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ALKALI TREATMENT OF MATURE *Pennisetum purpureum* FORAGE 1. EFFECT OF NaOH, $Ca(OH)_2$, NH_4OH AND UREA TREATMENTS ON NYLON BAG DIGESTIBILITY

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In Experiment 1 mature chopped *Pennisetum purpureum* forage was treated with water alone, with NaOH (2.4 or 4.8 % of forage dry matter (DM)), with urea (2.4 or 4.8 %) with or without added ground *Canavalia ensiformis* seed, or with mixtures of urea (2.4%) and NaOH (0.95, 1.9, 2.9, 3.8 and 4.8 %). The treated forage was ensiled in plastic drums for 30 days after which the pH, concentration of NH_3 and DM digestion in nylon bags exposed to rumen fermentation for 24 h were then measured. After 30 days the pH was acidic to neutral in all silos. All of the added urea was hydrolized to ammonia, but there was no effect of urea treatment on DM digestibility. There was a linear increase in DM digestibility with added NaOH; DM digestibility was increased by 12% with 4.8% NaOH and by 16% with (4.8% NaOH + 2.4% urea. In Experiment 2, 1.8, 3.6 and 5.3 % levels of NH_4OH, NaOH, $Ca(OH)_2$ or 50/50 mixtures of NaOH and $Ca(OH)_2$ were applied to similar forage and ensiled for 44 days. There was no effect of NH_4OH on DM digestibility compared to a control of forage ensiled with water. There were linear increases of up to 19% in DM digestibility due to treatment with NaOH or $Ca(OH)_2$ and NaOH tended to be more effective than $Ca(OH)_2$. In a third experiment similar responses were observed.

Key words: *Pennisetum purpureum*, Alkali treatment, digestibility.

Alkali treatment has been extensively investigated in temperate countries as a means of increasing the digestibility of poor quality fibrous materials. Investigations with tropical forages are however limited (Jackson 1977; Escobar and Parra 1983). The present experiment were undertaken to examine alkali treatment as a means of increasing the nutritive value of mature Elephant grass (*Pennisetum purpureum*) forage.

Materials and Methods

Experiment 1:

One kg batches of chopped mature Elephant grass forage were mixed in duplicate with either 250 ml water (Control Treatment 1), or NaOH, urea or mixtures of these chemicals as shown in Table 1 each dissolved in 250 ml water. The mixtures were ensiled in 4 litre plastic drums fitted with press lids, which were stored inverted so that drainage of liquid could occur. The forage contained 21.3% dry matter (DM), and on a DM basis 88.6% organic matter, 1.1% nitrogen, 80.0% cell wall constituents, 27.4% hemicellulose, 37.9% cellulose and 10.2% lignin. Digestibility *in vitro* was 35.8%. Ground seed (1 mm screen) of *Canavalia ensiformis* (50 g air dry) was mixed with the forage and chemicals for Treatments 1 to 10. In two further treatments (Treatments 11 and 12) urea was used, but without addition of ground *Canavalia ensiformis* seed.

After 30 days all silos were sampled. Wet material (100 g) was mixed with 300 ml distilled water and left to stand for 16 h at 5°C. The liquid was then separated by straining through cloth, the pH determined and the samples acidified with 5M H_2SO_4 (pH 4) before storage (5°C). Another sample from each silo was dried (70°C) and then ground (4 mm screen). Duplicate nylon bags (Ørskov et al 1980) containing 5 g samples from each silo were incubated for 24 h in the rumen of each of two cannulated steers consuming mature Elephant grass forage to determine DM digestibility. Digestion at zero time (in soluble DM) was also determined with nylon bags containing 5 g samples which were soaked in 0.15M NaCl for 4 h before washing.

Ammonia was determined by steam distillation under alkaline conditions, collection of the distillate into boric acid, and titration with 0.005M H_2SO_4. For determination of urea, the samples were centrifuged (3000 g., 15 min) before 5 ml of supernatant were brought to neutrality using NaOH, phosphate buffer (5 ml, approximately equal volumes of 0.2M K_2HPO_4 and 0.2M KH_2PO_4, pH 7) and a source of urease enzyme (ground *Canavalia ensiformis* seed, 5-10 mg) added and the mixture left to stand at room temperature overnight. Urea N was then determined as ammonia N by the distillation procedure described abov with subtraction of the ammonia N determined before urea hydrolisis. Recovery of urea added to supernatant of Treatment 1 was 101 ± 1.0% (x SE) confirming the accuracy of the determination.

Experiment 2:

One kg batches of chopped mature Elephant grass forage were treated in duplicate with the alkalis shown in Table 2 mixed with 250 ml of water in each case. The mixtures were ensiled as described for Experiment 1 except that the drums were not inverted during storage and no drainage of liquid could occur. The forage contained 27.6% DM, and on a DM basis 91.9% organic matter, 1.1% nitrogen, 80.0% cell wall constituents, 32.7% hemicellulose, 34% cellulose and 10.5% lignin. Digestibility *in vitro* was 36.9%. After 44 days all silos were sampled and soluble DM digestibility determined as described for Experiment 1.

Experiment 3:

One kg batches of chopped mature *Pennisetum purpureum* forage were treated in duplicate with water, NaOH or $Ca(OH)_2$ (Table 3) and ensiled as described for Experiment 1. For the treatments with water to be opened at 42 days, in one treatment the plastic drums were closed with the press-top lids with no further precautions, and in a second treatment the drums were also sealed with paper tape. The forage contained 21.4% DM, and on a DM basis, 88.7% organic matter, 1.2% nitrogen, 71.9% cell wall constituents, 28.2% hemicellulose, 30.4% cellulose and 2.7% lignin. Digestibility *in vitro* was 43.4%. Silos were sampled after 1, 3 and 42 days, and pH, soluble DM and DM digestibility measured as described for Experiment 1.

Results

Experiment 1:

The pH and concentration of ammonia N in the silos after 30 days are given in Table 1. The pH was acidic (pH 4.8) for the control, and addition of urea or mixtures of 2.4% urea and 0.95 - 4.8 % NaOH increased the pH only to the range 6.1 - 7.5 %. Concentrations of NH_3-N in the control or with addition of NaOH alone was low (0.3 g N/100 g DM). Addition of 2.4% urea increased the NH_3-N concentration to 1.1 - 1.6 g N/100 g DM, while addition of 4.8% urea increased the concentration to 2.6 g N/100 g DM. There was no detectable urea in any of the samples, indicating that the added urea was completely hydrolized to ammonia in either the presence or absence of ground Canavalia seed in the silos. This urea N was also completely recovered as ammonia N.

Digestibility of total DM is shown in Table 1 and Figure 1, while the solubility of DM in 0.15M NaCl and the digestibility of insoluble DM due to the digestive activity of rumen microorganisms is given in Table 1.

There was a significant ($P < 0.05$) depression in total DM digestibility due to ensiling with water (from 31% to 25%), and this was associated with a depression in digestibility of insoluble DM rather than a decrease in the proportion of soluble DM (Table 1). There was no

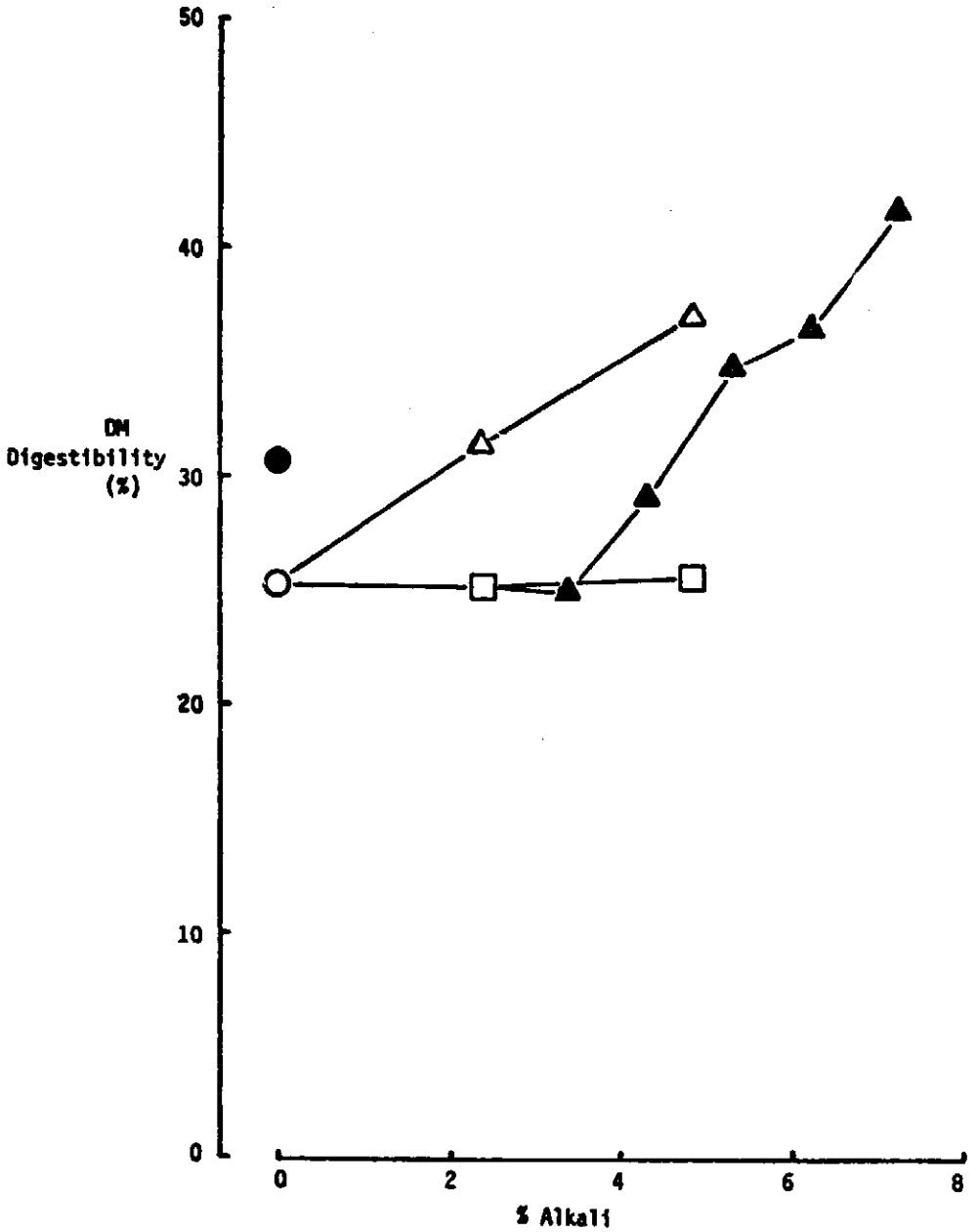
Table 1:

Effects of treatments of Pennisetum purpureum with water alone, NaOH and for urea on pH and N-NH_3 concentration after ensiling for 30 d in Experiment 1.

No.	Alcali treatment	pH	NH_3-N (g N/100 g DM)	Solubility of DM in saline (%)	DM Digestibility during 24 h (%)
0	Pasture before ensiling	-	-	13.8	30.6
1	Control ensiled with water	4.8	0.3	13.1	25.2
2	Urea (2.4%)	6.1	1.6	13.7	25.2
3	Urea (4.8%)	7.8	2.6	11.9	25.8
4	NaOH (2.4%)	5.1	0.3	18.0	28.9
5	NaOH (4.8%)	5.7	0.2	21.7	36.9
6	Urea (2.4%) + NaOH (0.95%)	6.4	1.5	15.0	25.1
7	Urea (2.4%) + NaOH (1.9%)	6.8	1.6	17.0	29.0
8	Urea (2.4%) + NaOH (2.9%)	7.0	1.6	19.3	34.8
9	Urea (2.4%) + NaOH (3.8%)	7.3	1.5	21.2	36.5
10	Urea (2.4%) + NaOH (4.8%)	7.5	1.1	21.4	41.6
11	Urea (2.4%) without	6.4	1.3	12.4	24.2
12	Urea (4.8%) without	7.8	2.3	11.6	24.5
	SEM	0.2	0.1	0.6	1.2

Treatments 2-10 also included ground *Canavalia* seed.

Figure 1:
Experiment 1. Digestibility of total DM in the control forage not ensiled (●) ensiled with water (○), or ensiled with various levels of ure (△), NaOH (▲) or 2.4% urea plus increasing levels of NaOH (□) for 30 d.



effect on DM digestibility of adding urea to the silos, but a large and significant ($P < 0.05$) effect of addition of NaOH at levels of 2.4 and 4.8 % of the DM.

The increased DM digestibility due to NaOH treatment was associated with an increase in soluble DM rather than increased digestibility of the insoluble DM fraction (Table 1) The increases in DM digestibility with the NaOH and urea mixtures were greater than could be attributed to NaOH alone, indicating a synergistic effect of urea in the presence of NaOH. At the 4.8% NaOH level the 2.4% urea increased total DM digestibility from 37% to 42%, and this was due to increased digestibility of the insoluble DM rather than an increased proportion of soluble DM.

Experiment 2:

The results for pH in Experiment 2 were similar to those for Experiment 1, with an acidic pH (4.5) for the control, and increases in pH up to 5.5 for the silos treated with hydroxide (Table 2).

Digestibility of total DM and solubility of DM are shown in Table 2 and Figure 2. In this experiment there was also a large depression ($P < 0.05$) in DM digestibility due to the ensiling process (from 40% to 29%) but in this case it was associated equally with reductions in

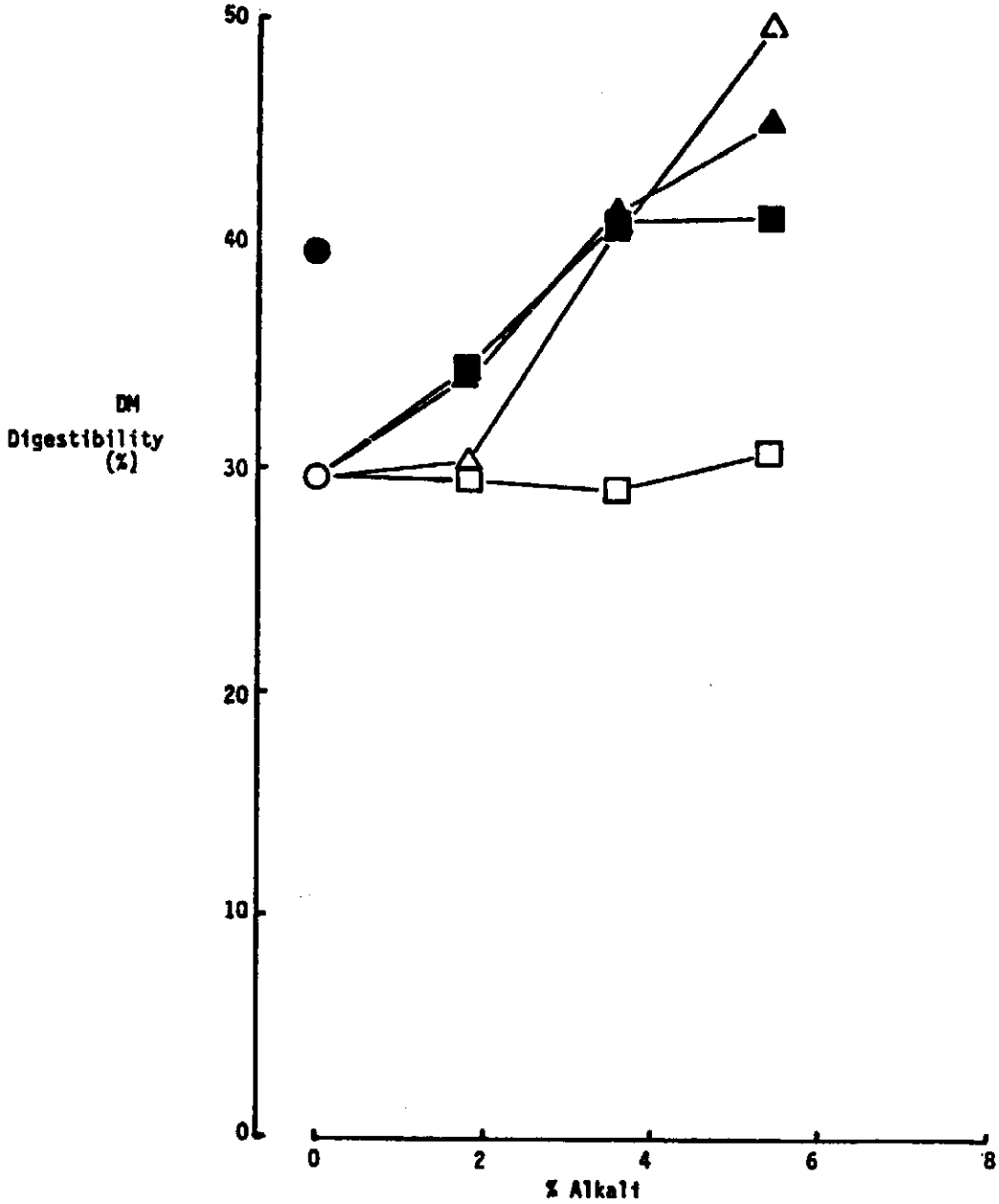
Table 2:

Effects of treatments of Pennisetum purpureum forage, and the pH after ensiling for 44 d, in Experiment 2.

No.	Alkali treatment	pH	Zero time solubility (%)	Digestibility of DM at 24 h (%
0	Pasture before ensiling		16.2	39.6
1	Control ensiled with water	4.5	11.2	29.4
2	NaOH (1.8%)	4.7	15.7	30.3
3	NaOH (3.6%)	4.9	18.8	40.7
4	NaOH (5.4%)	5.5	24.5	49.0
5	NaOH (0.9%) + $Ca(OH)_2$ (0.9%)	4.6	13.6	33.9
6	NaOH (1.8%) + $Ca(OH)_2$ (1.8%)	4.9	18.3	41.3
7	NaOH (2;7%) + $Ca(OH)_2$ (2.7%)	5.1	24.6	45.4
8	$Ca(OH)_2$ (1.8%)	4.6	14.3	34.6
9	$Ca(OH)_2$ (3.6%)	5.0	20.8	40.9
10	$Ca(OH)_2$ (5.4%)	5.4	21.9	41.2
11	NH_4OH (1.8%) (*)	4.6	13.4	29.0
12	NH_4OH (3.6%) (*)	5.0	14.9	30.8
13	NH_4OH (5.4%) (*)	5.2	14.8	30.8
	SEM	0.1	0.7	1.1

(*) Applied as aqueous solution containing 28% NH_4OH.

Figure 2:
Experiment 2: Digestibility of total DM in the control forage not ensiled (●) ensiled with water (○) or ensiled with various levels of NaOH (△), a mixture of equiv. mol of NaOH and $Ca(OH)_2$ (▲), $Ca(OH)_2$ (■) or NH_4OH (□) for 44 d.



soluble DM and digestion of insoluble DM. There was a large and significant ($P < 0.05$) increase in total DM digestibility due to treatment with NaOH, $Ca(OH)_2$ or a mixture of the two hydroxides. The effect of NaOH and $Ca(OH)_2$ for the 1.8% and 3.6% treatment levels was almost identical, but there was evidence for a reduced effectiveness of the $Ca(OH)_2$, either alone or mixed with NaOH, at the 5.3% treatment level. NH_4OH was completely ineffective in increasing DM digestibility.

Experiment 3:

In this experiment when forage was ensiled with water alone there was no effect on DM digestibility after 1, 3 or 42 days when the silos were carefully sealed, but a significant ($P < 0.05$) 4.3% decrease in DM digestibility when no special precautions were taken to seal the silos.

After treatment for 1 day the pH was alkaline in the NaOH and $Ca(OH)_2$ treatments (pH 9.8 and 8.0 respectively), and decreased to pH 5.2 after 42 days (Table 3). Digestibility of total DM was increased substantially ($P < 0.05$) due to treatment with NaOH and $Ca(OH)_2$, being

Table 3:
Effects of treatment of Pennisetum purpureum forage with water alone, NaOH or $Ca(OH)_2$ for various times in Experiment 3.

Alkali treatment		pH	Zero time solubility (%)	Digestibility of DM at 24 h (%
Forage before treatment		-	16.9	42.5b
Water	1 d	4.5a	14.6ab	42.0b
	3 d	4.2a	16.4ab	41.6b
	42 d	4.5a	14.8ab	38.2a
Water	42 d (sealed)	4.2a	14.2a	41.4b
NaOH (5.6%)	1 d	9.8e	25.2e	61.1e
	3 d	6.9c	21.7e	59.7e
	42 d	5.2b	26.0e	47.5c
$Ca(OH)_2$ (5.6%)	1 d	8.0d	19.5c	53.6d
	3 d	6.9c	22.1d	51.3d
	42 d	5.2b	22.9d	45.7c
	SEM	0.1	0.6	1.2

increased by 19% and 11% respectively after 1 day. However the DM digestibility subsequently decreased during the 42 days ensiling period to such an extent that, at the end of this period, the DM digestibility was increased by 5% and 3% for NaOH and $Ca(OH)_2$ treatments, respectively.

Discussion

With the mature Elephant grass forage there was a large and approximately linear increase in DM digestibility in comparison with a control of forage ensiled with water due to the addition of NaOH, $Ca(OH)_2$ or a mixture of these hydroxides. The increase of up to 16% and 19% in DM digestibility with NaOH treatment in Experiment 1 and 2 respectively compares closely with the increase of up to 11% in organic matter digestibility observed by Thomas (1978) when it is considered that organic matter digestibility would be increased less than DM digestibility due to the addition of ash in the hydroxides. These increases in digestibility are also comparable with results of other experiments in this department with NaOH treatment of mature Elephant grass forage where similar increases in nylon bag DM digestibility were observed (Dixon and Parra 1983; Castillo et al 1983).

In Experiment 3 it was observed that when special precautions were taken to seal the silos there was no decrease in DM digestibility due to ensiling with water alone, but a decrease in DM digestibility did occur in the silos treated normally. This indicates that the decrease in DM digestibility of the control ensiled with water in relation to the forage before ensiling (5, 10 and 4 % in Experiment 1, 2 and 3 respectively) was due to poor sealing of the silos and loss of the more readily fermentable (and therefore digestible) DM by aerobic fermentation.

Equal increases in DM digestibility in response to treatment with up to 3.6% $Ca(OH)_2$ or NaOH were observed in Experiment 2. However in both Experiment 2 and 3 treatment with 5.4% or 5.6% hydroxide resulted in an increase in DM digestibility with $Ca(OH)_2$ which was only about 60% of that obtained with NaOH. These observations are in agreement with the results of Wilkinson and González (1978) where, with a 90 days ensiling period, $Ca(OH)_2$ was 62% and 72% as effective as NaOH for the 2.5% and 5% levels of addition respectively. Treatment with $Ca(OH)_2$ rather than NaOH has advantages which may include increased safety of operation, lower cost and local availability, but has the disadvantage that longer treatments periods may be required due to the slower rate of reaction of $Ca(OH)_2$ than NaOH (Martin et al 1974; Rounds et al 1976). As Experiment 3 in this study demonstrates, efficient ensiling methods must be used during any prolonged treatment period to avoid a decrease in digestibility.

In contrast to many previous reports with straws (Jackson 1977; Horton & Steacy 1979; Saadullah et al 1982), both urea and NH_4OH alone were completely ineffective treatments to improve DM digestibility, although there was apparently sufficient urease enzyme, presumably of microbial origin, in the fresh forage to hydrolize all of the urea to ammonia. Perhaps the absence of a response was associated with acidic pH in the silos where ammonia would be present in the form of aqueous NH_4^+ ion rather than the volatile NH_3 form. This is consistent with the synergistic effect observed with urea in the presence of NaOH in Experiment 1 where the latter would be expected to raise the pH in the silos immediately after treatment and to result in the ammonia being

present in the NH_3 form. The observation that there was sufficient urease enzyme present in pasture to hydrolize all of the urea is in contrast to the observation of Torres et al (1982) that additions of poultry litter to bagasse was essential for effective treatment of this material with urea.

In conclusion, the DM digestibility of mature *Pennisetum purpureum* forage could be substantially increased by treatments with NaOH and $Ca(OH)_2$ either alone or together. Ammonium hydroxide and urea were ineffective, although there was some synergistic effect of the latter when used with NaOH.

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