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EFFECTS OF ALKALI TREATMENT OF FORAGE AND CONCENTRATE SUPPLEMENTATION ON RUMEN DIGESTION AND FERMENTATION

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three fistulated Zebu steers (286-344 kg) were given mature *Pennisetum purpureum* forage either freshly chopped or after treatment with alkali (DM basis 3.6% NaOH + 0.9% urea mixed in 25 l water/100 kg fresh forage), each with or without 3.6 kg DM/d of concentrate (90% maize flour residue + 10% cottonseed meal) in a randomised block experimental design. Animals were also given 100 g/d minerals (dicalcium phosphate), and the animals receiving untreated forage 50 g/d salt. Forage DM intake was decreased by 31% ($P < 0.01$) due to NaOH treatment, and by 34% ($P < 0.01$) due to addition of concentrates. Rates of DM digestion (T 1/2) of 8 feeds (*Pennisetum purpureum* forage with or without 3.2% NaOH treatment, *Cenchrus ciliaris* hay, maize cobs with 0, 4 or 8 % NaOH sorghum grain and maize flour residue) were determined using nylon bags, and rumen liquid samples were taken before and at 4 h and 8 h after feeding to determine pH, ammonia and VFA concentration and proportions. The rate of rumen DM digestion was significantly different (SEM 1.4, $P < 0.05$) for each of the 8 feeds incubated in the rumen except for ground sorghum grain (T 1/2 18.2 h) and maize flour residue (T 1/2 15.0 h). NaOH treatment of the incubated feed increased rate of DM digestion of both *Pennisetum purpureum* forage (T 1/2 66.6 h and 35.7 h) and maize cobs (T 1/2 80.5, 54.5 and 28.2 h), while T 1/2 of *Cenchrus ciliaris* hay was 47.2 h. Feeding NaOH treated forage did not affect rate of DM digestion or the other measures of rumen fermentation. Feeding concentrates reduced rumen pH from pH 6.5 before feeding to pH 5.9 after feeding, reduced the proportion of acetate ($P < 0.01$), increased the proportions of propionate ($P < 0.05$) and butyrate ($P < 0.05$), and increased total VFA concentration ($P < 0.05$). Rates of DM digestion of maize cobs treated with the various levels of NaOH were reduced much more (57%) than those of the other incubated feeds (20%) in response to feeding concentrates. The results are consistant with the frequently observed depression of fibre digestion with reduction in rumen pH due to addition to the diet of readily fermentable carbohydrate, whereas NaOH treatment of dietary forage was not associated with a rumen environment detrimental for fibre digestion. Concentrate supplementation had a small but significant ($P < 0.05$) effect to increase the proportion of large particle DM in the rumen.

Key words: *Pennisetum purpureum*, alkali treatment, rumen fermentation.

Numerous experiments using feeds characteristic of temperate climates have demonstrated a depression in the rate of fibre digestion in the rumen, and of overall *in vivo* digestibility of fibre, in response to addition of readily fermentable carbohydrates to a roughage diet (McCullough 1968; Chappell and Fontenot 1968; Ørskov and Fraser 1975). With tropical diets cellulose digestibility of *Digitaria decumbens* hay was reduced by large additions of starch supplements (Fick et al 1973), and rate of rumen fibre digestion was much slower in diets based on molasses or chopped sugar cane than forage (Ørskov and Hovell 1978; Hughes-Jones and Peralta 1981). However information on the effects of addition of starch to mature forage is limited (Sastradipradja et al 1976).

Alkali treatment of low digestibility roughages to improve digestibility and nutritive value has been widely investigated, but increases in dry matter (DM) digestibility *in vivo* have frequently been less than those observed *in vitro* (Jackson 1977; Owen 1978; Escobar and Parra 1983). With sheep fed diets based on maize cobs Berger et al (1980) reported a large decrease in rate of digestion of NaOH treated cotton fibre with increasing levels of NaOH treatment of the diet, and suggested that a depression in rate of fibre digestion in the rumen was involved in the differences between in vivo and in vitro digestibilities. It is clearly of importance in developing feeding systems to understand if a similar depression in rumen fibre digestion occurs with NaOH treatment of forages.

The present experiment was undertaken to examine the effects of NaOH treatment of the forage component of the diet and of addition of concentrate containing readily fermentable starch on rate of rumen digestion of feedstuffs ranging in digestibility (including with and without NaOH treatment), and to examine the effect of these dietary treatments on rumen fermentation.

Materials and Methods

Experiment 1:

Animals, diets and management. Three mature Zebu steers (286-344 kg liveweight) were prepared with 100 mm diameter rumen cannulae and allowed 4 months for recovery from surgery. The steers were housed in partially-roofed and partially-paved individual pens, and had free access to water.

The steers were given 4 dietary treatments consisting of mature (60-65 days regrowth) *Pennisetum purpureum* forage, the same forage treated with NaOH plus urea, or each of the above diets plus 4 kg (air-dry) concentrates. For treatment of forage each 100 kg of fresh forage was manually mixed with 1 kg NaOH + 0.25 kg urea dissolved in 15-20 l water, and the mixture was stored in open piles for 24 h before being fed. Average levels of NaOH and urea treatments were 3.6% and 0.9% of forage DM, respectively. The concentrate consisted, on an air-dry basis, of 90% maize flour residue and 10% cottonseed meal. All animals received 100 g/d of minerals consisting primarly of dicalcium phosphate, and the steers receiving forage without NaOH treatment also received 50 g/d of salt. Forage was given to allow 20-40 % feed refusals, and feed offered and refused was measured daily to determine DM intake. Concentrate was offered once daily, and was consumed immediately. The steers were allocated to the 4 diets in a randomized incomplete block design of 4 periods, and in each period 10-20 days were allowed for adaptation before measurements were commenced.

Nylon bag measurements: For determination of rate of DM digestion in the rumen, a number of feedstuffs were selected to represent a range in digestibility. *Pennisetum purpureum* forage typical of that being fed was dried at 70°, or treated with NaOH for 24 h (NaOH 5.2% of DM dissolved in a quantity of water equal to 25% of the fresh weight of the forage) before drying at 70°, and grinding (Christie and Norris Laboratory Mill, 3.5 mm

screen). *Cenchrus ciliaris* hay of 30 d regrowth was prepared from a field that had received nitrogen fertilizer and irrigation, and was ground through a 4.7 mm screen in a hammer-mill (New Holland). Maize cobs were ground through a 10 mm screen in the same hammer-mill, and water alone (4 l)or 4% or 2% NaOH (DM basis) dissolved in 4 l water added to 2 kg DM of maize cobs and stored for 4 d at ambient temperature. Each 2 kg batch of maize cobs was washed (50 l water) three times and dried at 70° before being ground (Model No. 3, Wiley Mill, 2 mm screen). Ground sorghum grain and maize flour residue were also used.

The rate of DM digestion in the rumen was determined using nylon bags (Ørskov et al 1980) made from cloth with a 12 µm pore size (HS 013 Nylon Filter cloth, Henry Simon Ltd, Stockport, Cheshire, England). Duplicate bags were incubated in the rumen for 8, 24 and 48 h. Digestion at zero time was determined using bags soaked in 0.15 M NaCl for 4 h before washing. A single exponential compartment always described more than 89% of the variance, and usually more than 98% of the variance of the rate of loss of DM from the nylon bags. Half-time (T 1/2) was therefore calculated assuming a single exponential component.

- *Rumen fermentation measurements:* On the day when the nylon bag measurements were commenced, rumen digesta were obtained from the ventral sac of the rumen before the morning feed and 4 h and 8 h after the feed using a sampling tube (40 mm diameter) that could be occluded at the lower end with a conical stopper. pH was determined immediately (Model 28; Radiometer, Copenhagen, Denmark), the digesta filtered through cloth, and the resultant rumen liquid acidified (5 M H_2SO_4, pH < 4) before being stored (-5°). Ammonia in rumen liquid was determined by steam distillation (Distilling Unit 1004, Tecator, Hoganas, Sweden) under alkaline conditions with collection of the distillate into 2% (w/v) boric acid, and subsequent titration using 0.005 M H_2SO_4. Concentration and proportions of VFA in rumen liquid were determined using a gas-liquid chromatograph (Series 200, Varian, California, USA) with iso-valeric acid as an internal standard.

Rumen particle size measurements: On the last day of each experimental period 3-4 kg of rumen digesta was sampled before the morning feed by bulking grab samples obteined manually from 6-8 sites within the rumen. Particle size distribution was determined (Dixon and Mora 1983) using screens of 4.0, 2.0, 1.0, 0.5 and 0.25 mm.

Experiment 2:

Particle size distribution in rumen digesta and faeces were measured in the three steers fed the mature *Pennisetum purpureum* forage *ad libitum* plus cottonseed meal (1 kg/d), minerals and salt. After a 2 week adaptation period the majority of the faeces were collected and subsampled each day for 5 d from the concrete floors of the pens. The rumen was completely emptied commencing 6 h after the daily feed of forage, and the digesta was weighed and subsampled. Particle size distribution in rumen digesta and faeces was determined using screens of 4.0, 3.2, 2.0, 1.4, 1.0, 0.7, 0.5, 0.25 and 0.15 mm.

Statistical analisis:

The results for measurements of rumen fermentation were analysed by split-plot analysis of variance, with effects of animals, NaOH treatment, concentrate and NaOH treatment x concentrate interaction tested in the main plot, and times, and times x diets tested in the subplot (Snedecor and Cochran 1967). The results for rate of DM digestion (T 1/2) or between particle size groups were subjected to two-way analysis of variance with independent analysis of each feedstuff and each particle size group. The slopes and elevations of the linear regressiones were compared using the methods of Snedecor and Cochran (1967).

Results

The proximal analysis of the dietary untreated or alkali treated *Pennisetum purpureum* forage and of concentrate are given in Table 1. Nitrogen

Table 1:

Composition (%) of dietary components and of feedstuffs used in the nylon bags.

	DM basis							
	Dry matter	Organic matter	Total N	NDF	ADF	Lignin	Solubility of DM	OMDIV
Dietary component (Exp. 1)								
Untreated forage								
Period 1	28.3	90.8	0.83	73.8				
Period 2	29.2	90.1	9.99	73.6				
3	31.4	87.8	0.99	73.2				
4	21.2	83.5	1.17	70.5				
$\bar{x}$	27.5	88.0	1.00	72.8				
NaOH treated forage								
Period 1	21.1	88.5	1.23	75.2				
2	27.3	88.7	1.21	72.5				
3	27.1	79.2	1.34	70.4				
4	22.5	83.7	1.31	70.0				
$\bar{x}$	24.5	85.0	1.27	72.0				
Concentrate	88.8	97.0	2.34					
Feedstuffs in the nylon bags:								
Cenchrus ciliaris	91.7	89.0	1.47	75.0	50.1	9.3	19.7	46.5
Pennisetum purpureum	95.4	86.4	1.40	78.4	57.0	12.8	16.5	35.3
P. purpureum + 5% NaOH	96.0	83.6	1.29	70.1	53.6	11.6	23.7	48.7
Maize cobs *	94.2	98.4	0.39	94.9	53.1	12.7	5.3	31.1
Maize cobs + 4% NaOH *	97.0	97.4	0.41	93.3	57.6	13.7	8.2	37.2
Maize cobs + 8% NaOH *	96.9	96.0	0.32	87.6	61.1	12.7	13.2	58.2
Sorghum grain	88.7	97.8	1.54	22.9	7.0	2.9	43.0	86.2
Maize flour residue	89.1	98.2	1.80	22.6	6.7	2.5	44.8	80.9

NDF: Neutral detergent fibre; ADF: Acid detergent fibre; Solubility of DM: determined using nylon bags soaked in 0.15 M NaCl; OMDIV: Organic matter digestibility *in vitro*.

* Washed after NaOH treatment.

content of the forage was increased from 1.00% to 1.27% due to treatment with 0.9% urea. Hence 35% of the added urea N was lost by volatilization either during storage following treatment or during drying of the samples.

The proximal analysis of the various feedstuffs incubated in nylon bags to determine rate of rumen DM digestion are also given Table 1. Amongst the forage materials neutral detergent fibre ranged from 70.1% to 94.9%, acid detergent fibre from 50.1 to 61.1 % and *in vitro* organic matter digestibility from 31.1% (untreated maize cobs) to 58.2% (maize cobs + 8% NaOH).

Table 2 gives the intake of forage, concentrate and total DM. Intake of forage was decreased ($P < 0.01$) by 31% due to NaOH treatment. Although forage intake was decreased by 34% ($P < 0.01$) due to addition of concentrates, total DM intake was increased ($P < 0.01$) by 32% such that forage constituted only 56% and 44% of total DM intake with untreated and alkali treated forage respectively.

Table 2:

Intake and rate of rumen DM digestion determined using nylon bags in 3 steers fed forage with or without alkali treatment and with or without concentrate.

	No concentrate		With concentrate		SEM	Significance		
	Forage	Forage + NaOH	Forage	Forage + NaOH		NaOH	Concentrate	Interaction
Intake forage DM (kg/d)	6.3	4.7	4.5	2.8	0.3	**	**	NS
Intake concentrate DM (kg/d)	0.0	0.0	3.6	3.6	-	-	-	-
Intake total DM (kg/d)	6.3	4.7	8.1	6.4	0.3	**	**	NS
T 1/2 DM digestion (h)								
Cenchrus ciliaris	43	42	47	57	2.0	NS	*	NS
Pennisetum purpureum	63	60	73	71	2.2	NS	*	NS
Pennisetum purpureum + NaOH	35	31	36	40	0.9	NS	**	NS
Maize cobs	68	63	98	94	3.8	NS	**	NS
Maize cobs + 4% NaOH	46	41	61	69	1.8	NS	**	NS
Maize cobs + 8% NaOH	22	19	34	38	1.0	NS	**	NS
Sorghum grain	16	17	18	23	0.7	*	**	NS
Maize flour residue	15	12	15	18	0.4	NS	**	NS

Between feeds **; SEM 1.4

The rates of DM digestion (T 1/2) of the various feeds when incubated in the rumen are also given in Table 2. There were significant differences ($P < 0.05$) between each of the feeds with the exception of ground sorghum grain and maize flour residue which were not significantly ($P > 0.05$) different. On average over all dietary treatments, 5.2% NaOH treatment of the *Pennisetum purpureum* forage decreased T 1/2 from 66.6 h to 35.7 h, while NaOH treatment of maize cobs decreased T 1/2 of DM digestion from 80.5 h (0% NaOH) to 54.4 h (4% NaOH) to 28.2 h (8% NaOH). Rate of DM

digestion of *Cenchrus ciliaris* hay (T 1/2 47.2 h) was intermediate between untreated and NaOH treated *Pennisetum purpureum*, while rate of DM digestion of ground sorghum grain (18.2 h) and maize flour residue (15.0 h) was relatively rapid. The solubility of DM at zero time (Table 1) was 16.5-23.7 % for the forages, and 43.0% and 44.8% for the concentrates. The solubility at zero time of the maize cob DM (5.3-13.2 %) was low presumably due to the removal of solubles during the washing procedures following the NaOH treatment.

Although there was no significant effect ($P > 0.05$), there was some tendency for rate of DM digestion to increase in the absence of concentrates and to decrease in the presence of concentrates due to the alkali treatment of the dietary forage (Table 2). The addition of concentrate to the diet resulted in a large and significant ($P < 0.05$ or $P < 0.01$) decrease in the rate of DM digestion with all the feedstuffs incubated in the rumen. When the relationship between this increase in T 1/2 of rate of rumen DM digestion and the T 1/2 of rumen DM digestion in the absence of concentrate was examined (Figure 1), there were separate relationships for maize cobs with 0, 4 or 8% NaOH and for the other feedstuffs.
significantly different in both slope ($P < 0.05$) and elevation ($P < 0.01$).

Measurements of rumen fermentation are given in Table 3. pH was significantly depressed due to consumption of concentrate 4 h ($P < 0.05$) and 8 h ($P < 0.01$) after the concentrate was offered but was not affected by diet before the daily feed at 0 h, or by the NaOH treatment of the dietary forage. Concentration of rumen ammonia was not affected by dietary treatment, but was significantly greater ($P < 0.05$) 4 h after feeding than before feeding, and was significantly less ($P < 0.05$) 8 h after feeding than before feeding. In steers given concentrate, concentration of total VFA was significantly greater ($P < 0.05$) 4 h and 8 h after feeding than before feeding. The proportion of acetate was significantly ($P < 0.01$) decreased from 74% in steers given forage alone to 69% in steers given forage plus concentrate, and was also significantly ($P < 0.05$) less 4 h and 8 h after feeding (71%) than before feeding (72%). The proportion of propionate was significantly ($P < 0.05$) increased by concentrate supplementation from 16% to 19%, and the proportion of butyrate was significantly ($P < 0.05$) increased from 10% to 13%. The proportions of the VFA were not significantly affected by alkali treatment of the consumed forage.

The particle size distributions in the rumen digesta of the steers when fed the 4 diets used in Experiment 1, and of the rumen digesta and faeces from Experiment 2 are given in Tables 4 and 5 respectively. In Experiment 2 the intake of forage was 6.10 ± SE 0.10 kg DM/d, and the weight of rumen digesta was 7.32 ± SE 0.31 kg DM. The particle size distribution of rumen digesta in Experiment 2 where the rumen was emptied completely was very similar to the particle size distribution in Experiment 1. Within Experiment 1 there was an effect of supplementation with concentrate to increase ($P < 0.05$) the proportion of total DM retained by the 4.00 mm screen from 43.6% to 47.8%, and to reduce ($P < 0.01$) the proportions of total DM in the 0.5 - 1.0 mm screen and 0.25 - 0.5 mm screen particle size groups.

Table 3:

Parameters of rumen fermentation in 3 steers fed forage with or without alkali treatment and with or without concentrates.

	Time after feeding (h)	Forage	Forage + NaOH	With concentrate: Forage	With concentrate: Forage + NaOH	SEM	Significance: NaOH	Significance: Concentrate	Significance: Interaction
pH	0	6.7	6.5	6.6	6.7	0.13	NS	NS	NS
	4	6.5	6.5	5.8	6.0	0.13	NS	*	NS
	8	6.6	6.6	5.9	5.8	0.13	NS	**	NS
		Between times **, SEM 0.03							
Ammonia (mg N/l)	0	83	79	77	79				
	4	93	87	80	112	11.5	NS	NS	NS
	8	56	70	54	59				
		Between times **, SEM 6.4							
Total VFA (mM/l)	0	73	86	72	65				
	4	72	72	95	87	3.0	NS	NS	NS
	8	56	69	92	95				
		Between times *, SEM 1.9							
Acetate (%)	0	74	73	70	70				
	4	73	74	67	67	0.6	NS	**	NS
	8	72	75	68	67				
		Between times *, SEM 0.4							
Propionate (%)	0	16	17	20	19				
	4	17	17	20	20	0.9	NS	*	NS
	8	17	17	19	20				
		Between times NS, SEM 0.3							
Butyrate	0	10	9	10	11				
	4	10	9	13	13	0.8	NS	*	NS
	8	11	8	13	14				
		Between times NS, SEM 0.4							
Non-gluconeogenic ratio (*)		5.9	5.6	5.5	4.8	0.3	NS	NS	NS

* Calculated as described by Ørskov (1975).

Discussion

The 31% reduction on forage DM intake in response to alkali treatment is in contrast to most experiments where DM intake has been increased by treatment with alkali at levels similar to that used in the present experiment (Jackson 1977; Escobar and Parra 1983) Furthermore in another similar experiment 5% NaOH treatment of similar *Pennisetum purpureum* forage reduced forage intake by 32% in growing heifers (Castillo et al 1983).

Table 4:

Experiment 1. Particle size distribution (%) in the rumen digesta of 3 steers fed forage with or without alkali treatment or with and without concentrates.

Particle size group	No concentrate		With concentrate		SEM	Significance		
	Forage	Forage + NaOH	Forage	Forage + NaOH		NaOH	Concentrate	Interaction
Screen: >4.0 mm	42.0	45.1	46.3	49.3	1.62	NS	*	NS
2.0-4.0 mm	7.2	6.3	6.6	5.5	0.57	NS	NS	NS
1.0-2.0 mm	10.1	8.0	8.5	8.6	0.60	NS	NS	NS
0.5-1.0 mm	7.6	6.4	4.9	5.0	0.37	NS	**	NS
0.25-0.5 mm	5.8	5.1	4.5	3.8	0.23	*	**	NS
<0.25 mm	27.4	29.2	29.2	28.0	1.14	NS	NS	NS

Table 5:

Experiment 2. Particle size distribution (%) in the rumen digesta and faeces of 3 steers fed Pennisetum purpureum forage plus 1 kg/d cottonseed meal.

Particle size group	Rumen (mean ± SE)	Faeces (mean ± SE)
>4.00 mm	44.8 ± 1.5	0.0 ± 0.0
3.2-4.0 mm	2.9 ± 0.1	1.9 ± 0.6
2.0-3.2 mm	2.8 ± 0.9	2.6 ± 0.4
1.4-2.0 mm	6.5 ± 0.7	6.8 ± 0.9
1.0-1.4 mm	4.8 ± 0.6	8.3 ± 0.5
0.7-1.0 mm	3.4 ± 0.2	10.1 ± 0.3
0.5-0.7 mm	3.6 ± 0.6	10.5 ± 1.3
0.25-0.5 mm	5.3 ± 0.3	15.8 ± 0.6
0.15-0.25 mm	2.6 ± 0.1	7.8 ± 0.1
<0.15 mm	23.5 ± 1.1	36.4 ± 0.7

Consequently it appears that alkali treatment is not a satisfactory method of increasing digestible energy intake of freshly chopped mature tropical forage despite a substantial increase in digestibility in both the present experiment and other experiments (Dixon and Escobar, 1983).

The supplementation at level of 1.1% of liveweight of *Pennisetum purpureum* forage with a concentrate which consisted primarly of maize flour residue considerably reduced the rate of DM digestion in the rumen of the fibrous materials. The observation that 45% of maize flour residue was soluble in 0.15 M NaCl, and that there was a rapid disappearance or the residual DM when incubated in nylon bags in the rumen (mean T 1/2 15 h) indicates that the concentrate was rapidly fermented in the rumen.

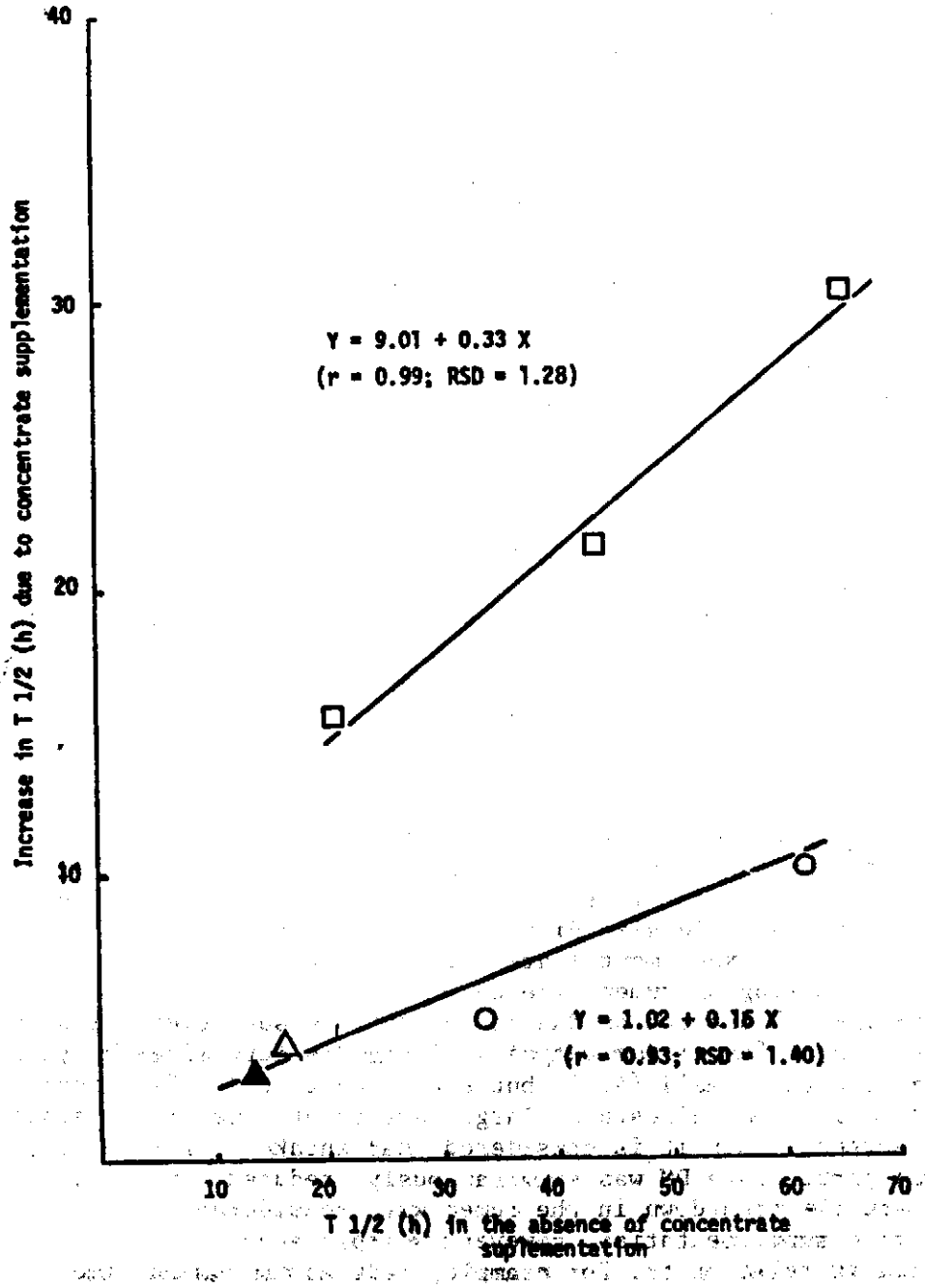
Rapid fermentation of the concentrate is also indicated by the decrease in ruminal pH from pH 6.5-6.7 before feeding, to pH 5.8-6.0 4 h and 8 h after consumption of the concentrate by steers. It is well established that rumen cellulose digestion is severely inhibited when pH approaches or is less than pH 6.0 (Terry et al 1969; Stewart 1977), and thereby rate of rumen digestion of fibrous materials and intake of forage may be reduced (Ørskov and Fraser 1975; Ørskov et al 1978). In the present experiment the addition of concentrate to the diet was associated with a reduction in the rate of rumen DM digestion by 17% and 14% for untreated and alkali treated *Pennisetum purpureum* forage respectively, and with a 34% decrease in forage DM intake.

Figure 1 indicates that the dietary concentrate of the type and at the level used in the present experiment on average depressed the rate of DM digestion of *Pennisetum purpureum* (with or without NaOH treatment), *Cenchrus ciliaris* and concentrate by approximately 20%. The 17 depression in T 1/2 of *Pennisetum purpureum* agrees closely with a 20% decline in 48 h nylon bag digestion of *Imperata cylindrica* forage due to a similar level of supplementation with cassava meal (Sastradipradja et al 1976). The relationship also indicates that the slower the rate of DM digestion of a feedstuff, the greater the reduction in absolute terms of the rate of DM digestion due to concentrate supplementation. This agrees with previous studies both *in vitro* (McCullough 1968; Monagas and Parra, unpublished results) and *in vivo* (Herrera et al 1981; Encarnación and Hughes-Jones 1981) where the reduction in DM digestion due to the addition of dietary concentrates was greater for fibre of low digestibility than high digestibility.

The much larger depression in rate of DM digestion of maize cobs (on average an increase in T 1/2 of 57%) than of the other feedstuffs, and the significantly different regression of increase in T 1/2 due to concentrates and the rate of digestion in the absence of concentrates (Figure 1) demonstrates that the maize cobs behaved differently from the other feedstuffs in response to the addition of readily fermentable carbohydrate to the diet. Perhaps the greater depression of DM digestion with maize cobs than with the other feedstuffs examined may be associated with the purified nature of the washed maize cobs as a microbial substrate. The important role in the digestion of plant cell wall materials of the microorganisms closely associated with the feed particles is recognised (Cheng and Costerton 1980). Such microorganisms digesting forages could presumably obtain at least some of their nutrient requirements (e.g.: nitrogen, sulphur, minerals and vitamins) directly from the feed material being digested, whereas the microorganisms digesting the maize cobs are likely to be more dependent on rumen liquid as a source of these nutrients. If concentrations of such nutrients in rumen liquid are reduced due to their rapid utilization by the microorganisms digesting the additional dietary readily fermentable carbohydrate, then digestion of materials such as the maize cobs could be reduced more than the digestion of other forages. In the present experiment the concentration of ammonia N in rumen liquid was similar for all of the dietary treatments (Table 3), and therefore changes in the rate of DM digestion due to the supplementation with readily fermentable carbohydrate

Figure 1:

The relationship between T 1/2 (h) of rumen DM digestion in the absence of concentrates and the increase in T 1/2 (h) due to concentrate supplementation for Pennisetum purpureum *with or without NaOH treatment* (o), Cenchrus ciliaris (●), *ground sorghum grain* (Δ), *maize flour residue* (▲), *or maize cobs treated with 0, 4 or 8% NaOH* (□).



were not likely to be associated with changes in the availibility of ammonia N for microbial synthesis. Furthermore the concentration of ammonia N in rumen liquid was probably sufficient to meet the requirements of microbes for growth (Satter and Roffler 1977). However the requirements for all other microbial nutrients may not have been met. This observation of a greater reduction in DM digestion of maize cobs than forage is consistant with other observations that the nylon bag digestion of NaOH treated maize cobs was decreased much more by concentrate supplementation than the digestion of *Pennisetum purpureum* forage (Romero et al 1983). Furthermore in the experiment of Herrera et al (1981) the T 1/2 of sisal pulp (which contains low concentrations of many nutrients) was increased much more (from 28 h to 114 h) due to the addition to the diet of 1.6% liveweight of molasses DM, but the T 1/2 of *Leucaena leucocephala* forage and sunflower meal were increased by only 20% and 22% respectively.

Conclusion

The absence of an effect of alkali treatment of dietary forage on rate of rumen DM digestion of the fibrous feeds examined is in contrast with the study of Berger et al (1980). In the latter experiment using diets based on maize cobs increasing levels of NaOH treatment resulted in a linear decrease in rate of digestion of NaOH treated cotton fibre measured using nylon bags; a 5% NaOH treatment resulted in a 40% depression in rate of DM digestion. Perhaps diets based on maize cobs are exceptional, since 5% NaOH treatment increases the proportion of soluble DM much more (e.g.: 15%; A. Escobar, unpublished results) than the 7% increase in this fraction with NaOH treatment of *Pennisetum purpureum*. Rapid fermentation of soluble DM could be expected to have a similar effect to the fermentation of starch to depress rumen fibre digestion. The absence of an interaction between alkali treatment of forage and concentrate supplementation on rumen digestion of fibre is in agreement with experiments where the depression *in vivo* crude fibre digestibility in cattle due to addition of dietary concentrates was similar for untreated or ammonia-treated straw (Horton 1978; Horton and Steacy 1979)

The observation with steers fed *Pennisetum purpureum* forage alone that the particle size distribution in rumen digesta when the rumen was emptied completely (Experiment 2) was similar to that when grab samples were taken from various parts of the rumen (Experiment 1) suggests that the latter sampling method did not introduce excessive error in the estimation of rumen digesta particle size distribution. Consequently the differences between diets in Experiment 1 are not likely to be associated with the method of sampling of rumen digesta.

The 15-17 % depression due to concentrate supplementation in the rate of digestion of *Pennisetum purpureum* forage as determined in nylon bags was associated with a small (4.2%) but significant ($P < 0.05$) increase in the proportion in rumen digesta of large particulate material retained by the 4.0 mm screen. When it is considered that intake of forage, and therefore of large particulate DM was simultaneously reduced by 34%, the rate of large particle breakdown in the rumen was considerably reduced by the concentrate supplementation. However the importance of the reduced microbial digestion in relation to, for example, reduced rumination time is not known.

The absence of a change in the proportions of rumen VFA in response to alkali treatment of the dietary forage is consistent with previous observations with sheep given NaOH treated *Pennisetum purpureum Canavalia ensiformis* forage (Dixon et al 1983), and observations with ammonia-treated straw (Horton 1978) and NaOH treated straw (Coombe et al 1979). The decrease in acetate and the increase in propionate and butyrate in response to dietary concentrate is in agreement with numerous previous reports on the effects of supplementation of forage with concentrate (Church 1979), even when the forage has been treated with alkali (Horton 1978). It is perhaps of interest that the non-gluconeogenic ratio of the VFA products (Ørskov 1975) in the present experiment was greater than 4.8 in all diets. In the absence of alternative gluconeogenic precursors growing animals might therefore be expected to have an efficiency of utilization of metabolizable energy for gain similar for untreated and alkali treated forage, and an efficiency less than that usually observed in animals fed high-starch diets.

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