SODIUM HYDROXIDE TREATED WHEAT STRAW FOR SHEEP

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OPSOMMING: NATRIUM HIDROKSIED BEHANDELDE KORINGSTROOI VIR SKAPE

Vrywillige voerinname, verteerbaarheid en rumen vloei- en fermentasiedinamiek is met skape bepaal. Bytsoda behandelde koringstrooi (5 % w/w) gewas of ongewas en onbehandelde strooi is vergelyk. Die was van die strooi het weinig effek gehad op *in vivo* verteerbaarheid, vrywillige voerinname, vervalkonstantes vir fermentasie en vervalkonstantes vir uitvloei. Waterinname en die retensityd van 'n water-oplosbare merker (Cr – EDTA) in die rumen is egter betekenisvol beinvloed.

Wanneer behandelde – met onbehandelde strooi vergelyk word, blyk dit dat bytsoda die *in vitro* fermenteerbaarheid (α) en die tempo van organiese materiaal uitvloei verhoog het. Hierdie faktore is waarskynlik verantwoordelik vir die verhoogde inname van verteerbare organiese materiaal wat dikwels gevind word met bytsodabehandelde voere.

Die vervalkonstante vir fermentasie. uitgedruk as 'n eerste-ordereaksie vervalkonstante, is blykbaar nie beinvloed deur bytsoda behandeling van hierdie diëte nie.

SUMMARY:

Voluntary feed intake, digestibility and rumen flow- and fermentation dynamics were studies using sheep. NaOH treated (5 % w/w) wheat straw, washed and unwashed as well as untreated straw were compared. Results indicated that washing the straw had little effect on *in vivo* digestibility, voluntary feed intake, rate constants for fermentations and rate constants for outflow, but water intake and the turnover time of a water soluble marker (Cr-EDTA) in the rumen and the percentage fermentable O.M. in the rumen were significantly influenced.

When compared to untreated straw. NaOH treatment appeared to increase the total *in vitro* fermentability (α) and rate of organic matter (O.M.) outflow. These seemed to be responsible for the increased voluntary intake of digestible O.M. often observed with NaOH treated forages. The rate constant for fermentation, expressed as a first order reaction rate constant, appeared to be unaffected by NaOH treatment of these diets.

The use of alkali treatment to increase digestibility and voluntary intake of low quality roughages has been well described in the literature recently reviewed by Hofmeyr & Jansen (1976) and Jackson (1977).

Not all responses with alkali treatment of roughages were positive. Workers such as Vosloo & Burger (1977) and Van der Merwe (1978) found that NaOH treatment did not always increase digestibility *in vjvo*. Since it is known that *in vivo* digestibility is influenced by rumen flow dynamics, it was decided to study extensively these aspects involving NaOH treatment.

It has been suggested, (Ørskov & Grubb, 1978) that the increased rate of O.M. intake often observed with NaOH treatment, may be due to an increased turnover rate of water in the rumen caused by the high sodium content of the diet.

Results published by Thiago, Kellaway & Leibholz (1979) indicate faster turnover rates for the outflow of cell wall constituents with some NaOH treated roughages, as well as an increased rate of digestion *in situ* of some feeds, when compared to untreated forages.

A study of NaOH treated and untreated roughages was undertaken in which some of the treated roughages were washed with water to remove excess sodium, while the rest were left unwashed. Washing of the feed would give an indication of the effect of a low versus a high sodium content of the diet on *in vivo* rumen

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dynamics, and *inter alia* the rate constant describing outflow. Comparison of treated and untreated roughages would give an indication of the alteration in flow and fermentation kinetics caused by NaOH treatment.

Materials and Methods

The experiment was conducted over 2 periods of 25 days each. During the first period 8 sheep were fed a diet of untreated wheat straw. Druing the second period the same sheep were randomly divided into 2 dietary groups. One group received wheat straw treated with NaOH. The other group received the same feed. but rinsed 3 times with water.

The first period served as a control period by which the accuracy of the experiment was increased, since consistent between-sheep variation was eliminated by covariance analysis (Snedecor & Cochran, 1971). The second period was used to compare rinsed and unrinsed straw, and the results were also compared to those for the first period so as to contrast the effects of treating and not treating straw. When the first and second periods were compared, period-effects were confounded with treatment effects. However, no serious period-effects were expected since the sheep used were mature wethers kept indoors in metabolism cages.

Eight mature South African mutton Merino wethers with an average live mass of 60,3 ± 8,2 kg, fitted with large (81 mm internal diameter) rumen cannulae and adapted to metabolism cages were used.

During each period, all sheep were first adapted for 15 days on the experimental diets. Measurements of rumen parameters and faeces collection were then commenced. The results of voluntary feed intake refer to intakes recorded for 10 days after the initial fifteen day adaptation period.

Mineral and protein needs were supplemented by placing, twice daily, 120 g of a mixture of fishmeal and required minerals in the feed troughs. Rumen ammonia determinations for each sheep were performed at 08h00, 12h15 & 14h30 and were found to always exceed the minimum of 50 mg ammonia nitrogen per litre of rumen liquor, as recommended by Roffler, Schwab & Satter (1976).

Diets were fed twice daily at 08h30 and 15h30 at a level of *ad lib* + 10%. The untreated wheat straw which was fed during the first period was ground through a 13 mm sieve and had a dry matter content of circa 90%. Wheat straw fed during the second period was similarly ground and treated with sodium hydroxide (5% w/w) using a 1% solution. The solution was sprayed onto the straw which was turned manually, the run-off was collected and the straw resprayed until no more NaOH could be detected in the solution. One half of the straw was left unwashed and the other half was washed 3 times with water. Each washing was done with 7 litres of water per

kg of dry straw with a run-off period of 15 minutes after each washing. After the last washing the straw was left in the container overnight to allow excess water to run off. The straw was then placed in plastic bags and frozen until needed. Unwashed straw was stored in the same manner. The treated straw had a dry matter content of about 20% when fed.

Total alkalinity of the NaOH solution and the run-off, when the straw was rinsed, was determined by titration with hydrochloric acid according to Scott (1927). By this method the hydroxyl, carbonate and bicarbonate content of a solution is determined with the assumption that the phosphate content is negligible.

Three rinses were selected since the carbonate content of the runn-off water was reduced from 1,6% to less than 0,01% by 3 rinses. The bicarbonate content followed the same pattern.

Measurements of ruminal dry — and organic matter content as well as samples for determining *in vitro* digestibility of rumen contents, were obtained after emptying each sheep's rumen manually and mixing the contents. To obtain representative values of rumen contents, rumens were emptied at 08h00, 12h00, 14h00 and 15h00. However, to minimize the possible disturbing effect of emptying the rumen, a schedule was drawn up whereby each sheep's rumen was emptied only once a day with at least 2 days intervening between 2 successive emptyings on the same sheep.

Means of rumen contents were calculated as weighted means, i.e. the average of the contents of 2 sequential measurements multiplied by the period (hours) between these 2 measurements. These were pooled for all intervals within 24 hours and divided by 24.

Rates of fermentation of O.M. and outflow of non-fermentable O.M. were expressed as first order reaction rate contants γ_1 and γ_2 respectively. These were calculated as the rate of intake of fermentable O.M. divided by the mass of fermentable O.M. in the rumen for γ_1, and rate of intake of non-fermentable O.M. divided by the mass of non-fermentable O.M. in the rumen for γ_2. No correction for the outflow of digestible O.M. was made in the calculation of γ_1.

Total fermentability of diets (α), and of rumen contents was determined by an *in vitro* fermentation technique (Tilley & Terry, 1964), but with a 72 hour incubation in the microbial phase and a 24 hour incubation in the pepsin phase. In the case of untreated and treated washed wheat straw, *in vivo* estimated of feed digestibility were higher than *in vitro* estimutes of α and *in vivo* estimates were consequently used for α. *In vivo* digestible O.M intake was calculated as O.M intake minus O.M. excreted in faeces and was normally less than *in vitro* fermentable O.M. intake, since some digestible O.M. is normally excreted in faeces.

Table 1

A comparison of NaOH treated wheat straw rinsed and not rinsed and untreated wheat straw fed to sheep

	Studying NaOH treatment			Studying rinsing		
	Untreated wheat straw	NaOH treated wheat straw	Test of significance	Rinsed straw	Straw not rinsed	Test of significance
O.M. intake (g/day)	627,5	973,7	p $\leq$ 0,01	965,3	982,0	N.S.*
In vitro O.M. fermentability (%)	51,0	60,0	No test	53,8	66,3	No test
In vivo O.M. digestibility (%)	57,2	57,6	N.S.*	56,1	59,0	N.S.
Fermentable (α) O.M. intake (g/day)	359	590	p $\leq$ 0,01	529	651	N.S.
In vivo digestible O.M. intake (g/day)	359	564	p $\leq$ 0,01	529	599	N.S.
Mass of O.M. in rumen (g)	897	1031	p $\geq$ 0,05	1063	998	N.S.
Percentage fermentable O.M. in rumen (%)	31,0	41,2	p $\leq$ 0,01	37,0	45,4	p $\leq$ 0,01
Mass of fermentable O.M. in rumen (g)	278	429	p $\leq$ 0,001	398	460	N.S.
γ_1, rate constant describing O.M. fermentation (day^{-1})	1,28	1,38	N.S.	1,33	1,43	N.S.
γ_1 expressed as turnover time (h)	19,9	17,4	N.S.	17,9	16,8	N.S.
γ_2, rate constant describing O.M. outflow (day^{-1})	0,44	0,64	p $\leq$ 0,001	0,66	0,63	N.S.
γ_2 expressed as turnover time (h)	57,4	37,8	p $\leq$ 0,001	36,7	38,8	N.S.
Apparent mean retention time of O.M. (h)	36,4	25,4	p $\leq$ 0,05	26,4	24,3	N.S.
Voluntary water intake (g/day)				234	4318	p $\leq$ 0,01
Mean retention time of Cr EDTA (h)	18,8	12,9	p $\leq$ 0,01	14,7	11,3	p $\leq$ 0,05

* N.S. is not significant

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Apparent mean retention time of O.M. in the rumen was calculated by a similar method to the one described by Minson (1967), but sheep were fed only twice daily as described above. Mean retention time of O.M. in the rumen was calculated as the mass of O.M. in the rumen divided by O.M. intake.

Mean retention time of a water soluble marker Cr-EDTA was determined as described by Warner (1966). The marker was mixed manually with the removed rumen digesta. The digesta was then returned to the rumen. Thereafter, samples of rumen contents were taken at approximately 0, 4, 7 and 24 hours. The marker concentration (Chromium concentration) was determined by atomic absorption spectrophotometry on samples of filtered rumen liquid.

Faeces were collected for 10 consecutive days during each experimental period by using faeces collection bags. Voluntary water intakes were determined only during the second period when rinsed and unrinsed straws were fed.

Results and Discussion

The effects of NaOH treatment and of rinsing NaOH treated wheat straw were compared using the data in Table 1.

It is clear (Table 1) that washing of NaOH treated straw had no significant effect on voluntary O.M. intake. Compared to untreated straw, NaOH treatment resulted in a considerable increase in voluntary feed intake. Possible explanations for this increase in voluntary feed intake were examined using the approach described by Pienaar, Roux, Morgan & Grattarola (1980).

In vitro results with NaOH treated straw have often shown large increases in feed digestibility (Wilson & Brigstocke, 1977; Wilkinson, 1978), but *in vivo* results do not always indicate a corresponding increase (Vosloo & Burger, 1977), especially when sheep are fed *ad libitum*.

In this experiment (Table 1), *in vitro* results showed an increase in fermentability from 51% for untreated straw to 66% for NaOH treated unwashed straw. This increase in *in vitro* fermentability with NaOH treatment is in agreement with the work of *inter alia* Wilson & Brigstocke (1977) who predicted an *in vitro* "digestibility" of 65% for wheat straw treated with 5% NaOH. Washing the treated straw apparently reduced *in vitro* fermentability to 54%. This reduction was not unexpected since soluble O.M. removed by washing would probably be highly digestible. No statistical comparison of these values was attempted since *in vitro* estimates were made on one bulked sample only for each diet.

In vivo digestibility determinations showed a pattern which differed considerably form the *in vitro* estimates. The largest increase in digestibility being from 56% to 59%, with no difference being statistically significant. Possible reasons for this sizeable difference between *in vivo* and *in vitro* estimates have been evaluated in conjunction with the discussion on outflow of O.M. from the rumen.

The fact that *in vivo* digestibility was higher than *in vitro* estimates on 2 diets, indicated that the *in vitro* technique may not always be consistent in estimating the total fermentability (α) of a diet even though a 72h incubation in the microbial phase was used. However, since it is the only technique available to differentiate between the fermentable and non-fermentable fractions, it was used unless it was contra-indicated, as was the case with washed straw and untreated straw. In this experiment it was decided to consider the highest estimate of digestibility as the best estimator of α whether it be determined by *in vitro* or *in vivo* methods.

The voluntary intake of fermentable O.M. is given by the data Table 1. It is clear that washing the wheat straw diets did not influence *in vitro* fermentable O.M. intake significantly. There was a tendency for the *in vitro* fermentability of the washed diets to be reduced, but when multiplied by O.M. intake to yield *in vitro* fermentable O.M. intake, the test of significance indicated a probability of greater than 0,05. *In vivo* digestible O.M. intake exhibited the same tendency, but was also not significant. When treated and untreated straw were compared, a highly significant difference in both *in vitro* and *in vivo* digestible O.M. intake was observed.

It is clear from Table 1 that washing the straw did not influence the mass of O.M. in the rumen significantly. However, a significant increase was observed with NaOH treatment. This is not easy to explain, but the observed increase could have had a significant effect on voluntary feed intake. It also shows that the organic matter content of the rumen under *ad lib* feeding regimes on low quality roughages is not necessarily constant in relation to live mass, but is significantly influenced by the diet fed. This result is in agreement with the work of Meissner, Pienaar, Liebenberg & Roux (1979), who found that the ratio between mass of organic matter in the rumen and live mass varied significantly between diets.

The data in Table 1 also showed that washing the straw did have a significant effect on the percentage *in vitro* fermentable O.M. in the rumen. Compared to untreated straw, NaOH treatment also resulted in a significant increase in percentage *in vitro* fermentable O.M. in the rumen.

Washing the straw did not influence the mass of fermentable O.M. in the rumen (Table 1) significantly. When comparing NaOH treated with untreated straw (Table 1), a highly significant increase was observed in mass of fermentable O.M. in the rumen with NaOH treatment. This measurement gives an indication of the pool size of active fermentation (i.e. digestible O.M.) and is a determinant of the mass of O.M. which ferments per day.

The rate constant describing fermentation, γ_1, with dimensions day^{-1}, as given in Table 1 is also conveniently expressed as turnover time in hours:

$$\text{turnover time h} = \frac{1}{\text{rate constant}} \times \frac{24}{1}$$

No significant difference in γ_1 between washed and unwashed as well as treated and untreated straw could be detected. This indicates that the increased voluntary feed intake observed between treated and untreated wheat straw can not be ascribed to an increased rate of digestion per unit of substrate. However the increased mass of fermentable substrate (pool size) would result in an increased mass of substrate being fermented per day.

The rate constant describing outflow of indigestible O.M., γ_2, is shown in Table 1, with dimensions day^{-1} and is also expressed as turnover time for convenience. It is clear that washing the straw did not change the rate constant (γ_2) significantly. Compared to untreated straw, however, this rate constant for outflow was increased significantly by NaOH treatment. This is also in agreement with the observed higher voluntary feed intake and together with a higher fermentability of the diet is probably responsible for the higher mass of fermentable O.M. observed in the rumen. The increased rate constant for outflow of indigestible O.M., or reduced turnover time, is probably also responsible for the relatively small increase observed in *in vivo* digestibility compared to the *in vitro* fermentability of the food. This is possible since the increased rate of outflow of indigestible substrate is most probably associated with an increased outflow of digestible O.M., thus effectively reducing the *in vivo* digestibility of the diet.

Since the apparent mean retention time of organic matter in the rumen (Table 1) is a function of both γ_1 and γ_2 it is not surprising that no significant differences were observed between washed and unwashed straw. Significant differences did occur between treated and untreated straws.

It is known that animals fed on NaOH treated roughages tend to consume more water than animals fed on untreated roughages, probably because more sodium and carbonate have to be excreted by the kidneys. Voluntary water intake could then serve as an indication of the effectiveness of washing and was measured only with

sheep fed washed and unwashed straw. In this case voluntary water intake did not include water taken in through the feed. The latter was very similar for both groups and amounted to 4300 g per sheep per day. From Table 1 it is clear that the animals fed unwashed straw drank significantly more water than those fed washed straw. This indicates that the washing of the straw was successful.

Retention time of a water soluble marker is also given in Table 1. It is clear that significant differences exist between both washed – and unwashed straw and treated and untreated straw. The difference in retention time observed between washed and unwashed straw is consistent with the increased water intake.

The fact that washing the straw influenced the retention time of water but not the turnover time of indigestible O.M. in the rumen, indicates that the hypothesis of an increased rate of O.M. removal from the rumen with NaOH treatment, because of an increased water intake (Ørskov & Grubb, 1978), is unlikely.

Conclusion

All the results indicated that washing of NaOH treated diets did not influence rumen function significantly, except for voluntary water intake, retention time of a water soluble marker in the rumen and the percentages digestible O.M. in the rumen contents.

A comparison of NaOH treated and untreated diets however, showed a highly significant increase in voluntary organic matter intake with NaOH treatment. This increase could be explained mainly by the faster outflow of O.M. from the rumen and the higher fermentability of the diet which resulted in larger mass of fermentable O.M. in the rumen and a larger mass of O.M. being fermented per day. This larger mass of O.M. fermented per day could not be explained by the rate constant for fermentation (γ_1) which was not influenced significantly by treatment with NaOH nor by washing the treated straw. It could only be expained by an increase in the active pool size, i.e. fermentable O.M. in the rumen.

The only aspect of importance when washing NaOH treated straw seems to be the removal of some fermentable soluble O.M. from the diet, although the voluntary intake of digestible O.M. and *in vivo* digestibility were not significantly influenced. It appears that sheep were well able to remove excess sodium from the diet by increasing voluntary water intake, at least for the duration of this experiment.

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