Cellulolysis in the fermentation chambers in Svalbard reindeer

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Introduction

Svalbard reindeer (*Rangifer tarandus platyrhynchus*) are distributed in areas with varying vegetation and rely on symbiotic rumen and DFC (distal fermentation chamber = *caecum* and *ansa proximalis coli*) micro-organisms to ferment plant fibres. Rumen wet weight content comprise from 14-24% of body mass (BM) (Staaland *et al.*, 1979; Sørmo *et al.*, accepted). The number of cellulolytic bacteria in the rumen fluid of Svalbard reindeer was 31.5 x 10^8/ml in summer and 12.6 x 10^8/ml in winter (Orpin *et al.* 1985), but only 0.9 x 10^8/ml and 0.09 x 10^8/ml in the *caecum* summer and winter, respectively (Mathiesen *et al.*, 1987). The DFC of Svalbard reindeer is large and comprise 10-17% of the weight of the rumen contents (Sørmo *et al.*, accepted). The volatile fatty acids (VFA) from this organ can contribute as much as 17% to the energy supply of Svalbard reindeer (Sørmo *et al.*, 1997). Ruminal digestion of plant cell walls is influenced by the availability of non protein nitrogen (NPN), amino acids and carbohydrates in the rumen contents (Ørskov, 1992). This work describes seasonal differences in the ruminal and DFC *in vitro* digestibility of pure cellulose in Svalbard reindeer shot in two different areas.

Material and methods

Rumen contents were sampled after death of the animals and were analysed for dry matter (DM), crude protein (CP), non protein nitrogen (NPN), water soluble carbohydrates (WSC) and plant fibres (hemicellulose, cellulose and lignin) while DFC contents were analysed for DM, NPN and fibres. The methods used are described in Aagnes & Mathiesen (1995). The *in vitro* dry matter digestibility (IVDMD) of pure cellulose was determined with rumen fluid and DFC contents from a total of 12 reindeer (Aagnes & Mathiesen, 1995). The reindeer were killed while grazing. Rumen fluid and DFC contents were obtained within 30 min after death. In winter 3 Svalbard reindeer were shot on Nordenskiöld Land (NL) and 3 animals were shot on Nordaustlandet (NA), which is characterised as an arctic desert (Staaland & Punsvik, 1980). In

Table 1. Chemical composition (%)(median and range) of the organic dry contents (ODM) of the rumen and distal fermentation chamber (DFC) of Svalbard reindeer on Nordenskiöld Land in winter (NLW) and on Nordaustlandet in winter (NAW) and in summer (NAS). WSC = water soluble carbohydrates, CP = crude protein, NPN = non-protein nitrogen (NH_4N), C = cellulose, HC = hemicellulose and L = lignin, NM = not measured*. Data are modified from Sørmo *et al.*, accepted.

	RUMEN			DFC		
	NLW*	NAW*	NAS*	NLW	NAW	NAS
ODM	11.4 (11.2-12.6)	13.9 (13.4-14.3)	13.9 (10.6-15.1)	11.6 (11.2-12.1)	11.9 (11.8-12.8)	17.1 (14.4-17.6)
WSC	1.4 (1.0-1.7)	7.6 (4.1-8.2)	3.8 (1.5-8.0)	NM	NM	NM
CP	12.6 (11.2-13.4)	19.3 (17.3-19.7)	29.5 (26.9-31.2)	NM	NM	NM
NPN	0.10 (0.08-0.16)	0.07 (0.07-0.08)	1.66 (0.88-2.26)	1.20 (1.16-1.50)	0.42 (0.42-0.7)	0.31 (0.20-0.34)
C	28.6 (27.2-28.6)	11.5 (10.4-11.9)	10.6 (8.6-12.5)	7.6 (5.9-14.1)	3.8 (3.2-5.2)	10.0 (8.5-11.1)
H	37.5 (36.5-37.7)	18.0 (15.7-18.2)	18.3 (11.2-25.8)	11.9 (9.7-20.3)	7.1 (6.7-9.7)	21.9 (16.7-28.0)
L	8.8 (6.7-12.2)	16.7 (15.1-17.3)	20.6 (10.2-21.8)	6.2 (4.3-9.5)	7.7 (6.9-9.7)	11.9 (9.6-18.2)

Table 2. In vitro cellulose digestibility (IVDMD) (%) after 48 h incubation with rumen fluid and DFC contents from Svalbard reindeer shot at Nordenskiöld Land in winter (NLW) and at Nordausrlandet in winter (NAW) and summer (NAS).

Animal no.	Sex	BM (kg)*	Location and season	% IVDMD after 48 h	
				RUMEN	DFC
SR1	M	52	NLW	15.3	32
SR2	M	62	NLW	19	30
SR3	M	65	NLW	2	52
SR4	M	52	NAW	10	85
SR5	F	59.5	NAW	6	74
SR6	F	44	NAW	49	100
SR102	M	57	NAS	67.0	50.6
SR103	M	73	NAS	50.4	NM**
SR104	M	57	NAS	50.4	11.5
SR105	F	51	NAS	34.7	22.4
SR108	F	59.5	NAS	46.6	19.9
SR110	F	48	NAS	45.2	7.3

* Dara from Sørmo *et al.*, accepred.

** NM=not measured

summer 6 animals were shot on NA. All experiments were carried out in six replicate tubes with six replicate control tubes from rumen and DFC for each time interval. The IVDMD of cellulose was calculated as percent DM disappearance of cellulose in each tube (Aagnes & Mathiesen, 1995). All results are presented as median and range. The non-parametric Wilcoxon rank sum test was used to determine differences among animal groups, at a significance level of 0.05 (Bhattacharyya & Johnson, 1977).

Results

On NL in winter, cellulose in the rumen contents comprised 27.2-28.6% of organic dry rumen contents (ODM) while crude protein comprised 11.2-13.4% (n=3), (Table 1). On NA in winter (n=3) and in summer (n=6), ODM contained 8.6-12.5% cellulose, but the crude protein comprised 17.3-19.7% of ODRC in winter and 26.9-31.2% of ODM in summer ($P<0.05$, $n_1=3$, $n_2=6$, $W_5=6$) (Table 1). On NL in winter the IVDMD after 48 h of fermentation was low (2-19%) in the rumen compared to NA where ruminal IVDMD of cellulose ranged between 6-49% in winter and 35-67% in summer (Table 2, Fig. 1). Ruminal cellulolytic activity was not related to the amount of cellulose in the rumen contents. However, total nitrogen content in the rumen was related to high ruminal cellulolytic activity. In the DFC, the cellulose content ranged from 5.9-14.1% on NL in winter compared with

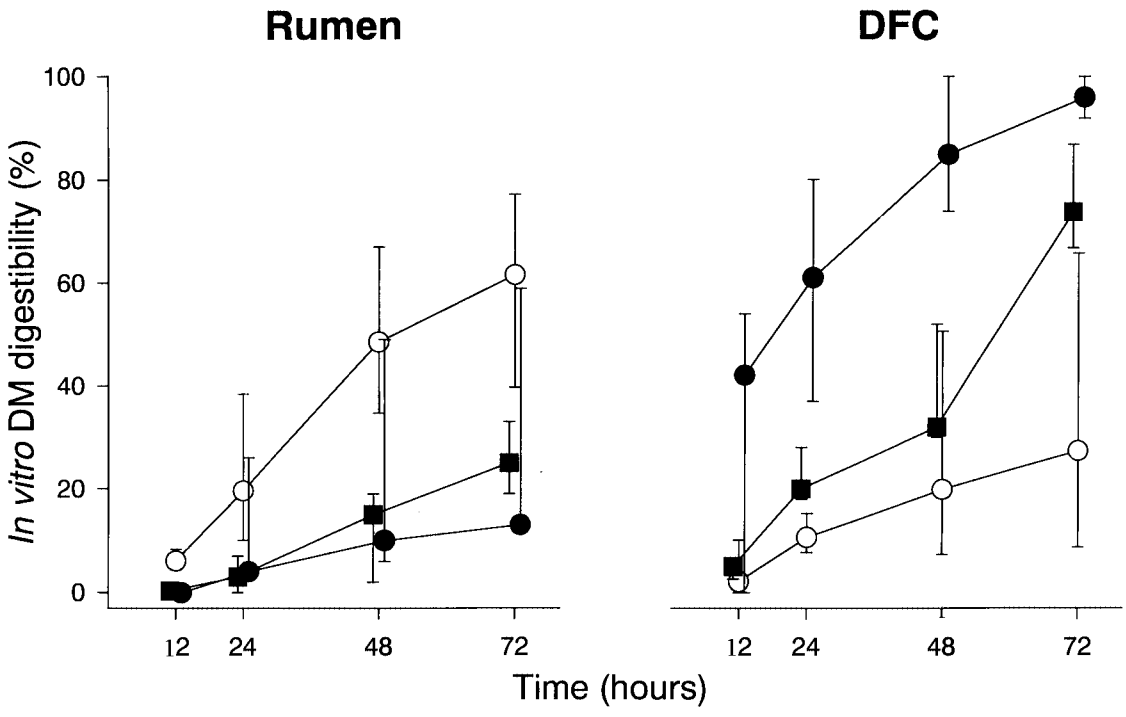

Fig. 1. *In vitro* DM cellulose digestibility (%)(median and range) after 12, 24, 48 and 72 hours of incubation with rumen fluid and distal fermentation chamber (DFC) contents from Svalbard reindeer on Nordenskiöld Land in winter (■) and on Nordaustlandet in winter (■) and summer (○).

3.2-5.2% on NA (P=0.05, n_1=3, n_2=3, W_s=6). In summer on NA the cellulose content in the DFC was 8.5-11.1% of ODM, higher than on NA in winter (P<0.05, n_1=3, n_2=6, W_s=6) (Table 1). The IVDMD of cellulose ranged from 30-52% in the DFC on NL in winter compared with 74 to 100% on NA in winter and 7.3-50.6% in summer (Table 2, Fig. 1). Differences in IVDMD could be related to differences in cellulose content in the DFC. High ruminal cellulose degradation seems to be followed by lower cellulolytic fermentation in the DFC, and vice versa, but there were individual differences.

Discussion

The ruminal *in vitro* fermentation of pure cellulose was low in Svalbard reindeer compared with reindeer from mainland Norway (Olsen *et al.,* 1997) but there were large individual variations. The cellulose used is pure and of standard quality, and the low utilisation must be considered as microbial. High ruminal *in vitro* DMD of cellulose was related to high production rates of ruminal short chained volatile fatty acids (VFA) (Sørmo *et al.,* 1997). This supports our hypothesis that available nitrogen and sugars and not the cellulose content in the rumen control ruminal cellulolysis. Easily available energy and nitrogen for the rumen micro-organisms could be a limiting factor for microbial growth and cellulolysis (Ørskov & Ryle, 1990). This is probably the main reason for the seasonal changes in the density of viable bacterial populations in the rumen of Svalbard reindeer (Orpin *et al,* 1985). This could explain the efficient ruminal degradation of cellulose in summer compared with winter in Svalbard reindeer at NA. Low availability of food due to snow and ice cover of the pastures in winter could reduce the number of bacteria in the rumen fluid of reindeer (Aagnes *et al.,* 1995). Starvation could therefore influence on ruminal IVDMD among individual animals in our experiment.

Reduced ruminal digestibility of cellulose seems to be partially compensated for by increased *in vitro* cellulolytic activity in the DFC of Svalbard reindeer (Table 2, Fig 1). Cellulose not digested in the rumen could become available to DFC micro-orga-

nisms and stimulate fermentation. The median cellulose contents contributed 7.6 and 3.0% of the ODM in the DFC in animals on respectively NL and NA in winter. This indicates more substrate available for fibre digesting bacteria in the DFC of animals on NL than on NA (Table 1). We could therefore expect the IVDMD in the DFC on animals from NL to be higher than that of animals from NA in winter. The opposite effect seem to be present with high cellulolytic activity in the DFC of animals on NA in winter and vice versa on NL in winter and on NA in summer. Other factors important for DFC cellulolysis is not known. Animals on NA in winter had an efficient cellulolysis in the DFC reaching 74-100% IVDMD after 48 h of incubation (Table 2, Fig. 1). In winter, the microbial population in *caecum* contributes only 17% of the microbial population in summer (Mathiesen *et al.*, 1987). If the DFC cellulolytic bacterial population occur in similar densities in our animals, their ability to utilise cellulose must be high in winter on NA (Table 2, Fig. 1).

In conclusion, the micro-organisms in the rumen and DFC in Svalbard reindeer are able to ferment cellulose *in vitro*, but not as efficient as that found in free-living reindeer from mainland Norway in winter. High ruminal cellulolysis seem to be followed by a low cellulolytic fermentation in the DFC and vice versa, but there are large individual variations, possibly due to differences in the previous history of the animals. The rate of fermentation of cellulose in the rumen specially reflects ruminal nitrogen contents, but not the ruminal contents of cellulose. In the DFC, fermentation of cellulose seem to be inversly related to cellulose content.

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