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THE REPLACEMENT OF MAIZE MEAL WITH SODIUM HYDROXIDE TREATED WHEAT STRAW IN GROWTH DIETS FOR LAMBS

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OPSOMMING: DIE VERVANGING VAN MIELIEMEEL DEUR BYTSODA BEHANDELDE KORINGSTROOI IN GROEIDIËTE VIR LAMMERS

Die moontlike vervanging van mielies met NaOH-behandelde koringstrooi in groei-diëte vir lammers is getoets. Vier diëte met 43; 29; 14 en 0 % mielies en 0; 24; 48 en 72 % behandelde koringstrooi is saamgestel sodat die kragvoer: ruvoerverhouding gewissel het van 65:35 tot 28:72 terwyl die energieverteerbaarheid van al vier rantsoene teoreties 68 % was. Verteerbaarheid en metaboliseerbaarheid van die diëte is met 'n 4 x 4 Latynse vierkant proefontwerp met 4 volwasse hamels bepaal. Dit het geblyk dat die urine-energie betekenisvol gedaal het met verhoogde strooi-insluiting, terwyl daar 'n neiging vir CH_4-produksie was om te styg. Die verhouding ME:VE was egter vir al die diëte dieselfde naamlik 0,79. Vrywillige voerinname, groei en liggaamsamestelling op die 4 diëte is bepaal deur 48 lammers met 'n gemiddelde aanvangsmassa van 27,5 kg in 4 groepe te verdeel en toe te sê aan die 4 proefdiëte. Een dier uit elke groep is met 7 dae intervalle geslag en ontleed vir liggaams- en karkas DM, proteïen- en vetinhoud. Liggaamsmassa en voerinname is weekliks genoteer. Hoewel DM-inname hoogs betekenisvol gestyg het met verhoogde behandelde strooi-insluiting was die ME-inname van al 4 groepe dieselfde. Liggaamsmassatoename en proteïentoename het nie tussen groepe verskil nie, maar DM- en vettoename het betekenisvol gedaal met verhoogde behandelde strooi-insluiting.

Hieruit blyk dus dat terwyl lammers op diëte met soveel as 72 % NaOH-behandelde strooi nog bevredigend kan groei (188 g/d), behandelde strooi nie mielies op gelyke ME-basis in sulke groeidiëte kan vervang nie.

SUMMARY:

The possible replacement of maize with NaOH–treated straw in growth diets of lambs were tested. Four diets with 43; 29; 14 and 0 % maize grain and 0; 24; 48 and 72 % treated straw were formulated in such a way that the concentrate:roughage ratio changed from 65:35 to 28:72 while the calculated energy digestibility for all 4 diets remained at 68 %. Maize straw was used with the maize grain to bring down the energy content. Digestibility and metabolizability of the energy in the diets were tested with 4 mature wethers in a 4 x 4 Latin square design experiment at maintenance level of intake. Faecal energy excretion increased significantly with increased level of treated straw, probably due to an underestimation of the digestibility of the maize straw. Urinary energy dropped with increased levels of treated straw, but the ratio of ME:DE remained constant at 0,79 due to a tendency for increased methane production with increased treated straw level. Voluntary feed intake, growth and body composition on the 4 diets were tested with Dohne merino lambs averaging 27,5 kg. Forty-eight lambs were divided into 4 groups, each group receiving one of the diets *ad libitum*. With 7 day intervals, one animal per group was slaughtered and analysed for body and carcass DM-, protein- and fat content. Body mass and feed intake of the growing lambs were measured weekly. Although DM-intake increased highly significantly with increased treated straw levels, the ME-intakes of the 4 groups were the same. Body mass and carcass mass as well as body and carcass proteins did not differ between groups. DM and fat gains of body and carcass decreased significantly with increased treated straw levels.

Although lambs can grow satisfactorily (188 g/d) on diets with as much as 72 % treated straw, such straw cannot replace maize on an equal ME-basis in growth diets for lambs.

Recent literature reviews of alkali treatment of low quality roughages indicate that despite worldwide research efforts in this field, there is a dearth of information on the influence of alkali treatment on the metabolizability and net energy values of such roughages (Jackson, 1977; Owen, 1978). The fact that the energy digestibility of cereal straws can be increased to values of 70% or higher, creates the interesting possibility that such roughages might be used as replacements for concentrates. However, it is well-known that digestibility is not always a true reflection of the production value of a particular feedstuff. The efficiency with which digestible energy is utilized for maintenance or a specific synthetic process by the animal, is amongst others, a function of the rate of production and the ratio of fermentation end products (Armstrong & Blaxter, 1957; De Meyer & Van Nevel, 1975; Schwartz & Gilchrist, 1975). This in turn is influenced by the fermentation substrate, being mainly starch in the case of concentrates and cellulose, hemicellulose and lignin in the case of alkali treated roughages. The ratio between digestibilities of treated straw and concentrates thus not necessarily reflects the relative productive values of these feedstuffs.

This experiment was carried out to determine to what extent NaOH treated wheat straw could replace maize grain in growth diets for lambs, with emphasis on the metabolizability of the diets and the relative efficiency of utilization of the ME for growth.

Procedure

Wheat straw was hammermilled through a 6 mm screen. The ground straw was treated with 5% sodium hydroxide by spraying a 10% aqueous solution onto the straw in a slow paddle mixer, equipped with a pump and spray nozzles. The straw was then suncured to a dry matter (DM) content of approximately 90%.

Four experimental diets were compiled as shown in Table 1. Maize meal, maize straw and sunflower oilcake (SOC), in the ratio of 4:3:1, were replaced with treated straw and SOC in the ratio of 7:2 on a mass basis, in such a way that the diets contained 0; 24; 48; and 72% of treated straw. In this way, the calculated percentage digestible energy

$$\left(\frac{\text{digestible energy (DE)}}{\text{gross energy (GE)}} \times 100\right)$$

and crude protein content of the 4 diets remained unaltered. The concentrate: roughage ratio however changed from 65:35 to 28:72. All 4 diets contained 11% fish meal in order to exclude protein as possible growth limiting factor. After mixing, the diets were pelleted through a 6 mm die.

Table 1

Composition of experimental diets (%) on an air dry basis[1]

Component	[2]DE /GE x 100	Diets			
		D1	D2	D3	D4
Maize meal	80	43	29	14	–
Maize straw	52	35	24	12	–
Wheat straw (5% NaOH)	68	–	24	48	72
Sunflower oilcake	70	11	13	15	17
Fishmeal	70	11	11	11	11
Concentrate: Roughage		65:35	53:47	41:59	28:72
[2]Crude protein %		16,5	16,5	16,5	16,5
[2]Energy digestibility %		68	68	68	68

1 Approximately 10% moisture content

2 These were assumed values

Determination of DE and ME content of the diets

Four Döhne merino wethers received the 4 experimental diets at maintenance level of intake, according to a 4 x 4 Latin square design. Each animal was allowed a 3-week adaptation period after changing the diet before any measurements were made. Urine and faeces were collected for 2 consecutive 7-day periods. During one of these periods the animals were kept in an open system respiration unit where methane production was measured over 4 consecutive 24-hour periods, as described by Roux, Meissner & Hofmeyr (1982). Feed, faeces and urine were analysed for dry matter, N and energy content according to standard procedures (A.O.A.C., 1970). Data on consecutive measurements for each animal treatment combination were averaged.

Statistical analyses were carried out by means of a two-way analysis of variance program (one observation per cell).

Intake, growth and body composition

Forty eight Döhne merino wethers of 12 weeks of age were randomly divided into 4 groups and allotted the 4 experimental diets. Slaughter dates, starting at onset of the experiment and following with 7-day intervals, were allotted to the animals within a group. In this way one animal per group per week were slaughtered for a period of 12 weeks. The lambs were treated for internal parasites before the trial as a precautionary measure and were allowed 5 weeks to adapt to the diets before onset of the experiment. Diets were offered *ad libitum* and weekly DM intakes and mass gains were recorded.

The slaughter procedure followed to determine body composition was similar to that described by Hofmeyr, Kroon, Van Rensburg & Van der Merwe (1972). The body was divided into two portions – the one portion consisting of the carcass only and the other consisting of the rest of the body. Homogeneous samples drawn from the whole minced carcass and rest were analysed for DM, nitrogen (N), ether extract and ash using the methods described by the A.O.A.C. (1970).

The statistical analysis was done by regressing Treatments 2, 3 and 4 on Treatment 1, assuming both x and y variables subject to error. It is natural to assume the error variances equal and hence to use the method for estimation of b (the slope) as described by Moran (1971). If the effect of the treatments does not differ from the control, one would expect a slope of unity and intercept of zero. The calculations were done assuming zero intercept, hence no corrections for the mean are included in the formulas involving sums of squares and products.

The t-test reported in Table 3 determines if the slope deviates significantly from unity. The assumption of zero intercept was checked by calculating $b' = \bar{y}/\bar{x}$, which implies $\bar{y} - b\bar{x} = 0$, and by comparing it with the b's previously calculated. The agreement was excellent.

The zero intercept allows the interpretation that for instance a slope of 1,12 indicates a 12% higher value for a specific treatment in comparison to Treatment 1. This experimental design does however not provide for the accurate determination of actual intake and growth rates of the treatment groups.

Results

Digestibility and metabolizability of experimental diets

The average GE intakes ($KJ.d^{-1}$ per $W_{kg}^{0,75}$) did not differ significantly and varied between 718 and 740 (Table 2). Faecal energy excretion, expressed as a percentage of GE intake, increased significantly with increase in treated straw content of the diet and varied between 25,61% on Diet 1 and 29,76% on Diet 4.

There was a tendency for increased methane production with increased treated straw content although this was found to be non significant. Urinary energy as a percentage of GE intake declined from 5,33% on Diet 1 to only 3,89% on Diet 4. This decline could however not compensate for the increase in faecal energy output with increased treated straw content. Thus the metabolizability of the diets also declined with increased straw content. The ratio of ME:DE remained virtually constant for all diets and averaged 0,79. The metabolizable energy concentration (MJ/kg DM) of the diets, which is influenced by both the metabolizability and the effect of sodium content of the treated straw on gross energy content of the diets, dropped with 12% from 10,83 in Diet 1 to 9,52 in Diet 4.

Intake, growth and body composition

In Table 3 the Slopes b2, b3 and b4 represent the regression of Treatments 2, 3 and 4 respectively on Treatment 1, calculated by the method of Moran (1971). Dry matter intake increased significantly to highly significantly with increased amounts of treated straw in the diets. Intake for Group 2 was 9,75% higher, Group 3 11,84% and Group 4 19,78% higher than Group 1. However, despite these differences, metabolizable energy intake did not differ between diets.

Table 2

Parameters related to the digestibility of the diets at maintenance level of intake

Parameter	Diet			
	D1	D2	D3	D4
Gross energy in dry matter (MJ/kg)	18,32	18,05	17,58	17,08
Gross energy intake (kJ/$W_{kg}^{0,75}$ d)	720,35 ± 25,88	727,70 ± 12,71	740,87 ± 28,08	718,29 ± 20,55
Faecal Energy (% of GE)	25,61 ± 1,15	26,42 ± 1,75	29,64 ± 1,58	29,76 ± 2,77
Methane Energy (% of GE)	9,95 ± 1,51	10,77 ± 1,26	10,84 ± 1,36	10,21 ± 2,16
Urinary Energy (% of GE)	5,33 ± 1,41	4,94 ± 1,55	3,67 ± 1,16	3,89 ± 1,14
DE/GE x 100	74,4 ± 1,2	73,6 ± 1,8	70,4 ± 1,6	70,2 ± 2,8
ME/GE x 100	59,11 ± 3,3	57,9 ± 1,4	55,8 ± 2,1	55,7 ± 1,5
ME/DE x 100	79,45	78,67	79,26	79,34
ME concentration (MJ/kg DM)	10,83	10,45	9,82	9,52

Table 3

Feed intake, growth and body composition of Groups 2, 3 and 4 relative to Group 1

Parameter	Slopes of the regression of Diets 2, 3 & 4 on Diet 1		
	b_2	b_3	b_4
DM intake	1,10*	1,12**	1,19**
ME intake	1,04	0,99	1,03
Body mass	0,99	1,00	0,98
Carcass mass	0,97	0,98	0,96
Body DM	0,96	0,92*	0,90*
Carcass DM	0,94	0,89*	0,92
Body protein	1,00	1,02	0,96
Carcass protein	1,00	0,99	1,00
Body fat	0,91	0,83*	0,85*
Carcass fat	0,89	0,82*	0,86*

* Slopes differ significantly from unity at $P < 0,5$

** Slopes differ significantly from unity at $P < 0,01$

Body mass did not differ between treatments and growth rate was calculated to be in the proximity of 188 g/d. Differences in carcass mass did not reach significance although all three b-values were smaller than unity. Body DM-content was significantly influenced by treated straw inclusion in the diet; Group 2 having 96%, Group 3,92% and Group 4 only 91% of the DM-content of Group 1. Carcass DM-content showed the same pattern. While there were no treatment differences in either body or carcass protein content, the fat content dropped significantly with increasing levels of treated straw in the diet. This was the case with body fat as well as with carcass fat.

Discussion

The fact that the *in vivo* digestibility of the diets was higher than originally calculated can probably be largely attributed to an underestimation of the digestibility of the maize straw fraction. This would also explain the progressive decline in digestibility of the diets with replacement of maize straw by treated wheat straw. When formulating the diets, maize straw energy was taken to be 52%. Unpublished data from our laboratory indicate that it can be even as high as 70%.

The tendency, although not significant, for increased methane production with increased inclusion of treated straw is in accordance with the following theoretical considerations: Although the digestibility of the diets was intended to be the same, and in fact did not differ substantially, it should be kept in mind that maize starch, with a high fermentation rate constant was replaced by a cellulose-hemicellulose-lignin complex. Even though the fermentation rate constant of this complex was increased by alkali treatment (Rexen & Thomsen, 1976), it would still be substantially lower than that of maize starch (Kistner, personal communication). Schwartz & Gilchrist (1975) consider fermentation rate as the most important determinant of the VFA ratio in the rumen, a high rate favouring propionate production. Propionate production in turn is associated with lower pH values in the rumen and lower methane production (De Meyer & Van Nevel, 1975). A second important aspect is the fact that increased treated straw inclusion levels in the diets were accompanied by HCO_3 addition to the rumen, which could be expected to contribute towards higher rumen pH values (Kristensen, Andersen, Stigsen, Thomsen, Andersen, Sǿrensen & Mason, 1978; Van Eenaeme, Lambot, Bienfait, Nicks & Van Nevel, 1979). Although rumen pH and VFA concentrations in the rumen were not measured in this experiment, it thus seems a fair assumption that increased inclusion levels of treated straw and decreased levels of maize favoured acetate and methane production and depressed propionate production.

Despite the tendency for increased methane production with higher levels of inclusion of treated straw, the ratio of ME to DE did not change between diets and remained fairly constant at 0,79. This can be attributed to the fact that urinary energy losses decreased with increased levels of inclusion of treated straw and so counteracted the effect of increased methane production. Wainman, Blaxter, McDonald, Dewey & Smith (1974) also noted a decrease in urinary energy when oat grain was replaced by oat husks in sheep diets.

There were no significant differences in ME-intakes between groups despite significant increases in DM-intake with increased levels of inclusion of treated straw. This can be interpreted as an indication of intake control on ME. Even though statistically not acceptable average ME-intake can be calculated by simply calculating each animal's daily ME-intake and the average for each group. According to this rough calculation daily ME-intake was between 12 and 13 MJ, which compares fabourably with *ad lib* intakes of comparable animals on high energy diets (Meissner, Roux & Hofmeyr, 1975).

Growth results of the lambs (Table 3) were in accordance with the results on digestibility and intake. Although lambs on the 4 diets grew at the same rate, body composition differed significantly between groups. Both DM and fat content of the bodies declined with increased levels of treated straw inclusion, while protein content did not differ between groups. If maintenance needs on the 4 diets were the same, which is a reasonable assumption (Blaxter, 1976) and the efficiency of ME utilization for maintenance (k_m) did not differ much (Agricultural Research Council, 1965), then efficiency of ME utilization for production (k_f) must have decreased with replacement of maize by treated straw. Decreased k_f values with lower ME-concentrations are well documented (Agricultural Research Council, 1965) but the differences in ME-concentration between the present diets were probably not large enough to explain the changes in growth composition experienced in this experiment. It seems more likely that these differences could be attributed to a possible shift in acetate: propionate ratio as already mentioned. Annison & Armstron (1970) have emphasized the importance of the presence of glucose or propionate for the efficient utilization of acetate for fattening. With the present diets there is a likelihood that with the high levels of treated straw this prerequisite of glucose/propionate could not be fully met. This would explain the present results on changes in body composition with changes in treated straw content of the diets.

It can thus be concluded that although alkali treatment markedly increases the digestibility and metabolizability of wheat straw, such treated straw cannot replace maize grain in growth diets for lambs on an equal ME-basis. This experiment emphasizes the fact that alkali treatment of wheat straw does not change it to a concentrate, but that it should still be considered as a roughage.

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