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Silage fermentation attributes and certain rumen parameters in sheep fed two grass silages harvested at different stages of maturity

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Abstract

The aim of this study was to compare two tropical grass species, *Panicum maximum* and *Digitaria eriantha*, in terms of silage fermentation attributes and certain rumen fermentation characteristics of silage made either at the boot or full bloom stages of growth. A lower silage pH was recorded for the *D. eriantha* than for the *P. maximum* silage. Neither species nor maturity stage had a significant effect on silage ammonia nitrogen, or lactic, acetic and butyric acid concentrations. For *P. maximum* silage total N was higher at full bloom than at the boot stage. *D. eriantha* had a higher total nitrogen content than *P. maximum* silage at the boot stage. Rumen pH was lower in sheep fed *D. eriantha* than *P. maximum* silage. In *P. maximum* fed sheep, a higher rumen NH_3-N concentration was recorded when silage from the full bloom stage was fed compared to silage from the boot stage. In sheep fed *D. eriantha* silage, higher concentrations of acetic, propionic, butyric and total volatile fatty acids in the rumen were recorded from full bloom than from the boot stage. Neither species nor stage of maturity had significantly influenced the acetic : propionic acid ratio. The results suggested no significant difference between the species, but the full bloom stage showed a higher nutritive value and better preservation compared to the boot stage silage in both *D. eriantha* and *P. maximum* silage.

Keywords: Boot stage, *Digitaria eriantha*, full bloom stage, *Panicum maximum*, rumen fermentation
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Introduction

Panicum maximum (Guinea grass) and *Digitaria eriantha* (Smuts finger) are high yielding subtropical perennial grasses grazed by cattle and sheep in southern Africa. Excess forage can be removed for hay or silage making. Ensiling tropical grasses such as *D. eriantha* and *P. maximum* showed sub-optimal (often poor) initial silage fermentation (Mühlbach, 2000) due to either a low dry matter (DM) content, high buffer capacities, low level of suitable lactic acid bacteria and a low water-soluble carbohydrate (WSC) content, or a combination of these factors (Mühlbach, 2000). The objective of this study was to compare silage fermentation attributes and certain rumen fermentation characteristics of *P. maximum* and *D. eriantha* silages made either at the boot or full bloom stages of growth.

Materials and Methods

Panicum maximum and *D. eriantha* pastures were harvested from an area of 0.4 ha at two different stages (boot and full bloom) of growth. The harvested forage for each species were separately wilted to a dry matter concentration of 30% and ensiled with an addition of 8 kg sugar/ton DM in airtight plastic bags (3.1 m x 2.75 m). The silos were opened at day 120 and representative samples were analysed to determine the fermentative and nutritive value characteristics. Silage nitrogen (N) content was analyzed according to AOAC (2000).

Four rumen cannulated sheep were randomly allocated to one of the four silage diets for the rumen fermentation study. It was a 2 x 2 factorial treatment consisting of two grass species (*P. maximum* or *D. eriantha*) and two growth stages (boot or full bloom stage of growth) at harvest. The sheep were housed in individual metabolism cages and were fed *ad libitum* three times daily. The animals had free access to a 50 : 50 dicalcium phosphate/salt lick and fresh water was available.

Sampling of rumen fluid was done over four consecutive days at 09:00 and 21:00 on day 1; at 12:00 and 24:00 on day 2; at 15:00 and 03:00 on day 3; and at 18:00 and 06:00 on day 4. The rumen pH was measured immediately after sampling and the rumen fluid was stored in a freezer for later analysis. These rumen fluid samples were thawed and then filtered. The supernatant was used for the determination of rumen ammonia nitrogen (NH_3-N) and volatile fatty acid (VFA) concentrations after separate samples from each treatment were preserved with 4 mL 0.5 M sulphuric acid or 2 mL of a 10% sodium-hydroxide solution, respectively. Volatile fatty acid and lactic acid concentrations were measured according to the methods of Payne & McDonald (1966) and Pryce (1969), respectively.

All parameters measured in the experiments were analyzed using Proc GLM of SAS (2001). The influence of grass species and growth stage was investigated and where the F ratio showed significance differences ($P < 0.05$), the means were tested using the Bonferroni's test according to Samuels (1989).

Results and Discussion

The silage DM content differed significantly between the grass species (Table 1). At boot stage, *P. maximum* had a higher DM content than *D. eriantha* silage, whereas at full bloom stage *P. maximum* had a lower DM concentration than *D. eriantha* silage. The DM concentration of the forages prior to ensiling and at feeding plays a key role in determining the silage fermentation characteristics and intake by the animal (Ingvartsen, 1992). In general, the organic matter (OM) concentration of *D. eriantha* silage was higher than that of *P. maximum* silage. At boot stage the N concentration of *D. eriantha* silage was higher than that of *P. maximum,* but when compared at full bloom stage the species did not differ in terms of their N concentrations. The NH_3-N concentrations were also not significantly different between the two species. In general, NH_3-N values were within an acceptable range (<100 g NH_3-N/kg N) for well-fermented silages (Stark & Wilkinson, 1988), and lower than values reported by Meeske *et al.* (1999) for *D. eriantha* (50.3 g N/kg) silage ensiled for 44 days. In general, *D. eriantha* silage had lower pH values than the *P. maximum* silage. However, the pH values for grass silage were closer or less than 5, and according to McDonald *et al.* (1991), for wilted silages, a stable silage can be achieved at pH values of 5 and above due to the higher

Table 1 Silage quality of *Panicum maximum* and *Digitaria eriantha* at boot and full bloom stage of growth

Silage fermentation parameters	Stage of growth at harvest	Pasture species	
		P. maximum	*D. eriantha*
pH	Boot	4.5_1 (± 0.40)	4.2_2 (± 0.40)
	Full bloom	4.7_1 (± 0.40)	4.4_2 (±0.40)
Dry matter (g/kg)	Boot	362.5_1^a (± 2.8)	299.8_2^b (± 2.8)
	Full bloom	350.8^b (± 2.8)	360.4^a (± 2.8)
Nitrogen (g/kg DM)	Boot	18.6_2^b (± 1.3)	23.9_1 (± 1.3)
	Full bloom	24.0^a (± 1.3)	22.3 (± 1.3)
Ammonia-N (g/kg N)	Boot	38.1 (± 4.3)	46.8 (± 4.3)
	Full bloom	49.6 (± 4.3)	36.2 (± 4.3)
Lactic acid (g/kg DM)	Boot	16.2 (± 3.4)	13.0 (± 3.4)
	Full bloom	12.6 (± 3.4)	24.1 (± 3.4)
Acetic acid (g/kg DM)	Boot	7.0 (± 2.5)	2.6 (± 2.5)
	Full bloom	13.7 (± 2.5)	9.3 (± 2.5)
Butyric acid (g/kg DM)	Boot	0.20 (± 0.4)	0.07 (± 0.4)
	Full bloom	0.06 (± 0.4)	0.23 (± 0.4)

Means within columns (a,b) and rows (1,2) with different super-/sub-scripts differ significantly at $P < 0.05$.

osmotic pressure associated with wilting that probably inhibits clostridial growth. In contrast, Marsh (1979) reported lower pH values for wilted silages. Accordingly, except for *P. maximum* silage at full bloom stage, the pH values of the four silages were within an acceptable range as recommended by the same authors. However, the best indicator of silage quality is the acid profile of the silage (Bethard, 2006). In the present study the silage from the two grass species did not differ (P >0.05) in terms of lactic, acetic and butyric acid concentrations.

In general, the rumen pH value of sheep fed *D. eriantha* silage was lower than that of sheep fed the *P. maximum* silage (Table 2). The rumen pH followed a similar pattern to that of silage pH. For all silage diets, however, the levels of rumen pH recorded were within the optimal pH recommendation ranges for high proteolytic (pH 6 to 7) and cellulolytic (pH 6.2 to 6.8) activities. The rumen ammonia, acetic acid, propionic acid and total volatile fatty acid concentrations did not differ (P >0.05) between the two grass species. However, sheep fed *D. eriantha* silage had a higher (P <0.05) rumen butyric acid concentration than *P. maximum* silage when compared at the full bloom stage. A similar pattern was recorded for silage pH, though the difference was not statistically significant. Higher butyric acid in silage is an indicator of undesirable fermentation and/or secondary fermentation (Schroeder, 2004). The rumen NH_3-N values recorded for sheep fed on both tropical grass silages were sufficient to support maximum microbial activity in the rumen. According to Satter & Roffler (1975) values lower than 2.5 - 5 mg/100 mL rumen fluid may inhibit rumen activity, while Ørskov (1982) suggested a rumen NH_3-N concentration of 20 - 24 mg per 100 g rumen fluid for maximum fermentation rate.

Table 2 Rumen parameters of sheep fed *Panicum maximum* and *Digitaria eriantha* silage harvested at the boot and full bloom stage of growth

Rumen parameters	Stage of growth at harvest	Pasture species	
		P. maximum	*D. eriantha*
Rumen pH	Boot	6.66_1 (± 0.4)	6.27_2 (± 0.4)
	Full bloom	6.81_1 (± 0.4)	6.35_2 (± 0.4)
Rumen NH_3-N (mg/100 mL)	Boot	15.6^b (± 1.5)	16.4 (± 1.5)
	Full bloom	20.0^a (± 1.5)	19.5 (± 1.5)
Acetic acid (mmol/100 mL)	Boot	9.7 (± 1.0)	8.1^b (± 1.0)
	Full bloom	9.6 (± 1.0)	10.4^a (± 1.0)
Propionic acid (mmol/100 mL)	Boot	2.4 (± 0.6)	2.0^b (± 0.6)
	Full bloom	2.4 (± 0.6)	2.5^a (± 0.6)
Butyric acid (mmol/100 mL)	Boot	0.75 (± 0.4)	0.77^b (± 0.4)
	Full bloom	0.68_2 (± 0.4)	0.98_1^a (± 0.4)
Total VFA (mmol/100 mL)	Boot	13.1 (± 1.2)	11.2^b (± 1.2)
	Full bloom	13.0 (± 1.2)	14.2^a (± 1.2)
Acetic : propionic acid ratio	Boot	4.0 (± 0.6)	4.1 (± 0.6)
	Full bloom	4.0 (± 0.6)	4.1 (± 0.6)

Means within columns (a,b) and rows (1,2) with different super-/sub-scripts differ significantly at P <0.05.

For *D. eriantha* silage, the DM concentration of the silage made at full bloom stage of harvest was higher than that made at boot stage (Table 1). In contrast, Van Niekerk *et al.* (2008) reported no difference in terms of DM% when ensiled in a 1 kg mini-silo. For *D. eriantha*, growth stage had no effect on the N concentration of the silage, while for *P. maximum* the N concentration of silages at full bloom stage was higher than for the boot stage silage. This was not expected and the reason for this is not clear, taking into consideration a decline in N concentration with advanced maturity (Relling *et al.*, 2001). In general, growth stage had no significant effect on silage pH, and NH_3-N, acetic, lactic and butyric acid concentrations of silage.

Growth stage had also no significant effect on the rumen pH of sheep fed on the two grass silages (Table 2). However, harvesting at full bloom stage resulted in a higher NH_3-N concentration of sheep fed *P. maximum* silage compared to silages made from the same species at boot stage. The NH_3-N concentration recorded for boot stage silage does not support maximal fermentation rate (Ørskov, 1982). In *P. maximum* silage, the observed higher N concentration recorded at full bloom stage and the corresponding higher rumen NH_3-N concentration of sheep on this diet confirmed earlier results (Meissner *et al.*, 1993; Relling *et al.*, 2001) that showed a positive correlation between N intake and rumen NH_3-N concentration. In *D. eriantha* silage, however, harvesting at full bloom stage resulted in higher rumen acetic, propionic, butyric and total volatile fatty acid concentrations than silages made at the boot stage. This is in accordance with Van Niekerk *et al*. (2008). Except for *D. eriantha* at boot stage, the values recorded for total VFA concentration are within the range reported for mature *P. maximum* pasture (Relling *et al*., 2001). Growth stage had no effect on the acetic acid to propionic acid ratio.

Conclusions

There were no significant differences between the important qualitative silage characteristics of *P. maximum* and *D. eriantha* silages. The higher nutritive value of the full bloom stage compared to the boot stage of *D. eriantha* silage was due to an improved VFA production in the rumen. Similarly, a higher rumen NH_3-N concentration was recorded for *P. maximum* harvested at the full bloom stage than at the boot stage.

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