EFFECT OF TROPICAL FORAGES ON RUMEN FUNCTION AND FLOW OF NUTRIENTS TO THE PROXIMAL DUODENUM IN CATTLE FED A MOLASSES/UREA DIET[1]

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In a latin square design experiment, the relationship between rumen degradation, rumen function and flow rates of nutrients to the proximal duodenum were determined in cattle fed molasses/urea ad libitum and restricted amounts (0.5 kg DM/100 kg LW) of 5 tropical forages: sweet potato (*Ipomea batata*), cassava (*Manihot esculenta*), leucaena (*Leucaena leucocephala*), banana leaves (*Musa acuminata*) or sugar cane tops (*Saccharum officinarum*). Urea was added above that present in the molasses/urea mixture to ensure the forage components were iso-nitrogenous. All the animals received 300 g/d fishmeal and 50 g/d of a commercial mineral mixture. The protein content of the forage was negatively correlated with the percentage of cell wall components (r^2 = .72). The half life for the degradation of forage in the rumen was positively related to the acid detergent fraction of the forage (r^2 =.71). There were no differences between the forages in terms of their effects on total dry matter intake, rumen volume and turnover rate, rumen ammonia levels or pH. All the values were similar to those previously reported in the literature. The dry matter flow to the duodenum was positively related to the half life and to the content of lignin in the forage (r^2 = .78 and .62 respectively). The flow of nitrogen through the duodenum was significantly greater when leucaena was the forage component of the diet (2.58 g N /100 g OM digested). When the forage intake in animals fed molasses/urea diets is restricted it is desirable to select those forages which have a high protein content and a fibre fraction which is slowly degradable in the rumen.

Key words: Molasses/urea, forages, rumen function, duodenal flow of nutrients

It is well known that on molasses/urea based diets the forage component of the ration is indispensable in order to prevent molasses toxicity (Cerebral cortical necrosis) (Elias et al 1968; Losada & Preston 1973; Losada & Preston 1974). It has also been observed that different forages influence animal performance (Salads et al 1977; Ffoulkes & Preston 1978; Rowe et al 1979). However it is not known whether these effects are related to the composition of the forages, their behaviour in the rumen or to the level of forage inclusion in the diet.

It is suggested that the fibre component of the forage in such a diet plays an important role as the regulator of rumen motility, directly stimulating the rumen wall and/or promoting rumen distension to a greater or lesser extent.

The object of the present experiment was to relate rumen function and rumen outflow of nutrients to the duodenum with fibre characteristics (composition and rate of rumen breakdown) and protein content of five different tropical forages, given to cattle receiving a molasses/urea based diet.

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Materials and Methods

Treatment and design: Five Brown Swiss x Zebu bulls of 220 - 240 kg were fitted with permanent rumen and duodenal cannulas and fed molasses/ urea ad libitum with 300 g/day of fishmeal and 50 g/day of a commercial mineral mixture.

The treatments were five tropical forages and the design was a 5 x 5 Latin square with experimental periods of 45 d.

The forages were:

(i) Sweet potato (*Ipomea batata*) : aerial part, including leaves and stems
(ii) Cassava (*Manihot esculenta*) : aerial part cut 20 cm above ground level
(iii) Leucaena (*Leucaena leucocephala*) : leaves and stem less than 5 cm diameter
(iv) Banana (*Musa accuminata*) : leaves only
(v) Sugar cane (*Saccharum officinarum*) :leaves taken from the top of the plant

Procedure: The molasses/urea mixture contained 88.5% molasses, 7.5% water and 4% urea. This was mixed manually at the beginning of each experimental period and served to the animals in large metal buckets. The fishmeal supplement was offered at 8 am. The fishmeal and molasses mixture was offered separately and the animals had free access to fresh water. One of the 5 fresh tropical forages was fed according to a 5 x 5 Latin square design using analysis of variance as described by Cochran & Cox (1978). Each experimental period consisted of 30 d adaptation and 15 d for measurements. The bulls were housed in individual 3 x 2 m pens with slatted floors and a roof. Each forage was given at the daily rate of 0.5 kg dry matter (DM)/100 kg animal liveweight, and was chopped to reduce the particle size to 10-30 mm in a chaff cutter. The forage components of the diet were offered to the animals once a day (8am) and were made iso-nitrogenous using a urea solution (50% w/w) which was sprinkled over them at the moment of feeding.

Measurements: The intake of molasses was measured daily and the values from the last 10 days of each experimental period used to obtain the mean intakes. The forages were analysed for DM by drying at 60!C, crude protein as N x 6.25, organic matter (OM) by oxidation at 500!C and neutral detergent fibre, acid detergent fibre and lignin (Goering and Van Soest 1979). The degradation rate of total DM and cell walls of the forages was determined using the rumen. bag digestibility method established by Mehrez and Ørskov (1977). Bags were removed after 12, 24, 48 , 72 and 96 hr. The results were analysed by the technique of Santana and Hovell (1979) to calculate the degradation rate in the rumen in terms of half life (T 1/2) and the soluble fraction of the forage.

The flow of the liquid phase from the rumen was measured using polyethylene-glycol (PEG) as a marker, Analysis was by the method of Melawar and Powell (1967), except that samples were filtered instead of centrifuged.

Flow of nutrients to the duodenum: The most efficient methods for estimating flow of the digesta to the duodenum are associated with the use of radioactive markers (51 Cr; 103 Ru). With continuous feeding the use of these two markers is better than the method using just one alone (Faichney 1980). When the use of radioisotopes is not

possible, other markers can be used such as chromium sesquioxide (Cr_2O_3) for estimating the flow of the solid phase (Kotb and Lucky 1972).

The marker used in this experiment was chromium trichloride($CrCl_3$) in the form of chromium EDTA, which is a marker known to move with the liquid phase of digesta, and with the fine particles associated with the solid phase (Hogan and Weston 1967; Faichney 1980). This characteristic of the marker was important in this experiment due to the low dietary concentration of cell wall material and the fact that the ration contained fractions which were highly soluble or finely ground (molasses/urea, fishmeal and minerals). We are also aware of the disadvantages associated with the use of "T" cannulas in this type of experiment,

The marker was infused into the rumen as chromium-EDTA twice a day, during the seven day period prior to the collection of duodenal material. The collection took place during a 24 hr period . Samples were collected during 3 minute periods every hour. The material collected from the cannula was sub-sampled (approximately 10%) and these samples bulked for laboratory determinations. The concentration of marker in the DM of the duodenal contents was determined as chromium sesquioxide. No correction values were used due to absorption of the marker (Faichney 1980). The percentage of DM, OM and total N were also determined in the duodenal digesta.

Results and Discussion.

The composition data (Table 1) of the different forages show a negative relationship between the cell wall fraction and the protein content ($\hat{r}$ = .72). This is similar to the results reported by MacRae (1976). The greater content of lignin in

Table 1:
Composition of the five forages

	Sweet potato	Cassava	Leucaena	Banana	Sugar cane leaves
Dry matter (DM) %	15.0 ± 2.9	22.5 ± 2:6	36.6 ± 2.6	17.5 ± 1.5	24.1 ± 2.4
Content in DM, %					
Organic matter	82.3 ± 1.9	91.5 ± 1.1	92.8 ± 1.0	88.9 ± 0.8	93.7 ± 0.1
N x 6.25	18.2 ± 1.0	19.1 ± 2.1	20.7 ± 1.8	13.6 ± 1.1	7.01± 0.4
Neutral detergent fibre (cell wall)	26.4 ± 1.3	22.0 ± 0.8	41.5 ± 2.5	47.6 ± 1.2	67.0 ± 0.8
Acid detergent fibre	22.3 ± 0.1	19.5 ± 0.4	33.3 ± 0.2	30.5 ± 0.4	37.7 ± 0.3
Lignin	5.7 ± 0.3	5.2 ± 0.3	11.6 ± 0.1	7.0 ± 0.1	4.6 ± 0.1
Cellulose[1]	16.6	14.3	21.6	23.5	33.1
Hemicellulose[1]	4.1	2.5	8.2	17.1	29.6

[1] By difference (see Van Soest 1967)

leucaena is in agreement with the work reported by Combellas et al (1974) and Van Soest (1974) in which the legumes were shown to have a consistently higher proportion of lignin. The differences in chemical composition and structure of the forages were reflected in their rate of degradability (Table 2).

Table 2:

Dry matter (DM) and cell wall degradation of the five forages in bags incubated in the rumens of cattle receiving molasses/urea diets

	Sweet potato	Cassava	Leucaena	Banana	Sugar cane leaves
DM degradation at 24 hr, %	63.9	79.0	48.5	50.0	22.9
T 1/2 for DM, hr	44.2	52.1	173.2	91.7	126.0
Soluble fraction, % in DM	50.5	67.6	43.8	33.8	9.4
Cell wall degradation at 24 hr, %	21.0	36.0	19.3	23.1	6.1
T 1/2 for cell wall fraction, hr	77.0	66.6	346.0	88.5	330

The lignin-cellulose fraction (acid detergent fibre) had the closest relationship with the rumen half life (r^2 = .71), confirming the reports of Combellas et al (1974) and Van Soest (1974). The changes in the digestibility of the DM can be explained almost certainly by the changes in digestibility of the fibre fraction of the plant (Van Soest 1974). In the present experiment, the changes in the half life of the DM can be explained principally by the changes in the half life of the cell wall fraction. The soluble fraction of the forages (Table 2) was negatively related with the cell wall fraction ($\hat{r}$ = .95). Although this is-theoretically obvious, it should be noted that this relationship was obtained with samples analysed in different ways (chemical analysis and rumen bag).

The voluntary feed intakes of the molasses/urea and total dietary DM (Table 3) are in agreement with values in the literature for production trials (Ugarte and Preston

Table 3:

Dry matter (DM) intake of dietary components

	Sweet potato	Cassava	Leucaena	Banana	Sugar cane leaves	$SE_{\bar{x}}$
Forage DM, % liveweight (LW)	.48 ± .08	.50 ± .05	.51 ± .02	.48 ± .03	.50 ± .03	
Molasses/urea, kg DM/100 kg LW	1.58	1.61	1.52	1.64	1.42	± .126
Total DM, kg/d	2.17	2.22	2.15	2.23	2.04	± 1.39
NPN, % of total N consumed	54.6	53.9	50.1	60.4	66.3	

1975; Fernandez and Preston 1978). The different forages did not affect the voluntary feed intake, possibly due to the low content of forage in the diet.

No significant differences were obtained in the rumen parameters (Table 4).

Table 4:

Effect of forage type on rumen function in cattle fed molasses/urea

	Forages				
	Sweet potato	Cassava	Leucaena	Banana	Sugar cane leaves
Liquid volume (litres)	38.2	39.4	44.2	44.2	42.8
Turnover (volume/d)	1.13	1.31	1.52	1.30	1.43
Dilution rate (% leaving /hr	.047	.054	.063	.054	.065
NH_3 (mg/100ml)3hr after giving the forage	16.1	15.8	15.5	16.1	15.7
pH 3hr after giving the forage	6.5	6.7	6.7	6.1	6.6

Considering the facts established by Sutherland (1976) for the control of liquid outflow from the rumen eg level and intake patterns, saliva production and rumen motility, it is important to note that the differences in composition and half life of the forages did not significantly affect rumen turnover.

The initial hypothesis was that "hardness" of the fibre in some forages would cause greater stimulation to the walls of the reticulo-rumen and therefore promote greater motility and outflow (Sutherland 1976). The total absence of this effect on rumen turnover could perhaps be explained by the low level of forage utilized, which did not cause sufficient stimulation of the control centres in the rumen, The values obtained for rumen turnover and outflow are in agreement with those reported in the literature for this type of diet (Reyes 1973; Rowe et al 1979). The values were low compared to those obtained in animals fed a diet of forages (Reyes 1973). This may be due to the low proportion of forage in the molasses diet and also to the low saliva production on such diets (Benavides and Rodriguez 1971).

The high rumen pH values observed in this experiment are in agreement with previously reported values in the literature (Reyes 1973; Fernandez et al 1977). The consumption pattern where the animals take molasses little and often throughout the day may explain the pH values close to neutrality. In this case the consumption is low (Benavides and Rodriguez 1971); the rumen buffering capacity on molasses diets does not appear to be increased according to Marty and Henderykx (1973). It can be seen from Tables 1, 2 and 5 that half life and the lignin content of the forages were related positively to the flow of duodenal DM(r^2 = 0.78 and .62 respectively). It would seem, therefore, that as the half life of the forages increased the quantity of solids in the rumen also increased which is presumably due to the difficulty involved in reducing the particle size to such a level that they are able to pass through the omasum. This

Table 5:
Effect of forage type on flow of nutrients to the duodenum in cattle fed molasses/urea diets

	Sweet potato	Cassava	Leucaena	Banana	Sugar cane leaves	$SE_{\bar{x}}$	Prob.
Duodenal flow, g/100 g OM consumed							
Dry matter	52.4	42.1	71.3	59.7	58.4	± 6.93	.22
Organic matter	41.4	36.0	57.7	46.4	45.3	± 5.55	.16
Nitrogen	2.07	1.53	2.58	2.10	1.91	± .24	.19
Total N consumed, g/d	196.0	212.3	195.3	206.7	195.8		
N flow to duodenum, g/d	165.5	141.2	204.2	186.2	157.7		
Difference in N, g/d	-30.4	-71.9	+8.9	-20.4	-38.0		

could explain the increase in DM flow and the effect it would have on the microflora once the system was stable. Observations made during the experiment showed that there was a greater content of solid particles in the rumens of cattle fed the forages of low digestibility (banana , sugar cane tops, leucaena), whereas in the rumen of the animals fed the high digestible forages (sweet potato and cassava) the rumen content consisted of a thin paste containing visibly less DM.

It is noticeable that the leucaena forage produced higher N flows at the proximal duodenum which cannot be attributed to differences in rumen function. It would seem that a considerable part of the N arriving at the duodenum could be forage protein escaping rumen degradation, or microbial protein due to greater synthesis stimulated by the amino acids present in the leucaena protein. U Ter Mueller et al (1979) indicated that the biological value of the leucaena protein is high and leucaena in growth trials has supported similar liveweight gains to peanut meal(Hulman et al 1978) in molasses/urea diets. A direct effect of the amino acids in leucaena on microbial protein synthesis is unlikely as Harrison and McAllen (1980) showed that supplementing the rumen with amino acids at low levels of dilution is an inefficient process which does not result in greater microbial growth.

It should be noted that the diet containing sugar cane tops had the highest content of non-protein nitrogen and those containing the sweet potato, cassava forage (highly degradable) showed greater losses of N across the rumen.

It is tentatively concluded that when the level of forage in molasses/urea based diets is equal or inferior to 0.5% (DM) of the animals liveweight the effect of the type of fibre on rumen function is limited, although there is a tendency to increase duodenal flows of DM when the forage is less degradable in the rumen.

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