Annual regrowth and edible biomass of two species of Atriplex and of Cassia sturtii after browsing. J. Arid Environ. 29:63-84.

Camacho LM, Rojo R, Salem AZM, Provenza FD, Mendoza GD, Avilés F, Montaņez-Valdez OD (2010). Effect of season on chemical composition and in situ degradability in cows and in adapted and unadapted goats of three Mexican browse species. An. Feed Sci. Technol. 155:206-212.

Coates Palgrave K (2002). Trees of southern Africa. Struik Publishers (Pty) Ltd, Cape Town, South Africa.

Gusha J, Ngongoni N, Halimani T. (2013). Nutritional composition and effective degradability of four forage trees grown for protein supplementation. Online J. An. Feed Res. 3:170-175.

Kamalak A (2006). Determination of nutritive value of leaves of a native

grown shrub, Glycyrrhiza glabra L. using in vitro and in situ measurements. Small Rumin. Res. 64:268-278.
Makkar HPS (1995). Quantification of tannins: A laboratory manual. International Centre for Agricultural Research in the Dry Areas, Aleppo, Syria.
McDonald I (1981). A revised model for the estimation of protein degradability in the rumen. J. Agric. Sci. 96:251-252.
Mehrez A, Ørskov E (1977). A study of artificial fibre bag technique for determining the dig estibility of feeds in the rumen. J. Agric. Sci. 88:645-650.
Melaku S, Peters KJ, Tegegne A (2003). In vitro and in situ evaluation of selected multipurpose trees, wheat bran and Lablab purpureus as potential feed supplements to tef (Eragrostis tef) straw. Anim. Feed Sci. Technol. 108:159-179.
Migongo-Bake W (1992). Rumen dry-matter digestive efficiency of camels, cattle sheep and goats in a semi-arid environment in eastern Africa. In Joint Feed Resources Network Workshop on the Complementarity of Feed Resources for Animal Production in Africa, Gaborone, Botswana, P. 27.
Ørskov E, McDonald I (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. 92:499-503.
Porter LJ, Hrstich LN, Chan BG (1985). The conversion of procyanidins and prodelphinidins to cyanidin and delphinidin. Phytochemistry, 25:223-230.
Ramírez-Orduña R, Ramírez-Lozano RG, Gómez-Meza MV, Armenta-Quintana JA, Ramírez-Orduña JM, Cepeda-Palacios R, Ávila-Sandoval JM (2003). Seasonal dynamics of ruminal crude protein digestion of browse species from Baja California Sur, Mexico. Interciencia, 28:408-414.
Ramírez R, Neira-Morales R, Ledezma-Torres R, Garibaldi-González C (2000a). Ruminal digestion characteristics and effective degradability of cell wall of browse species from northeastern Mexico. Small Rumin. Res. 36:49-55.
Ramírez R, Neira-Morales R, Torres-Noriega J, Mercado-Santos A (2000b). Seasonal variation of chemical composition and crude protein digestibility in seven shrubs of NE Mexico. Phyton, 68:77-82.
Salem A, Robinson P, El-Adawy M, Hassan A (2007). In vitro fermentation and microbial protein synthesis of some browse tree leaves with or without addition of polyethylene glycol. Anim. Feed Sci. Technol. 138:318-330.
SAS (2002). Statistical Analysis System user’s guide SAS Institute, SAS Campus Drive, Cary, NC, USA.
Ugwu DS (2007). The role of small ruminants in the household economy of southeast zone of Nigeria. Res. J. Appl. Sci. 2:726-732.
Vadiveloo J, Fadel J (1992). Compositional analyses and rumen degradability of selected tropical feeds. Anim. Feed Sci. Technol. 37:265-279.
Van Soest P, Robertson J, Lewis B (1991). Carbohydrate methodology, metabolism and nutritional implications in dairy cattle: Methods for dietary fiber, neutral detergent fiber and non-starch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.
Van Soest PJ (1994). Nutritional ecology of the ruminant. Cornell University Press, Ithaca, NY, USA.
Wendt JN (2003). Animal Feed: AOAC official method 990.03 protein (crude) in animal feed, combustion method. In Official methods of analysis of AOAC international (ed. W Horwitz), AOAC Inernational, Gaithursburg, Marland, USA. P. 26.