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EFFECT OF ALKALI TREATMENT ON DIGESTIBILITY FERMENTATION RATE AND INTAKE OF MAIZE COBS

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Maize cobs were ground and treated with sodium hydroxide at the following levels: A) 0, B) 20, C) 40, and D) 60 g NaOH/kg DM with a ratio of water to fibrous residue of 1.5:1. The material was ensiled at ambient temperature for 21 d, supplemented with molasses (15%) dried milk powder (10%) urea (1.5%) and a mineral mixture (1%) and fed to 16 sheep (4 sheep/treatment). Measurements were made of voluntary intake, digestibility of chemical fraction and rate of fermentation of the treated maize cobs. The alkali reduced the cell wall content, increased the *in vitro* digestibility of organic matter and increased the rate of fermentation of the cell wall of the maize cobs. There were significant differences ($P < 0.05$) between rations for voluntary intake (g digestible DM/kg$^{0.75}$) and for the *in vivo* digestibility of the cell wall constituents, but not for the digestibility of cell contents A) 39.2, 41.1 and 63.4 B) 49.2, 44.9 and 63.6 C) 55.2, 52.8 and 60.5 D) 73.6, 64.8 and 63.7 respectively.

Key words: Maize cobs, sodium hydroxide treatment, rate of fermentation, digestibility, intake, sheep.

It has been estimated that in Venezuela there is an annual production of 56 x 10^6 tons of dry matter of fibrous agricultural residues which can potentially be used for animal feed (Parra et al 1977). However, limitations to the use of this material are associated with its low density, low digestibility and reduced voluntary intake (Escobar and Parra, 1981).

Grinding and alkali treatment are commonly used in various countries to improve the nutritive value of fibrous residues. In an earlier study Escobar et al (1982) evaluated the effect of sodium hydroxide (NaOH) on the chemical composition and *in vitro* digestibility of 15 residues. However further information is required to determine the quantitative increase in nutritive value with chemical treatment, and therefore the present experiments were undertaken to determine the effects on consumption, *in vivo* digestibility and the efficiency with which the treated residue is utilized.

The present experiment was intended to evaluate the effect of different levels of alkali (NaOH) on voluntary intake, *in vivo* digestibility of the various chemical fractions and rate of fermentation of maize cobs.

Materials and Methods

Experiment 1: Maize cobs were ground though a hammer mill fitted with a 15 mm screen and treated with alkali at the levels of 0, 20, 40 and 60 g NaOH/kg DM. For the respective treatments 0, 3, 6 and 9 kg of NaOH were dissolved in 200 l of water and then mixed with 150 kg of maize cob DM at ambient temperature.

The treated material was ensiled in 200 litre cylinders for 21 d before being offered to the animals. The four diets were prepared daily and for 21 d offered *ad libitum* (with 20% refusals) to 16 adult crossbred sheep (4 per treatment) held in metabolism crates. For the last 7 d faeces were collected using faecal collection bags. The intake of food and water and the excretion of urine were determined daily, and the animals were weighed at the beginning and the end of the experiment.

The four diets were designed with maize cobs as the only source of fibre so that the effect of NaOH on maize cob fibre would not be confounded by the presence of other fibre (maize cobs 72.5%, molasse 15%, dried skim milk powder 10%, urea 1.5%, minerales mixture 1%). Since maize cobs have a low nitrogen content, dried skim milk powder and urea were included in the ration to provide respectively 20% protein nitrogen and 50% non-protein nitrogen of the total nitrogen in the diet.
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Samples of offered food, refusals and faeces were dried in a forced draught oven (65°C for 48 h), ground through a 1 mm screen and analysed for cell wall constituents, cell contents, cellulose, hemicellulose lignin (Van Soest, 1967; Van Soest and Wine, 1967, 1968), nitrogen and ash (A O A C, 1965). *In vitro* digestibility was determined by the methods of Alexander and McGowan (1966). The results were analyzed by analysis of variance (Sokal and Rohlf, 1979).

Experiment 2: Triplicate 500 g samples of maize cobs were ground through a 20 mm screen and treated at ambient temperature with 0, 20, 40, 60 and 80 g NaOH/kg DM; a ratio of water to maize cob DM of 2:1 was used and 24 h were allowed for the reaction. The treated material was later dried in a forced draught oven (60°C for 48 h) and ground through a 1 mm screen.

The samples were then submitted to the first phase of the *in vitro* fermentation method of Alexander and McGowan (1966) with fermentation times of 0, 12, 24, 36, 48, 60, 72 and 96 h at which times fermentation was terminated by the addition of 2 ml toluene and refrigeration. Subsequently the cell wall content of the residual material was determined by the method of Van Soest and Wine (1967).

The rate constant of fermentation *in vitro* of the cell wall constituents was calculated from the least squares fit to the exponential model: $Y = ae^{-Kt}$, where Y = g cell wall remaining/100 g initial cell wall at t = 0, a = constant, e = logarithin to base e, t = time in hours, K = rate constant of fermentation ($hours^{-1}$).

The K for both total cell wall and for potentially digestible cell wall were calculated. For the latter fraction it was assumed that the maximum extent of fermentation occurred after 72 or 96 hours (Waldo et al 1972). The K values were analysed statistically by the methods of

Steel and Torrie (1960) and were also used to calculate the half-time (T 1/2 = 0.693/K) of fermentation of cell wall.

Results

In Table 1 are shown the changes in chemical composition and *in vitro* digestibility of maize cobs. At the highest level of alkali there was the highest digestibility and the lowest content of cell wall constituents assiciated with the solubilization of hemicelulose. For the

Table 1:

Effect of NaOH on the chemical composition and digestibility in vitro of maize cobs (% DM).

	g NaOH/kg maize cobs			
	0	20	40	60
Ash	2.2	4.7	7.1	9.7
Crude protein (N x 6.25)	2.4	2.3	2.2	2.1
Cell wall	90.5	88.3	80.7	71.0
Acid detergent fibre	48.7	48.3	49.3	45.7
Cellulose	38.8	39.7	40.3	38.4
Hemicellulose	41.8	40.0	31.5	25.4
Lignin	9.9	9.2	9.2	8.9
OMDIV[1]	32.1	39.5	49.5	57.8

[1] *In vitro* digestibility of organic matter.

highrst level of alkali the increase in digestibility was approximately 25%, or 4.2% for each g NaOH/100 g DM. The chemical composition of the rations are given in Table 2; there were differences between the diets with a reduction in the content of structural carbohydrates with alkali treatment.

The *in vivo* digestibilities of all the chemical fractions except that of the cell contents increased significantly with each increment in level of alkali. The effectiveness of treatment expressed as the increase in digestibility per g NaOH was greater with the higher levels of alkali (Table 3). There was a large difference between the increases in digestibility of cellulose (12%) and hemicellulose (37%).

Voluntary intake significantly increased up to the level of 40 g NaOH/kg DM (Table 3). This suggests that levels of greater than 4% NaOH do not increase or reduce the digestion of dry matter. However the intake of digestible dry matter increased progressively with alkali treatment from 39.2 to 73.6 g digestible DM/kg $W^{0.75}$ and all treatments were significantly different (Table 3). Digestible MS intakes were significantly higher with 6% NaOH treatment. The chemical treatment also increased the intake of water and the excretion of urine.

The extent and rate of fermentation of the cell wall was increased with alkali treatment, and the differences between the levels of NaOH increased with time of fermentation.

Table 2:
Chemical composition of the rations (% DM).

	g NaOH/kg maize cobs			
	0	20	40	60
Ash	4.9	7.1	8.7	11.0
Crude protein (N x 6.25)	7.9	7.9	7.8	7.8
Cell wall	71.4	67.5	64.7	56.5
Acid detergent fibre	38.5	38.9	40.0	35.8
Cellulose	31.4	32.0	32.7	30.1
Hemicellulose	32.8	28.6	24.6	20.6
Lignin	7.2	7.3	7.2	6.1

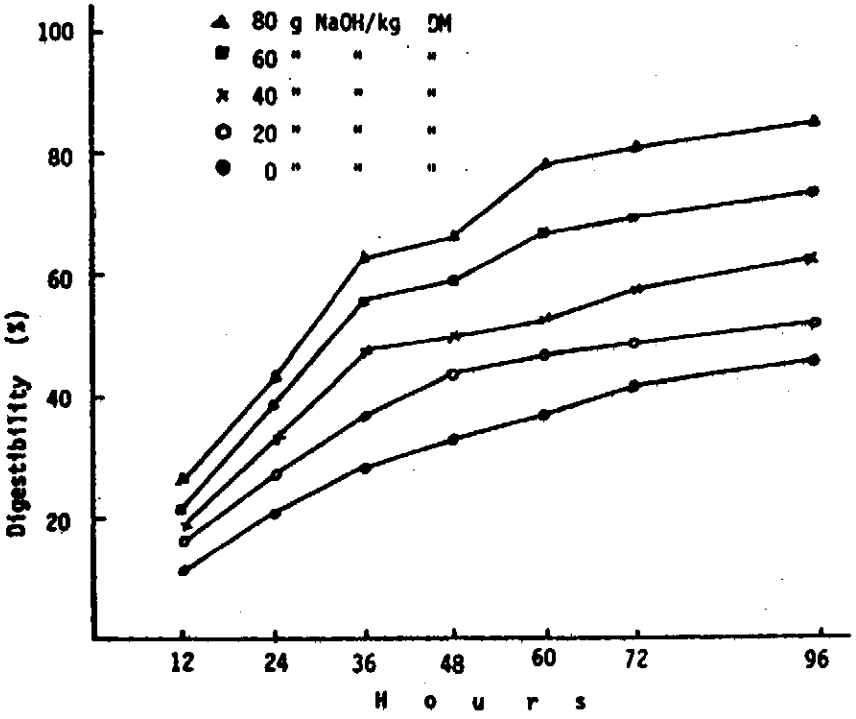
Values are the mean of 4 samples.

Table 3:
Effect of level of NaOH on in vivo digestibility, voluntary intake and urinary excretion of sheep.

	g NaOH/kg DM of maize cobs			
	0	20	40	60
Digestibility (%)				
Dry matter	48.8^{a}	51.2^{b}	55.5^{c}	64.0^{d}
Organic matter	49.1^{a}	50.8^{b}	54.6^{c}	62.4^{d}
Cell wall	41.1^{a}	44.9^{a}	52.8^{b}	64.8^{c}
Cell contents	63.4^{a}	63.6^{a}	60.5^{a}	63.7^{a}
Acid detergent fibre	38.5^{a}	42.3^{a}	49.1^{b}	55.5^{c}
Cellulose	46.4^{a}	50.4^{ab}	55.3^{bc}	58.4^{c}
Hemicellulose	43.9^{a}	48.2^{a}	60.7^{b}	80.6^{c}
Lignin	6.4^{a}	10.5^{a}	13.2^{a}	42.3^{b}
Voluntary intake				
Dry matter (g/d)	1121	1231	1372	1441
Dry matter (% PV)	3.3^{a}	4.1^{b}	5.2^{c}	5.0^{c}
Digested dry matter (g/kg $W^{0.75}$)	39.2^{a}	49.2^{b}	65.2^{c}	73.6^{d}
Water (ml/d)	2130^{a}	3013^{b}	3025^{b}	6738^{c}
Urine excretion(ml/d)	1110^{a}	1647^{b}	1897^{b}	4720^{c}

Mean values with different letters in the same row were significantly different ($P < 0.05$).

Figure 1:
Effect of NaOH on in vivo digestibility of maize cobs



For each time of incubation the effect of level of NaOH on cell wall digestibility was linear (correlation coefficients 0.96). The linear regression coefficients of increments of OMDIV with level of NaOH treatment obtained were related to the time of fermentation (Figure 2); it was observed that between 48 and 60 hours of fermentation the maximum increase in cell wall digestion per g of added NaOH had occurred.

The amounts of cell wall remaining after fermentation showed a highly significant fit to the exponential model (correlation coefficient 0.95). The fermentation rate constant (K) increased significantly with each level of NaOH (Table 4). The rate of fermentation of total cell wall constituents was influenced much more than the rate of fermentation of the potentially digestible fraction. Apparently the fraction of cell wall that was made digestible by the alkali treatment was fermented to the same extent as the digestible fraction of the original untreated cell wall. The half times (T 1/2) of fermentation express more clearly the effect of NaOH on the fermentability of the cell wall. While the T 1/2 of the potentially digestible cell wall showed a difference of only 6.5 h between the extreme levels of alkali, the difference in T 1/2 for the total cell wall was approximately 77 h.

Figure 2:

Relationship between increments in in vitro digestibility of cell wall/g of NaOH added per 9 of DM and time of in vitro fermentation, with maize cobs.

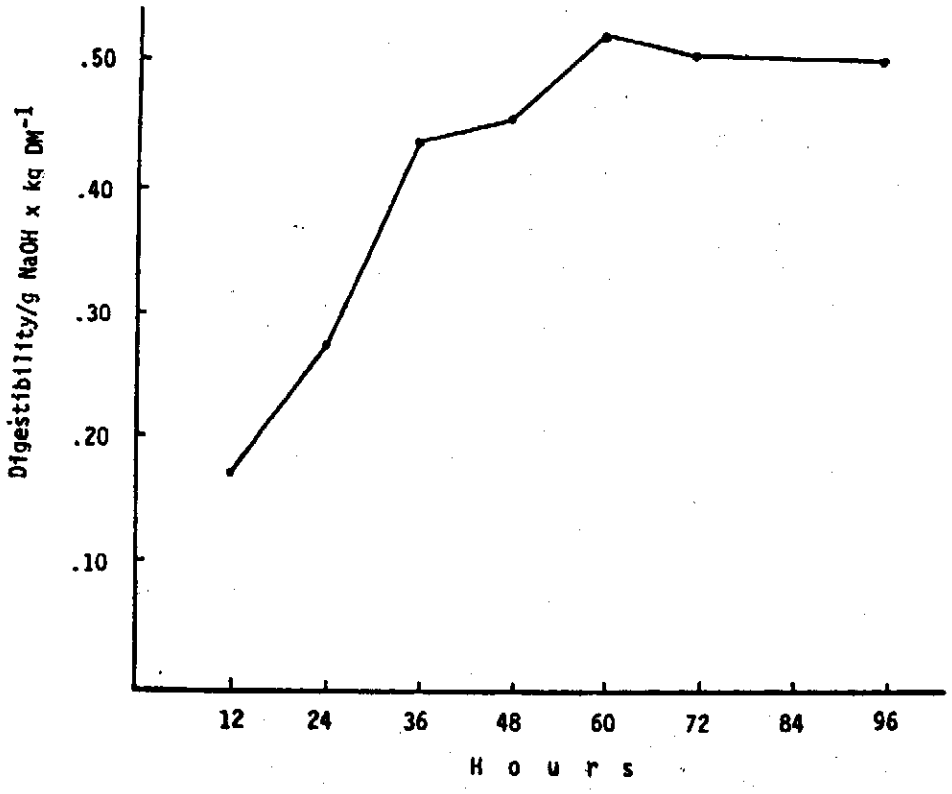


Table 4:

Effect of NaOH on the rate of fermentation of cell wall of maize cobs.

	g NaOH/kg DM				
	0	20	40	60	80
Total cell wall					
K(h^{-1})	-0.0065[a]	-0.007[b]	-0.0102[c]	-0.0210[d]	-0.0210[e]
r	0.98	0.95	0.96	0.97	0.98
T 1/2 (h)	107	90	68	48	13
Potentially digestible cell wall					
K(h^{-1})	-0.0311[a]	-0.0351[b]	-0.0339[ab]	-0.0403[c]	-0.0440[d]
r	0.99	0.99	0.99	0.99	0.99
T 1/2 (h)	22.3	19.4	20.4	17.2	15.8

K: Fermentation rate in hours^{-1}, r: Correlation coefficient,

T 1/2: Half-time of fermentation in hours.

Values with different letters in the same row were significantly different ($P < 0.05$).

Discussion

Alkali treatment had a marked effect on intake of dry matter and water, digestibility, rate of digestion of fibre and the excretion of urine. Although higher levels of NaOH than those used in the present experiment may be associated with further improvements, it is also possible that there would be a decrease in voluntary intake. With the ration treated with 60 g NaOH/kg DM, the diet contained 2.4% of sodium and the intake was similar to that with the diet treated with 40 g NaOH/kg DM. It is likely that levels greater then 2% sodium in the ration are associated with a decrease in voluntary intake (Jackson 1977).

Furthermore Kategile et al (1979) did not observe increases in intake and digestibility with levels of NaOH greater than 50 g/kg DM of maize cobs when the treated maize cobs constitued 67% of the ration.

Since with increasing level of alkali there was an increase in the proportion of non-structural carbohydrate and voluntary intake, it is possible that the digestibility of the fibrous fractions of the diet would be affected. A greater intake with a reduction in fibre in the diet is often associated with reduced digestion of cell wall constituents (Escobar and Parra, 1983).

A relatively low digestibility of the soluble fraction has also been observed by Hogan and Weston (1971) with treatment of wheat straw with NaOH, and these authors suggested that phenolic compounds liberated by the treatment were implicated. Alternatively the low digestibility may be due to the formation of oligomers of xylose and other constituents of hemicellulose during the solubilization process. Since these short chain oligomers would be associated with the liquid phase in the rumen they would be briefly exposed to rumen fermentation, would not be digested in the small intestine and only briefly exposed to fermentation in the large intestine.

Coombe et al (1979) reported for barley straw treated with NaOH rates of fermentation similar to those obtained in the present study. These rates of fermentation are relatively low in comparison with the values obtained by Smith et al. (1971) with temperate forages of similar potential digestibility.

Similarly to grinding, the high intakes of treated material are likely to be associated with an increased rate of passage (Coombe et al. 1979; Rexen et al 1976), which may cause reduction in the extent of ruminal digestion. With grinding, the increase in feed comsumption compensates for the detrimental effect that the particle size reduction has on digestibility. The alkali treatment could act on the ground material to increase, mantain, or reduce the digestibility of the processed residue depending on the relative increases in the rate of fermentation and rate of passage. If the rate of passage of the solid phase is very high and hence the time for rumen fermentation is reduced, it is to be expected that the digestibility of cell wall constituents with chemical treatment be reduced. This is demonstrated in Figure 2.

Similarly, Berger et al (1979) observed that the digestibility of cell wall constituents of maize cobs collected at the abomasum (ie after fermentation) increased with increasing levels of NaOH treatment of the diet, thus indicating an increase in the potentially digestible fraction escaping rumen fermentation.

Another interesting aspect, not yet evaluated, is the possible effect that the increased water intakes in diets containing alkali treated cobs (Table 2) could have on the dilution rate of the ruminal liquid phase and its subsequent effect upon rumen bacterial growth dynamics (Isaacson et al 1975).

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