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Particle size distribution and outflow rate from the rumen of cows fed rations with different protein sources*

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ABSTRACT

Three non-lactating cows of about 470 kg BW were fed rations of meadow hay and concentrate (79:21) containing fish meal (ration F) or rapeseed oilmeal (ration R).

Total rumen content was evacuated manually before feeding (0 h) and 4 and 8 h after feeding. The interval between two successive evacuations was 7 days. Rate of passage of solid particles from the rumen was measured using Cr mordanted hay, liquid fraction outflow using Co-EDTA as indicators. Particle size distribution in the digesta was determined by wet-sieving using screen mesh sizes 5.0; 1.0 and 0.25 mm.

The total amounts of rumen digesta, dry matter and crude protein measured at different times after feeding did not depend on the source of protein in the ration. The potential digestibility of crude fibre, ADF, NDF and ADL was higher ($P < 0.05$) on the ration with fish meal, particularly 8 and 12 h after feeding. The proportion of the different sizes of particles in DM of total digesta was uniform over time after feeding. The proportion of particles smaller than 1 mm was only a little higher in the rumen of cows fed ration F ($P < 0.05$). Crude protein content was higher ($P < 0.05$) in particles larger than 5 mm and of lignin in particles smaller than 1 mm when feeding the fish meal-containing ration. The proportion of particles in the rumen DM smaller than 1 mm was 64% at 4 and 8 h and increased to about 70% at 12 h after feeding both rations.

The critical particle size was found to be 0.52 mm, rumen outflow rate of the solid fraction was 6.6% and liquid fraction 15.5%/h ; these parameters were not affected by the protein source in the diet.

KEY WORDS: rumen, protein, particle size, chemical composition, outflow rate

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INTRODUCTION

Feed intake by ruminants depends to a considerable degree on the outflow rate of rumen digesta particles to the omasum and reticulum. The outflow of feed particles depends on their size. It is accepted that feed particles larger than 1 mm can not exit the rumen until they are reduced in size (Poppi et al., 1980, 1985). On the basis of particle size, the rumen content is divided into a pool of small particles (< 1.0 mm) that exit the rumen, and large particles (> 1 mm) that must be broken down before they can leave. The studies of Poppi et al. (1985) have shown that the size of the particles leaving the rumen does not undergo any major changes after passing through the remaining parts of the digestive tract. This suggests that the size of particles leaving the rumen can be determined on the basis of their size in the faeces.

Particle size and their proportion in the rumen digesta change with time after feeding and depend on feed mastication during its uptake and rumination (Ulyatt et al., 1986). Recently, the important role of bacteria in decreasing particle size was demonstrated using the *in sacco* method (Bowman and Firkins, 1996). Microorganisms do not reduce particle size directly, but by destroying the physical structure of plant tissues, facilitate reduction during rumination.

Numerous factors such as feed type, fibre content, and intake, may affect the rate at which feed particles are degraded in the rumen and their outflow rate. There is no information in the literature on the effect of nitrogen source on the above processes, although it is known that it can affect the digestion rate of organic substances and fibre in the rumen (McAllan and Smith, 1983; McAllan and Griffith, 1987; Dakowski, 1992).

The objective of this study was to determine the effect of protein source on changes in rumen particle size, chemical composition and the qualitative and quantitative chemical composition of the rumen contents at various times after feeding.

MATERIAL AND METHODS

Animals and feeds

The experiment was carried out on three non-lactating Black-and-White Lowland cows fitted with permanent Diamond rumen fistulae. The animals received rations (Table 1) composed of cut meadow hay, barley meal supplemented with a mineral mixture and rapeseed oilmeal (R) in the first part of the experiment, and fish meal (F) in the second. The feed was given in two rations at 8.00 and 20.00 h with free access to water.

TABLE 1

Composition of the diets and a proportion of dry matter (DM), crude protein and crude fibre from the particular feed in the diet

Feed	kg	Proportion in the diet, %		
		DM	crude protein	crude fibre
Diet R				
ground barley	1.0	9.9	9.4	1.9
rapeseed meal	1.1	11.3	31.0	5.7
meadow hay	8.0	78.8	59.6	92.4
Diet F				
ground barley	1.4	13.8	12.6	2.8
fish meal	0.7	7.4	30.4	0.0
meadow hay	8.0	78.8	57.0	97.2

Experimental design

Rumen content sampling was begun after 21 days of feeding the experimental diet. The entire content was removed from the rumen before feeding (0), and 4 and 8 h after feeding. The contents were weighed, mixed manually, and 9 kg samples were taken, after which the remainder was quickly replaced in the rumen. An effort was made to keep the duration of the entire procedure under 45 min. The next emptying of the rumen of the same cow was carried out no earlier than after 7 days. The rumen content samples were divided into 500 g aliquots and frozen at -18^{0}C.

The rumen content particles were separated into 3 fractions according to size (A: above 5 mm; B: 1 to 5 mm, C: 0.25 to 1 mm) by wet sieving using a Fritsch Analysette 3 (20 cm Ø) sieves. A vibration amplitude of 7, and 5 min duration of sieving with a water flow rate of 1.4 l/min were used, then the fraction was rinsed three times allowing free water fall (approx. 7 l portions each time), then sieving was repeated for 5 min under running water (1.4 l/min). The share of fraction D (under 0.25 mm) flowing out with the water in the separator was calculated.

The rate of passage of the solid fraction from the rumen was determined using Cr mordanted hay prepared according to Udén et al. (1980). Mordant was given in a single does of 120 g/cow (7.2 g Cr) into the rumen before the morning feeding. The total faeces collection was conducted for 168 h, taking samples every 4 h for the first 2 days, every 6 h for three days, every 8 h for the next two days, and every 12 h in the last two days.

The outflow of the liquid fraction from the rumen was determined ,using Co-EDTA (Udén et al., 1980). A solution of 300 ml Co-EDTA containing 2.5 g Co was instilled into the rumen before the morning feeding. Samples of rumen fluid were taken after 2, 4, 6, 8, 12, 16 and 24 h to determine Co content.

The content of the indigestible fraction in the rumen was determined after incubation of freeze-dried rumen contents (4 g) in nylon bags (pore size 42 mm, external dimensions 11 x 8 cm) in the rumen for 288 h. The content of potentially digestible rumen digesta components was calculated from the difference in the components of the freeze-dried sample of rumen contents and its indigestible fraction. The term „potentially" was used since the real rumen digestibility is lower than determined in the above way because small particles may exit the rumen before 288 h.

Analytical methods

Samples of rumen contents and its fractions were freeze-dried (Leybold GT3). These samples were used to determine dry matter, total N and crude fibre, NDF, ADF and ADL according to Van Soest (1973) using a Fibretec M apparatus.

The Cr and Co contents in faeces and in the rumen liquor were determined using a mass absorption spectrophotometer (Philips PU 9100X) in an acetylene flame and wave length of 357.9 nm (Cr) and 240.7 nm (Co) after previous mineralization of the samples.

The critical size of the particles was determined by wet sieving of 100 g of average daily faeces samples on a stack of 2.5; 2.0; 1.6; 1.0; 0.8; 0.25 i 0.1 mm sieves using the same procedure as for separation of rumen digesta particles. The pH of fresh rumen contents was determined potentiometrically using an Φ72 Beckman pH-meter.

Statistical analysis

The data were subjected to two-factor variance analysis using STATGRAPHIC® Plus 7.0 software.

RESULTS

Crude protein in rapeseed oilmeal and fish meal constituted about 30% of the crude protein content in the ration (Table 1). The proportion of meadow hay dry matter to the dry matter of concentrates was 79:21 in both rations.

Ration R contained slightly less crude protein and ether extract and somewhat more crude fibre and NDF, ADF and ADL than ration F (Table 2).

The largest amount of rumen digesta was found 4 h after feeding, on average 85 and 88 kg respectively for rations R and F (Table 3), ranging in individual cows from 81 to 95 kg. The least was found before feeding, on average 68 and 77 kg for rations R and F, respectively, while its mass in individual cows at this

TABLE 2

Chemical composition of feeds (%) and daily intake of nutrients (kg)

Feed	DM	Crude protein	Ether extract	Crude fibre	NDF	ADF	ADL
Ground barley	87.8	11.2	2.0	4.9	28.0	7.5	3.7
Rapeseed meal	91.5	33.7	4.4	13.7	26.0	24.3	14.9
Fish meal	94.3	54.2	14.2	–	–	–	–
Meadow hay	87.8	8.9	2.1	30.3	60.8	39.9	9.8
Daily intake, kg							
diet R	8.91	1.20	0.24	2.62	5.43	3.53	0.99
diet F	8.91	1.25	0.30	2.49	5.26	3.29	0.84

time ranged between 64 and 81 kg. The dry matter content of rumen digesta ranged from 97 to 134 and from 99 to 126 g/kg contents, respectively. The protein source did not have a significant effect on the amount of digesta and its dry matter content. It was found, however, that the pH of the rumen content of cows receiving fish meal was higher ($P<0.05$) than those fed the ration containing rapeseed oilmeal. The time after feeding also did not have a significant effect on the value of the determinations (Table 3), it was found, however, that 4 h after feeding there was more DM in the whole rumen contents than before feeding ($P<0.01$).

TABLE 3

Amount of rumen digesta (kg), pH and dry matter content, in different time after feeding

Diet	Time h	Digesta kg	pH	Dry matter	
				g/kg	kg
R	0	68.2	7.2^{a}	104	7.1^{A}
	4	85.3	7.1^{a}	121	10.3^{B}
	8	82.7	7.0^{a}	110	9.1^{AB}
F	0	76.6	7.4^{b}	116	8.9^{A}
	4	87.9	7.2^{ab}	118	10.3^{B}
	8	85.1	7.3^{b}	106	9.0^{AB}

a, b – $P<0.05$, A, B – $P<0.01$

When the fish meal-containing ration was fed, the crude protein content of the rumen (Table 4) was higher ($P<0.05$), while the ADL content lower ($P<0.01$) than when ration R was given. The percentage of ADL in rumen content DM 4 h after feeding was lower than in other periods ($P<0.05$). The ADL content in the DM of the rumen digesta before and 8 h after feeding did not differ

TABLE 4

Chemical composition of rumen digesta, as per cent of DM, in different time after feeding

Diet	Time h	Crude protein	Crude fibre	NDF	ADF	ADL
R	0	14.3[a]	28.1	62.3	37.9	13.4[Ab]
	4	14.2[a]	29.9	60.4	39.0	11.3[Aa]
	8	14.3[a]	29.1	61.7	40.0	12.3[Ab]
F	0	16.1[b]	29.0	62.4	41.4	9.8[Bc]
	4	15.4[b]	27.2	60.0	34.2	8.6[Bc]
	8	15.4[b]	29.1	62.5	40.1	11.2[ABa]

a, b – $P<0.05$

significantly. No differences were found either in the content of crude fibre, NDF or ADF depending on the type of feed and time of sampling.

The amount of dry matter, crude protein and fibre, NDF, ADF and ADL in rumen digesta 4 and 8 h after feeding were independent of the protein source (Table 5), but before feeding (i.e. 12 h after the previous feeding) there was 1.8 kg DM more in the rumen of cows fed fish meal and 0.4 kg more crude protein. At this time, the total amount of crude fibre, NDF and ADF was higher in these cows than in those fed the rapeseed oilmeal ration.

TABLE 5

The amount DM, protein, fibre, NDF, ADF and ADL in the rumen contents (kg) in different time after feeding

Diet	Time h	DM	Crude protein	Crude fibre	NDF	ADF	ADL
R	0	7.09±0.88	1.01±0.13	1.99±0.26	4.42±0.55	2.69±0.36	0.95±0.15
	4	10.31±1.52	1.47±0.27	3.11±0.85	6.28±1.51	4.04±0.85	1.17±0.24
	8	9.13±0.72	1.30±0.03	2.66±0.38	5.62±0.36	3.65±0.32	1.11±0.08
F	0	8.89±1.25	1.43±0.18	2.58±0.41	5.56±0.89	3.69±0.62	0.87±0.11
	4	10.33±0.63	1.59±0.05	2.80±0.12	6.19±0.25	3.53±0.20	0.89±0.03
	8	9.05±0.81	1.39±0.10	2.64±0.31	5.67±0.65	3.64±0.48	1.02±0.16

± SD

The content of nutrients that could potentially undergo degradation in the rumen (computed from the difference in the composition of the digesta and residue after its incubation in the rumen for 288 h, assuming that reaching the critical size by particles did not cause them to move to the further parts of the digestive tract) before feeding was somewhat larger when feeding the ration containing fish meal than rapeseed oilmeal (Table 6). This tendency was also observed 8 h after feeding, while 4 h after feeding the potential digestibility of

TABLE 6

Potential digestibility (%) of DM, protein, fibre, NDF, ADF and ADL of the rumen contents in different time after feeding

Diet	Time h	DM	Crude protein	Crude fibre	NDF	ADF	ADL
R	0	55.9	74.7	43.2[a]	46.4[a]	37.6[a]	41.0[a]
	4	66.5	84.5	57.4[b]	57.6[b]	55.1[b]	45.8[a]
	8	59.7	80.2	47.6[a]	50.7[ab]	45.6[abc]	42.7[a]
F	0	63.5	82.4	53.9[b]	55.9[b]	55.2[b]	39.3[a]
	4	64.9	82.2	55.6[b]	57.6[b]	47.6[c]	29.1[b]
	8	63.4	81.3	55.6[b]	57.4[b]	53.6[b]	45.9[a]

a, b – $P<0.05$

DM, crude protein, crude fibre, NDF, ADF and ADL in the rumen contents of cows receiving ration F was lower than in cows fed ration R. A significant effect of the protein source ($P<0.05$) was found on the potential digestibility of crude fibre, NDF, ADF and ADL, but no such effect was seen on the digestibility of dry matter and crude protein in the rumen contents.

TABLE 7

The amount (kg) of digested DM, protein, fibre, NDF, ADF and ADL in the rumen contents

Diet	Time h	DM	Crude protein	Crude fibre	NDF	ADF	ADL
R	0	3.98±0.76	0.76±0.12	0.86±0.19	2.05±0.39	1.01±0.23	0.39±0.12
	4	6.82±0.60	1.24±0.19	1.78±0.44	3.60±0.74	2.21±0.32	0.53±0.07
	8	5.48±1.02	1.05±0.10	1.29±0.43	2.86±0.47	1.68±0.42	0.47±0.04
F	0	5.64±0.69	1.17±0.11	1.39±0.19	3.10±0.43	2.03±0.26	0.34±0.07
	4	6.70±0.26	1.31±0.03	1.56±0.03	3.56±0.06	1.68±0.09	0.26±0.05
	8	5.73±0.43	1.13±0.06	1.46±0.14	3.24±0.31	1.94±0.23	0.47±0.10

± SD

The protein source also had no effect on the amount of potentially digestible dry matter and nutrients in the rumen (Table 7). The amount of digestible dry matter, crude protein and crude fibre, NDF, ADF and ADL available in the rumen 4 and 8 h after feeding was similar when both rations were fed. Before feeding, there was more DM and its associated nutrients in the rumen of cows fed ration F than in the rumen of cows fed ration R.

The largest part of DM (40-50%) in the rumen digesta was composed of the smallest fraction of particles (D below 0.25 mm), which in our study was not retained on the sieves, but flowed out of the separator along with the water (Table 8). Particles under 1 mm (fractions C and D) made up about 2/3 of the DM of rumen content. When feeding both rations, 4 and 8 h after feeding, at least

TABLE 8

Percentage of different particle fractions DM of total DM of the rumen contents

Diet	Time h	A >5 mm	B 1-5 mm	C 0.25-1.0 mm	D <0.25 mm
R	0	8.4	22.8[a]	27.2	41.6[A]
F	0	8.1	19.1[b]	22.5	50.3[B]
R	4	12.7	23.3	22.4	41.6[A]
F	4	13.5	22.3	19.9	44.3[B]
R	8	13.6	22.5	24.4	39.5[A]
F	8	11.7	21.2	19.9	47.2[B]

a, b – $P<0.05$

TABLE 9

Chemical composition of the particle fractions of rumen contents, %

Diet	Time h	Particle size	Crude protein	Crude fibre	NDF	ADF	ADL
R	0	A	7.9[b]	40.7[a]	82.4	51.6	9.3[A]
		B	7.2[a]	40.5[a]	84.0	53.5	11.1[B]
		C	8.4[b]	41.2[a]	82.7	53.0	13.9[C]
		mean	7.8	40.8	83.0	52.7	11.4
F	0	A	9.2[c]	40.4[a]	82.5	48.7	8.3[A]
		B	7.8[b]	43.9[b]	85.9	51.9	10.5[B]
		C	7.9[b]	42.8[b]	86.3	55.2	11.5[B]
		mean	8.3	42.4	84.9	51.9	10.1
R	4	A	8.4[b]	40.9[a]	82.0	50.2	9.1[A]
		B	7.5[a]	43.2[b]	83.8	52.5	11.0[B]
		C	9.2[c]	40.1[a]	82.0	52.9	14.9[C]
		mean	8.4	41.4	82.6	51.9	11.7
F	4	A	9.8[c]	40.8[a]	82.3	50.2	8.9[A]
		B	8.7[b]	42.0[b]	85.1	53.8	9.5[A]
		C	9.4[c]	40.2[a]	82.9	51.2	10.5[B]
		mean	9.3	41.0	83.4	51.7	9.6
R	8	A	8.4[b]	40.5[a]	82.5	51.5	10.4[A]
		B	7.1[a]	43.9[b]	84.9	54.8	11.2[A]
		C	8.2[b]	40.5[a]	82.1	54.5	14.9[B]
		mean	7.9	41.6	83.2	53.6	12.2
F	8	A	8.7[b]	40.4[a]	82.6	48.1	6.9[A]
		B	8.3[b]	41.6[ab]	84.2	50.7	10.5[B]
		C	9.3[c]	40.4[a]	82.4	50.9	10.8[B]
		mean	8.8	40.8	83.1	49.9	9.4

a, b – $P<0.05$; A, B – $P<0.01$

TABLE 10

Outflow rates (%/h) of rumen particulate and liquid fraction and critical particle size, mm

Indices	R	F
Solid outflow rate	6.5	6.7
Liquid outflow rate	14.9	16.1
Critical particle size	0.52	0.53

64% of the rumen DM was in a state allowing particles to flow out of the rumen, while 12 h (time 0 – before feeding) after feeding their amount rose ($P < 0.01$) to 69 and 73%, respectively when feeding rations R and F.

The type of ration had a significant effect ($P < 0.05$) on the share of particles in fraction B (1 to 5 mm) in the DM of the rumen content. More particles were found when the rapeseed meal was given. Also, the share of fraction D particles (under 0.25 mm) was higher in the rumen contents of cows fed the fish meal ration ($P < 0.01$).

The rumen content of cows fed ration F contained more protein in all of the fractions (Table 9) than in the cows receiving ration R. Fraction B particles contained ($P < 0.05$) less protein and more crude fibre than the other fractions, both when the rapeseed meal and fish meal rations were given. No effect of the ration on crude fibre or NDF and ADF in any of the fractions was found, but it did affect ($P < 0.01$) the amount of ADL. The average share of ADL in particles larger than 0.25 mm (fractions A, B and C) was about 12% when ration R was fed, and under 10% when the fish meal-containing ration was given. The ADL content differed ($P < 0.01$) between fractions, and rose as particle size decreased. No significant differences were found in chemical composition of the fractions depending on the time of sampling. Particles B and C sampled before feeding from the rumen of cows fed ration F contained less protein than when sampled 4 and 8 h after feeding, but when the ration R was given, no such tendency was noted.

The outflow rate of the solid and liquid fractions from the rumen and the critical size of particles did not depend on the type of ration provided (Table 10).

DISCUSSION

Rapeseed oilmeal or fish meal protein, which differ in their degradation rate in the rumen, constituted about 30% of crude protein in the rations. The effective degradability of rapeseed oilmeal protein is 68% (Dakowski et al.,1996) that of fish meal, 37% (Dakowski, 1992).

The rumen contents contained on average 76.8 to 87% of the solid fraction, and its share did not depend on the time from feeding or dietary protein source.

The rumen contents are characterized by a solid part that contains large particles of feed that is situated in the upper part of the rumen, and by the liquid fraction that is in the lower part and contains small particles and bacterial fermentation products (Van Soest, 1994). In this experiment, the division of rumen contents into its solid and liquid parts was imprecise, since by manual emptying of the rumen, the liquid separated away from the solid part during the removal of the contents from the rumen. The estimated proportion between the solid and liquid part could therefore be burdened with considerable error.

The studies of Gasa et al. (1991) showed that the type of silage fed has an effect on the amount of rumen content in cows, and that the amount of dry matter in the content depended on the amount of concentrate in the ration. In our experiment, both the average amount of digesta and its dry matter content were similar, which can indicate that the protein source does not affect these parameters. The slight differences in the amount of dry matter as well as protein and fibre in the rumen contents when rations F and R were fed resulted from the higher content of these components at time 0, i.e. 12 h after feeding ration F. May be that the slower degradation of fish meal protein than rapeseed oilmeal affected the amount of DM in the rumen content at time 0, but already after 4 h from giving a new portion of feed the amount of DM and its components were similar, regardless of the protein source in the diet. This may suggest that the rate of outflow of solid particles from the rumen during the day is not uniform and, in the case of ration F equaled at least 750 g DM/h, which is 8.4%/h, while when feeding ration R this figure equaled only 310 g/h, i.e. 4.4%/h of DM taken up, assuming that the portion of feed containing 4.46 kg DM was consumed immediately after being given. In reality, the intake of this portion took about 30 min. It was shown that the rate of outflow from sheep rumen of particles less than 1.19 mm was higher (3.59%/h) than that of larger particles, 1.68-2.38 mm (2.52%/h; Moon et al., 1986). In the rumen content of cows fed diet F at time 0 about 73% of DM was made up of particles under 1 mm, while when feeding diet R, they made up under 69% DM. After 4 h of given feed, in both cases the amount of particles under 1 mm was equal (64% of DM content), which may confirm the hypothesis about their greater outflow rate at time 0-4 h when ration F was fed.

The more intensive contractions of the reticulum during eating (Balch, 1971) and the rapid fermentation of barley starch, of which there was more in ration F than R, could have been the causes of the faster loss of dry matter from the contents of the rumen during the first 4 h after feeding.

The content of the potentially digestible dry matter and protein in the rumen of both rations did not differ significantly, while fibre in ration F was potentially better digested ($P<0.05$) in the rumen, which can be explained by the higher activity of carboxymethycellulase and xylanase attached to the in the digesta

particles when this ration was fed as compared with ration R (Michałowski et al., 1997). This supports the suggestion of McAllan and Smith (1984) on the beneficial effect of fish meal protein on digesting fibre, while being in disagreement with the results of Zerbini et al. (1988). It also seems that the poorer digestibility of ration R fibre may have been the result of the lower digestibility of rapeseed meal fibre, which accounted for almost 6% of the fibre in this ration.

The potential digestibility of DM in the rumen contents 4 h after feeding ration F was lower than when ration R was fed. It seems that this was caused not only by the slower fish meal protein degradation, which could have lowered the level of ammonia in the rumen and synthesis of bacterial protein (Hespell and Bryant, 1979), but also by the suggested above faster rate of outflow of particles 0-4 h after feeding ration F than when ration R was given.

Changes during the day in the share of variously sized particles in the dry matter of the rumen contents were small. After feeding, the proportion of the largest particles rose slightly while the share of particles smaller than 5 mm did not depend on the time when the sample was taken from the rumen. Gasa et al. (1991) and Huhtanen et al. (1992) obtained similar results, although in their experiments the reduction in the largest particles with time after feeding was greater, which can be explained by the easier and faster breakdown of silage particles than of the hay used in our experiment. Differences were found, however, in the proportion of dry matter in the fraction under 0.25 mm in the dry matter of the rumen contents between rations F and R, what could explained with faster passage into the liquid fraction of fish meal components and starch, which had a larger share in ration F than in ration R.

When the size of the particles in the rumen content and in faeces is determined by wet-sieving, the method of separation, i.e. time, amplitude, interval, as well as water pressure and flow rate through the separator, can have a considerable effect. These methodological details are not always reported in papers, which makes interpretation of results difficult. Mertens et al. (1984) pointed out this difficulty when writing about the need to characterize and evaluate the techniques used to separate particles of various size. The time of sampling did not affect the chemical composition of digesta particles, but in all of the fractions of rumen content in cows fed ration F a slightly higher protein content was found than when ration R was given, which is difficult to interpret. As the particle size decreased, their lignin content increased, which was also found by Jung et al. (1990) and Huhtanen et al. (1992). According to the latter authors, as the particle size decreases, the activity of cellulolytic and accompanying enzymes increases, which augments the decline in the content of susceptible components, thus increasing the proportion of the remaining difficult to digest lignin. The outflow rate from the rumen of the solid and liquid contents did not depend on the protein source in the ration and was close to the values given by other authors

(Eliman and Ørskov, 1981; Owens and Goetsch, 1986; Ørskov et. al., 1988; Huhtanen and Kukkonen, 1995).

The critical size of particles found in this experiment on the basis of particle separation in faeces was much smaller than that given by Poppi et al. (1980) and Lechner-Doll and Engelhardt (1989), which is difficult to explain, and could have been caused by using a different technique to separate particles.

Summarizing, it can be stated that protein with varying rates of degradation did not affect the amount of rumen content, or the outflow rate of the solid and liquid digesta fractions, or the critical size of particles.

After feeding a ration containing fish meal, the rumen content contained more protein in all of the digesta fractions and more small particles that could leave the rumen than when the rapeseed oilmeal ration was fed. Regardless of the type of protein in the diet, 4 and 8 h after feeding at least 64%, while after 12 h, about 70% of the feed dry matter was in a state permitting it to flow out of the rumen.

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STRESZCZENIE

Wielkość, skład i tempo wypływu cząstek ze żwacza krów żywionych dawkami z różnym źródłem białka

Trzy nielaktujące krowy o masie ciała ok. 470 kg żywiono dwa razy dziennie dawkami składającymi się z siana łąkowego i mieszanki treściwej (79 : 21) zawierającej mączkę rybną (F) lub pockstrakcyjną śrutę rzepakową (R). Białko mączki rybnej i śruty rzepakowej stanowiło 30% białka dawki.

Treść żwacza ewakuowano ręcznie przed karmieniem (czas 0) oraz 4 i 8 godz. po podaniu paszy. Przerwa między kolejnymi ewakuacjami treści wynosiła co najmniej 7 dni. Szybkość wypływu ze żwacza frakcji stałej oznaczono przy użyciu mordantu Cr (siana), a frakcji płynnej stosując Co-EDTA. Rozdział cząstek treści wykonano przy pomocy przesiewania na mokro na sitach o wielkości oczek 5,0; 1,0 i 0,25 mm.

Ilość treści żwacza oraz zawartej w niej suchej masy i białka w różnym czasie po karmieniu nie zależała od rodzaju białka w dawce. Potencjalna strawność włókna surowego, ADF, NDF i ADL treści żwacza była większa ($P < 0,05$) przy skarmianiu dawki zawierającej mączkę rybną, zwłaszcza w 8 i 12 godz. po podaniu paszy. Udział cząstek różnej wielkości w suchej masie całej treści nie zmieniał się z upływem czasu po karmieniu. Udział cząstek mniejszych niż 1 mm przy żywieniu dawką F był tylko nieco większy niż przy skarmianiu dawki R. Przy podawaniuaniu dawki F stwierdzono istotnie większą zawartość białka w cząstkach powyżej 5 mm i ligniny w cząstkach poniżej 1 mm. Przy skarmianiu obydwóch dawek w czasie 4 i 8 godz. po karmieniu 64% suchej masy treści stanowiły cząstki mogące opuścić żwacz, mniejsze niż 1 mm, a po 12 godz. ich ilość wzrastała do ok. 70%.

Wielkość krytyczna cząstek (0,52 mm) oraz szybkość wypływu frakcji stałej (6,6%/godz.) i frakcji płynnej (15,5%/godz.) treści żwacza nie zależały od rodzaju białka w dawce.