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PARTICULATE MATTER BREAKDOWN AND REMOVAL FROM THE RUMEN IN SHEEP GIVEN ELEPHANT GRASS FORAGE AND CONCENTRATES

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In a crossover experimental design three sheep prepared with rumen cannulas were fed *ad libitum* fresh chopped Elephant grass (*Pennisetum purpureum*) forage and 438 or 500 g/d one of two concentrate mixtures containing maize flour residue, minerals and either cottonseed meal or hammermilled *Canavalia ensiformis* seed. A single injection of polyethylene glycol water soluble marker was used to measure rumen volume and fractional outflow rate (FOR) of liquid from the rumen. Five days later 400-800 g of digesta were obtained from the rumen, and faeces were also sampled. Dry matter (DM) content and distribution of the DM among various particle sizes was determined in rumen digesta and faeces by wet-sieving techniques using screen sizes of 3.2, 2.0, 1.4, 1.0, 0.71, 0.50, 0.25 and 0.15 mm. Proportions of each particulate matter group in rumen digesta and faeces and the FOR from the rumen of each particulate matter group were calculated. Despite significant differences in rate of fermentation in the rumen determined in an associated experiment, there were no differences between the diets in distribution of the various particle size groups in rumen digesta or faeces, or in FOR from the rumen of various particle size groups. The FOR of liquid tended ($P > 0.05$) to be greater for sheep given cottonseed meal (3.21/d) than those given *Canavalia* (2.70/d). The FOR of particulate DM retained by the 3.2, 2.0 and 1.4 mm screens (45% of total rumen DM) was negligible, and therefore this DM appeared to constitute the large particle pool ineligible to leave the rumen. There was a linear increase in FOR for the particulate matter retained by the progressively smaller screen sizes (1.0, 0.71, 0.50 and 0.25 mm). The FOR of DM retained by the 0.25 mm screen was 2.32/d or 78% of the FOR of the water-soluble marker. A large proportion of both rumen digesta (33%) and faeces (48%) consisted of very small particles and soluble DM which passed through the 0.15 mm screen.

Key words: Rumen, particle size, particle flow.

With tropical forages of low digestibility the rate of breakdown of large particulate matter to particles sufficiently small to be eligible to leave the rumen, and the rate of removal of these small particles from the rumen, are likely to be limiting factors to the intake of forage and therefore to productivity (Balch and Campling, 1962; Poppi et al, 1981). These factors are also likely to influence the extent and type of rumen fermentation and efficiency of microbial synthesis (Mertens, 1977; Bull et al, 1979; Harrison and McAllan, 1980).

The following study was undertaken to examine the distribution of rumen and faecal dry matter (DM) among various particle sizes and the fractional outflow rate (FOR) of various sized particle groups and of liquid from the rumen in sheep given a diet of mature tropical forage and concentrate. Two concentrate supplements containing residue maize flour and either cottonseed meal or *Canavalia ensiformis* seed were compared.

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Materials and Methods

Three local crossbred sheep (30-35 kg liveweight) were prepared with 50 mm diameter rumen cannulas and allowed at least 2 months for recovery from surgery. The sheep were housed in metabolism crates in an open-sided shed and were given *ad libitum* freshly chopped mature Elephant grass (*Pennisetum purpureum*) pasture with an allowance of approximately 50% for refusals to permit selection. One of two concentrate supplements consisting on an air dry basis of 240 g maize flour residue, 7.5 g commercial mineral mixture, 2.5 g salt and either 188 g cottonseed meal or 250 g hammermilled (3 mm screen) *Canavalia ensiformis* seed were also given each day. Concentrates were given at 08:00 h and pasture at 12:00 h. Pasture offered and refused was sampled each day to measure DM intake, while there was complete consumption of the concentrates.

The experimental design consisted of a simple cross-over with 2 sheep given the concentrate containing *Canavalia* and one sheep the concentrate containing cottonseed meal during the first period, and the reverse in the second period. The present study was combined with measurements of rumen fermentation and rate of fermentation in nylon bags to be reported elsewhere.

The volume of water in the rumen and the fractional outflow rate (FOR) of water was measured using a single injection of polyethylene glycol (PEG; mol wt 4000; 7 g/sheep in 200 ml water) dosed into the rumen at 08:00 h. Samples of rumen fluid were taken using a sampling probe at 3, 6, 9, 12, 15 and 18 h after injection of marker, and were filtered through cloth and acidified before being stored (-5°C). PEG was analysed by turbidimetric methods (Malawar and Powell, 1967). Rumen water volume and FOR were calculated assuming first order kinetics (Shipley and Clark 1972; Batschelet, 1978). Five days after the marker injection, 400-800 g of digesta were removed from the rumen at 16:00 h. The majority of the faecal output for one 24 h period was also collected and subsampled.

The distribution of DM of various particulate sizes in rumen digesta and faeces was determined using the wet-sieving techniques of Dixon and Milligan (1983). The sieving apparatus consisted of a cylinder 100 mm in diameter with a screen fixed in one end. This cylinder was placed in a beaker 160 mm in diameter and 2.0 l of tapwater added. The sample (approximately 15 g of wet rumen digesta DM or 7.5 g faeces DM, the latter soaked in water for 3 d) was placed inside the cylinder with the fixed screen, and the slurry stirred in a rotary fashion while the cylinder with the fixed screen was lifted slowly within the beaker. This lifting and stirring cycle was carried out five times, and the particulate material retained on the screen was then quantitatively transfered to a dish for drying. The above procedures were carried out with successively smaller screen mesh sizes; mesh sizes used in succession were 3.2, 2.0, 1.0, 0.71, 0.50, 0.25 and 0.15 mm. Rumen digesta was added to the 3.2 mm screen in four equal batches each of which was sieved independently to reduce matting effects. The particulate matter that passed through the 0.15 mm screen plus the soluble DM (with correction for the solutes in tapwater) were determined by subsampling the slurry which passed through the 0.15 mm mesh screen.

The FOR of passage from the rumen to the small intestine of each particle size group in the rumen was calculated, assuming first order kinetics, as:

$$FOR_{(X)} = \frac{\text{Flow of particle fraction (X) to the small intestine (g DM/d)}}{\text{Pool size of particle fraction (X) in the rumen (g DM)}}$$

The flow of each particle size group from the rumen to the small intestine was estimated by assuming that 50% of DM consumed was digested in the rumen, and that the particle size distribution in digesta flowing from the rumen was the same as that measured in faeces. The pool size of total DM in the rumen was calculated from the DM content of rumen digesta and the volume of rumen water determined from the single injection of PEG. The pool size of each particle size group in the rumen was calculated from the total DM present in the rumen and the proportion of that particle size group in rumen digesta.

A split-plot analysis of variance (Snedecor and Cochran 1967) was used to test differences between sheep, diets and particle size groups in rumen digesta and faeces, and for FOR.

Results

The experiment was commenced with two sheep given each experimental diet, but since one sheep died before the second period the results for only three sheep are presented. These sheep were in good health throughout the experiment.

The proximal analysis of forage given in each period and of the concentrate are given in Table 1. There was little difference between the

Table 1:
Proximate analysis of forage and concentrate supplements

	Forage		Concentrates	
	Period 1	Period 2	Cotton seed meal maize meal	Canavalia maize meal
Organic matter (%)	89.2	89.7	8.3	6.9
Crude protein (N x 6.25)(%)	7.55	5.70	21.6	19.8
Neutral detergent fibre (%)	71.2	77.4	40.7	26.1

two periods in the composition of the forage. The intake of forage was similar for the two concentrate supplements (Table 2).

There were no significant differences between the cottonseed meal and *Canavalia* supplements in total rumen DM pool size (Table 2) or in the cumulative distribution of DM among the various particle size groups in either rumen digesta or faeces (Figure 1). In the present experiment 37% of total rumen DM was retained by the 3.2 mm screen, and 45% by the 3.2, 2.0 and 1.4 mm screens. Thirty-three % of total rumen DM was sufficiently small to pass through the 0.15 mm screen, and filtration of some samples indicated that approximately 13% of total rumen DM consisted of solubles.

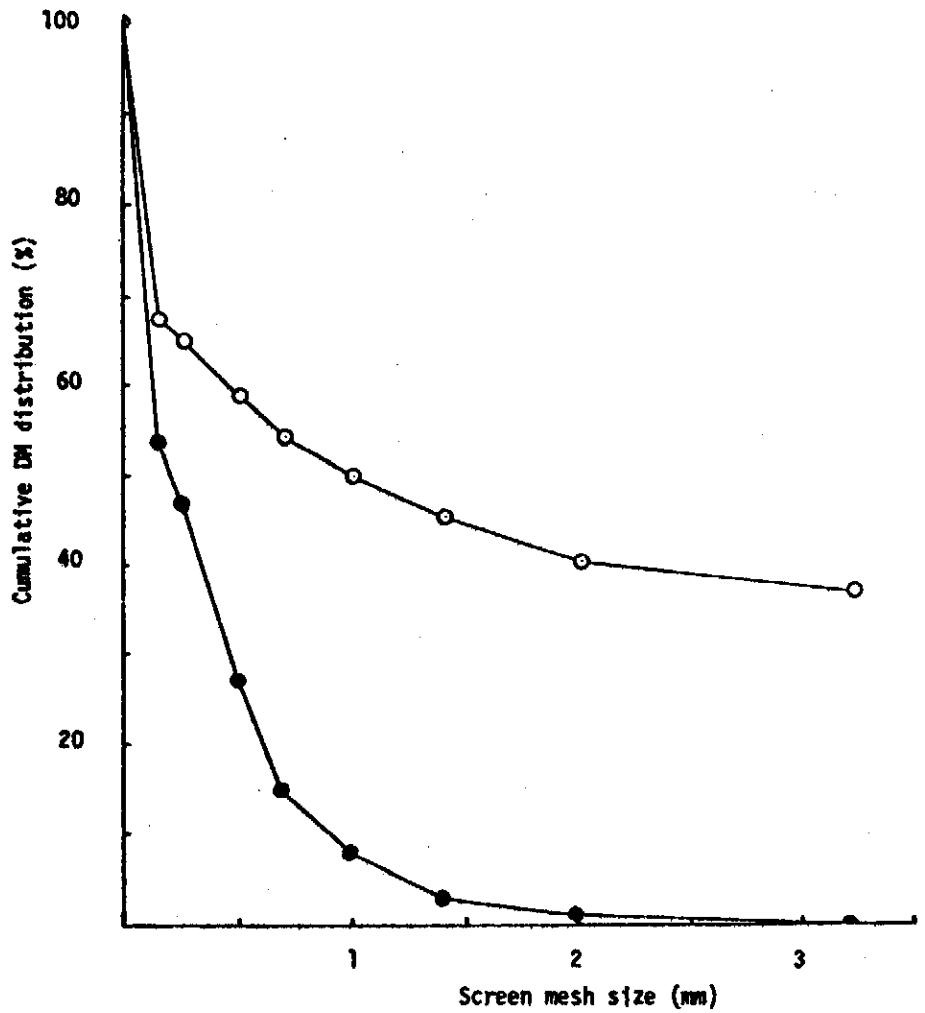
Table 2:

Intake of forage and concentrate and measurements in the rumen of three sheep given forage ad libitum and concentrate containing either cottonseed meal or Canavalia seed

Measurment	Concentrate supplement	
	Cottonseed meal maize meal	Canavalia maize meal
Intake forage DM (g/d)	546	528
Intake concentrate DM (g/d)	416	456
Rumen liquid volume (l)	4.74	4.60
Rumen liquid FOR (d^{-1})	3.21	2.70
Rumen DM pool size (g)	688	699

Figure 1:

Mean cumulative DM distribution with sieves of decreasing size in rumen digesta (o) or faeces (o) in three sheep given forage ad libitum with each of two concentrate mixtures. The SEM of percentage distribution in each particle group in rumen digesta was 0.91 and in faeces 1.15.

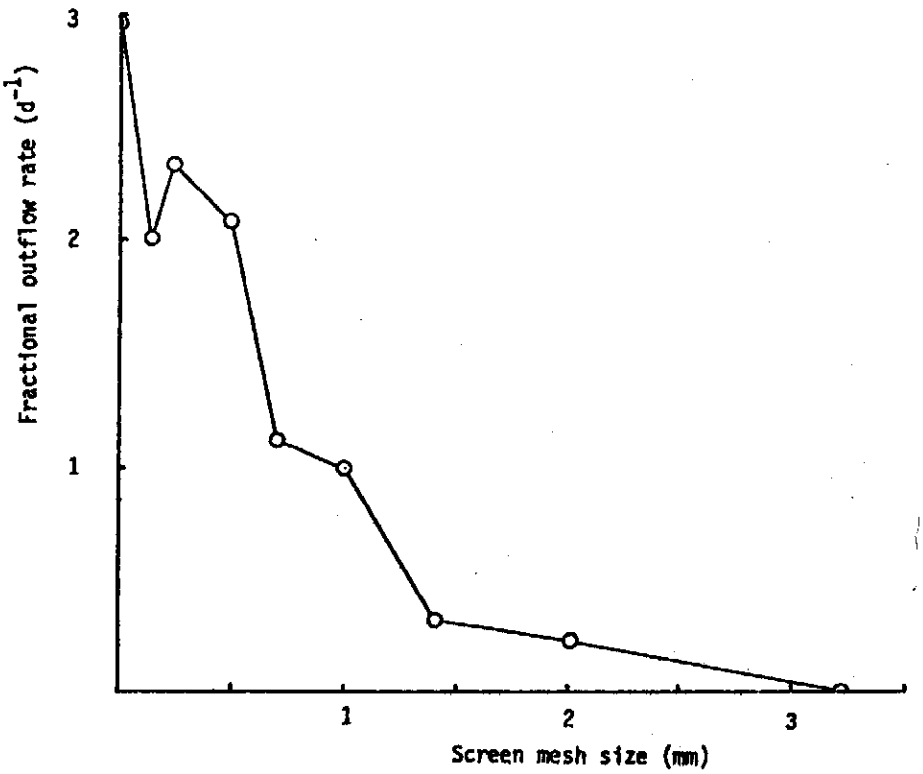


In faeces only 3% of total DM was retained by the 3.2, 2.0 and 1.4 mm screens, 48% of total DM passed through the 0.15 mm screen and approximately 16% of total faecal DM consisted of soluble DM.

The FOR from the rumen of each particle size group and of liquid measured with PEG are shown in Figure 2. There were no significant differences between the cottonseed meal and *Canavalia*.supplements for the FOR of the particle size groups. However the FOR of liquid tended to be greater ($P > 0.05$) for sheep given the cottonseed meal concentrate(3.21/d)

Figura 2:

Mean fractional outflow rates from the rumen for particle groups retained by various screen sizes and for liquid measured with polyethylene glycol in three sheep given ad libitum with each of two concentrate mixtures (SEM 0.19)



than those given *Canavalia* (2.70/d)(Table 2). The FOR was negligible for particles retained by the 3.2 mm screen, and was very low (0.23/d and 0.31 /d) for particles retained by the 2.0 and 1.4 mm screens respectively. There was a rapid and approximately linear increase in FOR with decreasing particle size to the group retained by the 0.25 mm screen (2.32/d). The particles retained by the 0.15 mm screen and DM passing through the 0.15 mm screen tended to have a lower FOR (1.98/d and 1.05/d respectively)than that retained by the 0.25 mm screen, but only the latter FOR was signifi-

cantly ($P < 0.05$) lower. The FOR of the particles retained by the 0.25 mm screen but passing the 0.50 mm screen was 78% of the FOR of the liquid marker.

Discussion

The limitations of this manual method of sieving to determine particle size distribution, and the errors associated with the use of these results to calculate FOR of particle size groups from the rumen have been discussed previously (Dixon and Milligan, 1983). In addition, variation during the day in particle size distribution in the rumen of these sheep fed once per day (Pearce, 1967) while calculations were based on a single rumen digesta sample obtained at 16:00 h would probably have led to overestimation of rumen DM pool size and the proportion of larger particles in the rumen. Nevertheless, although the absolute values for FOR may be in error, the relationship between FOR and particle size groups is not likely to be seriously affected by the assumptions.

Although intake of pasture and rumen DM pool size were similar, and in an associated study the rate of digestion of fibrous DM in nylon bags was about 20% greater for the cottonseed meal diet than for the *Canavalia* diet, no differences were observed between the two dietary treatments in particle size distribution in rumen digesta or faeces. This supports the concept that mastication and rumination are more important than microbial activity reducing particle size.

The most important observation of the present study is that there was a gradual increase in the FOR from the rumen with decreasing size of the particle groups. This is consistent with previous results with cattle (Dixon and Milligan, 1983) with the difference that with cattle the FOR of particles retained by the 2.0 and 3.2 mm screen were substantial, but with sheep these FOR were negligible. These results are also consistent with the changing "resistance to flow" measured by Poppi et al (1980). The lower FOR of particulate and soluble DM that passed through the 0.25 mm screen than of particulate DM retained by the 0.25 mm screen was also observed with cattle, and may be associated with more extensive digestion post-ruminally of this fraction than of the larger particle size fractions (Dixon and Milligan, 1983).

If a division is to be made of rumen digesta DM into large and small particle pools, then with the sieving methods used in the present study the material retained by the 1.4 mm and greater screens appears to constitute the pool of particulate DM physically too large to pass from the rumen in substantial quantities. This agrees with previous studies with sheep (Pearce, 1967; Poppi et al, 1980). Furthermore the FOR from the rumen of the small particle pool was considerably less than that of the liquid marker, and assuming that the FOR of these two fractions are equal is likely to introduce considerable error.

If the DM retained by the 1.4 mm screen is considered as the rumen large particle pool, 46% of rumen DM was too large to pass from the rumen (Figure 1). This is similar to the proportion of 45-55 % of rumen DM present in the large particle pool in steers fed temperate grass hay (Dixon and Milligan, 1983), and the proportion measured in mature sheep

given pelleted lucerne (44%; Mudgal et al, 1982). It however tends to be less than that measured in mature sheep given chopped *Bromus inermis* or lucerne (63 and 61 %; Kennedy et al, 1982).

In the present experiment the proportion of rumen DM passing through the 0.25 mm screen (36%) was much greater than that observed for sheep given temperate species forage diets such as pelleted lucerne(15%; Mudgal et al, 1982) or chopped lucerne or chopped *Bromus inermis* (19-23 %; Kenne dy et al, 1982), but is similar to that of sheep given barley-based concentrate (41%) in the latter experiment. Furthermore in the present experiment a large proportion (54%) of faecal DM passed through the 0.25 mm screen. Similar observations have been made with cattle fed a diet based on sugarcane tops (Boodoo and Dixon, unpublished results)where 58% of total rumen DM and 46% of total faecal DM passed through the 0.25 mm screen, as compared to only 27% of rumen DM and 31% of faecal DM passing through this screen in steers fed mature temperate species grass hay (Dixon and Milligan, 1983). These observations suggest that with tropical diets containing a large proportion of materials such as mature Elephant grass pasture or sugarcane tops, factors affecting removal of small particles from the rumen such as rumen motility or entrapment of small particles in the matrix of large particles may be more important in limiting intake than large particle breakdown *per se*. This concept is substantiated by modelling studies (Poppi et al, 1981) which have suggested that the rate of removal of small particles from the rumen is the primary factor limiting intake.

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