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Wet Belly in Reindeer (*Rangifer tarandus tarandus*) in Relation to Body Condition, Body Temperature and Blood Constituents

By *B. Åhman*[1], *A. Nilsson*[1], *E. Eloranta*[2] and *K. Olsson*[3]

[1]Department of Animal Genetics, Reindeer Husbandry Unit, Swedish University of Agricultural Sciences, Uppsala, Sweden, [2]Department of Physiology, University of Oulu, Finland and [3]Department of Animal Physiology, Swedish University of Agricultural Sciences, Uppsala, Sweden.

Åhman B, Nilsson A, Eloranta E, Olsson K: Wet belly in reindeer (*Rangifer tarandus tarandus*) in relation to body condition, body temperature and blood constituents. Acta vet. scand. 2002, 43, 85-97. – Wet belly, when the reindeer becomes wet over the lower parts of the thorax and abdomen, sometimes occurs in reindeer during feeding. In a feeding experiment, 11 out of 69 reindeer were affected by wet belly. The problem was first observed in 7 animals during a period of restricted feed intake. When the animals were then fed standard rations, 3 additional animals fed only silage, and 1 fed pellets and silage, became wet. Four animals died and 1 had to be euthanised. To investigate why reindeer developed wet belly, we compared data from healthy reindeer and reindeer affected by wet belly. Urea, plasma protein, glucose, insulin and cortisol were affected by restricted feed intake or by diet but did not generally differ between healthy reindeer and those with wet belly. The wet animals had low body temperature and the deaths occurred during a period of especially cold weather. Animals that died were emaciated and showed different signs of infections and stress. In a second experiment, with 20 reindeer, the feeding procedure of the most affected group in the first experiment was repeated, but none of the reindeer showed any signs of wet belly. The study shows that wet belly is not induced by any specific diet and may affect also lichen-fed reindeer. The fluid making the fur wet was proven to be of internal origin. Mortality was caused by emaciation, probably secondary to reduced energy intake caused by diseases and/or unsuitable feed.

feeding; health; wet abdomen; urea; plasma protein; glucose; insulin; cortisol.

Introduction

Semi-domesticated reindeer (*Rangifer tarandus tarandus*) normally feed all year on natural habitats of the forest or tundra. Food resources are limited during winter and sometimes reindeer herders are forced to feed the reindeer to prevent food deprivation or starvation. A transition from grazing to feeding could be critical to the health of the reindeer. "Wet belly" (or "wet abdomen"), when the reindeer becomes wet over the lower parts of the thorax and abdomen, is a disorder known to occur occasionally in reindeer as a consequence of feeding. This condition has been described from feeding experiments with reindeer made during the 1960's and 1970's, when special commercial feeds were first developed for reindeer (*Persson* 1967, *Jacobsen & Skjenneberg* 1979) and from experiments when reindeer were fed mainly grass silage (*Nilsson* 1994).

The present work developed due to the observed occurrence of wet belly in a feeding experiment with reindeer by *Nilsson et al.* (2000).

In addition we made a second experiment with the aim to provoke wet belly and examine the mechanisms further. In the present paper we discuss the possible role that malnutrition and specific diets may have had in inducing wet belly. To further understand why wet belly develops, we also examined whether the occurrence of wet belly correlates with changes in blood constituents associated with malnutrition or other stress.

Materials and methods

Experimental design and diets

The study was conducted at the Department of Biology, University of Oulu, Finland in the winters of 1996/97 (Exp.1) and 1997/98 (Exp. 2). The reindeer were kept in groups in outdoor pens and the ground was covered with snow throughout both experiments. Outdoor temperature was registered at the neighbouring Botanic Garden.

In Exp. 1 altogether 69 female reindeer calves were taken from the forest in December and January and were randomly allotted into 5 experimental groups. All reindeer were offered a simulated winter diet (lichen diet) composed of 80% lichens (*Cladina* spp.), on dry matter (DM) basis, combined with shrubs (*Vaccinium myrtillus*) and leaves (*Salix* spp.) *ad lib.,* from arrival until experimental start (day 0). A control group (group C) was continuously offered the lichen diet throughout the experiment. During 8 days (days 1-8), the other 4 groups were given half of the daily amount of the lichen diet consumed during the *ad lib.* feeding, followed by one day of total feed deprivation (day 9). Four feeding strategies were then applied. Group L was re-fed the lichen diet *ad lib.* Two groups were fed diets of 80% commercial reindeer feed (pellets, Renfor Bas, Lantmännen Fori, Holmsund, Sweden) combined with either 20% lichen (group PL) or 20% grass silage (group PS). The rations were gradually increased to *ad lib.* during the first week of feeding. Group SP was fed silage *ad lib.* for 5 days and thereafter gradually changed, during 2 weeks, to a diet with 80% pellets and 20% silage. The feeding continued until day 44. Further details regarding the experimental design and sampling in Exp. 1 are described in *Nilsson et al.* (2000).

In Exp. 2, twenty female reindeer calves were taken from their natural ranges at the end of November. The reindeer were randomly allotted into 2 groups and offered a lichen-based diet (80% *Cladina* spp. and 20% *Vaccinium myrtillus* shrubs) *ad lib.* from arrival until the start of the experiment (day 1). One group (controls) was continuously offered the lichen diet throughout the experiment. During 8 days (days 1-8), the other group (group S) was given half of the daily amount of the lichen diet consumed during the *ad lib.* feeding, followed by one day of total feed deprivation (day 9). Thereafter, group S was fed grass silage *ad lib.* until day 22. It was not possible to find the same quality of silage for Exp. 2 as the one used in Exp. 1. Both silages contained mainly timothy (*Phleum pratense*), but the silage used in Exp. 1 had a higher DM content and was higher in protein but slightly lower in calculated metabolisable energy (ME) content than the silage used in Exp. 2 (Table 1). The hygienic quality of the silage and pellets used in Exp. 1 was good. Growth of *Penicillium spinulosum* was found in the lichens, while *P. brevicompactum* was found in the shrubs. The hygienic quality of the feeds used in Exp. 2 was not examined. Mineral blocks (Natura Slicksten, Suomen Rehu, Helsinki, Finland) were available in all pens and the animals had access to temperated water (about 10 °C).

Sampling and slaughter routines

In Exp. 1, blood samples were taken 1 or 2 times per week from 5 animals per group. Ad-

Table 1. Dry matter (DM), chemical composition and calculated metabolisable energy (ME) in lichens (*Cladina* spp.), shrubs *(Vaccinium myrtillus),* leaves (*Salix* spp.), grass silage and reindeer pellets used in Exp. 1 and 2

	Lichens	Shrubs	Leaves	Silage	Pellets
DM (%)					
Exp. 1	45	55	72	57	89
Exp. 2	38	47	-	33	-
Crude protein (% in DM)					
Exp. 1	3.3	7.7	15.8	19.8	11.2
Exp. 2	3.9	6.7	-	13.1	-
Water-soluble carbohydrates (% in DM)					
Exp. 1	0.4	7.1	4.6	1.8	9.4
Exp. 2	0.3	9.7	-	9.9	-
Calculated ME (MJ kg^{-1} DM)					
Exp. 1	10.1	9.5	10.4	10.1	11.4
Exp. 2	10.1	10.9	-	11.1	-

ditional blood samples were taken from reindeer that got wet. Four reindeer that were later observed wet (Nos. 8, 23, 25 and 33) were not included among the animals that were blood sampled from the start. In Exp. 2, all animals were blood sampled 3 or 4 times a week. Body weight and rectal temperature were measured simultaneously and the sampling routine was the same in both experiments (*Nilsson et al.* 2000).

Reindeer in Exp.1 were slaughtered on 3 occasions as described earlier (*Nilsson el al.* 2000). The reindeer in Exp. 2 were all slaughtered at the end of the experiment (days 22 or 23). All slaughtered animals were inspected according to human food regulations and, in addition, stomachs and intestines were checked. The carcass weight and the weight of the rumen and rumen content were recorded. Necropsies were made on reindeer that died.

Blood analyses

The blood samples were collected, handled, and analysed according to *Nilsson et al.* (2000). In addition, Cortisol was assayed by radioimmunoassay (Coat-A-Count®, Diagnostic Products Corporation, Los Angeles, CA, USA). The assay was validated for reindeer plasma.

Statistical analysis

Results are presented as means and standard deviations (SD). Student's *t* test was used to test the difference between groups and between reindeer affected by wet belly (referred to as WB-reindeer and defined as reindeer observed with wet belly at any time during the experiment), healthy reindeer in the same groups and controls for each day separately. The level of significance was set at $p<0.05$.

Results

The animals seemed healthy at the start of both experiments and the animals slaughtered before the start of Exp. 1 (day 0) showed no signs of health problems.

Outdoor temperature

The weather was normal for the time of the year and was similar in the 2 experiments. In Exp 1 the temperature was, on average, -6 °C (-28 °C to +6 °C). The weather was milder at the beginning of the experiment (days 1 to 9) with temperatures above 0 °C during some days. On day 9 the temperature dropped. Particularly cold nights, and minimum temperatures below -27 °C, occurred on days 13, 20 and 21.

In Exp. 2 the mean temperature was -10 °C, ranging from -31 to +5 °C. At the start of the experiment the temperature was around -20 °C for two days but then rose to -8 to ±0 °C. On day 9 the temperature dropped and the weather stayed cold for the rest of the experiment, with temperatures from -28 to -10 °C.

Feed intake

All groups in Exp. 1 consumed similar amounts of the lichen diet before the start of the experiment. The feed intake in Group C was, on average, 1.3 kg DM and 64 g crude protein (CP) per animal and day and did not change during the experiment. When feed was restricted for the other groups, the consumption was 0.63 kg DM and 31 g CP on average. The feed intake did not differ between the restricted groups. During restricted feeding, the amount of feed residues was reduced from 10-20% to less than 1% of the given feed. On day 10, reindeer fed the pellet-based diets (group PL and PS) were given 0.6 kg DM per animal and day. The amount was gradually increased and after 2 weeks the reindeer consumed 1.8 kg DM per animal and day. The reindeer in group SP consumed 0.9 kg DM per animal and day when fed only silage, and the feed intake increased to the same as for groups PL and PS when pellets were included in the diet. Group L had the same feed intake when fed *ad lib.* as group C.

The feed intake in Exp. 2 was similar in both groups before the start of the experiment. The control group consumed the same amount of feed throughout the experiment, on average 1.24 kg DM and 57 g CP per animal and day. When feed was restricted, the reindeer in group S consumed 0.76 kg DM per day and the feed residues were reduced from 25% to less than 5% of the given feed. When group S was fed silage *ad lib.,* the intake was 0.68 kg DM and 88 g CP per animal and day.

Body weight

At the start of Exp. 1, the body weight was, on average, 43 kg (32 to 53 kg) and did not differ significantly between the groups or between animals that remained healthy and those that were later observed with wet belly. The reindeer lost live body weight when feed was restricted but most of the weight loss could be accounted for by loss of rumen content. The reindeer fed pellet-based diets (group PL, PS and SP) gained body weight (on average 2.5, 1.7 and 0.9 kg, respectively, during the whole experiment), while reindeer in the lichen-fed groups (groups L and C) lost some body weight (-2.0 and -1.4 kg, respectively). The amount of rumen content at the end of the experiment did not differ significantly between the groups.

The body weight at the start of Exp. 2 was 42 kg on average (ranging from 37 to 48 kg) and did not differ between the 2 groups. The controls lost some body weight during the experiment whereas reindeer in group S lost weight during restricted feeding and then gained weight during the period when they were fed silage *ad lib.* The overall weight gain in group S (2.8 kg), compared with a loss in the control group (-1.4 kg), was accounted for by 4 kg more rumen content in the silage-fed reindeer.

Wet belly

Altogether 11 reindeer in Exp. 1 were affected by wet belly (WB-reindeer). Seven of them showed the first symptoms of wet belly during the period of restricted feeding, when all groups except group C where treated alike, while the remaining reindeer were affected later (Table 2). Seven cases of wet belly occurred in group

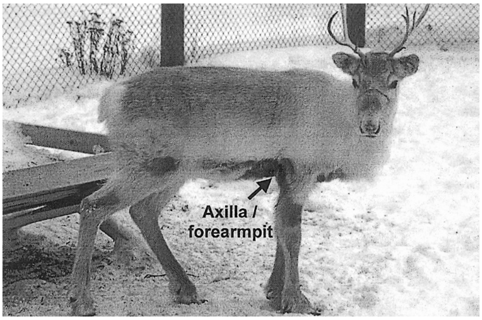
Table 2. The individual WB-reindeer in Exp. 1, day when first observed with wet belly, day when observed dry, day when slaughtered, dead/euthanised or excluded from the experiment, and findings at slaughter or death

Reindeer	Group[1]	Observed wet (day)	Observed dry (day)	Slaughtered, dead or euthanised (day)	Findings at meat inspection or necropsy
No. 8	PL	4	–	10 – Slaughtered	Normal
No. 23	PS	4	–	(excluded because of injury)	–
No. 25	SP	7	35	44 – Slaughtered	Normal
No. 13	SP	9	–	25 – Dead	Emaciated, pulmonary aspergillosis, blood in brain, liver and kidneys, red mucous embrane of abomasum, local skin infection on lower jaw
No. 18	PL	9	28	44 – Slaughtered	More fat than average, otherwise normal
No. 40	SP	9	–	13 – Dead	Rumen filled with undigested silage. Emaciated, rumenal ulcera and abscess, local peritonitis, petechial haemorrhages in the adrenal gland
No. 48	SP	9	–	11 – Dead	Rumen filled with undigested silage. Emaciated, enteritis, hepatitis, red mucous membrane of abomasum
No. 2	PS	14	35	44 – Slaughtered	Normal
No. 33	SP	14	–	21 – Dead	Emaciated, abomasal ulcera, petechial haemorrhages in the adrenal gland
No. 16	SP	18	28	44 – Slaughtered	Normal
No. 69	SP	18	–	23 – Euthanised	Abomasal ulcera, mycotic penumonia, arthritis, chronic focal interstitial nephritis, petechial haemorrhages in the adrenal gland. Nutritional state normal.

[1] All reindeer were treated alike on days 0-9 (restricted lichen diet + one day of starvation). From day 10 the groups were fed differently

SP and 4 in groups PL and PS. No animal in groups L or C showed any symptoms of wet belly. All reindeer in Exp. 2 were healthy and none of them showed any signs of wet belly.

The affected animals became wet, starting from the axillae, extending over the lower parts of the thorax and abdomen and sometimes also up the throat (Fig. 1a and 1b). The size of the wet area varied from individual to individual. Wet belly was first noticed when animals were seen licking themselves or their pen-mates. Later, as the reindeer gradually got wetter, other changes were seen in their behaviour. The affected animals were restless, spent more time at the feeding cribs, seemed hungry and were almost constantly eating from the silage. When they lay down they seemed to prefer icy and often dirty cavities rather than the dry snow. The wet fur became discoloured yellow-brown. The animals continued licking their fur and hair-less spots occurred in the coat. Severely affected animals developed an apathetic state, lying curled up and shivering. When the outdoor temperature was low they got frost in the fur. Reindeer



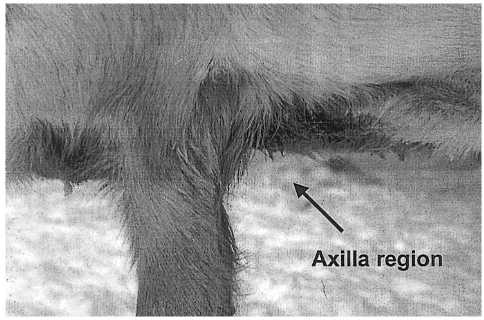


Figure 1. a) Female reindeer affected by wet belly b) detail from the axilla of the same animal.

in group SP lay closer together than those in the other groups, often under the roof at the feeding place. Some had pulled down silage on the ground and lay on it. Some reindeer were still eating silage while they were lying down. Tracks in the snow and observations of the behaviour showed that the animals in group SP spent most of their time around the feeding cribs and did not use the whole pen-area as the other groups did.

Five of the WB-reindeer were slaughtered according to the experimental plan, one of them on day 10, when she was wet, and the others on day 44 when they had all recovered. One WB-reindeer was excluded due to an injury. Four WB-reindeer (all in group SP) died between days 11 and 25 and 1 was euthansied. The 5 reindeer slaughtered according to the original experimental plan showed no poor nutrition or ulcers. The WB-reindeer that died were all in poor nutritional condition with no visible fat and jelly-like bone marrow. Necropsies from these animals and the one that was euthanised showed different signs of infections and stress (Table 2).

Three of the WB-reindeer were treated and observed individually. No. 23 had an infected leg wound and was treated with penicillin on day 5 and put into a pen with three other reindeer and fed the lichen diet *ad lib.* She was continuously wet for at least five weeks but did not seem to be affected otherwise. She recovered later during the spring but was affected by wet belly again the next winter, when she was used in another experiment and fed mainly lichens. No. 13, first observed wet on day 9, was restless and constantly chewed silage on day 14. She was then taken aside and offered some pellets, which she ate with good appetite. She seemed calmer the next day but was just as wet. On day 18 she was taken indoors and the fur was dried with a fan and she was left in a dry place indoors. She was wet again within about 2 h, starting between the front legs. She was returned to the pen the same day but was again taken indoors in the morning of day 21, since she was covered with frost and shivering, and then kept indoors. She seemed to recover and was almost dry on day 24, but was found dead the next morning. No. 69 seemed distressed on day 16, two days before she was observed wet, and did not come to the cribs at feeding time on day 17. She had an infection at the base of one antler and was therefore treated with penicillin. The infection seemed to heal but the following day she started to get wet. On day 22, she seemed distressed again and refused to eat, so she was taken indoors during the night. She did not get any better and was euthanised on day 23.

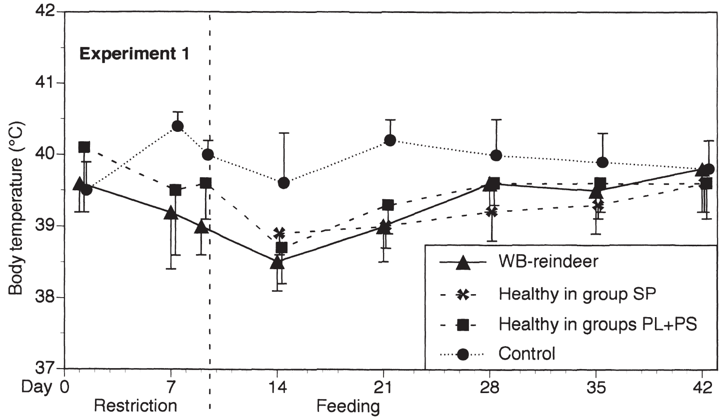


Figure 2. Body temperature in reindeer from experiment 1, mean ± SD for controls (group C, n=5), healthy reindeer in group SP (n=3, first observation on day 14), healthy reindeer in groups PL and PS (n=8) and WB-reindeer in groups SP, PL and PS (totally 11, but 4 not sampled until they showed signs of wet belly and 7 lost during the experiment, see Table 2).

Body temperature

The initial body temperature in Exp. 1 was 39.6 °C, on average. There was a decline in body temperature in all groups when the feed ration was restricted (Fig. 2). This decline continued during the first days of *ad lib.* feeding (until day 14). Body temperatures increased when the reindeer were fed *ad lib.,* but had not reached the level of group C until at the last reg-

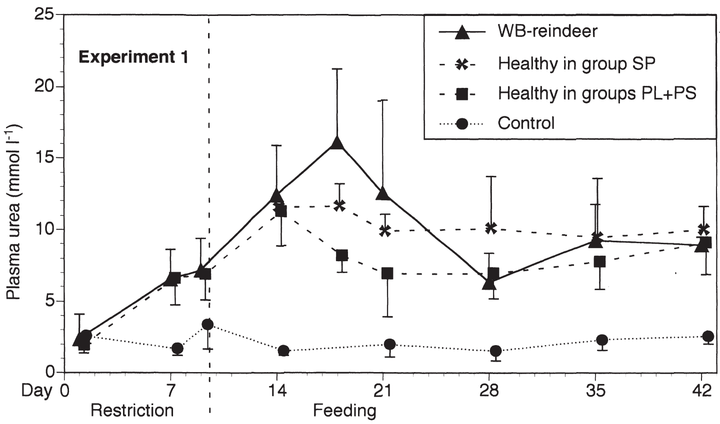


Figure 3. Plasma urea concentrations in reindeer from experiment 1, mean ± SD for controls (group C, n=5), healthy reindeer in group SP (n=3, first observation on day 14), healthy reindeer in groups PL and PS (n=8) and WB-reindeer in groups SP, PL and PS (totally 11, but 4 not sampled until they showed signs of wet belly and 7 lost during the experiment, see Table 2).

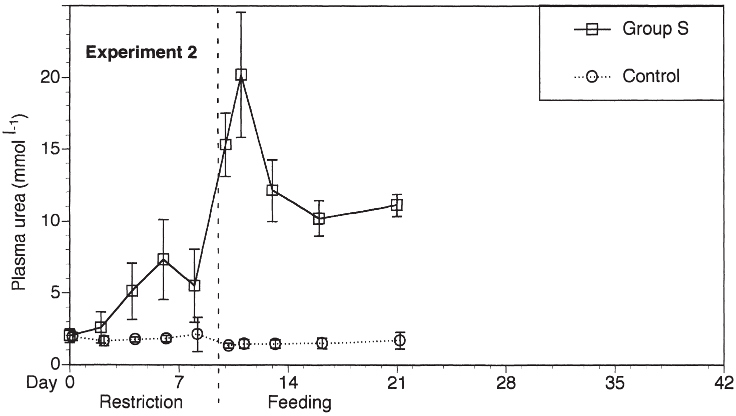


Figure 4. Plasma urea concentrations in reindeer from experiment 2, mean ± SD for reindeer fed lichens *ad lib.* (controls, n=10) and reindeer fed silage after a period of restricted feeding (group S, n=10).

istration on day 42. Already from the start of the experiment, the average body temperature was 0.5 °C lower in the WB-reindeer than in healthy reindeer from the same groups. The temperature continued to be lower in the WB-reindeer during the first 2 weeks and the difference was statistically significant on day 9. The WB-reindeer that recovered had the same body temperatures as healthy reindeer at the end of the experiment.

In Exp. 2 there was a general decline in body temperature during the experiment in both groups, with temperatures starting just below 40 °C in both groups and ending up at 39.3 °C in the control group and 38.5 °C in group S. The difference between the groups was significant from day 11.

Blood plasma constituents

The investigated blood constituents did not differ significantly between the groups at the start of Exp. 1. Initial plasma values were on average 2.5 ± 1.1 mmol l^{-1} of urea, 63 ± 6 g l^{-1} of protein, 5.3 ± 0.6 mmol l^{-1} of glucose, 6.4 ± 2.9 mU l^{-1} of insulin and 31 ± 16 nmol l^{-1} of cortisol. Urea concentrations increased as an effect of restricted feed intake (Fig. 3), while glucose decreased to 4.1 ± 0.8 mmol l^{-1}. The following feeding period with different diets resulted in a significant increase in urea, plasma protein and insulin concentrations to 8.5 ± 1.8 mmol l^{-1}, 74 ± 4 g l^{-1} and 10.9 ± 3.3 mU l^{-1}, respectively, on day 42 in the groups fed pellets (PL, PS and SP). The cortisol concentrations increased with time in all groups, to 57 ± 31 nmol l^{-1} on average on day 42.

No statistical differences were found between healthy and WB-reindeer as regards blood constituents, although some extreme values were observed among the individual WB-reindeer. The increase of plasma urea concentrations continued for a longer time after restricted feed intake in WB-reindeer, and three of the reindeer that died (Nos. 13, 33 and 69) had urea levels between 17 and 22 mmol l^{-1} prior to death. WB-reindeer that recovered returned to the same urea levels as the healthy reindeer. The variation in insulin concentrations was larger among the WB-reindeer (with a maximum at 29 mU l^{-1} on day 21) than among healthy reindeer (maximum 23 mU l^{-1}). The increase in cortisol over time seemed to be slower in the WB-reindeer than in healthy reindeer from the same groups.

The plasma urea concentrations in Exp. 2 were around 2 mmol l^{-1} in the control group throughout the experiment (Fig. 4). There was a considerable increase in urea in group S when feed was restricted and the levels continued to increase during the first 2 days of feeding with silage, with a maximum at 29 mmol l^{-1}. After this, the urea concentrations declined and seemed to stabilise around 11 mmol l^{-1}. Plasma protein concentrations were the same in both groups at the start of Exp. 2 (58 ± 3 g l^{-1} on average). Plasma protein increased in group S during the period of restricted feed intake but then returned to approximately the same level as before (59 ± 3 g l^{-1} on average). Plasma protein concentrations in the controls showed a slight decline during the experiment (to 56 ± 5g l^{-1}).

Discussion

The outbreak of wet belly in Exp. 1 was unexpected. Wet belly in reindeer is commonly associated with feeding and outbreaks described in the literature have occurred when reindeer have been offered diets based on hay (whole or milled), silage or straw (*Persson* 1967, *Nordkvist* 1971, *Jacobsen & Skjenneberg* 1979, *Nilsson* 1994). Hay containing much timothy *(Phleum pratense)* has been mentioned specifically as causing wet belly in reindeer (*Rehbinder & Nikander* 1999). In our experiment, the first cases of wet belly were observed when the reindeer were fed a restricted amount of a natural diet with mainly lichens. Since wet belly does not seem to occur when reindeer graze freely (*Sainmaa* 1998), the lichen diet as such should not cause wet belly. However, the limited amount of food may have forced the reindeer also to eat some litter (e.g. twigs, needles), with low energy content, which was rejected when the lichen diet was fed *ad lib.* It could also have resulted in some animals eating more, and perhaps other parts of the feed, than other animals in the group.

It was surprising that the problem with wet belly was dominant in one group (SP), before the groups were treated differently, and although there were no significant differences between the groups before the experiment. That the problem continued and got worse when the reindeer were fed solely silage is in accordance with earlier experiments, where reindeer have been fed diets with high fibre content. In one experiment (*Persson* 1967), reindeer were fed a mixture containing 15% straw meal and 25% grass meal, resulting in 24 out of 39 animals getting more or less wet. *Jacobsen & Skjenneberg* (1979) reported that a feed containing 47% straw meal and 20% grass meal could not be used for more than six weeks, since all eight reindeer calves eating this feed developed wet belly and five died. In a more recent experiment (*Nilsson* 1994), 21 out of 45 reindeer calves fed 50% grass silage and 50% commercial reindeer feed (pellets) showed different signs of poor health, many of them developed wet belly, and 12 died.

Grass silage or hay is usually not sufficient as the only feed for reindeer during longer periods of time (*Syrjälä-Qvist* 1982, *Aagnes & Mathiesen* 1995, *Nilsson et al.* 1996). The digestibility of most qualities of silage seems to be too low to provide the energy that the reindeer need, which can be explained by lack of cellulolytic bacteria in the rumen (*Nilsson et al.* 2001). The behaviour of the WB-reindeer, as they were restless and apparently hungry, indicates that they did not obtain the nutrients and energy they needed. Although no statistical differences were observed, the pellets-fed reindeer (group PL and PS) seem to have regained their blood glucose faster after the restricted feed intake than those that were first fed only silage. The increase in insulin concentrations, which has been shown to correlate positively with energy and protein intake, in e.g. sheep (*Bassett et al.* 1971), was also faster in groups PL and PS and is another indication that the silage did not provide enough energy. Although the calculated ME is very similar in all the diets, the structure of the feeds differs. Silage has to be physically more fractured than the other feeds to pass the rumen. Low passage of feed through the rumen may prevent the reindeer from eating as much as they need and could explain why silage-fed reindeer seem hungry even if there is food available. High appetite seems to be typical for reindeer with wet belly (*Nordkvist* 1971, *Jacobsen & Skjenneberg* 1979, *Nilsson* 1994) and usually remains, even if the condition develops to the point that the animals start to die. *Jacobsen & Skjenneberg* (1975) describe this as "maintaining a voracious appetite to the end". Reindeer fed hay or silage often have considerably more rumen content than those fed lichens or pellets (*Nilsson* 1994, *Aagnes & Mathiesen* 1996), which was also demonstrated in Exp. 2. The situation, being hungry but unable to eat the provided feed, because of a full rumen, may cause stress for the animal.

Signs of stress, abomasal ulcera (*Rehbinder & Nikander* 1999), were observed in 2 of the WB-reindeer and have been observed in connection with wet belly also in earlier experiments (*Jacobsen & Skjenneberg* 1979). Although behavioural conflicts within the group and the energy demand involved were not studied, these may be factors influencing the outcome of the feeding and could be a reason why most outbreaks of wet belly appeared in one single group and not in others that were treated similarly.

It has been shown that low energy intake reduces utilisation of protein in reindeer (*Syrjälä-Qvist & Salonen* 1983), and the combination of little energy and relatively high protein content in the diet may therefore cause a problem. Some reindeer owners claim that too much protein may cause wet belly (*Sainmaa* 1998). For the reindeer in Exp. 1, however, the problem with wet belly started when they were fed mainly lichens, with low protein content. High protein intake could therefore not be a main reason to the outbreak of wet belly, even if there might be single reindeer that ate less of the lichens and more of leaves, which had high protein content. An increase in plasma urea concentrations was observed in both experiments when the reindeer were fed restricted rations of the lichen diet. Elevated levels of plasma urea have been reported as an effect of malnutrition in reindeer (*Hyvärinen et al.* 1976, *Larsen et al.* 1985) and other ruminants (*DeCalesta et al.* 1975, *DeCalesta et al.* 1977, *Bahnak et al.* 1979), and can be explained by catabolism of muscle tissue when the energy intake is insufficient. Starved reindeer seem to reach higher levels of urea than e.g. mule deer and white-tailed deer in the same situation. This may be related to the low ability of reindeer to increase the concentration of nitrogen in urine compared with other ruminants (*Eriksson & Valtonen* 1974, *Valtonen & Eriksson* 1977, *Syrjälä et al.* 1980) and thus a limited ability to excrete excess of nitrogen without an increase in water intake. The observed peak in urea was higher in Exp. 2 than in Exp. 1, but the concentrations stabilized at lower level after only 4 days. Sampling was not done as often in Exp. 1 as in Exp. 2 and we may therefore have missed a higher peak during the first days of feeding with the new diets in Exp. 1. The delayed peak in plasma urea in some of the WB-reindeer could indicate that these reindeer differed from the healthy reindeer with regard to nitrogen balance. Moderately high concentrations of plasma urea, as later observed in the pellets- and silage-fed reindeer, were expected as an effect of the higher protein intake compared with the lichen-fed reindeer (*Hove & Jacobsen* 1975, *Valtonen* 1979).

Growth of *Penicillium* was found in the lichens and shrubs used in Exp. 1. The species found in lichens, *P. spinulosum,* has not been observed to affect animal health. *P. brevicompactum,* which was present in shrubs, is known to produce mycotoxines. The effects of these on animal health is, however, unknown (*Jacobsson* personal communication 1998). Unfortunately the hygienic quality of the feeds used in Exp. 2 was not examined. However, lichens fed to reindeer in later experiments have shown varying degree of *Penicillium* spp. growth, and in some case also growth of *Aspergillus* spp., without causing visible health problems (*Åhman,* unpublished results).

The appearance of wet areas on the body in this experiment is in accordance with what has been described by others (*Nordkvist* 1971, *Westerling* 1971). Most reindeer owners describe that the wetness starts from the axillae (*Sainmaa* 1998) and they also mention that the hair becomes yellow and hairless spots occur, which was also observed by *Nordkvist* (1971). Many reindeer owners report that wet animals prefer to lie in icy cavities rather than on the soft snow. This was observed in the present experiment and also by *Nilsson* (1994). For this reason, it has been suggested that the reindeer gets wet from the outside by melting snow or ice (*Rehbinder & Nikander* 1999). We showed that this was not the case and that reindeer may get wet even if they are kept indoors in a dry environment. Reindeer do not normally sweat so that moisture can be seen in the fur, even if they are exercised (*Folkow & Mercer* 1986). It is obvious from the measures of rectal temperature that the wet reindeer in the experiment were not generally warm, rather the opposite. However, glands with well-developed secretory epithelium have been found in reindeer (*Källquist & Mossing* 1977), and it appears that they are located in the areas (the foreleg pits, in the groins, on the belly and down the legs) that get wet when reindeer develop wet belly. Active sweat glands have also been found in the wet skin of reindeer with wet belly (*Nylund* personal communication 2001). It is still unknown when or why, these glands activate. To study this further, we suggest that skin samples are taken from reindeer when wet belly occurs. Histological findings on skin samples from animals with and without wet belly could then be compared. Chemical analysis of the fluid on the skin could give additional information.

Incidences of death following the occurrence of wet belly seem to be common (*Nordkvist* 1971, *Westerling* 1971, *Jacobsen & Skjenneberg* 1979). On the other hand, no cases of death occurred in the experiment made by *Persson* (1967), although 24 reindeer had wet belly, and only a minority of reindeer owners seem to have observed deaths among reindeer with wet belly (*Sainmaa* 1998). Obviously wet belly as such does not cause death and reindeer may very well recover, as was also observed in the present experiment. It may, however, take a long time as for No. 23, the WB-reindeer that recovered and was kept at the research station. This reindeer was affected by wet belly again the next winter, which may indicate that a reindeer that has previously been affected is inclined to get wet belly again. This might explain why older reindeer were affected by wet belly to a larger extent than younger animals (*Persson* 1967) in a herd that had been observed with wet belly several times before (*Nordkvist* 1971).

It has been shown earlier (*Nordkvist* 1971, *Jacobsen & Skjenneberg* 1979, *Nilsson* 1994) that reindeer with wet belly that die are usually in a poor nutritional state. Emaciation seems to have been the cause of death in all the WB-reindeer that died in our experiment. Low outdoor temperature and inability to keep the body temperature probably promoted death when the animals were already emaciated.

The present study shows that it is difficult to induce wet belly intentionally by feeding a certain diet. Since outbreaks of wet belly occur sporadically, such events could be used to further examine the role of the feed, and its nutritional and hygienic quality, in the development of wet belly.

Conclusions

This study shows that wet belly is not induced by any specific diet and that even reindeer on a restricted lichen-based diet may develop wet belly. It was further established that the fluid making the fur wet has an internal origin. Mortality among WB-reindeer was caused by emaciation, probably secondary to reduced energy intake caused by different diseases and/or unsuitable feed, in this case silage.

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References

Aagnes TH, Mathiesen SD: Round baled grass silage as food for reindeer in winter. Rangifer, 1995, *15,* 27-35.

Aagnes TH, Mathiesen SD: Gross anatomy of the gastrointestinal tract in reindeer, free-living and fed baled timothy silage in summer and winter. Rangifer, 1996, *16,* 31-39.

Bahnak BR, Holland JC, Verme LJ, Ozoga JJ: Seasonal and nutritional effects on serum nitrogen constituents in white-tailed deer. J. Wildl. Manage., 1979, *43,* 454-460.

Bassett JM, Weston RH, Hogan JP: Dietary regulation of plasma insulin and growth hormone concentrations in sheep. Aust. J. biol. Sci., 1971, *24,* 321-330.

DeCalesta DS, Nagy JG, Bailey JA: Starving and refeeding mule deer. J. Wildl. Manage., 1975, *39,* 663-669.

DeCalesta DS, Nagy JG, Bailey JA: Experiments on starvation and recovery of mule deer does. J. Wildl. Manage., 1977, *41,* 81-86.

Eriksson L, Valtonen M: Seasonal changes in renal urea concentration in the reindeer (*Rangifer tarandus* L.). Ann. Zool. Fennici, 1974, *11,* 200-203.

Folkow LP, Mercer JB: Partition of heat loss in resting and exercising winter- and summer-insulated reindeer. Am. J. Physiol. (Regulatory Integrative Comp. Physiol. 20), 1986, *251,* R32-R40.

Hove K, Jacobsen E: Renal excretion of urea in reindeer: effect of nutrition. Acta Vet. Scand., 1975, *16,* 513-519.

Hyvärinen H, Helle T, Nieminen M, Väyrynen P, Väyrynen R: Some effects of handling reindeer during gatherings on the composition of their blood. Anim. Prod., 1976, *22,* 105-114.

Jacobsen E, Skjenneberg S: Some results from feeding experiments with reindeer. In: Luick JR, Lent PC, Klein DR and White RG (eds.): Proc Ist Int Reindeer/Caribou Symposium, Fairbanks (1972). Biological Papers of the University of Alaska, Vol. Special report 1 Sept 1975, University of Alaska Fairbanks, 1975, pp. 95-107.

Jacobsen E, Skjenneberg S: Forsøk med ulike forblandinger till rein, Forverdi av reinfor (RF-71), Experiment with different diets to reindeer, Feeding value of reindeer feed (RF-71). Scientific Reports of the Agricultural University of Norway, 1979, *58,* 1-11. [In Norwegian]

Jacobsson K-G: National Veterinary Institute, Uppsala, Sweden, 1998, Personal communication.

Källquist L, Mossing T: The distribution of sudoriferous glands in the hairy skin of reindeer (*Rangifer tarandus* L.). Acta zool. (Stockh.), 1977, *58,* 65-68.

Larsen TS, Nilsson NÖ, Schytte Blix A: Effects of prolonged food restriction on some aspects of lipid metabolism in Norwegian and Svalbard reindeer. Acta Physiol Scand, 1985, *124,* 173-180.

Nilsson A: Vinterutfodring av renar till slakt. Feeding of reindeer during the winter. Swedish University of Agricultural Sciences, Department of Animal Nutrition and Management, Uppsala, 1994. Examensarbete 60. [In Swedish].

Nilsson A, Danell Ö, Murphy M, Olsson K, Åhman B: Health, body condition and blood metabolites in

reindeer after sub-maintenance feed intake and subsequent feeding. Rangifer, 2000, *20,* 187-200.
Nilsson A, Murphy M, Åhman B: Dietary effect on rumen microbes in reindeer. In: Haugerud RE (ed.): Programme and Abstracts, the 11th Nordic Conference on Reindeer Research, Kaamanen, 18-20 June 2001, Rangifer Report No. 5, 2001, 64.
Nilsson A, Olsson I, Lingvall P: Comparison between grass-silage of different dry matter content fed to reindeer during winter. Rangifer, 1996, *16,* 21-30.
Nordkvist M: Diskussion. Samnordisk renforskningskonferens, Gällivare 1969. Discussion. Nordic Conference on Reindeer Research. Gällivare 1969. Kungl. lantbruksstyrelsen. Meddelanden - Serie B, 1971, Nr 88, 88. [In Swedish].
Nylund M: National Veterinary and Food Research Institute, Oulu, Finland, 2001, Personal communication.
Persson S: Studier av renarnas energibehov. The energy requirements of reindeer. Kungl. lantbruksstyrelsen. Meddelanden - Serie B, 1967, Nr 75, 23 pp. [In Swedish].
Rehbinder C, Nikander S: Ren och rensjukdomar, Studentlitteratur, Lund, 1999. [In Swedish].
Sainmaa S: Blötbuk hos renar (*Rangifer tarandus tarandus* L.) i Finland och Sverige. Wet belly in reindeer in Finland and Sweden. Swedish University of Agricultural Sciences, Department of Clinical Nutrition, Uppsala, 1998. [In Swedish].
Syrjäla-Qvist L: Comparison of grass silage utilisation by reindeer and sheep. 1. Palatability, feeding values and nutrient supply. J. Sci. Agric. Soc. Finl., 1982, *54,* 119-126.
Syrjälä-Qvist L, Salonen J: Effect of protein and energy supply on nitrogen utilization in reindeer. Acta Zool. Fennica, 1983, *175,* 53-55.
Syrjälä L, Salonen J, Valtonen M: Water and energy intake and nitrogen utilisation in the reindeer. In: Reimers E, Gaare E, Skjenneberg S (eds.): Proceedings of the Second international reindeer/caribou symposium, 17.-21. September 1979, Røros, Norway, Vol. A, Direktoratet for vilt og ferskvannsfisk, Trondheim, Røros, Norway, 1980, 252-261.
Valtonen M: Renal responses of reindeer to high and low protein diet and sodium supplement. Journal of the Scientific Agricultural Society of Finland, 1979, *51,* 381-419.
Valtonen M, Eriksson L: Responses of reindeer to water loading, water retriction and ADH. Acta Physiol. Scand., 1977, *100,* 340-346.
Westerling B: Den svältande renen. The starving reindeer. Kungl. lantbruksstyrelsen. Meddelanden - Serie B, 1971, *Nr 88,* 75-82. [In Swedish].

Sammanfattning

Blöt buk hos renar (Rangifer tarandus tarandus) *i relation till kondition, kroppstemperatur och blodvärden.*

Blöt buk, när renen blir blöt över nedre delen av bröst och buk, förekommer emellanåt bland utfodrade renar. I ett utfodringsförsök drabbades 11 av 69 renar av blöt buk. Problemet observerades först hos 7 renar under en period med begränsat foderintag. När djuren sedan gavs normala fodergivor, drabbades ytterligare 4 renar av blöt buk, 3 som utfodrades med enbart ensilage, och en som fick pellets och ensilage. Fyra djur dog senare och en fick avlivas. För att undersöka varför renarna utvecklade blöt buk, jämförde vi data från friska renar och renar som fått blöt buk. Urea, plasmaprotein, glukos, insulin och kortisol påverkades av begränsat foderintag och av diet, men skilde inte generellt mellan friska renar och dem som drabbades av blöt buk. De blöta djuren hade låg kroppstemperatur och dödsfallen inträffade under perioder med särskild kallt väder. De djur som dog var utmärglade och obduktioner visade olika tecken på infektioner och stress. I ett andra experiment, med 20 renar, upprepades utfodringsstrategin för den mest drabbade gruppen i det första försöket, men ingen ren visade några tecken på blöt buk. Studien visar att blöt buk inte orsakas av något specifikt foderslag och att även renar utfodrade med lav kan drabbas. Vätskan, som gör pälsen blöt, visades komma inifrån kroppen. Dödsfallen orsakades av utmärgling, troligen en sekundär effekt av minskat energiintag vilket i sin tur kan bero på sjukdom och/eller olämpligt foder.

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Reprints may be obtained from: Birgitta Åhman, Department of Animal Genetics, Reindeer Husbandry Unit, Swedish University of Agricultural Sciences P.O.Box 7023, S-750 07 Uppsala, Sweden. E-mail: Birgitta.Ahman@hgen.slu.se, tel: +46 (0)18 672308.