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FINENESS AND CONCENTRATE TO LOW QUALITY ROUGHAGE RATIO OF COMPLETE DIETS FOR DAIRY COWS. I. INTAKE AND DIGESTIBILITY UNDER *AD LIBITUM* FEEDING CONDITIONS

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OPSOMMING: FYNHEID EN KRAGVOER TOT LAE KWALITEIT RUVOER VERHOUDING VAN VOLLEDIGE RANTSOENE VIR MELKKOEIE. I. INNAME EN VERTEERBAARHEID ONDER *AD LIBITUM* VOEDINGSTOESTANDE

Ses-en-dertig lakterende melkkoeie is gebruik in 'n proef waar 'n gedeeltelike omruil ontwerp toegepas is. Die effek van ruvoerfynheid en kragvoerpersentasie op inname en verteerbaarheid is ondersoek. Nege rantsoene verkry uit 'n kombinasie van 3 sifopeninggroottes (6, 13, 19 mm) en 3 kragvoer persentasies (35, 50, 65) is gebruik. Mieliestrooi is as 'n laegraadse ruvoerkomponent ingesluit. 'n Verhoging in die kragvoer- tot ruvoerverhouding en kleiner sifopeninggroottes het inname met 44 persent verhoog. Elke kombinasie van sifopeninggrootte en kragvoer tot ruvoerverhouding het inname beinvloed. Dit is aangedui dat die fynheid van 'n rantsoen minder belangrik is by rantsoene met 'n hoë kragvoerinhoud. Inname het toegeneem tot by die hoogste kragvoerinhoud (65 persent) wat daarop dui dat die moontlike punt van konstante VE-inname met mieliestrooi as ruvoerkomponent nie by 65 persent kragvoer bereik is nie. Verteerbaarheidstudies by *ad libitum* inname het aangedui dat sifopeninggrootte en kragvoerinhoud geen effek gehad het op die skynbare verteerbaarheid van DM en N nie. Skynbare veselverteerbaarheid is betekenisvol ($p < 0{,}01$) verlaag met 0,3 persent en 0,5 persent vir elke 1 persent verhoging in kragvoer en 1 mm verlaging in sifopeninggrootte, respektiewelik.

SUMMARY:

Thirty six lactating cows were used in a trial with a partially balanced change-over design to determine the effect of the fineness of roughage and concentrate to roughage ratio on intake and digestibility. Nine rations were used with combinations of 3 screen sizes (6, 13, 19 mm) and 3 concentrate percentages (35, 50, 65). Maize straw was included as a poor quality roughage component.

An increase in the concentrate component and a decrease in screen size resulted in an increased intake of 44 per cent. Each combination of screen size and concentrate to roughage ratio resulted in a different intake. It was found that the fineness of a ration becomes less important at high concentrate levels. Intake increased with increasing concentrates in the diet which indicated that at the 65 per cent concentrate level the possible point of constant DE-intake was not obtained with maize straw as roughage component.

Digestibility studies at *ad libitum* intake indicated that screen size and concentrate to roughage ratio had no effect on apparent DM and N digestibilities. Apparent fibre digestibility was significantly ($p < 0{,}01$) decreased by 0,3 per cent and 0,5 per cent with 1 per cent increase in concentrate and one mm decrease in screen size, respectively.

One of the most important input parameters in an intensive milk production system is the *ad libitum* feed intake of the cow. Physical, chemical and quality characteristics of diets determine their intake and digestibility (Rodrique & Allen, 1960; Blaxter, Wainman & Wilson, 1961; Balch & Campling, 1962; Conrad, Pratt & Hibbs, 1964; Campling, 1970; Cowan, Oliver & Elliot, 1970; Jarrige, Demarquilly, Journet & Béranger, 1973). Energy intake will increase with increasing energy concentration in the diet up to a certain level (Blaxter, 1962; Bines, 1975). If the digestible energy content of a feed increases above a certain level, DM intake decreases to the extent that DE intake becomes constant (Baumgardt. 1970; Van der Honing, 1975; Journet & Remond, 1976). In a review of the literature on the effect of grinding of roughage on intake, Van der Honing (1975) concludes that grinding does not always increase voluntary intake. The amount of concentrates in the diet could interact with the effect of grinding on voluntary intake (O'Dell, King & Cook, 1968). The quantitative interactions between the influence of particle size and concentrate percentage on intake in dairy cow feeding are known only superficially.

The influence of factors involved in depressing digestibility at higher levels of intake are poorly known. What is known however, is that roughage quality, concentrate to roughage ratio, percentage crude fibre in the diet, processing of the roughage (or whole diet), roughage species and the amount of structural material present are all factors that could contribute to possible changes in digestibility at higher levels of intake (Moe, Reid & Tyrrell, 1965. Montgomery & Baumgardt, 1965; Demarquilly & Journet, 1967; Dijkstra, 1972; Ekern, 1972; Jarrige *et al.*, 1973).

A decline in digestibility with higher intake is noted for mixed rations containing ground pelletted forages or concentrates. Depression in digestibility seems to increase with a reduction in particle size of low quality forage (specifically the fibre-fraction) and also with a higher proportion of concentrates (Blaxter & Graham, 1965. Conrad *et al.*, 1964; Reid, 1964; Wagner & Loosli, 1967; Leaver, Campling & Holmes, 1969; Alvash & Thomas, 1971; Porter, Balch, Coates, Fuller, Lotham, Sharp, Smith, Sutton & Jane Williams, 1972; Wainman, Blaxter & Smith, 1972; Dijkstra, 1972; Van der Honing, 1975). Quantitative effects of particle size in combination with the percentage concentrate present in a diet for lactating animals, are not well known, particularly when a poor quality roughage is used.

This paper describes the influence of varying concentrate : roughage ratios as well as fineness of grinding of the roughage component on *ad libitum* intake and apparent digestibility of complete diets in respect of the dairy cow. The roughage used was of low quality, namely maize straw.

Procedure

Thirty six lactating Friesland cows with a potential milk production of 15–20 ℓ/day over a 300 day lactation, in their third or subsequent lactation were chosen as experimental animals from the herd at the Animal and Dairy Science Research Institute.

Statistical design of experiment

A partially-balanced change-over design, Model 128, of a series described by Patterson & Lucas (1962), capable of providing treatment comparisons of high precision, was used. The latter may be ascribed to the elimination of individual animal variation from experimental error and an increase in the number of degrees of freedom from repeated measurements on the same animal. Hence, small numbers of animals can be used for experimental work. The model consists basically of 9 treatments applied in 12 blocks, with 3 periods (I, II & III) and 3 animals per block. Animals were grouped in homogenous blocks of three, with calving date, milk production potential and age as blocking factors. Each cow was randomly allotted to the first period in each block and completed the other two periods in its allotted order. Blocks were chosen randomly. In this report $p \leqslant 0{,}01$ was used throughout as significance level to accommodate the effect on significance levels resulting from simultaneous tests.

Model 128 of Patterson and Lucas (1962) allows for the determination of possible residual effects. As no computer programme was available for this specific statistical model, most of the analysis were done with a least-squares programme (Harvey, 1972). Residual effects for a few key parameters were determined separately. No significant residual effects were found. For this reason, direct treatment effects, ignoring residual effects, were used throughout. Means for each treatment were calculated by adding the overall mean to the estimated constants as determined by the model used.

Diets

Nine diets based on maize grain and maize straw supplemented with sunflower oil cake meal (8–11 per cent), urea (1 per cent), dicalcium phosphate (0,5 per cent), limestone powder (0,6–0,7 per cent), salt (1 per cent) and a commercial vitamin-mineral mixture were used. Diets were batch mixed in 400 kg lots. The maize straw used (whole maize plant without cob and cob-leaves) was coarsely ground (50 mm screen) and stored in bags. Maize grain was milled through a 6 mm screen. All dietary components were weighed in their specific ratios, blended and milled through a hammermill attached to a vertical feed mixer. The nine diets were finally mixed into combinations of three concentrate to roughage ratios and three screen sizes as indicated in Table 1. Diets were balanced for protein, calcium (Ca) and phosphorus (P). All diets were fed in an unpelletted form.

Table 1

Concentrate to roughage ratios, screen sizes and estimated dietary compositions

Screen size (mm)		Concentrate : Roughage (%)		
	6	65 : 35	50 : 50	35 : 65
	13	65 : 35	50 : 50	35 : 65
	19	65 : 35	50 : 50	35 : 65
Crude protein	(%)	13	13	13
Ca	(%)	0,6	0,6	0,6
P	(%)	0,3	0,3	0,3
Crude fibre	(%)	15	20	25
Digestible	Energy(MJ/kg)	13,0	12,5	11,9

The diets were analysed for crude protein, crude fibre, dry matter (DM), Ca and P. The Ca and P data will be reported in a separate publication.

Experimental routine

Animals were trained and accustomed to stable routine during a 30 day pre-trial steam-up period. A fixed amount of concentrate was fed with lucerne hay *ad libitum* according to the condition of each cow. The first 10 days *post partum* served as an adaptation period for the complete diets. From 10 days subsequent to calving the programme was as follows:

10– 40 days after calving–Allotted diet for period I
40– 50 days after calving–Digestibility determination
50– 80 days after calving–Allotted diet for period II
80– 90 days after calving–Digestibility determination
90–120 days after calving–Allotted diet for period III
120–130 days after calving–Digestibility determination

Digestibility was determined over a period of 10 days. Faeces was collected by means of a light harness for dairy cows (Liebenberg & Papenfus, 1975) and urine by an indwelling catheter (Neitz & Hartman, 1974). DM intakes were measured daily. Cows were fed individually in stanchions with rubber insertions (6 mm) fixed on slatted wooden floors as bedding. Animals were exercised for 2 hours daily, one hour after morning milking (06h00) and one hour before afternoon milking (15h00).

Results and discussions

Average fibre contents of the diets are given in Table 2.

Table 2

Fibre contents and standard deviations of the experimental diets

Concentrate (%)	Screen size (mm)	Fibre (%)
35	6	23,6 ± 1,9
35	13	22,8 ± 1,0
35	19	24,8 ± 2,2
50	6	18,8 ± 1,2
50	13	18,4 ± 0,9
50	19	18,6 ± 1,4
65	6	13,5 ± 1,1
65	13	13,3 ± 1,2
65	19	13,4 ± 1,1

From Table 2 it is clear that increases in concentrate percentage from 35 to 65 were associated with decreases in the fibre content of the diets from about 23 to about 13 per cent.

The coefficient of variation (C.V.) for fibre was 7,8 per cent. From these results it appears that the variation in fibre content of the diets was affected little by the fact that they were mixed in small batches over a period of 3 years. The average crude protein, ash, Ca and P content of the diets were 12,9 ± 1,7; 6,8 ± 0,7; 0,6 ± 0,1 and 0,3 ± 0,03 respectively.

Intakes

Data on amounts of the different diets voluntarily taken in are presented in Table 3.

Table 3

Voluntary intake differences between diets varying concentrate : roughage ratio and screen size

Screen size	DM intake kg/$W_{kg}^{0,75}$/day Concentrate : Roughage (%) 35 : 65	50 : 50	65 : 35	Mean
6	*$0,143^{cde}$	$0,154^{abcd}$	$0,163^{a}$	0,153
13	$0,122^{hg}$	$0,141^{def}$	$0,160^{ab}$	0,141
19	$0,113^{h}$	$0,133^{efg}$	$0,158^{abc}$	0,135
Mean	0,126	0,142	0,160	0,143

*Means with different superscripts differ significantly ($p \leqslant 0,01$)

From Table 3 it can be seen that at the 35 per cent concentrate level a decrease in screen size from 19 mm to 13 mm, resulted in a non significant increase in intake from 0,113 to 0,122 kg/$W_{kg}^{0,75}$. Decreasing screen size from 13 mm to 6 mm increased intake significantly ($p \leqslant 0,01$) to 0,143 kg/$W_{kg}^{0,75}$.

At the 50 per cent concentrate level a decrease in screen size from 19 mm to 6 mm resulted in a significant ($p \leqslant 0,01$) increase in intake from 0,133 to 0,154 kg/$W_{kg}^{0,75}$. At the 65 per cent concentrate level, intake increased from 0,158 kg/$W_{kg}^{0,75}$ with a 19 mm screen to 0,163 kg/$W_{kg}^{0,75}$ with a 6 mm screen.

From Table 3 it is clear that DM intake did not change significantly when screen size was decreased from 19 to 13 mm. The latter holds for all the different concentrate percentages. The average DM intake over all concentrate percentages for diets milled with 6,13 and 19 mm screens were 0,153; 0,141 and 0,135 kg/$W_{kg}^{0,75}$ respectively, which indicate an overall increased intake with a decrease in screen size. From Table 3 it is also clear that an increase in concentrate level resulted in a significant ($p \leqslant 0,01$) increase in DM intake. Intake increased from 0,143 to 0,163 kg/$W_{kg}^{0,75}$ when the concentrate percentage of diets milled through a 6 mm screen increased from 35 to 65 per cent. With diets milled through a 13 mm screen, intake increased significantly ($p \leqslant 0,01$) from 0,122 to 0,141 kg/$W_{kg}^{0,75}$ with an increase in concentrate from 35 to 50 per cent, and a further significant ($p \leqslant 0,01$) increase in intake to 0,160 kg/W $_{kg}$ ^{0,75} when concentrate level increased from 50 to 65 per cent. With diets milled through a 19 mm screen intake also increased significantly ($p \leqslant 0,01$) from 0,113 to 0,133 and 0,133 to 0,158 kg/W $_{kg}$ ^{0,75} with an increase in concentrate level from 35 to 50 and 50 to 65 per cent, respectively. The average DM intakes for diets containing 35, 50 and 65 per cent concentrate were 0,126; 0,142 and 0,160 kg/W $_{kg}$ ^{0,75} respectively, indicating an overall significant ($p \leqslant 0,01$) increase in DM intake with an increase in concentrate percentage.

Dry matter intakes of the complete diets for different experimantal periods are given in Table 4.

Table 4

The mean intake of diets in different periods post partum

Experimental periods (days *post partum*)		Daily DM intake	
		kg/$W_{kg}^{0,75}$	As percentage of live mass
10	50	0 139	2,88
50	90	0,146	3,04
90	130	0,144	2,99

The means in Table 4 did not differ significantly.

The overall mean daily DM intake of 0,143 kg/W $_{kg}$ ^{0,75}, 15,5 kg or 3 per cent of live mass, compares favourably with intakes on other complete diets under *ad libitum* conditions for lactating cows (Cowan *et al.*, 1970; Bull, Baumgardt & Clancy, 1976; Neitz, 1974). From the results on DM intake it is clear that the diets offered to the cows followed the generally expected trends concerning an increase in concentrate level and a decrease in screen size, namely an increased intake with an increase in concentrate level and a decrease in particle size (Van der Honing, 1975). Results also indicated that the fineness and concentrate content of a complete diet had an important combined effect on intake by dairy cows if a poor quality roughage is used. It is clear from Table 3 that the level of feed intake was influenced by screen size and concentrate percentage resulting in a specific intake for a specific screen size: concentrate percentage combination. Results clearly stress the importance of the fineness of complete diets. Although the rate of increased intake associated with an increase in concentrate was less for the 6 mm screen size diets, the intake of these diets were always higher than those of the diets milled through the other screen sizes. From the results it is clear that increased intakes, resulting from decreases in screen sizes, became less pronounced when the diet had a high concentrate content. Over the range of diets milled through 6–19 mm screens, DM intake increased by 4, 17 and 28 per cent with diets containing 65, 50 and 35 per cent concentrate respectively. The different intakes between periods represent an increase in DM intake of only 5 per cent between 10 and 90 days *post partum* and of only 4 per cent between 10 and 130 days *post partum.* The latter represents an increase in daily DM intake of less than 1 kg. Thus, the variation caused by different time intervals (10 – 130 days *post partum)* did not have a marked influence on the intake of the experimental diets.

Apparent digestibility

In this experiment digestibility was measured at *ad libitum* intake. The results on digestibility indicate no significant differences in the apparent digestibility of DM, OM and N between experimental diets. The overall mean apparent digestibilities for DM, OM and N was 60,0 per cent (range 58 – 63 per cent); 62,4 per cent (range 59,4 – 64,4 per cent) and 63,2 per cent (range 61 – 65 per cent), respectively.

Table 5

Apparent digestibility of crude fibre in diets varying in concentrate: roughage ratio and screen size

Screen size (mm)	Apparent fibre digestibility (%) Concentrate : Roughage (%) 35 : 65	50 : 50	65 : 35	Mean
6	*51,3^{abcd}	45,4^{cdefg}	42,0^{efgh}	46,2
13	53,9^{abc}	48,0^{cde}	44,9^{defgh}	48,9
19	57,0^{a}	55,4^{ab}	46,8^{cdef}	53,1
Mean	54,1	49,6	44,6	49,4

*Means with different superscripts differ significantly ($p \leqslant 0,01$).

From the results in Table 5 it can be deduced that at 35 per cent concentrate, a decrease in screen size from 19 mm to 6 mm decreased apparent fibre digestibility from 57,0 to 51,3 per cent. This decrease was not significant. At 50 per cent concentrate the decrease was from 55,4 to 45,4 per cent which was significant ($p \leqslant 0,01$). At 65 per cent concentrate, apparent fibre digestibility decreased from 46,8 to 42,0 per cent with a decrease in screen size from 19 to 6 mm. With diets milled through a 6 mm screen an increase in concentrate from 35 to 65 per cent resulted in a significant ($p \leqslant 0,01$) decrease in apparent fibre digestibility from 51,3 to 42,0 per cent. With diets increasing in concentrate from 35 per cent to 65 per cent apparent fibre digestibility of diets milled through 19 and 13 mm screen also decreased significantly ($p \leqslant 0{,}01$) from 57,0 per cent and 53,9 per cent to 46,8 per cent and 44,9 per cent respectively. The screen size means indicate a significant ($p \leqslant 0{,}01$) decrease from 53,1 to 46,2 per cent in apparent fibre digestibility with a decrease in screen size from 19 to 6 mm. The concentrate to roughage ratio means show a significant ($p \leqslant 0{,}01$) decrease in apparent fibre digestibility from 54,1 to 44,6 per cent with an increase in concentrate from 35 to 65 per cent. It is consequently clear that a decrease in screen size and an increase in concentrate decreased apparent fibre digestibility significantly ($p \leqslant 0{,}01$).

Conclusions

The results on the intake of these complete diets tend to follow the general trend for an increase in concentrate and a decrease in particle size of complete diets with poor quality roughage (Campling, 1970; Bines, 1976) in the sense that it was possible to increase DM intake by 44 per cent (daily DM intake from 0,113 to 0,163 $kg/W_{kg}^{0,75}$) when the percentage concentrate was increased from 35 to 65 per cent and the screen size was decreased from 19 to 6 mm. Based on the results in this trial the expected DE intakes of cows under an *ad libitum* feeding regime, were estimated for cows on complete diets with different concentrate percentages and a poor quality roughage component varying in fineness (Table 6).

The threshold at which physical limitations of a diet cease to be important in the regulation of intake (Conrad *et al.*, 1964; Montgomery *et al.*, 1965; Baumgardt, 1970) seems not to have been reached with the experimental diets containing maize straw as roughage. The highest intake was achieved with the smallest (6 mm) screen size and highest concentrate (65 per cent) diets.

Table 6

Estimated voluntary DE intakes of dairy cows on a diet varying in fineness and concentrate percentages

Fineness of roughage expressed as screen size (mm)	Percentage concentrate	DE intake MJ/day		
		400 kg cow	500 kg cow	600 kg cow
6	35	127,9	151,2	173,4
6	50	139,4	164,8	188,9
6	65	162,1	191,7	219,7
13	35	111,0	131,2	150,4
13	50	130,7	154,5	177,1
13	65	156,4	184,9	212,0
19	35	103,5	122,4	140,3
19	50	128,9	152,4	174,8
19	65	148,5	175,6	201,3

It is furthermore concluded that the main influence that concentrate to low quality roughage ratio and screen size had on digestibility was related to the roughage fraction of the diets. This is clear from the significant ($p \leqslant 0{,}01$) effect on apparent fibre digestibility. Because of a lower retention time of particles in the reticulo-rumen and a faster rate of passage (Blaxter & Graham, 1956) diets milled through the 6 mm screen and containing 65 per cent concentrates had the lowest fibre digestibilities. On average, 1 per cent increase in concentrate resulted in a 0,3 per cent decrease in apparent fibre digestibility. A 1 mm decrease in screen size resulted in 0,5 per cent decrease in apparent fibre digestibility.

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