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## RUMEN FLOW DYNAMICS AND VOLUNTARY INTAKE IN RUMINANTS

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Pienaar *et al.* (1979 a) proposed a mathematical model to predict voluntary intake of roughages by ruminants. The principles of simulation by sets of differential equations are similar to the passage model of Blaxter *et al.* (1956) and Mertens and Ely (1978) and the rumen fibre kinetic model of Waldo *et al.* (1972). The approach of Pienaar *et al.* (1979 a), however, was based on the assumption that the rate of outflow from the rumen would be balanced by the rate of inflow. The differences in voluntary intake between roughages would then be mainly reflected in the rate constants for fermentation and outflow of digesta in addition to the relative fill of the rumen.

The proposed model proved to have exciting possibilities when intakes of sheep on *Eragrostis curvula* hay with treatment differences stages of cutting and levels of fertilizer, were predicted with a mean error of  $5 \pm 2\%$  (Pienaar *et al.*, 1979 b). These were totally independent figures from another research station.

The model was developed using data from sheep. The aim of this study was to see if the model could be extended to predict intake of roughages by cattle without having to resort to extensive experimentation. It could be postulated that since rumen flow dynamics and the amount of rumen digesta can be described to a large extent by ordinary physical concepts, the difference between sheep and cattle in some of these

variables would be proportional without or after the applicable correction for size.

### Material and Methods

#### 1. Design

Fourteen steers weighing 300 to 480 kg and 16 wethers between 30 and 50 kg were used. Seven steers and 8 wethers were allotted a diet of *Eragrostis curvula* (hay diet) and the remaining animals one of wheat straw (straw diet). Voluntary intakes were measured for two weeks following a two week adaptation period, wherea all animals were slaughtered to determine the amount of digesta in the rumen and to measure the pertinent variables related to flow (Pienaar *et al.*, 1979 a).

#### 2. Diets

The hay and straw were ground through a 50 mm sieve. N (urea, casein and sunflower oil cake), minerals and essential vitamins were added in sufficient quantities according to the specifications of N.R.C. A 1: 10 w/v mixture of molasses and water was sprayed on the hay or straw before adding the supplements. This procedure ensured satisfactory homogeneity.

The *in vitro* digestibility of organic matter (OM) was 63.5% and 54.3% for the hay and straw diets respectively. The source of rumen fluid was from a sheep receiving lucerne hay.

### 3. Food supply

Food was supplied in equal quantities every 4 hours to minimize the irregular pattern noticed between days, but voluntary intake was measured on a daily basis. The mean intake of every animal for the last 14 days prior to slaughter was considered a representative figure. Water was freely available at all times.

### 4. Measurements and Calculations

The following variables were measured or calculated (notations are given in brackets):

- a) body weight,
- b) voluntary intake of OM per day ( $\Delta I$ ),
- c) the solubility of the diet - this is a constant for a diet and was therefore not considered in the statistical analysis,

d) the insoluble fermentable fraction of the diet (K),

e) the rate constant for fermentation ( $\gamma_1$ ),  
 f) the rate constant for outflow of fermentable and unfermentable OM from the rumen - it is hypothesized that the two rate constants would be about the same, therefore only the rate constant for outflow of unfermentable OM is considered ( $\gamma_2$ ),  
 g) the amount of OM in the rumen (Z).

Diets and rumen digesta were fermented for 72 h by an adapted one-stage Tilley and Terry method. All other applicable chemical analyses were according to AOAC procedures.

### 5. Statistical analysis

A two-way analysis of variance on

Table 1. — Measured and calculated data

	Hay		Straw	
	Cattle	Sheep	Cattle	Sheep
W (kg)	382 ± 66	38.8 ± 3.5	380 ± 78	43.1 ± 4.5
I (kg)	9.54 ± 0.96	1.20 ± 0.13	4.46 ± 0.76	0.72 ± 0.09
K (%)	40.6 ± 2.2	44.6 ± 4.6	30.0 ± 4.1	29.8 ± 1.9
$\gamma_1$ (day <sup>-1</sup> )	0.74 ± 0.11	0.91 ± 0.24	0.48 ± 0.12	0.84 ± 0.23
$\gamma_2$ (day <sup>-1</sup> )	0.64 ± 0.09	1.09 ± 0.20	0.35 ± 0.04	0.65 ± 0.11
Z <sup>2</sup> (kg)	9.30 ± 0.84	0.73 ± 0.07	8.43 ± 1.71	0.77 ± 0.12

Table 2. — F-values for differences between diets, species and diets x species for rumen variables

Variable	Diets	Species	Diets x species
K (%)	101 ***	2.20 N.S.	2.64 N.S.
$\gamma_1$ (day <sup>-1</sup> )	5.16 *	13.0 **	1.72 N.S.
$\gamma_2$ (day <sup>-1</sup> )	57.3 ***	61.7 ***	2.66 N.S.
Z (kg)	1.53 N.S.	—	1.81 N.S.

Table 3. — F-values for differences between diets, species and diets x species for  $\Delta I$  and Z relative to  $W^{0.75}$  or W

	Diets	Species	Diets x species
$\Delta I/W^{0.75}$ (kg/kg)	221 ***	286 ***	160 ***
$\Delta I/W$ (kg/kg)	207 ***	28.3 ***	0.08 N.S.
$Z/W^{0.75}$ (kg/kg)	1.87	360 ***	4.29 *
$Z/W$ (kg/kg)	4.92 *	35.9 ***	0.56 N.S.

unweighted cell means was used with two diets and two species as rows and columns.

## Results

### 1. Measured and calculated data

Table 1 shows the means and standard deviations of all results of importance to the model.

### 2. Rumen variables

Table 2 shows the results of the variance analysis for the pertinent rumen variables.

Tables 1 and 2 are discussed together.

The main concept arising from Table 2 is that there was no significant interaction between diets and species, i.e. all relevant variables to the model differ with a constant proportion between diets and species. With regard to the individual variables the following:

K) The percentage insoluble fermentable fraction of the diet is species independent but differs highly significantly between diets due to quality differences.

$\gamma_1$ ) The rate constant for fermentation differs significantly between diets: the hay was fermented at a higher rate than the straw as expected. It also differs highly significantly between species, being fermented at a higher rate in sheep than in cattle. The reason is not clear. However, it could be postulated that in order to allow passage from the rumen, the sheep had to masticate considerably more than the cattle. Therefore the material in the rumen would have contained smaller particles and more fermentable surface area, which could have facilitated fermentation rate.

$\gamma_2$ ) The rate constant for outflow of unfermentable OM (also by definition that of fermentable OM) differs highly significantly between diets and species. It was higher for hay than for straw and higher for sheep than for cattle. This result follows if it is considered that both  $\gamma_1$ , and intake relative to mass are higher for hay than for straw and higher for sheep than for cattle - the rate of outflow should be higher if a steady state between inflow and outflow is presumed ( $\Delta I/W$  was about twice as high on hay as on straw and about 30% higher for sheep than for cattle).

Z) The amount of OM in the rumen does not differ significantly between

diets. However, this result is coincidental in view of the significant result of Z relative to W (table 3), but shows that differences are small, so that for most practical purposes, Z can be regarded as a constant within species for all roughages of similar quality to the ones used here.

### 3. Intake and rumen fill relative to mass

The object in table 3 was to relate  $\Delta I$  and Z to the two standard ways of correction for size to establish the desirable one. The most probable way would be the one which does not show interaction between diets and species in the variance analysis.

The results in terms of interaction convincingly show that for correction for size, W should be used and not  $W^{0.75}$ , which is in accordance with the principle of « capacity » control of intake of roughages, where one would expect  $\Delta I$  and Z to be isometric to W. It also suggests that  $\Delta I/W$  and Z/W would differ by a constant proportion between sheep and cattle on diets of similar quality to the ones used here.

With regard to the significant and highly significant results of  $\Delta I/W$  and Z/W between diets and species:

—  $\Delta I/W$  was about double on hay compared to straw and about 30% higher for sheep than for cattle.

— Z/W differed by about 8% between diets, hay > straw and was about 27% higher for cattle compared to sheep.

## Conclusions

All variables in the model of relevance to intake prediction show proportionality between sheep and cattle, so does  $\Delta I/W$ . Therefore in these experiments the intake of the two roughages by cattle could be accurately predicted from  $\Delta I/W$  of sheep alone. However, since this comparison included only adult castrated animals, the prediction would have to be tested with a wider range of roughages and with animals at different stages of growth and physiological state before it could be used without restricted conditions.

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