INTAKE, RUMEN LIQUID FLOW RATES AND FERMENTATION IN BULLS FED SISAL PULP SUPPLEMENTED WITH LEUCAENA FORAGE, PASTURE OR RICE POLISHINGS

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Supplementation of ensiled sisal pulp with several levels of leucaena forage, with pasture or with rice polishings increased DM intake by bulls, but the supplements did not increase the intake of pulp. The increase in intake was associated with a tendency (non-aignificant) for increased flow of liquid from the rumen with supplementation at the 1% and 2% levels of leucaena forage (from 54 to 73 1/d) and with pasture (from 64 to 76 1/d). This apparent increase in flow was associated with increases in both rumen volume and rumen dilution rate. There was no such tendency for flow to be greater than that of the basal sisal pulp diet when the leucaena supplement was fed at the 3% level with either ad libitum pulp or restricted pulp. The increase in intake was not related to changes in rumen VFA concentration.

Key words: Cattle, sisal pulp, leucaena, rumen kinetics, VFA

The production of sisal fibre from Agave fourcroydes is an industry of considerable importance to the economy of the Yucatan peninsula of Mexico, as well as in Kenya, Brazil and Tanzania, Processing of this plant for fibre production also yields large quantities of pulp or bagasse which are usually discarded. Utilization of this byproduct for animal production is potentially of considerable benefit to both the sisal and cattle industries in Yucatan and elsewhere.

It has been shown that sisal pulp supplemented with urea, although having a dry matter digestibility of 53-55%, will only support maintenance of cattle (Ferreiro et al 1979; Godoy et al 1979). However, moderate growth rate and lactational responses have been obtained by these workers and also by others (Herrera et al 1979) to supplements of fishmeal, ramon, (*Brosimum alicastrum*), leucaena and *Cynodon dactylon* pasture. Preliminary work (Ferreiro et al 1978) suggested that there were major changes in liquid flow rate from the rumen in response to supplements of pasture or concentrates but some later experiments (Priego et al 1979ab) have not found similar changes. In general the importance of changes in rumen fermentation and volume and retention time of digesta components in the rumen which may occur in response to these supplements are poorly understood.

The following experiments were undertaken to examine the influence of supplements of fresh *Leucaena leucocephala* forage in Experiment 1, or of rice polishings or fresh pasture (*Cenchus ciliaris*) in Experiment 2, on fermentation in the rumen and the flow of liquid from the rumen.

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Materials and Methods

Experiment 1: Zebu-Brown Swiss cross bulls (148, 166, 223, 262 kg initially) prepared with permanent rumen cannulas were housed in single pens with slatted flooring in an open-sided shed. The bulls were fed sisal pulp ad libitum and were given Leucaena leucocephala forage at 0%, 1%, 2%, or 3% (fresh weight) of the liveweight of the animal. The sisal pulp was similar to that described by Ferreiro et al (1979), and was ensiled for 2-7 d before being fed. Mature growth of *Leucaena leucocephala* was cut each morning from roadsides near the Research Station and only the leaves and small twigs (up to approximately 5 mm diameter) were fed. Water was freely available to the animals. Following a Latin square of four periods with each of the above treatments, each bull was fed a restricted amount of sisal pulp (2.5% liveweight) and 3% liveweight *Leucaena leucocephala* forage (fresh weight basis). At least 8 d were allowed for the bulls to adapt to dietary changes before measurements were made over 24 hours. All diets were supplemented with aqueous urea solution (3.5 g urea/kg fresh pulp) and 100 g/d of salt-mineral mixture (50% salt, 47% rock phosphate, 3% trace minerals). Feed refusals were weighed daily at 10:00 am, when supplements and fresh pulp were also offered.

Experiment 2: Three bulls (2 Zebu-Brown Swiss, 1 Zebu) weighing initially 177, 185 and 144 kg were each prepared with cannulas in the rumen and duodenum, and housed as described above. The bulls were fed sisal pulp silage ad libitum and were supplemented in consecutive periods with 5 kg/t of freshly cut pasture (*Cenchus ciliaris*), with 1 kg/d of rice polishings, with both pasture and rice polishings or were given no supplement. Feed, water, urea and minerals were offered as in Experiment 1

Measurements: A single injection of ^{51}Cr-EDTA (100 μCi with Cr-EDTA carrier) in 500 ml of water was dosed into the rumen immediately before supplements were offered in the morning, and was distributed through the rumen contents with the aid of rigid plastic tubing, Samples of rumen fluid were obtained by suction through a nylon-gauze covered metal cage 1 hr before feeding and 6-8 times during the 24 hr following feeding, and were immediately acidified. Samples of rumen fluid were analysed for ^{51}Cr-EDTA using a Nuclear Enterprises (Model 8312) gamma counter. During one period of Experiment 1 it was necessary to use polyethylene glycol as a marker, and this was analysed by the method of Malawar and Powell (1967).

Dry matter (DM) of dietary constituents was determined during each experimental period by drying 500 g subsamples for 48 hr at 100°C. Dried samples were ground before subsamples were ashed at 500°C for 8 hr to determine organic matter. Total nitrogen wan determined by Kjeldahl oxidation procedures. Volatile fatty acids (VFA) concentrations and proportions in the rumen fluid were determined in acidified samples obtained 1 hr before feeding and 6 hr after feeding using the methods described by Rowe et al (1979).

Calculations: When the change in in marker concentration was plotted against time of sampling after the initial injection of marker a linear relationship was obtained, indicating that first-order kinetics were approximated. The dilution rate was calculated from the slope of the least squares regression of the line described above, the volume of the rumen was calculated from the zero-time intercept, and the flow of water from the rumen as the product of the volume and the rate constant (Shipley and Clarke 1972).

Statistical comparisons were made using analysis of variance. Since there were was no significant difference between the four periods of the Latin square in Experiment 1, comparisons were made between the five treatments using a pooled error mean square.

Results

The composition of the dietary components fed during both experiments are given in Table 1. Although a number of batches of ensiled sisal pulp were used, and leucaena was cut over an 8 week period, the standard errors indicate that the change in composition of measured dietary components during the experiment was small.

Table 1:

Analysis of feed constituents used in Experiment 1 and 2 (mean ±SE). Subsamples were analysed from each experimental period.

	DM%	DM basis: % Organic matter	DM basis: % Crude protein	DM basis: % Crude fibre
Sisal pulp	20.2 ± .8	89.1 ± .8	6.2 ± .4	28.0 ± .7
Leucaena	31.2 ± 1.3	94.1 ± .3	23.9 ± .4	21.6 ±1.5
Pasture	36.9	93.0	17.6	35.8
Rice polishings	86.0	92.0	14.4	10.7

Table 2:

Measurements of DM intake and of rumen liquid kinetics of bulls fed ad libitum ensiled sisal pulp supplemented with increasing levels of leucaena forage or with restricted pulp intake in experiment 1

	Leucaena forage, % of body weight: 0	1	2	3	3.0[1/]	$SE_{\bar{x}}$	Significance
Intake							
Pulp, kg/d[2]	2.90[a]	3.31[a]	3.01[a]	3.49[a]	1.09[b]	.280	.005
Leucaena, kg/d	0.0	0.60	1.20	1.81	2.14	-	-
Total, kg/d[3]	2.90	3.91[a]	4.21[a]	5.30[b]	3.23[a]	.373	.004
Rumen kinetics							
Volume, litres	32.1	35.4	39.2	36.0	34.5	2.60	0.45
Dilution rate,/d	1.69	1.83	1.85	1.72	1.69	.105	.70
Flow, litres	53.6	65.7	72.5	61.5	58.6	5.35	0.19

[1] On this treatment the pulp was restricted to 2.5% of body weight (fresh basis)

[2] Mean daily intake over 7 days

[3] Does not include minerals or urea

The intakes of dietary components and the measurements of rumen fluid kinetics for Experiment 1 are given in Table 2. Intake of sisal pulp when offered ad libitum did not change with leucaena supplementation, and was 2.9 - 3.5 kg DM/d. Consequently there was an increase in total DM intake from 2.9 to 5.3 kg DM/d as the level of leucaena supplementation was increased. Liquid flow rates from the rumen were increased from 53.6 l/d on the pulp alone diet to 65.7 l/d and 72.5 l/d respectively for the 1% and 2% levels of supplementation (Table 2). However there was no such tendency for the 32 level of leucaena with ad libitum pulp where liquid flow was 61.5 l/d, or for this level of leucaena with restricted pulp where it was 58.6 1/d (Table 2). Table 3 gives the intakes of dietary components and rumen fluid kinetics for Experiment 2.

Table 3:

Measurements of DM intake and rumen liquid kinetics of bulls supplemented with pasture (P) or rice polishings (RP) in Experiment 2

	Pulp alone	Pulp +P	Pulp +RP	Pulp +RP +P	Pooled SE$_{\bar{x}}$	Significance P	RP	Interaction
Intake								
Pulp, kg/d[1]	3.93	3.34	3.54	2.74	.209	.01	.05	.64
Supplements, kg/d	0	1.77	.86	2.77	-	-	-	-
Total[2]	3.94	5.11	4.40	5.51	.209	.002	.08	.89
Rumen kinetics								
Volume, litres	34.5	37.7	-	-	1.67	.31	-	-
Dilution rate,/d	1.84	2.03	1.86	-	.045	.10	-	-
Flow, litres/d	63.5	76.3	-	-	4.73	.19	-	-

1 Mean daily intake over 7 days

2 Total intake does not include minerals or urea

Since there was no significant interaction between the two supplements, the following comments were based on the means of the two treatments with or without each supplement. The pasture supplement significantly (P=.015) decreased the ad libitum pulp intake but because of the intake of 1.8 kg of pasture, total DM intake increased significantly (P=.002). Addition of the rice polishings tended to decrease pulp intake (P=.054) but the total DM intake tended to increase (P=.085). The results for rumen liquid kinetics were incomplete and it was only possible to examine the effects of pasture supplementation. There was an increase in dilution rate from 1.84 to 2.03 d^{-1} (P=.10), and since rumen volume did not change, this resulted in a tendency for flow from the rumen to increase from 64 1/d to 76 1/d. The dilution rate in response to supplementation with rice polishings was similar to that on the basal diet (1.86 and 1.84 d^{-1}) although this was not included in the statistical analysis.

Table 4 gives the concentrations and proportions of VFA before feeding and 6 hrs after feeding for each of the dietary treatments.

Table 4:

Mean total VFA concentrations and proportions (Ac = acetate, Pr = propionate, Bu = butyrate, Val = valerate) in rumen fluid with supplements of leucaena (L) in Experiment 1 or with pasture (P) and/or rice polishings (RP) in Experiment 2

Treatment	Sampling time (hr)	Total (m-mol/litre	Molar proportions (%) Ac	Pr	Bu	Val
Experiment 1						
Pulp & 0% L	0	150	68	22	9	1
	6	194	63	25	11	2
Pulp & 1% L	0	116	70	21	7	1
	6	136	70	20	9	1
Pulp & 2% L	0	95	73	20	6	2
	6	-	68	23	7	2
Pulp & 3% L	0	91	74	18	8	1
	6	180	74	18	6	1
Experiment 2						
Pulp alone	0	104	68	22	9	1
	6	-	62	26	10	1
Pulp + P	0	171	70	22	7	1
	6	102	71	20	8	1
Pulp +P +RP	0	102	73	17	8	1
	6	178	69	20	10	1

Total VFA concentration did not increase with supplementation even though organic matter digestion and VFA production in the rumen were presumably greater at the higher level of DM intake. There appeared to be an increase in proportion of acetate and a decrease in proportion of propionate with increasing levels of all of the supplements.

Discussion

There was an increase in total DM intake by the bulls with all the supplements fed in these experiments. However, this increase was due to consumption of supplement per se, rather than due to stimulation of intake of sisal pulp. This additive effect is similar to that observed in most previous experiments where pasture, leucaena forage, ramon forage, concentrates or rice polishings were used to supplement sisal pulp (Ferreiro et al 1978, 1979; Herrera et al 1979; Priego and Vargas 1979; Priego et al 1979). Supplementation with sorghum or fishmeal by Godoy et al (1979) appears to be the only experiment where stimulation of pulp intake was achieved.

The increase in total DM intake due to the supplement has important implications for increasing productivity in cattle fed diets based on sisal pulp, since digestible energy intake and therefore presumably productivity have been increased by the forage supplement, However, at some point addition of a particular supplement must result in no increase in digestible energy intake due to depression of the intake of basal diet. The decrease in pulp intake with the consumption of 1.8 kg DM/d of the pasture supplement suggested that this limit was being approached in the present experiment for pasture supplement. However the absence of any depression of pulp intake with the highest level of leucaena supplement (1.8 kg DM/d) suggests that leucaena may be of greater value than pasture for increasing DM intake. The risk of mimosine toxicity (see Meulen et al 1979) would probably preclude leucaena supplementation at levels greater than that used in the present experiment, but combinations of leucaena with other forages may be successful, There are limited data on supplementation of sisal pulp with forages, but experiments with chopped sugar cane as a basal diet suggest that the above increase in total DM intake may not occur with all forages. Sweet potato forage has had an additive effect (Meyreles and Preston 1978a; Meyreles et al 1979), but cassava and banana forage have tended to have a substitution effect (Meyreles et al 1977; Meyreles and Preston 1978b) on intake of sugar cane. Further experimentation is obviously required with sisal pulp as a basal diet to determine when additive effects occur, and to what extent a particular forage can be used to supplement sisal pulp in order to maximize digestible energy intake.

In sheep fed temperate forages increased feed intake has been associated with increases in both rumen volume and rumen liquid dilution rate (Grovum and Williams 1977). In cattle fed sisal pulp the tendency for rumen liquid flow to increase with the 1% and 2% levels of leucaena supplements, with pasture supplement in Experiment 2, and also in the experiment of Ferreiro et al (1978), is consistent with this observation. An increase in rumen liquid flow was also observed by Priego and Vargas (1979) in response to supplements of rice polishings or ramon forage. In view of the importance of rumen fill, and of rumen dilution rate in influencing efficiency of microbial synthesis and time available for substrate fermentation, further experimentation is obviously of interest.

References

Ferreiro H M, Elliott R, Rios V 6 Preston T R 1978 Rumen function and fermentation on sisal pulp based diets Tropical Animal Production 3:69-73

Ferreiro H M, Preston T R & Herrera F 1979 Sisal byproducts as cattle feed: Effect of supplementing ensiled pulp with rice polishings and ramon (Brosimum alicastrum) On growth rate , digestibility and glucose entry rate by cattle Tropical Animal Production 4:73-77

Godoy R, Elliott R & Preston T R 1979 Byproducts of the sisal industry as cattle feed: Effect of ground sorghum, fishmeal or rice polishings in cattle given diets based on sisal bagasse and ensiled sisal pulp Tropical Animal Production 4:276-280

Grovum W L & Williams V J 1977 Rate of passage of digesta in sheep 6. The effect of level of food intake on mathematical predictions of the kinetics of digesta in the reticulo-rumen and intestines British Journal of Nutrition 38:425-436

Herrera F, Ferreiro H M & Wyllie D 1979 Effect of different levels of Leucaena leucocephala on digestibility and performance of cattle fed ensiled henequen pulp Tropical Animal Production 4:100 abs

Malawar S J & Powell D W 1967 Improved turbidimetric analysis of polyethilene glucol utilising

Meulen U ter, Shruck S, Shulke E & El Harith E A 1979 A review on the nutritive value and toxic aspects of *Leucaena leucocephala* Tropical Animal Production 4:113-126

Meyreles Luz & Preston T R 1978a Sweet potato forage as cattle feed: Effect on voluntary intake of different amounts added to a basal diet of chopped sugar cane stalk Tropical Animal Production 3:224-228

Meyreles Luz & Preston T R 1978b The banana-plant as cattle feed: Effect of different levels of banana leaves on voluntary intake of chopped sugar cane stalk Tropical Animal Production 3:229-233

Meyreles Luz, Rowe J B & Preston T R 1979 The effect on the performance of fattening bulls of supplementing a basal diet of derinded sugar cane stalk with urea, sweet potato forage and cottonseed meal Tropical Animal Production 4:255-262

Priego A & Vargas J 1979 Pattern of feed intake and rumination in cattle fed diets of henequen pulp supplemented with ramon forage and rice polishings Tropical Animal Production 4:104 abs

Priego A, Dixon R M, Elliott R & Preston T R 1979a Studies on the digestion in the forestomachs of cattle of a diet based on sisal pulp: 1. Supplementation with *Leucaena leucocephala* and rice polishings Tropical Animal Production 4:281-286

Priego A, Elliott R & Preston T R 1979b Studies on the digestion in the forestomachs of cattle of a diet based on sisal pulp: 2. Supplementation with Ramon (*Brosimum alicastrum*) forage and rice polishings Tropical Animal Production 4:287-291

Rowe J B, Bobadilla Milagros, Fernandez Angela, Encarnacion J C & Preston T R 1979 Molasses toxicity in cattle: Rumen fermentation and blood glucose entry rates associated with this condition Tropical Animal Production 4:78-89

Shipley R A & Clarke R E 1972 In: Tracer Methods for In Vivo Kinetics. New York and London: Academic Press.

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