EFFECT OF SHORT TERM WET ALKALINE AND UREA TREATMENT ON
DEGRADABILITY OF MAIZE AND SORGHUM GRAIN IN NYLON BAGS

A.C. SCHLINK*

Laboratory studies and rumen incubation with nylon bags were used to determine
the effect of a 16 hour treatment with NaOH and/or urea solutions on water absorption parameters and ruminal digestion of whole maize or sorghum grain. In 16 hours a maximum of 52.2 ml water was absorbed/100 g of air dried grain and the inclusion of urea reduced water absorption. Urea was absorbed onto the grain at the rate of 0.48 g urea/g urea added to the solution. All forms of wet soakage significantly increased the fraction immediately soluble in nylon bags. Alkaline treatment was the only wet soakage treatment to significantly improve the rate of dry matter degradation from nylon bags.

INTRODUCTION

Early weaned calves gained 190 g/d when given molasses/protein but gained 422 g/d when 12.5% crushed maize was added to the diet (Schlink unpubl.). In comparison with molasses/urea mixtures, molasses/grain combinations resulted in increased energy intakes and hence improved animal performance (Gulbransen 1985). Wet or dry processing of cereal grains increases the efficiency of utilization of starch by increasing access to the starch granules for enzymes in rumen micro organisms and/or the animal digestive tract (Hale 1973). Excessive processing should be avoided in order to prevent ruminitis with grain diets and depression of cellulose digestion when grain is given with roughages (Orskov and Greenhalgh 1977).

Sodium hydroxide treatment has been found to increase the digestibility of several cereal grains (Orskov et al. 1980; Berger et al., 1981). The response to sodium hydroxide is due in part to disruption of the seed coat by solubilization of hemicellulose. Berger et al. (1981) observed the maximum effect on digestion of whole grain within a 48 hour reaction time after sodium hydroxide was sprayed onto the grain.

Considerable amounts of molasses/urea are used in Northern Australia as a dry season supplement (Wythes and Ernst 1984); usually the supplement is mixed mechanically to avoid toxicity problems. In many situations it would be advantageous to add crushed grain to the mixture but few properties have facilities to crush the grain. As part of a study on the incorporation of whole grain into molasses diets, experiments were conducted to determine whether short term treatment of whole maize and sorghum grain with sodium hydroxide with and without urea would disrupt the seed coat and increase the digestibility of the grain while allowing the mixing of grain and molasses with existing station machinery designed to mix urea and molasses.

MATERIALS AND METHODS

Preliminary experiments were carried out in the laboratory to determine the water and urea absorption capacity of whole maize (Zea mays) and sorghum (Sorghum vulgare) grain. Whole grain was allowed to stand for 16 hours in 40, 60, 80 or 100 ml water per 100 g of air dried grain with regular stirring for the first hour. Absorption of water was determined from the amount of free water that did not drain from the grain after 16 hours.

* Division of Tropical Animal Production, CSIRO, Davies Laboratory, Private Mail Bag, PO Aitkenvale, Townsville, Qld. 4814.
Urea absorption was determined by placing whole grain (100 g) into solutions of 5, 10 and 20 g urea in 60 ml water for 16 hours. Absorption of water and urea was determined from the residual solution poured from the grain with urea nitrogen being estimated by steam distillation (McSweeney and Wesley-Smith 1986).

Commercially crushed maize and whole grain maize or sorghum were used in the digestion studies; (1) dried whole grain; (2) whole grain in water; (3) whole grain in urea (167 g/l) solution; (4) whole grain in urea (333 g/l) solution; (5) whole grain in NaOH (35 g/l) solution; (6) whole grain in NaOH (35 g/l) and urea (333 g/l) solution; (7) commercially crushed maize. The solutions were used at the rate of 60 g/100 g of air dried grain and left standing for 16 hours with regular hand mixing during the first hour. Processed grain equivalent to 10 g dry matter was placed into nylon bags measuring 230 x 90 mm (Nytrel screen of mean pore size 43 f). The bags were placed into three zebu cross ovariectomized heifers, aged 3 years and fitted with rumen cannulae. The heifers were fed Verano (Stylosanthes hamata) hay ad libitum supplemented with 1 kg of crushed maize and 0.5 kg of formaldehyde treated sunflower seed meal (Norco Cooperative Ltd., Lismore). The bags were withdrawn after 3, 6, 12, 24 and 48 hours of incubation in the rumen. The bags were thoroughly washed and continuously squeezed until the running rinse water was clear, oven dried at 60°C and dry matter disappearance determined.

Patterns of water absorption by grain and rates of dry matter degradation were determined by fitting the exponential $p = a + b (1 - e^{-ct})$ where $p$ is the percentage of component change after time $t$ and $a$, $b$ and $c$ are constants fitted by an iterative least squares procedure. If the iterative least squares procedure failed to converge, the rates of change ($c$) and intercept ($a$) were analysed by linear regression. The dry matter losses were evaluated with an exponential fit but with all treatments except crushed maize, with a calculated potential degradability of 84%, the iterative least squares procedure failed to converge. The rate of dry matter loss ($c$) and intercept ($a$) were analysed by linear regression, including crushed maize where the $r^2$ value was increased by the linear regression analysis. Data for dry matter disappearance in 24 and 48 h were analysed by analysis of variance.

RESULTS

It was found from preliminary studies that 60 g water completely covered 100 g grain. Water absorption occurred exponentially where the maximum potential uptake ($a+b$) was 52.2 ml of water/100 g of grain and $c$ was 0.29 ml ($\pm$ 0.01) ml absorbed/ml water added to the whole grain. The addition of urea to the water resulted in a linear decline in water absorption where

$$\text{Water absorbed (g/100 g grain)} = 40.1 \ (\pm \ 0.8) - 1.20 \ (\pm \ 0.08) \text{ g urea}$$

so that after 16 h at the highest urea concentration 27% of added water was absorbed. Absorption of urea into the grain was described by the linear relationship

$$\text{Urea absorbed (g/100 g grain)} = 0.48 \ (\pm \ 0.02) \text{ g urea added}$$

with the intercept not significantly different from zero. There were no significant differences between maize or sorghum grains in their responses to water or urea.

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Dry matter degradation from ruminal incubation of the grains in nylon bags is shown in Table 1.

Table 1  Dry matter disappearance (% s.e.) from nylon bags for specific ruminal incubation times for intercept (a) and slope (c) for linear regression relating disappearance to time

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Disappearance in incubation time (h)</th>
<th>Parameters</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 (%)</td>
<td>48 (%)</td>
<td>a (%)</td>
<td>c%/h</td>
<td>r²</td>
<td></td>
</tr>
<tr>
<td>Maize</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>4.6 (1.6)</td>
<td>11.7 (2.2)</td>
<td>-</td>
<td>0.23(0.01)</td>
<td>97.5</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>6.7 (2.5)</td>
<td>10.9 (0.9)</td>
<td>1.7 (0.5)</td>
<td>0.20(0.02)</td>
<td>86.3</td>
<td></td>
</tr>
<tr>
<td>16.7% Urea</td>
<td>106 (1.8)</td>
<td>17.8 (3.4)</td>
<td>3.6 (1.1)</td>
<td>0.30(0.05)</td>
<td>75.1</td>
<td></td>
</tr>
<tr>
<td>33.3% Urea</td>
<td>9.5 (1.3)</td>
<td>16.7 (1.6)</td>
<td>4.5 (0.8)</td>
<td>0.25(0.03)</td>
<td>81.6</td>
<td></td>
</tr>
<tr>
<td>3.5% NaOH</td>
<td>48.5 (8.8)</td>
<td>60.8 (14.4)</td>
<td>17.5 (5.4)</td>
<td>0.98(0.14)</td>
<td>78.2</td>
<td></td>
</tr>
<tr>
<td>3.5% NaOH in 33.3% Urea</td>
<td>55.0 (11.6)</td>
<td>71.2 (9.6)</td>
<td>24.9 (3.8)</td>
<td>1.01(0.15)</td>
<td>75.4</td>
<td></td>
</tr>
<tr>
<td>Crushed</td>
<td>80.0 (7.8)</td>
<td>93.3 (4.9)</td>
<td>33.6 (4.2)</td>
<td>1.38(0.17)</td>
<td>82.5</td>
<td></td>
</tr>
<tr>
<td>Sorghum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry</td>
<td>5.3 (0.5)</td>
<td>12.0 (1.2)</td>
<td>-1.4 (0.3)</td>
<td>0.28(0.01)</td>
<td>98.2</td>
<td></td>
</tr>
<tr>
<td>Water</td>
<td>3.4 (2.2)</td>
<td>11.4 (2.4)</td>
<td>-3.0 (0.8)</td>
<td>0.30(0.03)</td>
<td>86.9</td>
<td></td>
</tr>
<tr>
<td>16.7% Urea</td>
<td>8.6 (0.7)</td>
<td>14.6 (2.5)</td>
<td>3.0 (0.8)</td>
<td>0.24(0.03)</td>
<td>78.7</td>
<td></td>
</tr>
<tr>
<td>33.3% Urea</td>
<td>15.8 (1.8)</td>
<td>21.3 (2.3)</td>
<td>7.3 (0.9)</td>
<td>0.30(0.04)</td>
<td>83.4</td>
<td></td>
</tr>
<tr>
<td>3.5% NaOH</td>
<td>44.6 (5.7)</td>
<td>64.5 (10.8)</td>
<td>21.0 (2.2)</td>
<td>0.91(0.09)</td>
<td>88.1</td>
<td></td>
</tr>
<tr>
<td>3.5% NaOH in 33.3% Urea</td>
<td>43.9 (6.2)</td>
<td>73.4 (11.7)</td>
<td>17.0 (0.3)</td>
<td>1.19(0.12)</td>
<td>87.8</td>
<td></td>
</tr>
<tr>
<td>l.s.d.</td>
<td>8.9</td>
<td>11.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All treatments increased the amount of dry matter immediately soluble in rumen fluid (parameter a) (P < 0.05) compared with dry grains even though the residual solution was removed from the treated grains before being placed into the nylon bags. There was complete absorption of the treatment solutions onto the grain with the addition of NaOH. The increase shown in the immediately soluble fraction was generally not evident in the slowly degradable fraction and the only treatments to consistently improve dry matter disappearance for the grains at 24 and 48 hours were sodium hydroxide treatment and crushing. For water and urea soakage of grain dry matter losses were similar to that of the dried grains. The rate constant (parameter c) was significantly higher (P < 0.05) for sodium hydroxide treatment of both grains and the crushing of maize. Although the addition of urea to the sodium hydroxide solution did improve the rate of dry matter disappearance from nylon bags the improvement was not significant.

DISCUSSION

The soaking of grain overnight in NaOH solutions presents many advantages for livestock feeding on the northern pastoral areas. The grain is soft and can be handled in existing molasses mixers, the rate and extent of fermentation is improved, surplus alkali should help to moderate rumen pH decline; the additional water being effectively absorbed into grain, will not dilute the molasses. The treatment should thus facilitate an increase in the ME content of the mixture (Gulbransen 1985) within the existing molasses/urea supplementary feeding system.

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The uptake of water in 16 h occurred in an exponential fashion that indicated a maximum value of 52.2 ml/100 g grain, whereas the addition of urea to the solution reduced the water absorption by grain. Sodium hydroxide further weakened the seed testa and the 60 ml of solution/100 g of grain was completely absorbed. The close association of readily fermented sources of energy and nitrogen should also benefit the animal but this possibility was outside the scope of the present studies.

There were no significant differences between the two grains in rates of dry matter disappearance which agrees with the results of Berger et al. (1981) who treated 30% moisture grain with 3.5% sodium hydroxide. The 16 hour wet treatment of the two grains with sodium hydroxide is as effective in increasing DM disappearance as the reported studies with longer-term storage with sodium hydroxide (Berger et al. 1981; Orskov and Greenhalgh 1977). The short-term wet sodium hydroxide treatment is superior to the limited reaction time spraying procedure used by Berger et al. (1981) as measured by nylon bag dry matter digestion at 24 and 48 hours.

Valentine and Bartsch (1988) used an exponential fit to describe the pattern of degradation of dry matter for ground lupin and barley grain where the increased rates of degradation were associated with the reduction in particle size used in their study. Estimates of degradability are sensitive to particle size (Mohamed and Smith 1977) and would account for increased rate parameters of crushed maize, whereas the grain is intact with the alkaline treatment but the seed coat has been partially solubilized to allow the enzymatic attack of rumen micro-organisms on the starch in the grains (Berger et al. 1981).

Water with or without urea had no overall effect on the rate of dry matter degradation from nylon bags of maize and sorghum grains. Even without a significant effect on nylon bag degradation rates, urea absorption onto grains may provide some production advantages with concentrate rations (Orskov and Grubb 1977) or a slower release of urea into the rumen on roughage based diets that leads to improved roughage intakes (Romero et al. 1976).

Short-term wet alkaline treatment of grain improves the nylon bag dry matter degradation of whole maize and sorghum grain. The use of the alkaline soaking procedure for grains is envisaged to expand a supplementary feeding system for molasses/urea which is currently available in northern Australia.

ACKNOWLEDGEMENTS

The author wishes to thank Mr R.J. Thompson who aided in the development of molasses mixers suitable for molasses/grain mixtures and the AMLRDC for partial financial support.

REFERENCES