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Digestibility of Plants in Ruminal Fluids of Barren-Ground Caribou

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ABSTRACT. The comparative digestibilities of plants and their rates of digestion *in vitro* were assessed by fermentation with ruminal fluids obtained from barren-ground caribou (*Rangifer tarandus groenlandicus*) shot on their winter range in the southern Northwest Territories. There was a near-linear increase in the *in vitro*, dry-matter disappearance (IVDMD) with fermentation time (30-120 h) for all eight lichen species that we tested. In contrast, IVDMD was essentially maximal after 60 h fermentation for 10 of 11 non-lichen species. The green leaves of *Carex rostrata* and *Equisetum variegatum* were the only species with IVDMDs higher than 50% after a 60-63 h fermentation period. The two species of mosses and a liverwort were poorly digested (15-27%). The addition of 63 mg of urea to each tube markedly increased the digestibilities of both species of lichens tested, and that of *Vaccinium vitis-idaea*, but it lowered the IVDMD of *Salix* and *Betula* stems and the green and cured parts of *Carex rostrata*. The IVDMDs of four lichen species collected on the Canadian Arctic Islands were higher than those of eight terricolous species obtained from the mainland winter range of *R.t. groenlandicus*.

Key words: *Rangifer*, caribou, *in vitro*, digestibility, forages, lichens, rates, Canada

RÉSUMÉ. La digestibilité comparative de plantes et leur taux de digestion *in vitro* ont été évalués par la fermentation de fluides ruminaux obtenus de caribous des landes (*Rangifer tarandus groenlandicus*) tirés dans leur habitat hivernal dans le sud des Territoires du Nord-Ouest. Il y a eu une augmentation quasi-linéaire de la disparition *in vitro* de matière sèche (DIVMS) avec un période de fermentation (30-120 h) pour les huit espèces de lichens mises à l'épreuve. Par opposition à ceci, la DIVMS était essentiellement maximale après une fermentation de 60 h dans 10 des 11 espèces de non-lichens. Les feuilles vertes du *Carex rostrata* et de l'*Equisetum variegatum* étaient les seules espèces démontrant une DIVMS supérieure à 50% après une période de fermentation de 60 à 63 h. Les deux espèces de mousse et une hépatique ont été mal digérées (15 à 27%). L'addition de 63 mg d'urée à chaque tube a augmenté de façon marquée la digestibilité des deux lichens mis à l'épreuve, ainsi que du *Vaccinium vitis-idaea*, mais elle a diminué la DIVMS des tiges de *Salix* et de *Betula* et des parties vertes et séchées de *C. rostrata*. Les DIVMS des quatre espèces de lichens recueillies des îles Arctiques canadiennes étaient supérieures à celles des huit espèces à croissance terrestre obtenues des terres de l'habitat hivernal du *R. t. groenlandicus*.

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INTRODUCTION

In vitro digestibility techniques are used extensively to obtain data on the comparative digestibilities of livestock forages (Johnson, 1966). In many studies of domestic and wild species there was close agreement between the results of *in vitro* and nylon-bag techniques (e.g. Johnson, 1966; Urness *et al.*, 1977; Milchunas *et al.*, 1978). The nylon-bag method is thought to yield digestibilities similar to what occurs in the animal (*in vivo*), and the nylon-bag method usually is termed the *in vivo* technique. Person *et al.* (1980) compared the results of the two techniques as applied to *Rangifer* and found major differences for some plant species. They attributed the relatively low *in vitro*, dry-matter disappearance (IVDMD) values for lichens and shrubs to the inhibitory actions of toxic substances in the plants and to nitrogen deficiencies.

We chose the Tilley and Terry (1963) technique and used fluids from freshly-killed Peary caribou (*R.t. pearyi*) to assess the relative digestibilities of arctic plants in summer and winter (Thomas and Kroeger, 1980). We also investigated the rates of digestion *in vitro* by altering the fermentation period. We obtained high IVDMD values for many species of lichens and suggested that nitrogen probably was not limiting digestion to any significant degree in our tests. Further, there was no indication of interaction, inhibition or synergism, in mixed forages.

In March 1980 we duplicated the procedure to assess the relative digestibilities of plants in the ruminal fluids of barren-ground caribou collected on the winter range in the forests of north central Canada. Although there was information on the diets of barren-ground caribou in that region (Scotter, 1967; Kelsall, 1968; Miller, 1976), there were no data on the relative digestibilities of forages. We give our results in this report and compare them with those of the previous studies.

METHODS

We obtained the plants and caribou specimens 110-280 km east of Fort Smith, Northwest Territories, on the winter range of the Beverly herd. That herd calves in the Beverly Lake region and winters in northern Saskatchewan and adjacent regions of Manitoba and the Northwest Territories. Plants obtained at feeding sites of caribou were returned to a laboratory at Fort Smith, partially air dried, sorted to species, oven-dried at 50°C for 12-24 h, ground twice in a Wiley mill (no. 20 screen), and further dried at 50°C for 12-24 h. We then placed 0.5 g samples in 25x200 mm (75 ml) test tubes and followed Procedure D of Tilley and Terry (1963), with the exception that the first stage of digestion (fermentation) was varied in time from 16-120 h. We placed one blank (no plant material) near each end of the racks of 40 test tubes and placed the duplicates containing plant samples as far apart as possible in the racks.

Rumen fluid obtained within 3-5 h of the deaths of four males on 17 March (donors A) and from five females on 20 March (donors B) was pooled in each case and mixed with McDougall's buffer (Johnson, 1966) in large batches. Then we added 50 ml of the solution to each test tube. The fluid

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TABLE 1. *In vitro* dry-matter disappearance (%) of lichens and mosses fermented at various intervals with ruminal fluids of barren-ground caribou

Plant species	Fermentation period (h)					
	16	30	60	63[1]	90	120
Arboreal lichens						
1. *Evernia mesomorpha*	48	33	53	43	47	70
2. *Usnea hirta*		32	39	52		65
3. *Alectoria jubata*		24	42	42	51	
4. *Parmelia physodes*			32			
Terricolous lichens						
5. a. *Cladina mitis*	27	27	41	44	53	61
b. *C. mitis*[2]	21	23	45	44	47	67
c. *C. mitis*[2]				48		
6. *C. rangiferina*				45		
7. *Cladonia amaurocrea*	27	20	30	41	47	55
8. *Cladonia* spp.				44		
9. *Cetraria nivalis*	24	20	20	34	36	52
10. *Cetraria islandica*				50		
11. *Stereocaulon paschale*	24	16	30	24	32	34
12. *Peltigera aphthosa*			33	38		
Mosses and liverworts						
13. *Sphagnum* spp.[3]			26	19	21	21
14. *Polytrichum piliferum*				15		
15. *Ptilidium ciliare*			29	24		

[1]Ruminal fluids from donors A; donors B were used for all other trials.
[2]Samples from different locations.
[3]*Sphagnum magellanicum* and *S. augustifolium*.

TABLE 2. *In vitro* dry-matter disappearance (%) of plants fermented at various intervals with ruminal fluids from barren-ground caribou

Plant species	Fermentation period (h)					
	16	30	60	63[1]	90	120
16. *Equisetum variegatum*			52	51		
17. *E. variegatum*[2]		42	63	64	63	66
18. *Carex rostrata*, cured leaves			43	49	49	56
19. *Carex rostrata*, green leaves and stems	37	48	67	63	64	73
20. *Ledum groenlandicum*, leaves			31	37	37	
21. *L. groenlandicum*, stems				31		
22. *Empetrum nigrum*, leaves and stems				30		
23. *Vaccinium vitis-idaea*, leaves	44	25	36	44	48	48
24. *V. vitis-idaea*, stems			25	43		
25. *Chamaedaphne calyculata*, leaves	27	34	47	49	52	49
26. *Chamaedaphne calyculata*, stems	36		27	32	28	31
27. *Andromeda polifolia*, leaves				47		
28. *A. polifolia*, stems				27		
29. *Oxycoccus microcarpus*, leaves and stems				34		
30. *Betula glandulosa*, stems	27		28	32	31	34
31. *Salix* spp., stems and buds	29	18	29	33	31	34
32. *Picea mariana*, needles		38	44	40	43	45

[1]Ruminal fluids from donors A; donors B were used in all other trials.
[2]Sample from a different location.

was not allowed to cool below 32°C and it was periodically infused with CO_2 gas. We added 63 mg of urea per tube to a second set of tubes containing nine species representative of several plant groups and paired them to the 63 h trial. That amount was used in the Ohio medium (Johnson, 1966). We also tested the digestibility of a few ground and dried samples of lichens from the Canadian Arctic Islands which were previously tested in the ruminal fluids of Peary caribou (Thomas and Kroeger, 1980).

RESULTS

1. Variability between the two sources of ruminal fluids

Differences in values between the 60 h trial (donors A) and the 63 h trial (donors B) were not significant (paired t test, $P > 0.05$). The IVDMD values were higher in the 63 h trial in 61% of the 23 comparisons and the differences averaged 6% of the 60 h values. We therefore ascribed the differences to variability inherent in our particular procedures, rather than to differences in the digestive capacities of the two sources of fluid.

2. Effect of varying fermentation time on IVDMD values

There was a near-linear ($r = 0.95$-0.99) increase in IVDMD values with fermentation intervals from 30-120 h (60 h and 63 h values averaged) for all eight lichen species in our trials (Table 1). In contrast, IVDMD was essentially maximal after 60 h fermentation for all other species tested except for the green leaves of *Carex rostrata* (Table 2). The 16 h trial produced high values for many species relative to the trends established by the other trials. Those data were obviously in error and they were excluded from further consideration.

3. The relative IVDMD values of plant species

Comparisons based on the means of the 60 h and 63 h trials indicated that the green parts of *Carex rostrata* had the highest IVDMD value (65%), followed by dry stems of *Equisetum variegatum* (64% and 52%), leaves of *Chamaedaphne calyculata* (48%), *Evernia mesomorpha* (48%), leaves of *Andromeda polifolia* (47%), *Usnea hirta* (46%), dry leaves of *Carex rostrata* (46%), *Cladina mitis* (48%, 45% and 43%), *C. rangiferina* (45%) and *Cladonia* spp. (44%). Of lowest apparent digestibility were the two mosses and a liverwort (15%, 23% and 27%), *Stereocaulon paschale* (27%), and the stems of *Andromeda polifolia* (27%).

TABLE 3. Influence of 63 mg/tube of urea on *in vitro* dry-matter disappearance (IVDMD) of representative species in which the fermentation period was 63 h

Plant species	IVDMD (%)		
	No urea	Urea added	Difference (%)
Cetraria nivalis	34	64	88
Stereocaulon paschale	24	40	67
Vaccinium vitis-idaea, leaves	44	54	23
Chamaedaphne calyculata, leaves	49	53	8
Sphagnum magellanicum & S. augustifolium	19	18	5
Betula glandulosa, stems	32	26	19
Salix spp., stems and buds	33	26	21
Carex rostrata, green leaves and stems	63	52	17
Carex rostrata, dry leaves and stems	49	31	37

4. The effect of adding urea

In the 63 h trials, the addition of 63 mg of urea per tube increased the IVDMD of *Cetraria nivalis* by 88%, of *Stereocaulon paschale* by 67%, and of *Vaccinium vitis-idaea* leaves by 23%. In contrast, there were 19% and 21% decreases in the IVDMD of the stems of *Betula* and *Salix*, and 17% and 37% decreases in the IVDMD of green and cured parts of *Carex rostrata*, respectively (Table 3).

5. Digestibility of plants collected on the Canadian Arctic Islands

The digestibilities of five plant species after 63 h fermentation with ruminal fluids of *R.t. groenlandicus* and the corresponding values (parentheses) obtained after 60 h fermentation in ruminal fluids of *R.t. pearyi* collected in the winter (Thomas and Kroeger, 1980) were: *Alectoria ochroleuca* 75% (83%), *Cetraria delisei* 59% (61%), *Cetraria cucullata* 54% (74%), *Thamnolia vermicularis* 51% (62%), and *Cassiope tetragona* 48% (49%). Subsamples of the same sample of plant material (ground and dried) were used in each instance. Peary caribou appeared to be more efficient in the digestion of three of the four lichen species than were *R.t. groenlandicus*, however, those lichen species were uncommon or absent on the winter range of the latter. All four species of lichens obtained on the Arctic Islands were more digestible in the ruminal fluids of *R.t. groenlandicus* than the 12 species of lichens collected on the winter range of the donor caribou (Table 1).

6. Technical problems

Ruminal fluids contained coarse particles that passed through four layers of cheesecloth. Those particles settled rapidly and homogeneous samples were not obtained, although the ruminal fluid-buffer mixture was stirred vigorously in a 6 *l* container before extracting samples in 500 ml beakers and before adding it to each tube. The proportions of coarse particles in the 50 ml samples increased as the fluid level decreased in both containers even though a third of each vessel's capacity was not used. Thus, blanks located at opposite ends of the racks differed significantly. That problem led to variability between the duplicates which were widely spaced in the racks. The problem can be overcome by straining the ruminal fluid through nylon, by decanting the fluid after settling occurs, and by placing blanks at more frequent intervals in the racks and using them for calculating the IVDMDs in adjacent tubes.

DISCUSSION

The progressive increase in the IVDMD of lichens with longer fermentation periods was in keeping with our earlier results on Peary caribou (Thomas and Kroeger, 1980). Even 120 h may be too short a period to obtain a good estimate of *in vivo* digestibilities in barren-ground caribou. With the addition of a nitrogen source, much shorter fermentation intervals may suffice. The IVDMDs of *Cetraria nivalis* and *Stereocaulon paschale*, with a 60 h fermentation period and added urea, were 23% and 18% higher (at 64% and 40%) than they were with a fermentation period of 120 h and no added urea. Trudell *et al.* (1980) and White and Jacobsen (unpubl. in Person *et al.*, 1980) raised the digestibility of mixed lichens 17-18% by adding urea at the start of a 48 h fermentation period.

The lichen species that predominate in the diets of barren-ground caribou that winter in the taiga of north central Canada (Scotter, 1967; Kelsall, 1968; Miller, 1976) generally contain less than 3% protein (Scotter, 1965; Kelsall, 1968; Parker, 1975; Miller, 1976) and nitrogen deficiencies may prevail in late winter as in reindeer in Europe (Nieminen *et al.*, 1980). Shortages of nitrogen are partly overcome by the highly efficient recycling of urea via the saliva (Wales *et al.*, 1975). Captive *R.t. groenlandicus* and *R.t. tarandus* recycled 45% and 58% of labelled urea in summer and winter, respectively. The amount of digestible nitrogen required for N equilibrium in captive reindeer and caribou in winter was 0.462 $gN/W^{0.75}$ per day, an amount similar to the requirements of cattle and sheep (McEwan and Whitehead, 1970).

The *Cladina* and *Cetraria* species that predominate in the winter diets of reindeer and barren-ground caribou contain low levels of crude fiber, the soluble carbohydrate content is very high, and the content of digestible cellulose and minerals is low. *Rangifer* in winter may suffer from protein and mineral deficiencies even when lichen forage is readily available (Hyvärinen *et al.*, 1977). The fermentation of lichenin and isolichenin, the main carbohydrates in lichens, is poorly understood. Rumen fermentation may be relatively unimportant and significant amounts of lichen particles may pass into the abomasum (Nieminen *et al.*, 1980). Finely-ground lichens do not wet easily and they may float on the rumen contents and be swept into the abomasum.

A seasonal shift occurs in the ruminal microbes of reindeer in Finland (Nieminen *et al.*, 1980). Higher proportions of protozoa and lower proportions of bacteria occur in the winter, apparently because of the low content of crude fiber in the winter diets. The low *in vitro* digestibility of lichen species reported by Person *et al.* (1975, 1980) and in our trials with short fermentation periods and no supplemental nitrogen, may be explained by low bacterial activity in the ruminal fluids. Addition of urea presumably stimulates the bacteria and enhances digestion. The growth of fiber-digesting bacteria in the rumen is most commonly limited by shortages of nitrogen (Milchunas *et al.*, 1978). Addition of urea *in vivo* reduces retention times and increases the intake of forage (Milchunas *et al.*, 1978).

In digestibility trials conducted on two captive reindeer, the IVDMD estimates, relative to nylon-bag estimates, averaged 67% (46-70%) lower for shrubs (n = 6), 39% (5-82%) lower for lichens (n = 13), and were variable for monocotyledons: five higher and three lower (Person *et al.*, 1980). Our IVDMD values for shrubs and lichens were

closer to the nylon-bag estimates obtained by Person *et al.* (1980) than to their IVDMD values. Their low IVDMD values must be related to differences in techniques and not attributable to their shorter fermentation period (48 h). Person *et al.* (1980) centrifuged the contents of each tube between the two stages and we did not, the only reported major difference between our techniques.

The nutrition of barren-ground caribou on the winter range is obviously a complex subject but insights can be made by attempting to simulate some of the processes in the laboratory. More data are needed on the effect of various concentrations of urea, minerals, and trace elements on digestion in artificial systems.

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REFERENCES

ANNISON, E.F. and LEWIS, D. 1959. Metabolism in the rumen. London: Methuen and Co. Ltd. and New York: John Wiley and Sons Inc. 184 p.

HYVÄRINEN, H., HELLE, T., NIEMINEN, M., VÄRYNEN, P. and VÄYRYNEN, R. 1977. The influence of nutrition and seasonal conditions on mineral status in the reindeer. Canadian Journal of Zoology 55(4):648-655.

JOHNSON, R.R. 1966. Techniques and procedures for *in vitro* and *in vivo* rumen studies. Journal of Animal Science 25:855-875.

KELSALL, J.P. 1968. The migratory barren-ground caribou of Canada. Canadian Wildlife Service Monograph No. 3. 340 p.

McEWAN, E.H. and WHITEHEAD, P.E. 1970. Seasonal changes in the energy and nitrogen intake in reindeer and caribou. Canadian Journal of Zoology 48(5):905-913.

MILCHUNAS, D.G., DYER, M.I., WALLMO, O.C. and JOHNSON, D.E. 1978. *In vivo/in vitro* relationships of Colorado mule deer forages. Colorado Division of Wildlife Special Report No. 43. 44 p.

MILLER, D.R. 1976. Biology of the Kaminuriak population of barren-ground caribou. Part 3: Taiga winter range relationships and diet. Canadian Wildlife Service Report Series No. 36. 42 p.

NIEMINEN, M., KELLOKUMPU, S., VÄYRYNEN, P. and HYVÄRINEN, H. 1980. Rumen function of the reindeer. In: Reimers, E., Garre, E. and Skjenneberg, S. (eds.). Proceedings Second International Reindeer/Caribou Symposium, Rørøs, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim. 213-223.

PARKER, G.R. 1975. An investigation of caribou range on Southampton Island, NWT. Canadian Wildlife Service Report Series No. 33. 83 p.

PERSON, S.J., WHITE, R.G. and LUICK, J.R. 1975. *In vitro* digestibility of forages utilized by *Rangifer tarandus*. In: Luick, J.R., Lent, P.C., Klein, D.R. and White, R.G. (eds.). Proceedings First International Reindeer-Caribou Symposium, Fairbanks, Alaska, 1975. Biological Papers of the University of Alaska Special Report No. 1. 251-256.

PERSON, S.J., PEGAU, R.E., WHITE, R.G. and LUICK, J.R. 1980. *In vitro* and nylon-bag digestibilities of reindeer and caribou forages. Journal of Wildlife Management 44(3):613-622.

SCOTTER, G.W. 1965. Chemical composition of forage lichens from northern Saskatchewan as related to use by barren-ground caribou. Canadian Journal of Plant Science 45(3):246-250.

———. 1967. The winter diet of barren-ground caribou in northern Canada. Canadian Field-Naturalist 81:33-39.

STEEN, E. 1968. Some aspects of nutrition of semi-domestic reindeer. Symposium, Zoological Society of London 21:117-128.

THOMAS, D.C. and KROEGER, P. 1980. *In vitro* digestibilities of plants in rumen fluids of Peary caribou. Arctic 33(4):757-767.

TILLEY, J.M.A. and TERRY, R.A. 1963. A two-stage technique for *in vitro* digestion of forage crops. Journal of the British Grasslands Society 18:104-111.

TRUDELL, J., WHITE, R.G., JACOBSEN, E., STAALAND, H., EKERN, K., KILDEMO, K. and GARRE, E. 1980. Comparison of some factors affecting the *in vitro* digestibility estimate of reindeer forages. In: Reimers, E., Garre, E. and Skjenneberg, S. (eds.). Proceedings Second International Reindeer/Caribou Symposium, Rørøs, Norway, 1979. Direktoratet for vilt og ferskvannsfisk, Trondheim. 262-273.

URNESS, P.J., SMITH, A.D. and WATKINS, R.K. 1977. Comparison of *in vivo* and *in vitro* dry-matter digestibility of mule deer forages. Journal of Range Management 30(2):119-121.

WALES, R.A., MILLIGAN, L.P. and McEWAN, E.H. 1975. Urea recycling in caribou, cattle and sheep. In: Luick, J.R., Lent, P.C., Klein, D.R. and White, R.G. (eds.). Proceedings First Reindeer/Caribou Symposium, Fairbanks, Alaska. Biological Papers of the University of Alaska Special Report No. 1. 297-307.