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PATTERNS OF INTAKE AND DIGESTIBILITY BY CATTLE AND SHEEP OF FEED MIXTURES WITH ROUGHAGE SOURCE, PARTICLE SIZE AND LEVEL OF INCLUSION AS VARIABLES

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(Key words: *Concentrate, roughage, intake, digestibility)*

(Sleutelwoorde: *Kragvoer, ruvoer, inname, verteerbaarheid)*

OPSOMMING: PATROON VAN INNAME EN VERTEERBAARHEID DEUR BEESTE EN SKAPE VAN VOERMENGSELS MET RUVOERBRON, – PARTIKELGROOTTE EN – INSLUITINGSPEIL AS VERANDERLIKES

Dit word gepostuleer dat inname van voermengsels tot 'n piekwaarde sal toeneem indien die persentasie kragvoer in die mengsel stelselmatig vermeerder word, waarna inname daal aangesien die ruvoer te min word om 'n gesonde rumenomgewing in stand te hou. Op grond hiervan behoort die gewenste insluitingspeil van 'n ruvoer in byvoorbeeld 'n afrondingsdieet geïdentifiseer te kan word indien die innameresultate ook ondersteun word deur waarnemings betreffende 'n goed-funksionerende rumen.

Bogenoemde postulaat is ondersoek met behulp van 6 eksperimente op beeste en skape met ruvoerbronne: *Eragrostis curvula* hooi gemaal deur verskillende sifgroottes, lusernhooi, koringstrooi, ook deur verskillende sifgroottes gemaal, sonneblomdoppe en suikerrietbegasse beide in verkorrelde- en nie-verkorrelde vorm.

Die ondersoeke het die postulaat bevestig, maar het beslis ook onderstreep dat piekinname baie spesifiek is vir ruvoerbron, die partikelgrootte daarvan, die massa/volume verhouding van die voermengsel, asook die tipe dier (skaap of bees). Dit was ook duidelik dat die mees gewenste insluitingspeile van ruvoere in afrondingsdiëte langs hierdie weg gevind kan word. Die verteerbaarheid van verskillende voermengsels skyn nie altyd additief te wees nie as gevolg van voedingspeil - en moontlik ook assosiatiewe effekte.

SUMMARY:

It has been postulated that intake of feed mixtures will increase with increasing levels of concentrate until a peak is reached, whereafter it will decline again due to a lack of roughage to ensure a healthy rumen environment. Thus, it should be possible to determine the most desirable level of inclusion of a particular roughage in a feedlot diet for example, if peak intake results are also substantiated by observations that the rumen is in a satisfactory functional condition.

The postulate referred to above was tested in a series of 6 experiments with cattle and sheep involving the following roughages: *Eragrostis curvula* hay milled through screens with different apertures, lucerne hay, wheat straw - also milled through different screen apertures, sunflower hulls and sugarcane begasse in the pelleted and unpelleted form

The studies confirmed the postulate and clearly emphasized that peak intake is a function of type of roughage, its particle size, the mass/volume ratio of the feed mixture and also type of animal (sheep or cattle). It was also evident that the most desirable level of inclusion of a roughage in a feedlot diet can be established in this way. The digestibility of different feed mixtures is apparently not necessarily additive due to feeding level effects and probably also, associative effects.

Montgomery & Baumgardt (1965) proposed that the factors controlling dietary intake in the ruminant change from physically limiting ones to ones regulating energy intake to a constant level, when the nutritive value of the diet increases. On the other hand, very high levels of dietary energy (concentrates) could reduce intake due to factors such as low rumen pH, sub-acute bloat and papillae clumping (Fell, Kay, Ørskov, Boyne & Walker, 1972; Mann & Ørskov, 1975). Although various factors may influence both proposals, it would be generally expected that a relationship exists between dietary enery concentration and intake which could reach a peak at a particular concentrate to roughage ratio. This in fact, has been demonstrated by McCullough (1969) and Sejrsen & Brolund Larsen (1977) and one would imagine that the peak could amongst other depend on source and particle size of the roughage. Thus, by determining intake at various concentrate to roughage ratios covering the whole span of the above proposals, it sould be possible to determine the peak level of intake of a specific diet and consequently the most desirable level of inclusion

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of a particular roughage in that diet which would ensure maximum growth and efficiency in a feedlot, for example.

One of the aims of the investigation was to test the postulate of a peak level of energy intake. A second one was to determine this conceptual peak level, if it exists, for a number of commercially important roughages in feedlot operations. Finally, the relationship between the apparent digestibility of the diet and the concentrate to roughage ratio was studied. A simple relationship does not necessarily apply, since it is known that associative effects depending on roughage source, may influence the pattern of fermentation in the rumen (Byers, Johnson & Matsushima, 1976; Byers, 1980). Secondly, rate of passage of digesta due to level of intake may depress digestion which would also cause deviation from a simple relationship.

Material and Methods

1. **Animals:**

Sheep and cattle were used. Cattle were involved in 5 studies and sheep in 2. In one study the patterns of intake and digestion on different concentrate to roughage ratios involving the same roughage source of cattle and sheep were compared.

2. **Diets:**

The roughage sources investigated were sugarcane bagasse in pelleted and unpelleted form, *Eragrostis curvula* hay milled through various screen sizes, lucerne hay, sunflower hulls and wheat straw, also milled through various screen sizes. The roughages ranged in apparent digestibility of organic matter (OMD) from about 25% for the sunflower hulls to about 60% for the lucerne hay, which categorizes them as low to medium quality roughages.

The concentrate mixture used contained 850 kg maize meal; 102 kg sunflower oil cake meal; 20 kg urea; 1,8 kg S; 13 kg $CaCO_3$; 12 kg NaCl and 1,2 kg of a commercial premix of vitamins and trace elements. The concentrate had about 170 g/kg crude protein to ensure sufficient N even when mixed with large proportions of low quality roughage. This also applied in the case of all other essential nutrients. Concentrates and roughages were mixed together in a complete diet in the applicable proportions of interest.

2.1 *Experiment 1:*

Eragrostis curvula hay was hammermilled through 51, 25, 13 and 6 mm screens respectively, and then added in proportions of 5, 15, 25 or 35% to the concentrate part. Sixteen yearling steers with initial live masses of about 280 kg were allocated at random to one of the 4 x 4 combinations according to a factorial design. The steers were fed *ad lib* for 2 to 3 months on their respective diets whereafter they were slaughtered for analysis of rumen variables and visual inspection of the rumen wall, papillae reduction or clumping, liver abscesses etc. Only the intake and digestibility data are considered. The other data form part of a M.Sc. thesis by one of us (J.P. Campher). So do the corresponding data in the other studies.

Food was given 4 times daily, the daily amount being calculated as *ad lib* + 10%, while water was freely available. Refusals were bulked every week and analysed for DM and ash according to standard procedures. The steers were also weighed at the end of every week. Faeces were collected for 1 week at the end of the experiment. Representative samples were analysed for DM and ash.

2.2 *Experiment 2:*

Eight young steers similar to the ones in Experiment 1 were allocated at random to one of 8 diets containing respectively 5, 10, 15, 20, 25, 30, 35 or 40% sunflower hulls. The diets were offered *ad lib* for 2 to 3 months and measurements of intake, live mass, apparent OMD and post-slaughter data done in a manner similar to those in Experiment 1.

2.3 *Experiment 3:*

Sugarcane bagasse pellets were compared to the unpelleted form. Levels of inclusion were 6, 12, 18, 24, 30 and 36% respectively. One steer, similar in initial live mass and age to the above experiments, was allocated per treatment and measurements of *ad lib* intake done within the live mass interval of approximately 280 to 400 kg. This again represents about 2 to 3 months of measurement. Faeces collection for measurement of digestibility was done during two fortnightly periods. Experiences from Experiments 1 and 2 showed that a one week collection period at *ad lib* intake was too short to get a reasonable representative figure (Campher, 1982). All other procedures were similar to those of the previous experiments.

2.4 *Experiment 4:*

Wheat straw was hammermilled through 51, 25, 13 or 6 mm screens and added in proportions of 6, 12, 18, 24, 30 or 36% to the concentrate part of the diet. One steer was allocated per treatment making a total of 24 of the 4 x 6 factorial design. In addition, inclusion levels of 42, 48, 54, 60, 66 and 72% for the 13 and 6 mm screen treatments were also studied. Measurements were the same as those described for Experiment 3.

2.5 *Experiment 5:*

Comparisons were made between weaner sheep and cattle on diets where *Eragrostis curvula* hay milled through a 51 mm screen, replaced the concentrate part of the diet in small increments from 0 to nearly 100%.

The increments were $^1/_{20}$ for sheep and $^1/_{12}$ for cattle. Two wethers or heifers were allocated each at zero concentrate or the highest proportion of concentrates and one each at all other proportions. Voluntary intake and live mass were recorded every week between live masses of 25 and 45 kg and 250 and 400 kg respectively, while faeces were collected at intervals throughout the study period. Nine to 11 separate collections on every individual were consequently made resulting in the same number of calculated OMD's. These were pooled when it was established that OMD was not significantly influenced by time or size of the animal. All wethers and heifers were slaughtered at the end of the study period. The amounts of OM in the rumens were measured in order to study the retention time of digesta.

2.6 *Experiment 6:*

Procedures similar to the ones adopted in Experiment 5 were followed. Lucerne hay was replaced by 0, 20, 40, 60, 80 or 100% concentrates and 3 to 4 wethers of similar age were allocated at random to each of the proportions. The main difference in this experiment was that the diets were pelleted. As in Experiment 5 one wether per treatment was slaughtered at the start of the experiment and the other following a period of measurement of voluntary intake, live mass and apparent OMD which covered the life span of 25 to 45 kg.

3. **Statistical methods:**

The relationships between concentrate to roughage ratio and respectively voluntary intake or apparent OMD were described by singular or multiple linear and polynomial regression equations. The best equation was established by comparing the amount of variation in the dependent variable being explained by the variation in the independent variable (r^2 and R), by inspection of the distribution of points about the regression line and by determining whether the multiple linear or polynomial regression equations were significant or not.

The rationale of the approach adopted in all experiments can be described as follows:

Fitting equations to experimental observations lead to the combination of the information on all experimental points, with the gain in information obtained form the average variance of a prediction from the fitted equation which is equal to $r\sigma^2/n$, where r is the number of estimated parameters in the fitted equation, n the number of observations and σ^2 the variance of a single observation. The gain in information is n/r, i.e. a point estimated by prediction from an equation is of equal accuracy to a mean value based on n/r observations.

Results and Discussion

1. **Organic matter intake:**

Table 1 compares (in terms of r^2 or R) the amount of variation in OM intake which could be ascribed to % concentrate in the diet when ordinary least squares analyses or polynomial regression analyses were used. It also indicates the occasions when the second order regression coefficient in the case of polynomial fit was significant.

It is clear from Table 1 that in most cases a better description was realized by the second order polynomial equation even where the second order regression coefficients were not significant. How much value one

Table 1

R and r^2 values of the relationship between % concentrate and OM intake in kg/day

Animal	Roughage source		Linear (r^2)	2nd order polynomial (R)
Wethers	*Eragrostis curvula*		0,464	0,684
Wethers	Lucerne		0,466	0,745*
Heifers	*E. curvula*		0,332	0,743*
Steers	*E. curvula*	(51 mm screen)	0,146	0,854*
Steers	*E. curvula*	(25 mm screen)	0,475	0,894*
Steers	*E. curvula*	(13 mm screen)	0,179	0,956*
Steers	*E. curvula*	(6 mm screen)	0,943	0,989
Steers	Sunflower hulls		0,867	0,933
Steers	Wheat straw	(51 mm screen)	0,856	0,926
Steers	Wheat straw	(25 mm screen)	0,566	0,822*
Steers	Wheat straw	(13 mm screen)	0,230	0,826*
Steers	Wheat straw	(6 mm screen)	0,207	0,880*
Steers	Sugarcane bagasse	(pelleted)	0,516	0,743
Steers	Sugarcane bagasse	(unpelleted)	0,382	0,806*

* 2nd order regression coefficient is significant ($p < 0,05$)

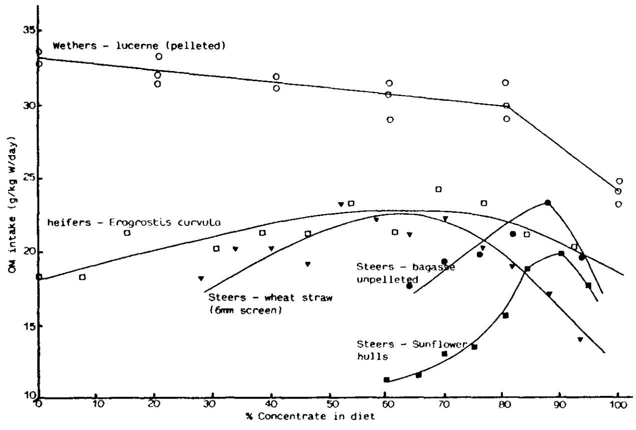

Fig. 1 *The relationship between voluntary intake of OM and % concentrate in the diet of various concentrate-roughage mixtures*

however should attribute to the t-test for significance of the regression coefficient here is not clear, since the independent variables are highly correlated.

A graphic illustration of the data of 5 of the roughage sources, chosen at random, is also presented in Fig. 1.

With the exception, perhaps, of the data for wethers on the pelleted lucerne diet, all other relationships between OM intake and % concentrate in the diet deviate substantially from linearity (Fig. 1). The general pattern appears to be low levels of intake at high roughage levels, that increase with increasing levels of concentrate until a peak is reached, whereafter intake declines again, thus supporting the postulate presented in the Introduction.

If the proposal of Montgomery & Baumgardt (1965) and many others in later work is accepted, the pattern realized on the pelleted diet (lucerne diet of the wethers) falls into line. One would not expect physical limitations to intake on pellets, so energy regulating factors would probably dominate. Therefore, OM intake would already tend to decrease from very low levels of concentrate because the energy content of the diet increases.

2. **Organic matter digestibility**:

A simple (linear) relationship does not necessarily apply between % concentrate in the diet and % apparent digestibility of OM (OMD). Feeding level could be altered with increasing concentrates or associative effects between roughage and concentrate could be realized. Both could lead to deviation from linearity. However, it is not possible in an analysis of this kind to distinguish effectively between feeding level effects and associative effects. These would be correlated in regression analyses.

It would appear from the literature though, that associative effects might be less pronounced for the types of roughages used here. Generally, roughages with large amounts of structural carbohydrates with a high potential digestibility but a low rate of fermentation appears to be most susceptible to depression in digestion when rapidly fermentable carbohydrates are added (Byers, 1981). The problem apparently relates very much to a drop in pH and an increase in rate of passage. None of the roughages studied actually falls into this class. Roughages containing very little fiber but high in solubles or having fiber with fast rates of digestion (lucerne) or large amounts of indigestible fiber (wheat straw, sugarcane bagasse, sunflower hulls) would tend to suffer the

Table 2

R and r^2 of the relationship between % concentrate and % OMD or % concentrate, feeding level and % OMD

Animal	Roughage source		Linear (r^2)	Multiple Linear (R)
Wethers	*Eragrostis curvula*		0,835	0,914
Wethers	Lucerne		0,843	0,955
Heifers	*E. curvula*		0,664	0,848*
Steers	*E. curvula*	(51 mm screen)	0,952	0,968
Steers	*E. curvula*	(25 mm screen)	0,877	0,925
Steers	*E. curvula*	(13 mm screen)	0,736	0,978*
Steers	*E. curvula*	(6 mm screen)	0,975	0,983
Steers	Sunflower hulls		0,962	0,988
Steers	Wheat straw	(51 mm screen)	0,974	0,998*
Steers	Wheat straw	(25 mm screen)	0,914	0,994*
Steers	Wheat straw	(13 mm screen)	0,746	0,958*
Steers	Wheat straw	(6 mm screen)	0,771	0,913
Steers	Sugarcane bagasse	(pelleted)	0,996	0,998
Steers	Sugarcane bagasse	(unpelleted)	0,962	0,989

* Feeding level is significant ($p < 0,05$)

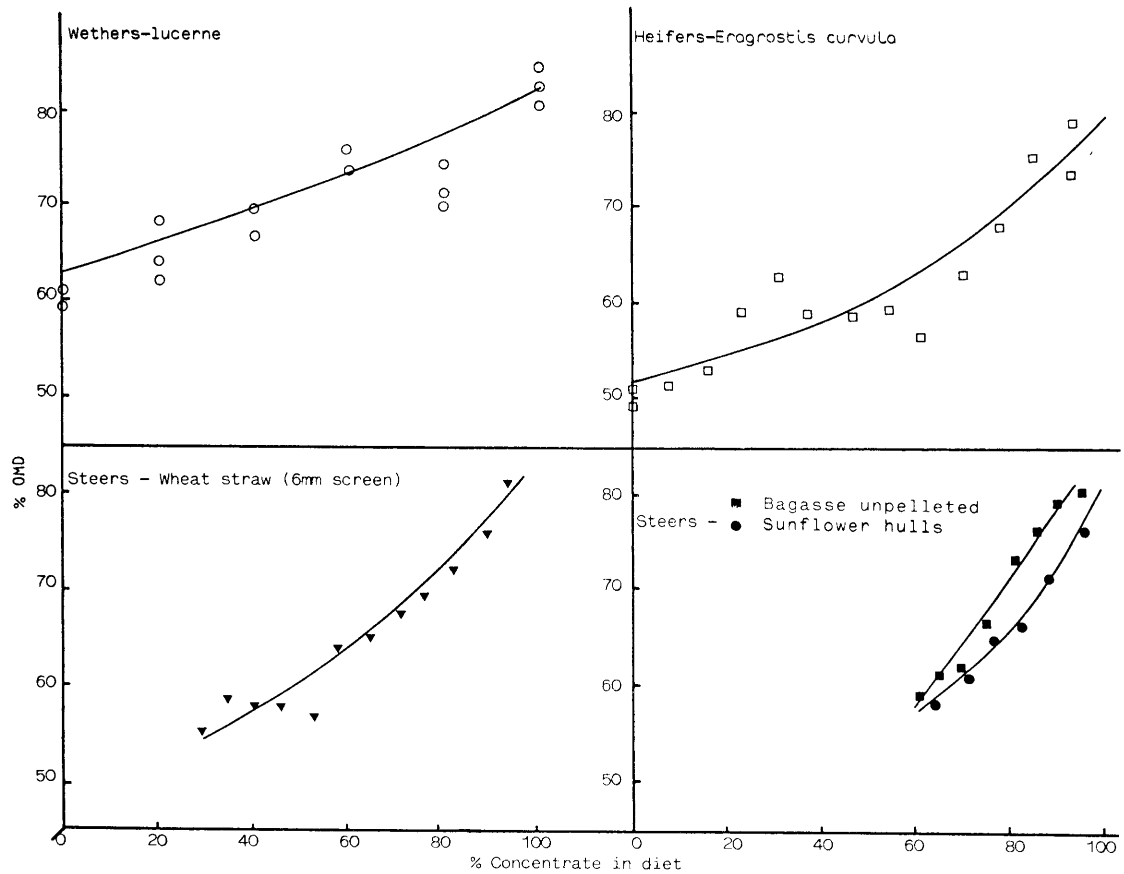

Fig. 2 *The relationship between apparent digestibility of OM and % concentrate in the diet of various feed mixtures.*

least when grain is added. This being the case, it has been assumed that feeding level effects would express the major influence.

The probable effects of feeding level were tested in a multiple linear regression analysis with % concentrate and intake as a percentage of live mass as independent variables. The amount of variation in % OMD which could be explained in this way was compared to when only % concentrate was used as independent variable. The results appear in Table 2.

The effects of feeding level were only significant in a few instances (Table 2). Yet, on inspection of the distribution of points about the line when plotting the data, it was evident that a single linear equation very often gives biased fit. The plots of the same 5 roughage sources used for Fig. 1 are shown in Fig. 2.

Of the 5 roughages plotted only the equation for the heifers on *E. curvula* hay showed a significant regression coefficient for feeding level.Despite this, it would appear that for the majority of the other sources a depression of % OMD was experienced at the lower levels of concentrate. This depression appears to relate to an increase in feeding level, although other factors could also have been responsible. Feeding level effects were also experienced by Meissner, Liebenberg, Pienaar, van Zyl & Botha (1981) in an experiment where *E. curvula* hay was supplemented by maize grain, fed in various physical forms.

Calculated values for OM intake and % OMD established with the best fit with the assumption that intake and digestibility at a 100% concentrate intake should theoretically be the same, are compiled in Appendices 1 and 2 respectively.

3. **Intake patterns of digestible OM**

3.1 *Effect of screen size:*

The patterns of OMD intake of wheat straw and *E. curvula* hay milled through screen sizes of respectively 51, 25, 13 and 6 mm and added at different levels to the concentrates, are illustrated in Fig. 3.

The apparent peak level of OMD intake shifted with screen size. In general, peak intake levels were realized at higher levels of roughage inclusion when smaller screen sizes were used (Fig. 3). The apparent ranking order was 6 mm > 13 mm > 51 mm ≥ 25 mm. The reasons why the levels on the 51 mm screen apparently reached a peak at an equal or higher level of roughage inclusion than that of the 25 mm screen are not clear. It may however be possible that the pattern was not

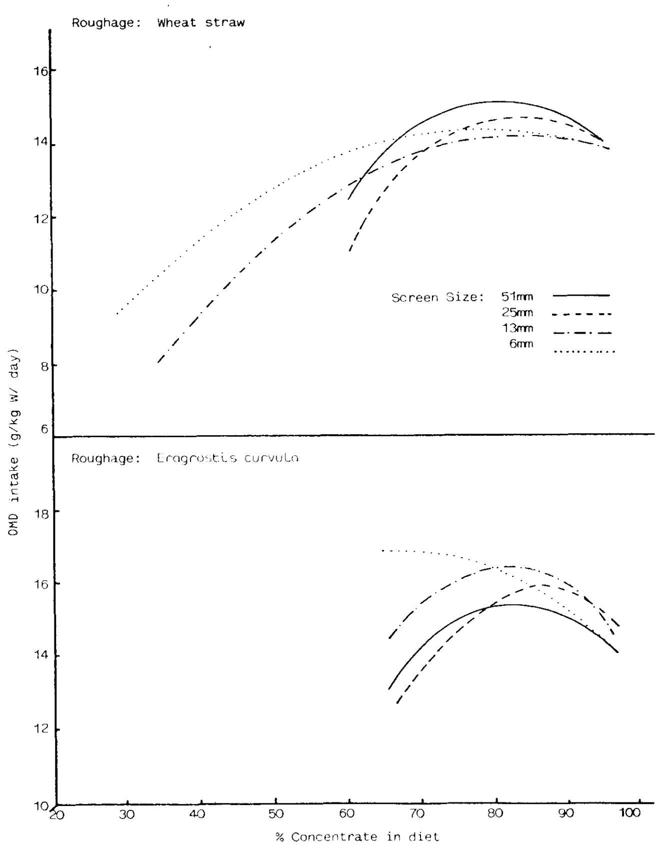

Fig. 3 *The effect of screen size in the hamermill on apparent peak level of OMD intake.*

effectively described due to a lack of degrees of freedom thus making the analysis not sensitive enough to distinguish between such small differences.

The patterns of OMD intake in Fig. 3 conform to the theory of physical limitation to intake of roughage materials (Montgomery & Baumgardt, 1965). One would expect less limitation if the roughage particles are smaller. This is effectively demonstrated by the curves for the 13 mm and 6 mm screens in Fig. 3. In general, these results corroborate many others (Campling, 1970; Bines, 1975; Liebenberg, 1979, a).

However, due to the fact that more roughage is apparently needed when the roughage is milled through a small screen size to realize a peak level of intake, one could conclude that fine particles of roughage in the presence of relatively large amounts of concentrates lead to similar adverse conditions in the rumen than when the amount of roughage in the diet is not sufficient. This was substantiated by visual inspection of the rumen and its contents. The effects of roughage material in promoting a healthy rumen environment have been the subject of many studies and speculation without much quantitative success, because a vast amount of factors which interact are apparently responsible. Thus, it serves no purpose to discuss the probable reasons for the behaviour of the smaller roughage particles within the rumen.

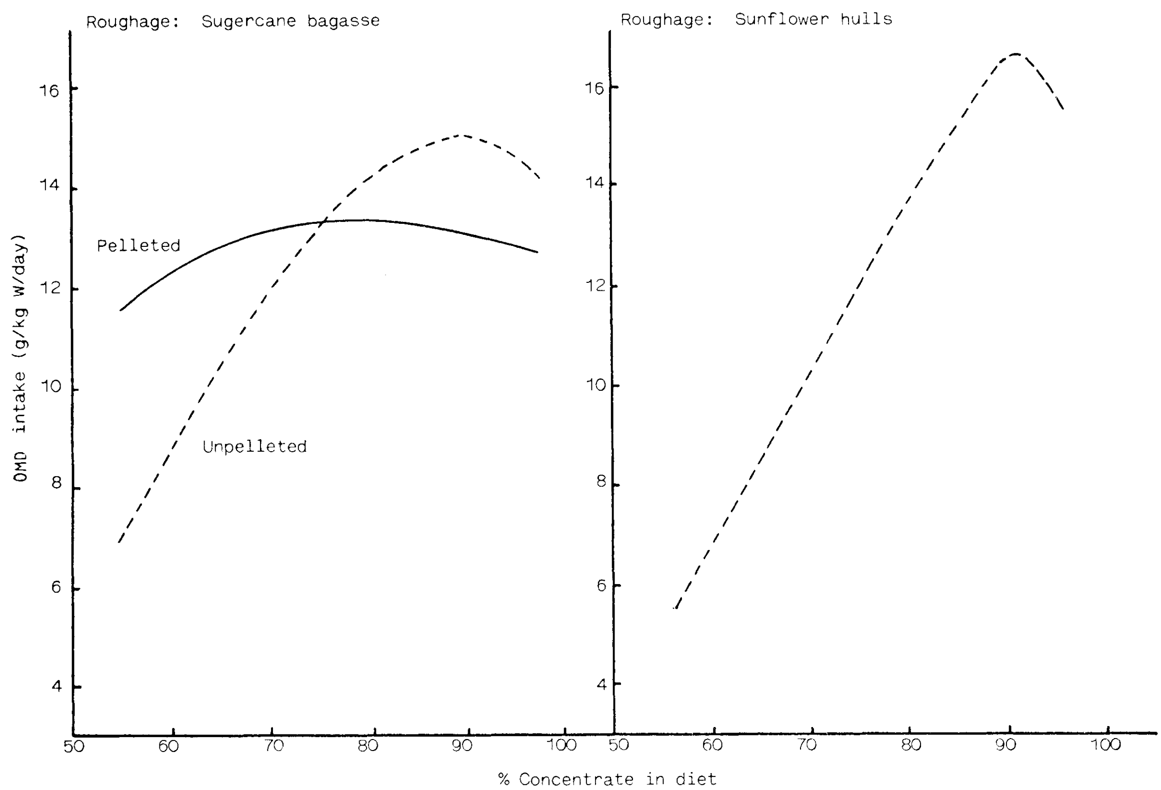

Fig. 4 *The effect of mass/volume ratio on apparent peak level of OMD intake*

3.2 Effects of mass/volume ratio:

The effects of mass/volume ratio on apparent peak level of OMD intake are evident from Fig. 4 where calculated OMD intake is plotted against % concentrate in the diet for the roughages pelleted and unpelleted sugarcane bagasse and sunflower hulls. In order to visualize the difference in mass/volume ratio of these roughage forms the mass/volume ratio* was measured at a 30% roughage inclusion in the mixture. The values were 658 kg/m^3 for bagasse pellets, 273 kg/m^3 for unpelleted bagasse and 375 kg/m^3 for sunflower hulls (Campher, unpublished).

The very low mass/volume ratios of unpelleted bagasse and sunflower hulls apparently caused profound limitations to intake (Fig. 4). Intake increased approximately linearly with every increment of concentrate. The peak levels of OMD intake were consequently realized at very high levels of concentrate; at 90% for unpelleted bagasse and at 92% for sunflower hulls. In contrast to less bulky roughages, the peak has a very narrow range. In a follow up study this very "specific" peak was confirmed for sunflower hulls (Campher, 1982).

Low mass/volume ratios lead to the description of DE intake in terms of energy units/unit volume by Baumgardt and colleagues with better predictive value (Baumgardt, 1970). Unfortunately, this proved to be of limited value as a universal intake predicter of roughages fed alone or in combinations. Campher (1982) working on a number of roughages reported mass/volume ratio as a measure of intake to be specific for a roughage source and the screen through which it was milled. For example (Fig. 4), the mass/volume ratio of unpelleted bagasse was less than that of sunflower hulls, although OMD intake on the unpelleted bagasse was higher at the high levels of roughage inclusion and also increased at a different rate as the % concentrate in the diet increased (The different influences of mass/volume ratio on OMD intake can also be deduced from Fig. 3).

3.3 Effects of species:

The OMD intake patterns of wethers and heifers on feed mixtures containing *E. curvula* hay, milled through a 51 mm screen, are given in Fig. 5. For comparison, the pattern of wethers on the pelleted lucerne mixtures are also shown.

The OMD intake of the heifers increased as the percentage concentrate increased from 0% and reached a peak at about 80% concentrate whereafter it declined again (Fig. 5).

The wethers on *E. curvula* feed mixtures exhibited an intake with similar increasing slope until about 50% concentrate, but at a level 25% higher in terms of g/kg W than that of the heifers. At higher levels of

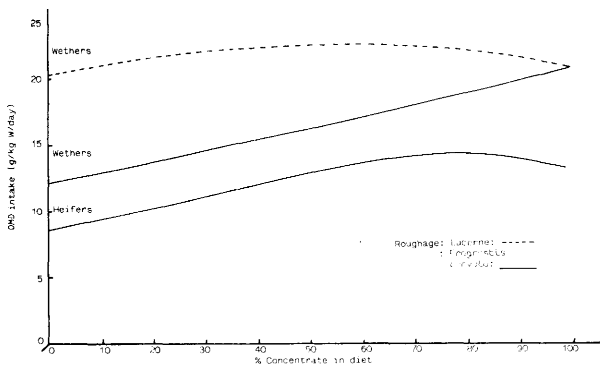

Fig. 5 *OMD intake pattern of wethers on pelleted lucerne - concentrate diet and that of wethers and heifers on unpelleted* Eragrostis curvula - *concentrate diet.*

concentrate, in contrast to the pattern of the heifers, OMD intake continued to increase only to realize its peak at 100% concentrate.

In comparison, OMD intake of the wethers on the pelleted lucerne mixtures peaked at about 55%. The most interesting feature of the relationship however, is the fact that on average these diets were consumed at a 40% higher level than the *E. curvula* diets (Fig. 5). These observations confirmed what was expected during the study period of *E. curvula* intake - the *E. curvula* hay particles produced when using a 51 mm screen, exhibited a profound physical limitation to intake when fed to the wethers but not with the heifers. In comparison to other roughages, heifers had a "normal" intake (see Appendix 1). This physical limitation apparently affected intake even at relatively high levels of concentrate, because, with every increment of concentrate, intake increased linearly. However, since it is unlikely that a physical limitation could hamper intake at roughage levels of only 20% or even less, one has to conclude that other factors also played a role, probably palatability ones. This is highly likely in view of previous experiences with *E. curvula* diets and wethers (Meissner, unpublished).

The pattern of retention time of OM in the rumen and in the total GI tract serves to illustrate the relative differences in level of intake between the wethers and heifers on unpelleted *E. curvula* diets and wethers on pelleted lucerne diets. Retention time of OM was calculated as:

$$\mathrm{Rt\,(h)} = \frac{\text{OM in rumen or GI tract (kg)}}{\text{OM intake (kg/d)}} \times 24\ \mathrm{h}$$

* The mass of the diet which completely filled a 0,125 m^3 square container was determined. The average of four replications was considered representative.

Table 3

Parameters of the equations relating % concentrate in the diet to retention time in the rumen and the G1 tract and F-tests for differences between wethers and heifers on the E. curvula *diets*

Animal	Roughage source	Slope	Intercept	r	S.D. (h)	F-test for differences between	
						Slopes	Intercepts
A. Rumen							
Wethers	*E. curvula*	-0,214	35,3	-0,850**	4,32	0,143	2,91
Heifers	*E. curvula*	-0,233	33,5	-0,851**	5,01		
Wethers	Lucerne	-0,035	15,7	-0,522*	2,10	–	–
B. Total G1 tract							
Wethers	*E. curvula*	-0,242	42,2	-0,853**	4,86	0,058	9,34**
Heifers	*E. curvula*	-0,228	35,8	-0,812**	5,73		
Wethers	Lucerne	-0,036	19,4	-0,481	2,40	–	–

* $p < 0{,}05$
** $p < 0{,}01$

where the OM in the rumen and G1 tract was obtained after the animals were slaughtered. The linear relationships between % concentrate in the diet (X) and retention time in hours (Y) for the wethers and heifers on the *E. curvula* and wethers on the lucerne diets are shown in Table 3. The results of covariance analyses for species effects on the *E. curvula* diets are also shown.

Despite the fact that the procedure of determining OM in the rumen and elsewhere i.e. following slaughter, is evidently not a very accurate procedure to estimate mean retention time, the method of least squares analysis of retention time vs % concentrate in the *E. curvula* diets enabled realistic quantification, giving correlation coefficients of -0,8 +, and an error of determination of about 5 hours (Table 3). The results of covariance analyses on the rumen relationships of the wethers and heifers on the *E. curvula* diets showed non-significant differences ($p < 0{,}05$) between intercepts and slopes. On the total G1 relationships intercepts were highly significantly ($p < 0{,}01$) different while slopes were not significantly different, which means that the differences between wethers and heifers were the same for all roughage-concentrate proportions. The rumen retention time on the pelleted lucerne mixtures was just significantly ($p < 0{,}05$) correlated to % concentrate in the diet while the G1 retention time was not significantly correlated (Table 3) which means that retention time changed little with % concentrate in the diet.

In view of the fact that the slopes between the rumen and total G1 tract relationships also did not differ significantly, the parameters of the relationships in Table 3 were adapated to:

Unpelleted *E. curvula* mixtures

	Retention time in:	Common slope	Adjusted intercept (h)
Wethers	rumen	-0,229	36,1
	G1 tract		41,4
Heifers	rumen		33,3
	G1 tract		35,8

Pelleted lucerne mixtures

Wethers	rumen	-0,036	15,7
	G1 tract		19,4

The equations suggest that the retention time in the rumen and the G1 tract when feeding 100% *E. curvula* was respectively 36,1 and 41,4 h in wethers and 33,3 and 35,8 h in heifers, that retention time was less in heifers than in wethers on all the *E. curvula* - concentrate proportions, that retention time in wethers on the pelleted lucerne mixtures changed very little with % concentrate in the diet and that the retention time of 100% pelleted lucerne hay (intercept) was only about half that of 100% unpelleted *E. curvula* hay.

The longer retention time of *E. curvula* diets in the wethers than in the heifers probably explain their higher apparent digestibilities of OM in comparison to the latter

(Appendix 2). In contrast, the wethers on the pelleted lucerne mixtures exhibited very short retention times which is in accordance with their very high intakes. Due to the fact that the pellets did not present physical limitations to intake, retention time was only slightly altered by % concentrate in the diet.

Conclusions

1. The OM intake of unpelleted diets increases with % concentrate in the diet, reaches a peak which is specific for a particular roughage, its particle size and its mass/volume ratio, and which is apparently different for sheep and cattle, then declines at yet higher levels of concentrate which amongst others could be associated with adverse conditions within the rumen. The pattern of OMD intake is similar but usually peaks at a higher level of concentrate than OM intake.

2. It is possible to determine the most desirable inclusion level of a roughage in a feedlot diet through method of description of intake at various levels of concentrate.

3. The relationship between apparent digestibility of OM and % concentrate in the diet may deviate from linearity since it is influenced by feeding level and probably also by associative effects, although it is unlikely that the utilization of typical South African roughages would be markedly affected by the latter.

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Appendix 1

Organic matter intakes in g/kg W/day for various feed mixtures

Animal	Roughage source	% Concentrate									
		0	10	20	30	40	50	60	70	80	90
Wethers	*E. curvula*	20,9	21,4	21,9	22,3	22,7	23,2	23,5	23,9	24,2	24,6
Wethers	Lucerne (pelleted)	32,3	32,7	32,7	32,6	32,2	31,7	30,9	29,9	28,7	27,2
Heifers	*E. curvula*	18,0	19,0	19,9	20,8	21,5	22,2	22,7	22,9	22,0	19,8
Steers	*E. curvula* (51 mm screen)	–	–	–	–	–	–	16,5	18,6	19,7	18,5
Steers	*E. curvula* (25 mm screen)	–	–	–	–	–	–	16,9	19,5	21,0	20,6
Steers	*E. curvula* (13 mm screen)	–	–	–	–	–	–	19,7	23,4	24,3	21,9
Steers	*E. curvula* (6 mm screen)	–	–	–	–	–	–	24,7	24,0	22,2	19,7
Steers	Sunflower hulls	–	–	–	–	–	6,97	11,6	15,3	18,6	21,2
Steers	Wheat straw (51 mm screen)	–	–	–	–	–	22,1	23,1	22,7	21,1	18,9
Steers	Wheat straw (25 mm screen)	–	–	–	–	–	16,1	19,0	20,3	20,0	18,4
Steers	Wheat straw (13 mm screen)	–	–	–	13,2	16,5	18,9	20,3	20,7	20,2	19,0
Steers	Wheat straw (6 mm screen)	–	–	15,4	18,4	20,5	21,5	21,5	20,9	19,7	18,1
Steers	Sugarcane bagasse (pellets)	–	–	–	–	–	18,8	20,1	20,0	18,9	17,7
Steers	Sugarcane bagasse (not pelleted)	–	–	–	–	–	9,46	15,4	19,3	21,0	20,5

Appendix 2

Percentage OMD for various feed mixtures

Animal	Roughage source	% Concentrate									
		0	10	20	30	40	50	60	70	80	90
Wethers	*E. curvula*	58,1	60,6	63,2	65,7	68,2	70,8	73,3	75,8	78,4	80,9
Wethers	Lucerne (pelleted)	63,0	64,5	66,1	67,8	69,6	71,5	73,4	75,5	77,6	79,8
Heifers	*E. curvula*	51,6	53,2	54,8	56,3	57,8	60,0	62,9	66,2	70,2	74,7
Steers	*E. curvula* (51 mm screen)	–	–	–	–	–	–	70,7	74,8	78,4	80,6
Steers	*E. curvula* (25 mm screen)	–	–	–	–	–	–	67,4	70,5	73,7	77,4
Steers	*E. curvula* (13 mm screen)	–	–	–	–	–	–	68,5	65,3	67,5	73,4
Steers	*E. curvula* (6 mm screen)	–	–	–	–	–	–	68,1	70,9	73,8	77,5
Steers	Sunflower hulls	–	–	–	–	–	50,2	59,2	66,9	73,8	79,1
Steers	Wheat straw (51 mm screen)	–	–	–	–	–	45,3	54,9	64,2	72,4	78,0
Steers	Wheat straw (25 mm screen)	–	–	–	–	–	48,8	58,3	66,4	73,6	79,2
Steers	Wheat straw (13 mm screen)	–	–	–	54,4	56,5	59,4	62,4	66,6	71,0	75,6
Steers	Wheat straw (6 mm screen)	–	–	49,3	52,5	55,6	59,8	63,8	68,3	72,8	77,5
Steers	Sugarcane bagasse (pellets)	–	–	–	–	–	57,0	61,1	65,4	70,0	75,5
Steers	Sugarcane bagasse (not pelleted)	–	–	–	–	–	53,6	56,8	61,1	66,6	73,3