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Ruminal degradation and *in vitro* gas production characteristics of foliage from *Atriplex* species and *Cassia sturtii*

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Abstract

This study was undertaken to determine the degradation characteristics and *in vitro* gas production kinetics of drought tolerant shrubs (*Cassia sturtii*, *Atriplex nummularia* and three *Atriplex canescens* cultivars, *viz.* Santa Rita, Field Reserve 1 and Rincon) growing under South African conditions (Hatfield in the Gauteng Province and Mier and Lovedale, both in the Northern Cape Province). Edible forage was incubated for 72 h to record *in sacco* neutral detergent fibre (NDF) degradability parameters and *in vitro* gas production. No significant difference was found between locations in terms of the NDF degradation parameters, except the NDF effective degradation (ED). However, the species differed in terms of the slowly degradable NDF fraction (NDF b-value) and rate of the degradation of NDF (NDF c-vlaue) in the Hatfield samples. Species differed significantly in terms of NDF ED value for samples collected at Mier. Species also differed in the rate of gas production (c) the volume of effective gas produced (EGP) and the potential extent of gas production (b) values. *Atriplex nummalaria* was ranked better than *A. canescens* (Field Reserve 1) in terms of NDF ED-value in Mier and NDF b-value in Hatfield, though the latter had shown higher c-values for samples collected in Hatfield. A similar trend was recorded in the gas production study, where *A. canescens* (Field Reserve 1) ranked least in terms of effective gas production and the potential extent of gas production compared to the other *Atriplex* species and *C. sturtii*. This indicates a lower feeding value of this cultivar as a ruminant feed compared to other *Atriplex* cultivars and *C. sturtii*.

Keywords: *Atriplex*, *Cassia sturtii*, *in sacco* degradation, neutral detergent fibre, shrubs
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Introduction

Fibrous feeds are the most important diet ingredient for ruminants under extensive livestock production systems. Due to the low rainfall, especially in the Northern Cape Province of South Africa, the quantity of forage is often limiting. *Atriplex* species may have potential of increasing animal production in such areas because of their drought and salt tolerance (Kleinkopf *et al.*, 1975; Le Houérou, 1992). The nutritive value of these feeds could be predicted from their ruminal degradation characteristics which are highly correlated to voluntary intake, compared to *in vivo* digestibility or chemical composition alone (Ahmed & El Hag, 2004). Nsahlai *et al*. (1994) also reported that fibre degradation and gas production using the *in situ* nylon bag (Ørskov *et al.*, 1980) and the *in vitro* gas production (Menke & Steingass, 1988) methods, respectively, are reliable techniques for screening fodder trees and shrubs for nutritive value. The aim of this study was to evaluate the feeding value of three *Atriplex* spp. on the basis of their NDF degradation and gas production characteristics, and to compare them with *Cassia sturtii*, reported previously by Le Houérou (1980) for its adaptability to low rainfall areas of Africa and other regions.

Materials and Methods

This study used *Atriplex canescens* (Santa Rita), *A. canescens* (Field Reserve 1 and Rincon) and *A. nummularia*. Edible foliage (leaves and stems of less than 5 mm diameter) of these species was collected from three different sites in South Africa during March 2002. The sites were Hatfield, Pretoria (Gauteng Province), Mier and Lovedale (both the latter in the arid regions of the Northern Cape Province) with average annual rainfalls of 600, 200 and less than 100 mm, respectively. The samples were dried at 60 °C for 48 hours. The samples destined for *in situ* degradation were ground to pass through a 4 mm screen, while those intended for *in vitro* gas production were ground to pass through a 1 mm screen. For the *in sacco* NDF degradation study samples of 5 g (AFRC, 1992) were incubated for 8, 16, 24 and 72 h in rumen fistulated

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sheep using nylon bags (10 x 20 cm bag, 12.5 mg/cm^2). Bags of the zero hour interval as well as the incubated ones were washed under a running tap until the water ran clear. The NDF for the residue was analyzed according to the procedures of Van Soest et al. (1991). The values at different time intervals were used to calculate degradation constants of NDF using the nonlinear model: $y = a + b\ (1- e^{-ct})$ suggested by Ørskov & McDonald (1979), where y = the disappearance of NDF at time t; a the washing loss (g/kg DM) (rapidly soluble fraction); b the slowly degradable NDF fraction (g/kg DM), and c the rate (%/h) of degradation of fraction b. These degradation constants were used to estimate effective degradability (ED) following the model of Ørskov & McDonald (1979): ED = a + [bc/(k + c)] where k is the passage rate from the rumen, estimated to be 4%/h.

For the *in vitro* gas production analysis the procedure of Pienaar (1994) was used. Due to cost limitations, only samples from the Hatfield site were analysed. They included *Cassia sturtii*, *A. canescens* (Santa Rita), *A. canescens* (Field Reserve 1), *A. nummularia* and *A.* canescens (Rincon). Rumen fluid was obtained from rumen-fistulated sheep consuming a good quality lucerne hay. Volume of gas produced was recorded at 0, 8, 16, 24 and 72 h of incubation. The potential extent of gas production and the gas production rate (%/h) were calculated using the nonlinear model: $y = b(1-e^{-ct})$ suggested by Ørskov & McDonald (1979), as modified by Osuji et al. (1993), where y is the volume of gas produced (mL/g DM) with time (t) (h), b is the potential extent of gas production (mL/g DM) and c is the gas production rate (% of b/h). The intercept is not included in the model as there will be no gas production from unfermented feed, as explained by Osuji et al. (1993). Effective gas production (EGP) was calculated using the equation: EGP= (bc/(c+k)), where k is the outflow rate from the rumen, assumed to be 5%/h.

Analysis of variance was performed using the General Linear Model (SAS, 1994) to establish the effect of species and location on the measurements and means and standard errors (s.e.) were calculated. Means were separated using Bonferroni's test (Samuels, 1989) at P < 0.05 confidence limit.

Results and Discussion

The NDF degradation characteristics of *Atriplex* species collected at the three locations are presented in Table 1. The a-value was not affected by location, but within locations, species differences were observed for samples collected from Hatfield and Mier. Similarly the slowly degradable portion (b-value) was not affected (P > 0.05) by location. Differences between species were observed for samples collected from Hatfield, but not from the other locations. In Hatfield, *A. nummularia* had a higher (P < 0.05) b-value (511 g/kg DM) than *A. canesecens* (Field Reserve 1) (296 g/kg DM).

The rate of ruminal degradation ranged between 0.020 and 0.093%/h, but rates of corresponding species from different locations did not differ (P > 0.05). However, the individual species differed in the rate of degradation, e.g. at Hatfield, *A. canescens* (Field Reserve 1) had a higher (P < 0.05) rate of degradation than *A. canescens* (Santa Rita) and *A. nummularia*. The average rate of degradation of 0.053%/h of these *Atriplex* species is lower than average values of 0.099%/h, 0.074%/h and 0.064%/h reported for DM degradability by Kaitho (1998) for *A. halimus*, *A. nummularia* and *A. rhagodiodes*, respectively. El Hassan *et al.* (2000) also reported rates of degradation of DM values (/h) of between 0.032 to 0.110 for six browse species.

Effective degradability (ED) ranged between 247 to 389 g NDF/kg and the respective species from different locations differed in ED. The ED of NDF in *A. canescens* (Santa Rita) from the Hatfield sample was lower than that from Lovedale and the ED of NDF in *A. nummularia* from Hatfield was lower than that from Mier. The ED of NDF in *A. nummularia* from Mier was higher in than that from the other two species at Mier. These average NDF ED-values are lower than those reported by El Hassan *et al.* (2000) for some browse species such as *Acacia angustissima* (515 g/kg), *Chamaecytisus palmensis* (725 g/kg), *Leucaena leucocephala* (613 g/kg), *Sesbania sesban* (704-706 g/kg), *Vernonia amygdalina* (580 g/kg) and *Medicago sativa* (662 g/kg).

The *in vitro* gas production of *C. sturtii* and the four *Atriplex* species is presented in Table 2. The potential extent of gas production ranged between 125 to 164 mL/g DM. These values are very low as compared to values of 289.5 to 334 mL/g recorded for four browse leaves in Turkey (Kamalak *et al.*, 2004). In the present study the potential extent of gas production was lower in *A. canescens* (Field Reserve 1) than in *A. canescens* (Santa Rita), *A. nummularia*, *A. canescens* (Rincon) and *C. sturtii*. The volume of effective

Table 1 Mean (± s.e.) ruminal degradation parameters of NDF (g/kg) in *Atriplex* species harvested at different locations in South Africa

Degradability constant	*Atriplex* species	Location		
		Hatfield	Mier	Lovedale
a (g/kg)	*A. canescens* (Santa Rita)	70_1 (±15.1)	$44_{1,2}$ (±15.1)	68 (±15.1)
	A. canescens (Field Reserve 1)	13_2 (±15.1)	18_2 (±15.1)	47 (±15.1)
	A. nummularia	$37_{1,2}$ (±15.1)	85_1 (±15.1)	54 (±15.1)
b (g/kg)	*A. canescens* (Santa Rita)	$350_{1,2}$ (±46.7)	373 (±46.7)	417 (±46.7)
	A. canescens (Field Reserve 1)	296_2 (±46.7)	376 (±46.7)	278 (±46.7)
	A. nummularia	511_1 (±46.7)	433 (±46.7)	356 (±46.7)
c (%/h)	*A. canescens* (Santa Rita)	0.026_2 (±0.0143)	0.048 (±0.0143)	0.049 (±0.0143)
	A. canescens (Field Reserve 1)	0.081_1 (±0.0143)	0.049 (±0.0143)	0.093 (±0.0143)
	A. nummularia	0.020_2 (±0.0143)	0.054 (±0.0143)	0.052 (±0.0143)
ED (g/kg)	*A. canescens* (Santa Rita)	252^b (±23.8)	$282^{ab}{}_2$ (±23.8)	347^a (±23.8)
	A. canescens (Field Reserve 1)	247 (±23.8)	280_2 (±23.8)	271 (±23.8)
	A. nummularia	278^b (±23.8)	$389^a{}_1$ (±23.8)	309^{ab} (±23.8)

$^{a,\,b}$ For each degradability parameter row means with common superscripts do not differ (P > 0.05)
$_{1,\,2}$ For each degradability parameter column means with common subscripts do not differ (P > 0.05)
a, b and c are described by the equation $y = a+b\,(1-e^{-ct})$, where y is the percentage degraded NDF at time t (h); a the zero time intercept (washing loss); b the slowly degradable NDF fraction (g/kg DM), and c the rate of degradation (%/h) of fraction b. ED is the effective degradability calculated using the equation $ED = a+ (bc/(c+k))$, where k is outflow rate from the rumen, assumed to be 4%/h

Table 2 *In vitro* gas production of foliage of several *Atriplex* species and C*assia sturtii* collected at Hatfield (mL/g DM)

Species	Gas production parameter (mL/g D M)		
	b	c	EGP
C. sturtii	146^b (±5.8)	0.087^a (±0.0027)	92.5^a (±5.1)
A. canescens (Santa Rita)	157^{ab} (±4.8)	0.061^b (±0.0022)	86^{ab} (±4.2)
A. canescens (Field Reserve 1)	125^c (±4.8)	0.073^{ab} (±0.0022)	74^b (±4.2)
A. nummularia	164^a (±4.8)	0.070^b (±0.0022)	96^a (±4.2)
A. canescens (Rincon)	150^{ab} (±4.8)	0.067^b (±0.0022)	86^{ab} (±4.2)

$^{a,\,b}$ Column means with common subscripts do not differ (P > 0.05)
y, b and c are described by the equation $y = b\,(1-e^{-ct})$, where y is the volume of gas produced with time (h); b the potential extent of gas production (mL/g DM) and c the gas production rate (%/h). The intercept is not included in the model as there will be no gas production from unfermented feed (Osuji et al., 1993). EGP is the effective gas production calculated using the equation $EGP = (bc/(c+k))$, where k is outflow rate from the rumen, assumed to be 5%/h

gas production (EGP) ranged between 74 to 96 mL/g DM, which is lower than the 169-206 mL/g DM estimated for tree species (*Glycrrhiza glabra*, *Arbutus andrachne*, *Juniperus communis* and *Pistica lentiscus*) and a barley cultivars in Turkey (Kamalak *et al*., 2004; Colkesen *et al*., 2005). In the present study the EGP volume was lower in *A. canescens* (Field Reserve 1) than in the other *Atriplex* species and *C. sturtii*. The amount of gas released is closely related to the digestibility of the feed (Osuji *et al*., 1993), and a highly digestible feed will produce more gas than a feed with a low digestibility (Ouda *et al*., 2005). However, for those feeds with a similar digestibility, the one with lowest gas production could be regarded to have a higher nutritive value since more of its degraded fraction is likely to be incorporated into the microbial biomass or be absorbed directly by the host animal (Rymer, 1999). In this study *C. sturtii* had the highest average gas production rate, that was higher (P > 0.05) than the average rates measured for *A. nummularia*, *A. canescens* (Santa Rita) and *A. canescens* (Rincon). The rate of gas production is also a better predictor of *in vitro*

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organic matter digestibility and hence can be used to predict the feeding value of forages (Chenost *et al*., 2001). In general, the ranges of gas production rates (c-values) in this study were higher than values reported by Ammar *et al*. (2005) (0.04%/h) for shrub species in the Mediterranean and by Apori *et al*. (1998) for Ghanaian browse species (0.0361%/h to 0.0654%/h), but are within the range of c-values reported by Kamalak *et al*. (2004) for tree leaves in Turkey (0.070 to 0.087%/h).

Conclusion

In this study location did not have any effect on NDF degradability parameters. However, the species differed significantly within a location for some of the NDF degradability parameters. *A. nummalaria* was ranked higher than *A. canescens* (Field Reserve 1) in terms of NDF ED-value in Mier and NDF b-value in Hatfield, though the latter had a higher rate of degradation for samples collected in Hatfield. This indicates that the former cultivar has the best potential as a ruminant feed. The gas production study supported this pattern. *A. canescens* (Field Reserve 1) ranked least in terms of effective gas production and the potential extent of gas production compared to the other *Atriplex* species and *C. sturtii*. This indicates a lower feeding value for this cultivar as a ruminant feed compared to other *Atriplex* cultivars and *C. sturtii*.

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