Effects of administration of potassium- and sodiumchlorides on faecal excretions and salivary and alimentary concentrations of, Na, K, ^{134}Cs, Ca, Mg and P in reindeer fed a lichen diet

Hans Staaland[1], Knut Hove[2], Øyvind Pedersen[2] & Luise Charlotte Birke[1]

[1] Department of Biology and Nature Conservation, Agric. Univ. of Norway, Box 5014, 1432 Ås, Norway (hans.staaland@ibnf.nlh.no).
[2] Department of Animal Science, Agric. Univ. of Norway, Box 5025, 1432 Ås, Norway.

Absract: A comparison of the effects of administration of 350 mmol d^{-1} of KCl or NaCl on faecal excretions, salivary concentrations and concentrations and pools of Na, K, ^{134}Cs, Ca, Mg, P, and water in the alimentary tract of reindeer was carried out using three groups of three 10 months old reindeer fed a lichen diet. One group was used as a control group with no mineral supplementation. The level of K supplementation mimicked K intakes from summer pastures. NaCl was given at a rate which would mimic intake from salt licks by domestic ruminants of similar body size. Treatment with KCl increased the salivary and alimentary concentrations and the alimentary pool sizes of K and faecal excretion of K increased. A decrease in ^{134}Cs concentrations in all parts of the gastrointestinal tract indicated greater absorption of ^{134}Cs during the KCl treatment than in NaCl treated and control animals. Increased intake of Na or K had no significant effect on the digestibility of the lichen diet, but urine production increased. Little effects on pools or concentrations of Ca, Mg and P were observed. NaCl treatment increased urinary and faecal excrerion of Na, but did not affect the metabolism of any of the other studied minerals.

Key words: *Rangifer,* mineral metabolism.

Rangifer, 18 (1): 27–34

Introduction

Supplementary intake of potassium (K) in ruminants affects the metabolism of sodium (Na) and other minerals, and may also affect dry matter digestibility (Warner & Stacy, 1972; Grings & Males, 1987; Staaland & Garmo, 1987). Also considerable interest has been focused on findings of reduced uptake and retention time of radiocaesium (^{134}Cs and ^{137}Cs) in reindeer which are consuming green forage (grasses, herbs, green leaves etc.) or other diets high in K (Holleman & Luick, 1975; Åhman, 1988; Birke *et al.*, 1995).

During winter as much as 80-90 percent of the diet of reindeer can be lichen (Gaare & Staaland, 1994). Lichens generally have low concentrations of minerals compared to green forage. Typical concentrations in a Norwegian lichen dominated diet in inland areas are about 10 mmol Na and 30 mmol K per kg dry matter (DM) (Garmo, 1986; Staaland & Sæbø, 1993; Gaare & Staaland, 1994). These low concentrations are nevertheless sufficient to sustain concentrations of these minerals in the blood and gastrointestinal contents of reindeer during a long winter. Recent studies indicate that reindeer grazing in mountain regions in Southern Norway can maintain Na balance during winter on diets containing 5-6 mmol kg^{-1} DM (Staaland & Hove, unpubl.). The concentrations of these different mineral elements in reindeer are also typical of those recorded in domestic ruminants fed mixed rations of hay and concentrates and for wild ruminants, but seasonal variations are common (see e.g. Church 1979; Staaland *et al* , 1992; Holand & Staaland, 1995).

When spring comes, green pasture with a much higher K concentration is available. A shift in alkali mineral concentrations in the rumen towards a K dominance has been reported. Through spring and summer, rumen concentrations of K can increase from about 30 mmol in winter to as much as 160 mmol kg^{-1} wet weight, with a concomitant decrease in Na concentrations from 150 to 25 mmol kg^{-1} wet weight (Staaland & Sæbø, 1987). At the same time, radiocaesium levels in reindeer grazing contaminated pastures from nuclear weapon tests or fallout from the Chernobyl accident decreases rapidly, and reaches their lowest annual values in the period June-August (Pedersen *et al*, 1993; Åhman & Åhman, 1994).

Daily intake of Na by a reindeer is about 10-20 mmol in both summer and winter. This is only a small fraction of the normal gastrointestinal pool which can be 1300-1400 mmol in a reindeer weighing about 40 kg. For comparison, 1 kg DM of foraged green vegetation can contain about the same amount of K as the gastrointestinal content, i.e. 300-400 mmol. The exchange of Na between different sections of the alimentary tract and the body, and the flow between alimentary sections, is nevertheless many-fold higher than for K (Staaland *et al.*, 1984; White *et al.*, 1984).

We have previously reported from experiments with the same animals as in the present publication (Birke *et al.*, 1995). The main purpose of that study was to examine the effects on accumulation and excretion of ^{134}Cs when animals were fed a lichen diet supplemented with Na and K. An enhanced intake of alkali elements for a prolonged period may also influence the size of the alimentary pools of these elements and further alter concentrations and absorption of other minerals and the dry matter digestibility. The aim of the present study is to report on the effects of a forced increase of K or Na intake on the alimentary pools and concentrations of K, Na, ^{134}Cs, Ca, Mg and P measured at slaughter. I addition salivary concentrations and faecal excretion were measured.

Materials and methods

Nine male reindeer calves, approximately 10 months of age, were obtained from the herd belonging to the Vågå reindeer company in the Jotunheimen mountain range of southern Norway. They were brought ro the Agricultural University at Ås and transferred to metabolism pens in a barn.

The animals were used in 2 continuos experiments, one that lasted for 29 days and the present one which continued for 4 days until the animals were slaughtered. The first experiment was designed to examine the effect of NaCl and KCl administration on the accumulation of ^{134}Cs and excretion of ^{137}Cs in the reindeer (Birke *et al.*, 1995).

Food consumption, and urine and faeces production were measured throughout both experiments. Body mass (BM) was recorded regularly throughout the experiment and ar slaughrer (Table 1).

All animals were fed a diet of hand-picked lichen, mainly *Cladonia stellaris* and *C. rangiferina.* The reindeer were fed in the morning and evening and offered a total daily intake of 1300 g DM. Food remains were collected and weighed every morning, and the animals consumed on an average 0.75-0.95 kg DM d^{-1} for a period of 33 days. Three animals were given a daily dose of 26g KCl, and 3 animals a dose of 20g NaCl. Three others were kept as controls and not fed extra minerals. Animals given minerals would, including minerals in the food, have a daily intake of $\approx$350 mmol K or Na. KCl and NaCl were given dissolved in 1 l water prior to feeding through a tube placed in the proximal part of the oesophagus. ^{134}Cs was sprayed on small dots of lichens given to the animals before regular feeding in the morning and the quantities given were correlated to the ^{137}Cs activity in the animals at the start of the first experimental period (Birke *et al.*,1995).

Saliva was collected 10, 7 and 3 days before slaughter by forcing the animals to chew on a perforated polyethylene tube for about 5 min as described by Staaland *et al.* (1980).

During the last 4 days of the experimental period samples were collected for calculation of faecal production and digestibility. Also urine volumes were measured in the 4 days period prior to slaugh-

Table 1. Daily food intake and faecal excretion of dry matter (DM), DM digesribility, daily mineral intake and faecal and urinary water and mineral loss ± S.D. Figures followed by different letters are significantly different ($P<0.05$). Estimates are based on total intake and excretion through the 4 days prior to slaughter.

	Control ($n=3$)	Treatment KCl ($n=3$) 350mmol d^{-1}	NaCl ($n=3$) 350mmol d^{-1}
Body mass (kg)	49±5	49±8	50±5
Food intake (g DM d^{-1})	747±77a	954±43b	829±68ab
Faecal output (g DM d^{-1})	198±23a	275±22b	230±43ab
DM digestibility (%)	73±1	71±3	72±4
Faecal water output (g d^{-1})*	401±59a	691±121b	580±116ab
Urine production (ml d^{-1})	755±104a	2294±464b	2294±264b
Urine excr. Na (mmol d^{-1})**	0.5	30	312
Urine excr. K (mmol d^{-1})**	1.1	266	2.7
Na			
Intake, mmol d^{-1}	7±1a	9±1b	350±1c
Faecal loss, mmol d^{-1}	14±4a	14±5a	53±14b
K			
Intake, mmol d^{-1}	21±2a	361±1b	23±2a
Faecal loss, mmol d^{-1}	18±2a	64±10b	19±7a
^{134}Cs			
Intake, Bq d^{-1}	6600±346	6300±755	8067±1563
Faecal loss, Bq d^{-1}	4265±913	4014±678	4688±363
Ca			
Intake, mmol d^{-1}	17±2a	22±1b	19±2ab
Faecal loss, mmol d^{-1}	11±2	13±2	9±2
Mg			
Intake, mmol d^{-1}	11±1a	14±1b	12±1ab
Faecal loss, mmol d^{-1}	11±2	15±2	11±2
P			
Intake, mmol d^{-1}***	11±1a	13±1b	12±1ab
Faecal loss, mmol d^{-1}	18±3a	23±1b	21±2ab

* Estimates based on water percentage in the distal colon (D2) and daily DM faecal producrion in different animals.

** Estimates of urinary excretion of Na and K is based on data presented in a previous publication (Birke *et al.*, 1995).

*** Based on P concentrations in lichen (Staaland & Sæbø, 1993).

ter. Treatment with minerals and ^{134}Cs continued until the day before slaughter, but food was offered as usual in the morning before slaughter started (about half the daily food amount). The animals were slaughtered 1-6 hrs after the last feeding.

Immediately after the reindeer were killed the gastrointestinal tract was removed (and spread on a table). The total content of the 11 following sections were collected and weighed: Rumen and reticulum, omasum, abomasum, 3 equally long sections of the small intestine, caecum, ascending spiral colon, descending spiral colon, and finally 2 equally long succeeding sections of the distal colon including rectum. Thoroughly mixed samples from each section were transferred to counting vials for the measurement of ^{134}Cs. After measurements of ^{134}Cs

activity concentrations the samples were freeze dried to constant weight to determine water and dry matter content.

For chemical analyses of Na, K, Ca, Mg and P the dried samples were ashed at 525 °C for 4 h. The ash was dissolved in *aqua regia* and further diluted with deionized water. Mineral concentrations were measured on a GBC 906AA Spectrophotometer and radionuclide activity concentrations on a Minaxi Y, (Auto Gamma 5000 series, Packard Instruments.)

Duncan multiple range test was used to compare treatment means.

Results

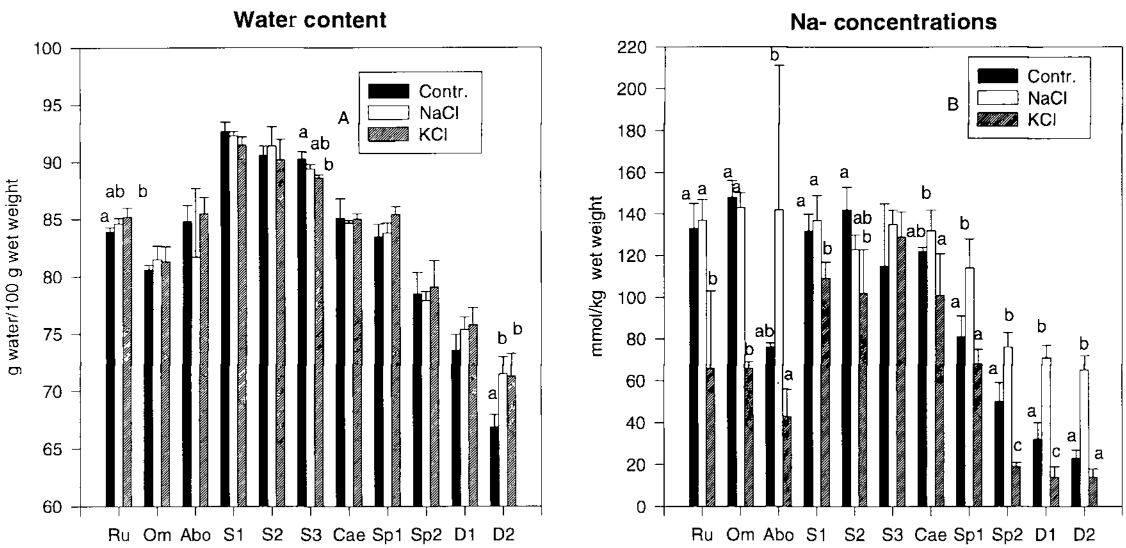
All animals maintained their initial body weights and remained in good conditions throughout the experiment. Body masses at slaughter were 49-50 kg. Based on data from the last 4 d before slaughter the control group had the lowest food intake. Digestibility of DM in the ration was 71-73 % and was not significantly different between the 3 experimental groups. Urine production was highest in the mineral treated animals (Table 1).

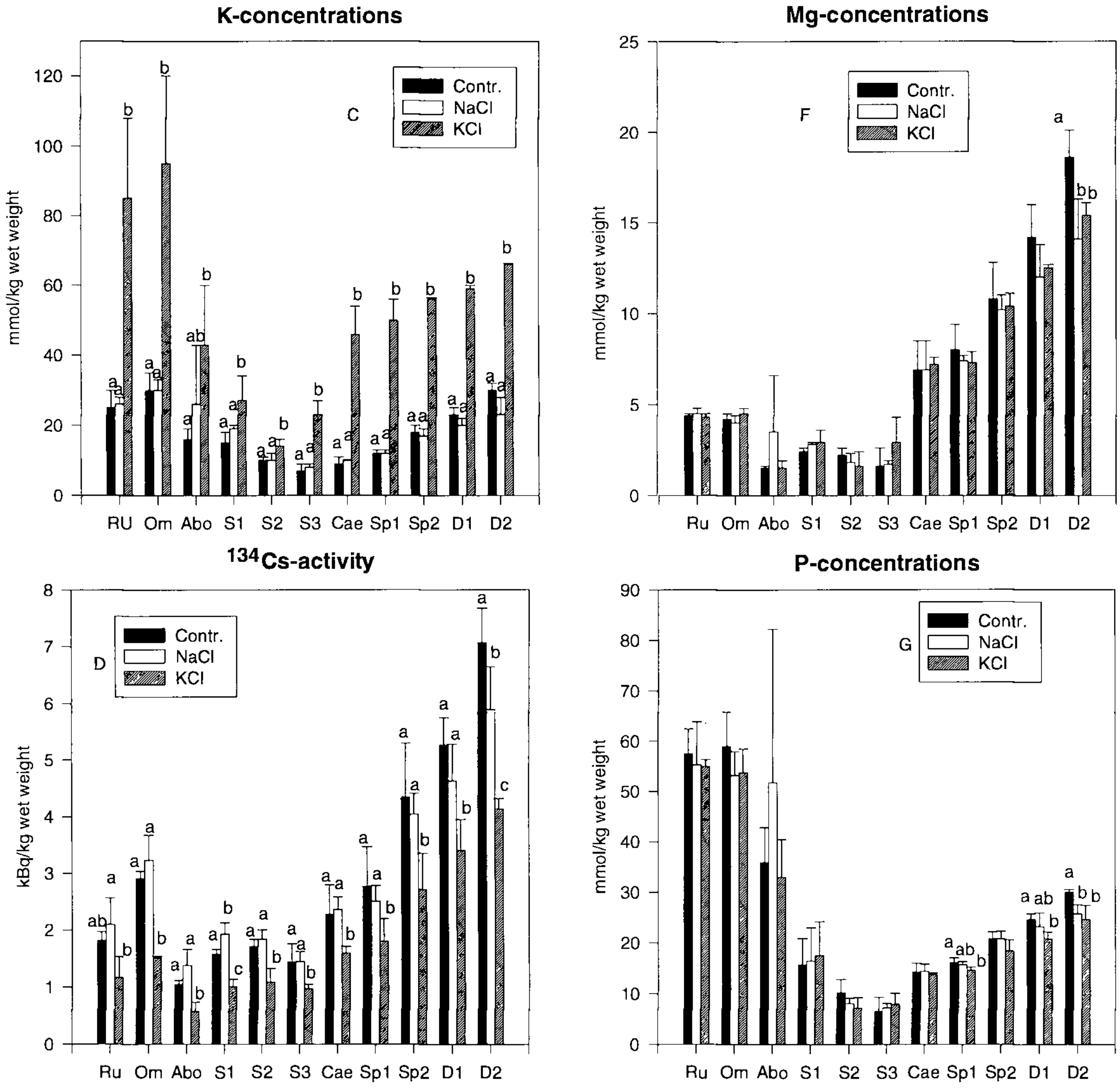
Water and mineral concentrations in the alimentary tract

There were no significant effects of either KCl or NaCl treatments on water concentrations in the alimentary tract, except for a slightly higher water content in the distal colon of the Na and K treated animals when compared to controls (Fig.1A). Animals given KCl had the lowest sodium concentrations throughout the alimentary tract, most significantly in the stomach region and in the distal colon (except D2). Animals given KCl had significantly higher K concentrations in all sections of the alimentary tract compared to the control and Na treated animals (Fig. 1B,C). Treatment with KCl apparently reduced the ^{134}Cs concentrations throughout the alimentary tract compared to the animals given NaCl and to the control animals. Sodium treatments increased Na concentrations in the abomasum and caecum-colon, but appeared to have little effects on K and ^{134}Cs concentrations (Fig. 1 B,C,D). Except for slightly higher concentrations of Ca, Mg and P in some sections of the distal alimentary tract in the control animals, Na and K treatments did not appear to affect the alimentary concentrations of these elements (Fig. 1E, F, G).

Alimentary pools

The total alimentary pools of minerals and dry matter were calculated per kg BM after pooling of the alimentary contents. Animals supplemented with KCl had larger alimentary pools of K (4-5 times), and smaller Na pools, than controls and those given NaCl. On the contrary, sodium treatment did not affect the alimentary pools of either Na or K (Table 2). Also, the total ^{134}Cs activity relative to BM seemed to be lower in the K treated animals. The differences are, however, not significant different from other groups (P>0.05). Also, doses of ^{134}Cs given to





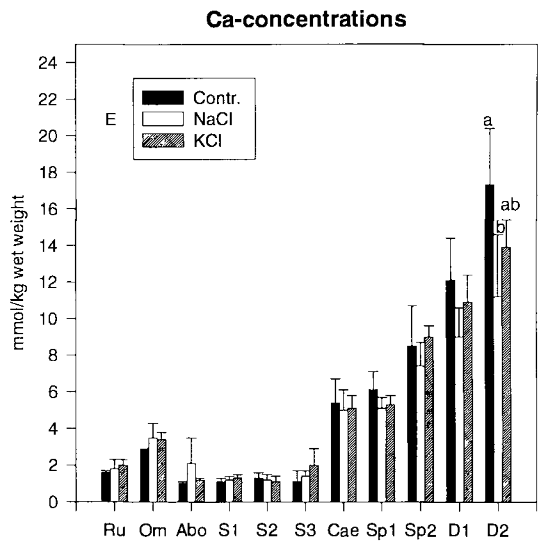


Fig. 1. Water percentage and Na, K, ^{134}Cs, Ca, Mg and P concentrations in different sections of the alimentary tract of the reindeer (±S.D.). Columns followed by different letters are significantly different $P<0.05$, $n=3$. Ru=Rumen; Om=Omasum; Abo=Abomasum; S1, S2, S3=Small intestine; Cae=Caecum; Sp1=Ascending spiral colon; Sp2=Descending spiral colon; D1, D2=Distal Colon.

the KCl treated animals were lower than for the 2 other groups (Table 1). No effect of NaCl or KCl treatment was observed with respect to total alimentary pools of Ca and Mg, and P content was a little higher in the K treated animals. Throughout

Table 2. Total fill, water, K, Na, ^{134}Cs, Ca, P and Mg in the alimentary tract of reindeer given 350 mmol KCl or NaCl per day compared to control animals given the same diets withouth extra minerals. Values are given per kg of body mass (BM)±S.D.

	Control (*n*=3)	Treatment KCl (*n*=3)	NaCl (*n*=3)
Total wet weight fill (g kg^{-1})	168±15a	197±13b	164±8a
Water (g kg^{-1})	142±13a	168±12b	138±5a
K (mmol kg^{-1})	3.1±0.4a	15.0±4.4b	3.8±0.6a
Na (mmol kg^{-1})	21.0±3.0a	13.3±5.6b	22.1±1.2a
^{134}Cs (Bq kg^{-1})	1833±69	1387±382	1971±302
Ca (mmol kg^{-1})	0.39±0.03	0.48±0.03	0.42±0.08
P (mmol kg^{-1})	7.9±0.0a	9.2±0.7b	7.7±0.6a
Mg (mmol kg^{-1})	0.78±0.07	0.89±0.04	0.77±0.09

Figures followed by different letters are significantly different ($P<0.05$).

the 4 days prior to slaughter significant ($P<0.05$) increased excretion of Na and K was observed in animals given extra doses of these elements.

Saliva

In animals given daily doses of KCl, increased salivary K concentrations were observed compared to the NaCl and control groups (Table 3). Sodium concentrations were lower than in animals given Na, but were not significantly different from the control animals. The mean activity of ^{134}Cs was higher in saliva from KCl treated animals than from the two other groups.When calculated relative to the daily doses of ^{134}Cs, the activity of ^{134}Cs was higher in the K treated animals, but the observations were not significant, possibly due to large variations ($P>0.1$).

Discussion

As shown in the previous study on these animals the kidneys were the main pathway of excretion of the increased loads of the minerals as evidenced by increased urinary volumes and increased urinary concentrations and excretion of K and Na. In addition, the excretion of the two isotopes ^{134}Cs and ^{137}Cs increased. The total water flux in the control animals was about half that of the mineral treated animals (Birke *et al.*, 1995). In the present study concentrations of minerals and ^{134}Cs was not measured in the urine, but estimates based on data from the publication by Birke *et al.* (1995) indicate that the urinary excretion of ^{134}Cs was in the order of 12 and 16 % of total daily dose given to K and Na treated animals. This would amount to an urinary excretion of about 760 and 1290 Bq ^{134}Cs d^{-1} in K and Na treated animals and about 330 Bq d^{-1} in the control group. This is much less than the faecal excretion (Table 1). Contrary high intake of Na or K give a higher excretion rate in the urine than in faeces of these two minerals. High intake of K does also increase the Na excretion in the urine, whereas Na seems to have little effect on urinary excretion of K (Table 1).

Varying intake ratios of alkali elements may affect rumen functions including digestibility (Staaland *et al.*, 1986; Staaland & Garmo, 1987). Earlier studies have shown a rapid exchange of

Table 3. Concentrations of K, Na and ^{134}Cs (± S.D.) in reindeer saliva collected on three occasions during the last week before slaughter. Values are the means of the mean values for each animal in the different groups.

	Control (*n*=3)	Treatment KCl (*n*=3)	NaCl (*n*=3)
K (mmol l^{-1})	12±4a	48±29b	10±1a
Na (mmol l^{-1})	67±15a	53±15a	98±13b
^{134}Cs (Bq l^{-1})	1226±451	1949±1310	1575±237
^{134}Cs (Bq l^{-1}/dose d^{-1})*1000	185±67	303±176	197±24

Figures followed by different letters are significantly different ($P<0.05$).

alkali elements (Na, K, Cs) between the alimentary tract and body pools (Staaland et al., 1990), and that the concentration of one element can influence the transfer of other elements. In sheep, high concentrations of K in the rumen reduce the rate of Na absorption, whereas low concentrations of K increase the rate of Na absorption through the rumen wall (Warner & Stacy, 1972). In the present experiment the daily intake of K in the KCl treated animals was about twice the size of the alimentary K pool in the control animals and led to a large increase in the pool size. The increased intake of K, 350 mmol d^{-1}, corresponded to the amount of K which can be obtained from eating about 1 kg green vegetation (DM) in early summer, whereas the intake of Na from the same diet would be in the order of 10-20 mmol d^{-1} (Staaland & Sæbø, 1993). High intakes of K give reduced salivary secretion of Na and increased K secretion (Staaland & Garmo, 1987). High K concentrations in the alimentary tract lead to increased absorption of the element as evidenced by increased urinary excretion (Birke *et al.*, 1995). Although not measured directly, it appears likely that an increased absorption of K has induced an increased absorption of Cs, which could explain the reduced alimentary concentrations of ^{134}Cs in the animals in the present study given a forced intake of K. Since ^{134}Cs appears to be higher in the saliva of K treated animals (Table 3) it also appears likely that an increased salivary secretion of K increases salivary secretion of ^{134}Cs into the alimentary tract. Due to the errors involved and the small number of animals studied, further studies are required to establish the significance of this recycling of absorbed radiocaesium.

The increased intake of K increased both absorption and secretion of this element. Similar trends in the movement of ^{134}Cs suggest that the Cs ions to some extent follow K. To fully document the relationship between K and Cs transfer it would be of interest to measure the concentrations of non-radioactive Cs in the alimentary system. The quantities of non-radioactive Cs in the alimentary tract have not been measured in the reindeer. Measurement of the total concentrations of Cs would therefore be important to fully understand the metabolism of this element. However, the present interpretation of our results depends on the assumption that the ^{134}Cs isotope given experimentally will not interfere with the total concentrations of this ion or with the physiological mechanisms that govern the absorption and secretion of Cs. There is no clear evidence of any biological function of Cs (McDowell, 1992), and several publications have indicated that Cs follows K in physiological transport processes (Wasserman & Comar, 1961; Holleman & Luick, 1975; Birke *et al.*, 1995). Since the increased K intake resulted in increased absorption and secretion rates of K (Fig. 1), relatively more Cs could also have been transported. It is also possible that high Cs concentrations could have an effect on K metabolism.

The NaCl treated reindeer had an additional intake of Na which amounted to 1/3 of the alimentary Na pool. The relatively small increase in Na relative to total alimentary pool and also relative to the high salivary excretion of this element, is probably the reason why no significant effects on the alimentary pools of Na , K or ^{134}Cs were observed. The NaCl treated animals had the highest Na concentrations in saliva, but it appears that increased intake of Na had little effect on K and ^{134}Cs metabolism.

Increased intake of K and Na had little effect on the alimentary concentrations and pools of Ca, Mg and P. However, the increased urinary production (Birke *et al.*, 1995) and increased faecal volumes could result in increased loss of these elements also. It has been shown that high intake of K can reduce the absorption of Mg in domestic ruminants (Anonymous, 1988). High K concentrations in the rumen can also reduce the digestibility of organic material (Grings & Males, 1987) as also observed by *in sacco* studies with reindeer (Staaland & Garmo, 1987). In the present study, however, DM digestibility did not differ significantly between the 3 groups of animals.

In conclusion, high intakes of K or Na increased the faecal excretion of these two elements, but had limited effects on faecal excretion of ^{134}Cs, Ca, Mg and P. A high intake of K reduced the alimentary pools and concentrations of Na and ^{134}Cs. K treated animals had decreased Na concentrations and increased ^{134}Cs concentrations in saliva. Although an increased salivary secretion of ^{134}Cs would increase the input to the alimentary system, high K concentrations in the alimentary tract will apparently lead to increased absorption of both K and ^{134}Cs and therefore maintain comparatively low alimentary concentrations of ^{134}Cs. The level of K supplementation in the present study was in agreement with what could have been found in reindeer on summer pasture, and would indicate that a summer diet with high K content can have important effects on both Na and Cs metabolism of reindeer.

Acknowledgements

The study was supported by funding from "Reindriftens utviklingsfond", Norway.

References

Anonymous, 1988. *Mineral tolerance of domestic animals.* National Academy of Sciences. Washington, D.C. 577pp.

Birke, L.-C., Pedersen, Ø., Hove , K. & Staaland, H. 1995. Effect of sodium and potassium supplementation on accumulation and excretion of radiocaesium in reindeer. – *Rangifer* 15 (2): 71–77.

Church, D. C. 1979. *Digestive physiology and nutrition of ruminants.* Vol.2. O&B Books, Inc. Corvallis, Oregon, USA. 452pp.

Gaare, E. & Staaland, H. 1994. Pathways of fallout radiocaesium via reindeer to man. – *In:* Dahlgaard, H. (ed.). *Nordic radioecology. The transfer of radionuclides through Nordic ecosystems to man.* Elsevier. Amsterdam. pp. 303-334.

Garmo, T. H. 1986. Chemical composition and *in vitro* dry marrer digestibility of lichens. – *Rangifer* 6 (1): 8–13.

Grings, E. E. & Males, J. R. 1987. Effects of potassium on macromineral absorption in sheep fed wheat straw-based diets. –*J. Anim.Sci.* 1987: 872–879.

Holand, Ø. & Staaland, H. 1995. Mineral absorption and secretion patterns in the alimentary tract of the roe deer (*Capreolus capreolus*). – *Comp. Biochem. Physiol* 110A: 243–252.

Holleman, D. F. & Luick, J. R. 1975. Relationship between potassium intake and radiocaesium retention in the reindeer. – *In:* F. G. Howell, J. B. Gentry & M. H. Smith (eds.). *Mineral cycling in Southeastern Ecosystems.* ERDA Symp. Series. (CONF-740513). pp. 557–563.

McDowell, L. C. 1992. *Minerals in animal and human nutrition.* Academic Press, Inc. San Diego. 524 pp.

Pedersen, Ø., Hove, K. & Staaland, H. 1993. Seasonal variation and effective half life of ^{137}Cs in semi-domestic reindeer grazing mountain pasture contaminated by deposition from the Chernobyl accident. – *In:* P. Strand & E. Holm (eds.). *Environmental radioactivity in the Arctic and Antarctic.* Scientific committee of Environmental Radioactivity in the Arctic and Antarctic. Østerås, Norway. pp. 303-304.

Staaland, H., White, R. G., Luick J. R. & Holleman, D. F. 1980. Dietary influences on sodium and potassium metabolism in reindeer. – *Can. J. Zool.* 58: 1728–1734.

Staaland, H., Jacobsen, E. & White, R. G. 1984. The effect of mineral supplements on nutrient concentrations and pool sizes in the alimentary tract of reindeer fed lichens or concentrates during winrer. – *Can. J. Zool.* 62: 1232–1241.

Staaland, H., Hove, K. & White, R. G. 1986. Mineral absorprion in relarion to nutritional ecology of reindeer. – *Rangifer* Special Issue No. 1: 279–287.

Staaland, H. & Garmo, T. 1987. A note on the manipulation of sodium and potassium concentrations in the rumen of reindeer and the possible effect on digestibility. – *Rangifer* 7 (2): 33–36.

Staaland, H. & Sæbø, S. 1987. Seasonal variations in mineral status of reindeer calves from Elgaa reindeer herding district, Norway. – *Rangifer* 7 (1): 22–28.

Staaland, H., Hove, K. & Pedersen, Ø. 1990. Transport and recycling of radiocesium in the alimentary tract of reindeer. – *Rangifer* Special Issue No. 3: 63–72.

Staaland, H., Pehrson, Å., Jordan, P. & Palo, R. T. 1992. Seasonal variation of alimentary mineral and nitrogen pools in the moose. – *Comp. Biochem. Physiol.* 98A: 543–549.

Staaland, H. & Sæbø, S. 1993. Forage diversiry and nutrient supply of reindeer. – *Rangifer* 13 (3): 169–177.

Warner, A. C. I. & Stacy, B. D. 1972. Water, sodium and porassium movements across the rumen wall of sheep. – *Quart. J. Experimental Physiology.* 57: 103–119.

Wasserman, R. H. & Comar, C. L. 1961. The influence on dierary potassium on the retention of chronically ingested ^{137}Cs in rhe rat. – *Radiation Research* 15: 79–77.

White, R. G., Jacobsen, E. & Staaland, H. 1984. Secrerion and absorption of nutrients in the alimentary tract of reindeer fed lichens or concentrates during winrer. – *Can. J. Zool.* 62: 2364–2376.

Åhman, B. 1988. Intag och utsöndring av vatten hos renar vid utfodring med foder innehållande tillsatser av kalium eller bentonit. – *Rangifer* Special Issue No. 2: 44–55.

Åhman, B, & Åhman, G. 1994. Radiocaesium in Swedish reindeer after the Chernobyl fall-our: seasonal variations, transfer from fall-out and long-term changes. – *Health Physics* 66: 503–512.

Manuscript received 12 May, 1997
accepted 25 August, 1997