The Intake and Palatability of Four Different Types of Napier Grass (*Pennisetum purpureum*) Silage Fed to Sheep

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ABSTRACT : Four different types of silage from new cultivars of Napier grass (*Pennisetum purpureum*), cv. NG 1 and NG 2, were fed to eight wethers in order to evaluate their preference and intake by sheep. The silages were prepared from direct-cut NG 1 herbage; pre-wilted NG 1 herbage; NG 1 herbage with maize meal (5% inclusion) and NG 2 herbage with maize meal (5% inclusion). All silages were palatable to sheep. Maize-treated silage had high quality fermentation, characterized by high Fleig scores and low pH, volatile fatty acids (VFA) and ammoniacal nitrogen contents. The pH, Fleig score, *in vitro* digestible organic matter (IVDOMD) and ammoniacal-N contents for maize-treated cv. NG 1 silage were 3.7, 78, 540 g kg^{-1} dry matter (DM) and 0.18 g kg^{-1} DM whereas, in maize-treated cv. NG 2 they were 3.6, 59, 458 g kg^{-1} DM and 0.18 g kg^{-1} DM, respectively. The superior quality of maize-treated silages made them more preferable to sheep. Among the maize-fortified silages, palatability and intake were significantly ($p<0.001$) greater with cv. NG 1. Although direct-cut silage had better fermentation quality compared to wilted silage, wilted silage was significantly ($p<0.001$) more preferable to sheep. However, there were no significant differences ($p<0.05$) in the levels of preference and intake of wilted silage compared to maize-treated cv. NG 2 silage, even though the latter tended to be more palatable. There were indications that high pH (4.6 vs 3.5) and IVDOMD content (476 vs 457 g kg^{-1} DM) of wilted silage contributed to higher intake, compared to direct-cut silage. It was generally concluded that pre-wilting and treatment of Napier grass with maize meal at ensiling enhances intake and palatability. ***(Asian-Aust. J. Anim. Sci. 2003. Vol 16, No. 6 : 823-829)***

Key Words : Napier Grass, Penisetum Purpureum, Silage, Pre-wilting, Maize Meal, Additives

INTRODUCTION

Napier grass (*Pennisetum purpureum*) is generally high yielding in Natural Regions I and II of Zimbabwe (Manyawu et al., 1998). Some new cultivars of Napier grass contain adequate concentrations of water soluble carbohydrate (WSC) to make silage (Manyawu, 2000). The high concentrations of WSC ensure lactate-dominated fermentation and such silages tend to be readily consumed by livestock (Catchpoole and Henzel, 1971; Petterson and Lindgren, 1990). Forages that have low WSC are prone to secondary fermentation, and this often depresses silage nutritive value and intake by livestock (Wilkinson, 1983).

Other factors also influence the palatability and intake of silage and identification of these factors continues to be a major area of research. Steen et al. (1998) found that silage intake is mostly affected by factors that influence the extent of digestion and passage rate of material through the gastrointestinal tract of the ruminant animal. These factors include digestibility, degradability, and the concentration of fibre and nitrogen. In some cases, pH and lactic acid, butyric acid and ammoniacal-N contents have been reported to affect the intake of silage (Cushnahan et al.,1994). Pre-ensiling treatment of forage, such as wilting, has been known to increase the intake of silage DM by livestock (Wilkins, 1984; Petterson et al., 1996 and Dawson et al., 1999). Likewise, application of cereal additives at the time of ensiling was reported to enhance intake and the productivity of livestock by Jones (1988) and Harrison et al. (1990). However, this whole area of research is beset with contradictions over what factors are most important. Further research is required to accurately predict the intake and performance of livestock fed grass silage diets.

Recent efforts to improve the ensilability of high yielding accessions of Napier grass in Zimbabwe have demonstrated the benefits of pre-wilting herbage and the use of cereal-based additives when Napier forage was conserved in laboratory silos (Manyawu, 2001). However, results on silage making have been known to vary between laboratory and field conditions. Since literature cites some uncertainties on the effects of pre-wilting and the application of cereal additives, the current experiment was designed to screen different types of Napier grass silage that are made from pre-wilted forage treated with or without maize-based additive, for palatability and intake. It was anticipated that this research would give indication of how smallholder resource-poor farmers can ensile Napier grass efficiently, using minimum resources.

MATERIALS AND METHODS

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Table 1. Description of silage treatments

Treatment No.	Accession of Napier grass that was ensiled	Pre-ensilage treatment
1	cv. NG 1	Direct-cut (no wilting and no additive)
2	cv. NG 1	Pre-wilted for 1.5 days, no additive.
3	cv. NG 1	Maize meal at 5% (w/w), no wilting.
4	cv. NG 2	Maize meal at 5% (w/w), no wilting.

N.B. Treatment 1 served as the control treatment

Herbage production and silage-making

The experiment was conducted at Grasslands Research Station, in Marondera (Zimbabwe), using two new high yielding cultivars of Napier grass (cv. NG 1 and cv. NG 2). The accessions were planted in two adjacent 1.8 ha plots in the 1996/97 wet season. They were established from stem cuttings. The cuttings were planted at an inter-row spacing of 90 cm and intra-row spacing of 30 cm. In November 1997 the plants were cut back and top-dressed with ammonium nitrate (34.5% N), agricultural lime and single superphosphate (18.5% P_2O_5) fertilizers at rates of 175, 500 and 250 kg ha^{-1}, respectively. The regrowth obtained was used to make silage.

The two cultivars were harvested at midday on 21 and 23 January, 2001 to make silage. The cut herbage was exposed to treatments described in Table 1 before ensilage. The silages were prepared in 8.0 m^3 trench silos. The silos were opened after five months for the feeding experiment.

Treatments and experimental design

The four different types of Napier grass silage were stall-fed to eight Merino wethers. The experiment had a randomized complete block design and animal to animal variation was used as the blocking factor. The wethers were penned individually and fed the grass silage in four separate troughs. The troughs were arranged in random order along one side of each pen. The sheep had free access to equal amounts (1.5 kg per day) of the different types of silage, for four weeks. They were also provided with No. 2 stargrass hay and concentrate feed as non-test supplements, in two separate troughs, which were hung on a different side of the pen.

Concentrate feed was supplied at the rate of 20% of the estimated daily DM intake. The amount of concentrate feed was adjusted at the beginning of each week, after weighing the sheep. The concentrate comprised 60% maize, 28% cottonseed meal, 10% soyabean meal and 2.0% mineral supplement. It contained 193, 872 and 8.31 g kg^{-1} DM of crude protein) CP, IVDOMD and ADF, respectively. The stargrass hay was fed only in the initial 10-day period to facilitate a smooth change-over to the new diets. During the first week of the experiment, 1.0 kg of hay was offered daily. This was reduced to 0.5 kg per day in the second week and none thereafter. The sheep were given three weeks to adapt to the silage diets. Thereafter, there was one week for data collection.

Sampling procedures and measurements

The pre-ensiling period : Four random samples of fresh Napier grass were collected from the cut grass before it was ensiled. The samples were used to determine the dry matter (DM), crude protein (Kjeldhal-N×6.25), neutral detergent fibre (NDF) and WSC contents, and *in vitro* organic matter digestibility (IVDOMD) of the fresh grass. Similarly, samples were collected after pre-wilting in Treatment 2 for the same analyses. The *in vitro* DM and OM digestibilities were determined by the method of Tilley and Terry (1963). The neutral detergent fibre content was determined by the method of Van Soest et al. (1985). Water soluble carbohydrate content was determined using the method of Deriaz (1962) which was modified as described by Manyawu et al. (2000). Dry matter content was determined by drying samples in a forced draught oven, at 80°C for 48 hours.

Silage opening : The silos were opened on 15 June 1999 to collect samples for the determination of IVDOMD, crude protein, neutral detergent fibre (NDF), WSC, volatile fatty acids (VFA), lactic acid and ammoniacal-N contents of the fermented herbage. Four samples were taken by hand and auger, from various depths in each silo. Thereafter, the silage samples were collected 50 cm beyond the face of the silage at the beginning of each week, during the feeding period.

The volatile fatty acid contents were determined by gas chromatography (Manyawu et al., 2000). Lactic acid was determined by the method of Eldsden and Gibson (1954) and ammoniacal-N was determined by the method of Van Soest et al. (1965). Fleig scores were calculated as outlined by Woolford (1984).

Feeding management

Mature wethers that had been grazing a No.2 Stargrass pasture were used in the experiment. Their initial liveweights ranged from 30 to 36 kg. They were given a vitamin 'A' injection on the first day of the experiment.

During the experiment, fresh water, hay and silage were provided daily, at 08:00 h. Each wether was allowed to choose between the different types of silages throughout the day. Within a pen, consumption from each of the four silage troughs was measured twice daily, at about 12:00 h (four hours after feeding) and around 07:00 h the following morning (24 h after feeding). Every morning, a sample of silage refusals from the previous day was collected from each trough to determine DM content. The refusal samples

Table 2. Composition of pennisetum grasses at cutting

Grass accession	Dry matter (g kg^{-1})	Crude protein (g kg^{-1} DM)	Digestible organic matter (g kg^{-1} DM)	Water soluble carbohydrate (g kg^{-1} DM)
cv. NG 1	262	66.0	653	174
cv. NG 2	180	67.6	620	105

were then sealed in plastic bags and kept in a freezer at -4°C until the end of the week, when they were subsequently mixed in equal amounts before sub-sampling. The sub-samples were used to determine the mean weekly DM content of refusals in each treatment. Voluntary intake (g) was determined as the difference in the amount of silage DM offered at the beginning of a day and the DM remaining at the end of 4 and 24 h. In each period of consumption (4 or 24 h), preference of a particular silage by sheep was determined by calculating the amount of that silage which was consumed and comparing it to the level of consumption of other silages. Silages that were consumed more were considered to be more palatable.

Statistical analysis

Data on silage quality and intake by livestock were analysed using the General Linear Models procedure (Proc GLM) of SAS (1996) statistical package (Statistical Analytical Institute Inc. Cary. North Carolina. USA). The general model of the analysis was of the form:

$$Y_{ijkl} = \mu + b_i + d_j + s_k + (d \times s)_{jk} + \varepsilon_{ijkl}$$

Where. Y = the measured response;

μ = general mean;

b = block effect (animal effect);

d = day effect;

s = silage treatment

(d* s) = day×silage interaction (variation in preference from day to day);

ε = deviation from true response. due to random error (residual error).

Least square means were used to compare the effects of different treatments and standard error was calculated using the error mean square of residual variance. Mean separation was effected by Duncans multiple range test.

RESULTS

Quality of fresh and conserved forage

Herbage from cv. NG 1 had significantly ($p<0.001$) higher levels of DM content compared to cv. NG 2 (Table 2). Wilted herbage of cv. NG 1 contained 286 g DM kg^{-1}. Weather conditions during wilting were generally overcast. As a result. there were only small increases in DM content of the forage. The crude protein contents of fresh cv. NG 1 and cv. NG 2 herbage were similar. but WSC and IVDOMD contents were lower in cv. NG 2.

Due to unusually high rainfall in January 1999, the area where trench silos had been sited succumbed to a high water-table shortly before ensiling. To avoid moisture ingress in silos, plastic sheeting was used on all sides of the trenches. However, the DM content of the silage still came out lower than the original herbage.

The chemical composition of the different types of silage is presented in Table 3. The pH values of the silages were generally low. except those of wilted silage that were relatively higher. Direct-cut and pre-wilted silage had lower lactic acid contents in relation to acetic acid. Treatments supplied with maize additive had lactate-dominated fermentation. Only wilted silage produced propionic acid.

Table 3. Composition of Napier grass silages that were used in an experiment to compare preference and intake of different silages by sheep

Silage constituents	Silage type			
	cv. NG 1* (control)	cv. NG 1 wilted for 1.5 days	cv. NG 1 with maize meal at 5% inclusion	cv. NG 2* with maize meal at 5% inclusion
Silage dry matter content (g kg^{-1})	160.0	162.0	202.0	151.0
Silage pH	3.5	4.6	3.7	3.6
Lactic acid (g kg^{-1} DM)	17.3	12.8	34.3	45.8
Acetic acid (g kg^{-1} DM)	20.8	22.4	12.4	5.8
Butyric acid (g kg^{-1} DM)	14.1	27.2	3.3	3.3
Propionic acid (g kg^{-1} DM)	0	7.5	0	0
Fleig score	32.0	19.5	78.0	59.0
Ammoniacal-nitrogen (g kg^{-1} DM)	1.4	2.3	1.8	1.8
WSC (g kg^{-1} DM)	3.4	1.4	4.0	5.1
Digestible org. matter (g kg^{-1} DM)	457.0	476.0	540.0	542.0
Crude protein (g kg^{-1} DM)	58.5	64.0	60.7	61.9
Acid detergent fibre (g kg^{-1} DM)	456.0	457.0	373.0	400.0

* CV. NG 1 and CV. NG 2 are high yielding accessions of Napier grass. recommended for Zimbabwe.

WSC = water soluble carbohydrate

Table 4. Intake and preferences of different types of Napier grass silage by sheep

Silage type	Silage DM intake in 24 h ($g\ kg^{-1}$ BW[#])	Silage DM intake in initial 4 h of feeding ($g\ kg^{-1}$ BW)	Percentage of daily DM intake consumed in initial 4 h of feeding ($g\ kg^{-1}$ BW)
1. cv. NG 1 (control)	1.45*a*	0.51*a*	21.8*a*
2. cv. NG 1 wilted over 1.5 days[#]	3.89*b*	2.18*b*	51.8*b*
3. cv. NG 1+maize meal (5%)	6.34*c*	4.83*c*	68.0*b*
4. cv. NG 2+maize meal (5%)	4.47*b*	2.27*b*	51.8*b*
s.e.d.	0.77	0.60	9.9
Significance of differences	***	***	**

[#] BW refers to body weight. Values in the same column, followed by different letters are significantly different ($p<0.05$)
**** and ** refer to significant differences at $p<0.001$ and $p<0.01$, respectively.

Fleig scores of the direct-cut and wilted silages were low, indicating that fermentation was poor, especially in the wilted silage. The latter silage was characterised by high butyric acid and ammoniacal-N contents. Ammoniacal-N content was lowest in the direct-cut silage.

Residual WSC contents were higher in silage treated with maize meal. Silage DM content was also highest in the cv. NG 1 that had been treated with maize meal. The DM content of cv. NG 2 silage that was treated with maize meal remained lower than cv. NG 1 in the control treatment and fermentation was better in the latter silage. Digestible organic matter content was greater in the maize treated silages. Thus, the incorporation of maize meal was more effective than pre-wilting in overcast weather conditions.

In general, cv. NG 1 treated with maize meal gave the best silage in terms of chemical composition. It was followed by cv. NG 2 that had been treated with maize meal. Wilted silage had the worst chemical quality. Ensiling reduced DM, digestible organic matter and WSC contents of Pennisetum forage markedly.

Preferences and intake of silage by sheep

Intake of the four silages in the initial four hours of the day was used to reflect the animals' preferences. Maize-treated silage was generally more preferred, followed by wilted silage (Table 4). In particular, cv. NG 1 silage that contained maize meal, was most preferred. However, the preference for maize treated cv. NG 2 silage was not significantly different ($p>0.05$) from that of wilted cv. NG 1, although cv. NG 2 tended to be more preferred. Direct-cut silage was the least preferred.

Silage intake was of the order: cv. NG 1+maize>cv. NG 2+maize>wilted cv. NG 1>cv. NG 1 control. However, as with preferences, the difference between the intake of cv. NG 2+maize and wilted cv. NG 1 was not significant ($p>0.05$). In terms of both preference and intake, direct-cut silage was less than half as acceptable as wilted silage, although values on aspects of chemical quality portrayed a reverse order for the two silages. The differences in intake and in preference were significant at $p<0.001$.

Over a 24 h period, silage and concentrate intake generally amounted to 21.4 $g\ kg^{-1}$ body weight (Table 4). Sheep ate the silage rapidly in the first hours of the morning such that, by the end of that feeding period, almost 50% of the silage had been consumed. This shows that there was considerable selectivity for plant parts during feeding. During the course of the experiment it was also noticed that the sheep fed selectively.

Although there were large differences in intake between animals, the order of preference remained relatively similar throughout the feeding period. The order of preference also remained the same when the intake from a specific silage was expressed as a percentage of total daily intake from the four silages. All silages were acceptable to sheep and there were no indications of metabolic disorders associated with their intake. However, one sheep succumbed to worm infestation and it was removed from the experiment.

DISCUSSION

The current experiment was a culmination of several experiments that were conducted at Grasslands Research Station between 1994 and 1999, to improve the ensilability of Pennisetum forage on smallholder farms (Manyawu, 2001). Research in this series of experiments facilitated the identification of high yielding accessions of Pennisetum (such as cv. NG 1 and cv. NG 2) that can be used by smallholder farmers to provide fresh and conserved forage for livestock. The research also established that the Pennisetums should be harvested between six and seven weeks of regrowth to optimize herbage yields, nutritive quality and WSC content; and between midday and late afternoon to maximise the concentration of WSC. Further work indicated that pre-wilting forage to levels between 350 and 450 g DM kg^{-1}, and the use of maize meal as a moisture absorbent, were two low-cost measures that could be adopted by the Zimbabwean smallholder farmers to improve the quality of fermentation in Pennisetum silage. The current experiment tested this knowledge under field conditions to verify recommendations that would be subsequently extended to the farmers. Therefore, some results of the current experiment are discussed in the context of results obtained from previous research in these series.

Aspects of silage quality

In general, results of the current experiment demonstrated that silage prepared from Napier grass was acceptable to livestock. There were no risks of disease and metabolic disorders associated with these silages.

Although the silages were generally palatable to sheep, the results suggest that it is necessary to process or provide additives to Pennisetum herbage at the point of ensiling. Such pre-ensiling treatments improve the quality of fermentation and subsequent consumption of silage by livestock. The recommendation is particularly imperative when conditions for ensilage were sub-optimal and when longer chop-length is used, as was the case in the current experiment. Overcast weather and humid edaphic conditions in the current experiment made the environment sub-optimal for silage making, in spite of the high concentrations of WSC in fresh Pennisetum forage.

Generally, silages treated with maize meal had better preservation. They were characterized by lactate-dominated fermentation, low pH, low concentrations of butyric acid and relatively high organic matter digestibility. Similar responses in silage quality and digestibility were reported by Manyawu (2000) when graded levels of maize meal were used as an additive in Bana grass silage. The results of the latter research demonstrated that digestibility improved as the amount of maize meal applied increased and that the optimum level of application was 5% (w/w). Therefore, a 5% level of maize inclusion was used in the current experiment. Jones et al. (1990), Morseley and Ramanathan (1994) and Harrisson et al. (1994) have also shown that addition of cereals to fresh temperate forage at ensiling improves silage fermentation and digestibility.

Carpintero et al. (1969) and Woolford (1984) defined a pH below 4.2 as ideal for aerobic stability of ordinary silage. Therefore, the pH values of the maize-treated silage in the current experiment were ideal.

On the contrary, fermentation of direct-cut and pre-wilted silage was below standard, as evidenced by the higher butyric acid contents (particularly with wilting), acetate-dominated fermentation and the relatively low digestible organic matter contents. The high concentrations of acetic acid, relative to lactic acid, could be a result of propionic acid bacteria. Woolford (1984) indicated that saccharolytic *Propionibacterium* form CO_2, propionic acid, acetic acid and mixtures of other organic acids including butyric acid under anaerobic conditions. The high acetate:lactate ratios, high butyrate concentrations and the presence of propionic acid in the wilted silage support this deduction.

The slow drying of cv. NG 1 under cloudy and humid conditions led to a depletion of WSC and extensive proteolysis in Pennisetum forage. The depletion was evidenced by relatively lower amounts of residual WSC and high concentrations of butyric acid in the wilted silage. Reviews of literature by Ruxton et al. (1975), Woolford (1984) and O'Keily and Muck (1998) indicated that respiration and other plant enzymatic processes that lead to a depletion of WSC and protein continue if wilting is not fast enough. Under temperate conditions, Dawson et al. (1999) showed that rapid wilting brings out desired effects by halting plant enzymatic processes and conserving WSC. Under ideal conditions, pre-wilting conserves plant protein by preventing proteolysis (Tamminga and Sudekum, 2000).

It is not known why the concentration of digestible organic matter was markedly lower in silage compared to the original herbage. Dulphy and Dernaquilly (1991) compared the digestibility of silage and fresh grass from the same source and concluded that direct effects of ensilage on the digestibility of forage were very small. Therefore, it was presumed that external factors such as leaching caused by effluent loss or moisture ingress were responsible for the lower digestibility of silage in the current experiment.

Differences in preference ratings and intake of silage by sheep

In general, the maize-treated silage from cv. NG 1 and cv. NG 2 were more preferred. High DM intakes were also recorded on the same silages. The work of Baumont (1999) shows that high palatability (or preference) can lead to high intake. In addition, research by Dulphy and van Os (1996) and reviews of literature by O'Keily and Muck (1998) shows that intake tends to be high in well-preserved silage.

The addition of maize meal at ensiling is likely to have enhanced DM intake of cv. NG 1 and cv. NG 2 silage. Moseley and Ramanathan (1989) found that the addition of rolled barley to ryegrass-clover herbage at ensiling increased DM intake of the silage by wether sheep. Similar observations were reported by Jones et al. (1990) when they fed a similar type of silage to cattle.

The differences in the intake and preference of the maize-treated silages themselves are likely to be a reflection of differences in the DM content of the original herbage. Many workers, including Haigh and Porter (1985) cited by Yokota et al. (1992) have shown that silage of high DM content tends to be associated with high intake by livestock. Thomas et al. (1961) and O'Keily and Muck (1998) stated that DM content at the point of ensiling is more important in determining the intake of silage than the DM of silage at which it is consumed, because the latter affects silage fermentation. This observation could explain why cv. NG 2 had lower DM intake and preference by sheep, when it actually had better fermentation than cv. NG 1. The argument is also supported by the findings of Butris and Phillips (1987). The latter found that changes in intake only become pertinent when comparisons are made with silages of low DM content (e.g. 180 g kg^{-1}DM). In the present experiment, the DM content of cv. NG 1 was 202 g DM kg^{-1} whereas that of cv. NG 2 was 150 g DM kg^{-1}. Therefore, the differences in DM content were large enough to explain the differences in the levels of intake by sheep.

The lower preferences for both wilted and direct-cut silage can be explained, to a large extent, by poor fermentation and low digestibility. Although the results of chemical analyses showed that fermentation was inferior in wilted than direct cut silage, sheep still preferred the wilted silage. The reasons for the preference of wilted silage are not clear. Steen et al. (1998) argued that pH, total acidity, buffering capacity and the concentration of lactic acid, acetate and butyrate have little influence on silage intake. In their experiment, the r^2 values in the relationship of the latter factors to intake only ranged between 0 and 0.11. Instead, Steen et al. (1998) argued that factors that influence the extent of digestion and rate of passage through the rumen would influence intake. The hypothesis was supported by Baumont et al. (1999) who compared formic acid treated silage, direct-cut silage, fresh forage and hay. The latter workers concluded that intake was mostly influenced by forage digestibility and crude protein content and that sheep would prefer a forage that readily meets their nutritional requirements. These arguments, therefore, suggest that sheep in the current experiment preferred the wilted grass mainly because it had a higher organic matter digestibility content. Therefore, in the current experiment, it is felt that the higher pH ($p<0.01$) in wilted grass improved palatability and this subsequently led to high intake of the wilted silage, compared to direct-cut silage. Results of the current experiment indicate that there is significant potential in the use of pre-wilting to enhance DM intake, especially when the forage is wilted adequately.

CONCLUSION

This experiment demonstrated that silages made from the two new accessions of Napier grass are safe and acceptable to livestock. Irrespective of accession, it will be necessary to provide additive and/or pre-wilting treatment to Napier grass silage to enhance its palatability and intake by livestock. Plain-maize meal is an effective additive, particularly when forage DM content is low or when a long chop-length is used at ensiling. Its action on fermentation quality is mediated through moisture absorption and reduction of air spaces in compacted herbage. It will also improve the digestibility, palatability and intake of the resultant silage. Maize-treated silage is more preferred than wilted silage and, in turn, the wilted is more preferred to direct-cut silage. The incorporation of maize meal will be more effective than pre-wilting under moist and overcast weather conditions.

Although further research is required to re-examine the palatability of pre-wilted silage in comparison /or combination with maize at a field-scale, there is ample evidence from the current experiment that pre-wilting enhances palatability and intake of Napier grass silage.

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