Body burden and distribution of ^{137}Cs in reindeer

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Abstract:
The whole body was collected from 6 reindeer that had been grazing contaminated pasture and from 6 reindeer that had been fed uncontaminated feed the last weeks before slaughter. The body was emptied from ingesta and weighed. Samples were taken from skeletal muscle, kidneys, heart, liver, lungs, rumen wall, bone and blood. The total activity of ^{137}Cs in the ingesta-free body and the acitivity concentration of ^{137}Cs in the different tissues were determined. The highest acitivity concentrations of ^{137}Cs were found in skeletal muscle and in kidneys. Activity concentrations in kidneys, heart, liver, lungs and rumen wall, relative to skeletal muscle, were lower in reindeer with decreasing radiocaesium levels, compared to reindeer with continuous intake of radiocaesium, indicating a more rapid elimination in these tissues than in muscle. The ratios between average activity concentration of ^{137}Cs in whole body and acitivity concentration in muscle from the same animal, ranged from 0.51 to 0.62. A factor of 0.57 is suggested for calclulating average body activity concentration of radiocaesium from known activity concentration in muscle.

Key words: *Rangifer tarandus*, radiocaesium, muscle, kidney, heart, lung, liver, rumen wall, bone, blood, whole body

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Introduction

Fallout of radiocaesium (^{134}Cs and ^{137}Cs) after the Chernobyl accident resulted in elevated levels of these nuclides in grazing animals in many parts of Europe (Howard *et al.*, 1991). It was well known, from investigations made after fallout from nuclear weapon tests during the sixties, that reindeer are particularly exposed to fallout radiocaesium, due to high intake of lichens during winter (Lidén & Gustafsson, 1967). Activity concentrations up to 80 kBq kg^{-1} in muscle of reindeer were found in the most contaminated areas of Sweden during the first winter after the Chernobyl fallout (Åhman & Åhman, 1994).

Several studies on uptake and elimination of radiocaesium in reindeer have been made, as parts of efforts to find appropriate countermeasures against contamination of food products (Åhman *et al.*, 1990; Hove & Hansen, 1992). When interpreting results from these types of investigations, information on the total body content (body burden), or the average body activity concentration, of radiocaesium in the studied animals may be valuable.

With advanced equipment, it is possible to make whole body measurement of radiocaesium activity in larger animals. In most studies of reindeer and farm animals, however, small portable gamma counters are used to monitor radiocaesium activity in the animal (Hove & Hansen, 1992; Åhman, submitted), or blood samples are taken for determination of activity concentration of radiocaesium (Åhman *et al.*, 1990; Hove & Hansen, 1992). From the obtained values the activity concentration of radiocaesium in skeletal muscle can be estimated.

The ratio between body burden, or average body activity concentration of radiocaesium, and activity concentration in muscle tissue or blood of reindeer is incompletely documented. Values on body burden of ^{137}Cs has been reported by Moiseyev *et al.* (1969) for one reindeer, and by Holleman *et al.* (1971) for four lichen-fed animals.

The relation between average body activity concentration of radiocaesium and muscle acitivity concentration may be affected by differences in distribution of radiocaesium within the body, depending on whether the animal is in a state of uptake or elimination of radiocaesium.

The aim of the present investigation was to relate the average body activity concentration and body burden of radiocaesium in reindeer to activity concentrations in muscle and some other tissues. Another aim was to compare this relationship in reindeer that were in radiocaesium balance, with that of reindeer with decreasing radiocaesium levels.

Material and methods

Material from 12 reindeer slaughtered on two occasions was used in this study.

Six free-ranging, grazing reindeer (one adult female, one two-year-old bull and four calves, about 10 months of age) were collected at an ordinary reindeer slaughter in March 1991. The animals were taken from an area in the central part of the reindeer management district of Sweden (64° N, 19° E). The deposition of ^{137}Cs within the area was 30–60 kBq m^{-2}.

Six male one-year-old reindeer were slaughtered in April 1992. The animals had been kept at the Swedish University of Agricultural Sciences in Uppsala since November 1991. They had been fed commercial reindeer feed (about 1 kg per day) and lichens contaminated with radiocaesium (5 kBq ^{137}Cs per day) as a part of an experiment described by Åhman (submitted). During the last three or four weeks prior to slaughter, the animals received no lichens and had no intake of radiocaesium. During this period, three of the reindeer were given feed containing 0.05 % of the caesium binder ammoniumferric(III)-cyano-ferrate(II) (AFCF), and one animal was given feed containing another caesium binder, bentonite (2.5 %). The other two reindeer received no caesium binder. Radiocaesium levels in the animals were measured once a week with a portable NaI detector. Based on these measurements, the half-life of radiocaesium for each animal was determined.

The animals were stunned with a bolt pistol and bled immediately. The blood was collected, weighed and mixed, and a sample (200 g) was taken for determination of ^{137}Cs activity. The hide was weighed and cut in smaller parts from which a sample (200 g) was taken. The intestinal tract was emptied of ingesta. Ingesta from the fed reindeer was weighed. Six muscle samples (from each rump steak, shoulder and front leg, respectively) were taken from the grazing animals. Three muscle samples were taken from the fed animals (rump steak, shoulder and a mixed sample from different parts of the carcass). The muscle samples (200 g) were prepared, as far as possible, free from sinews and visible fat. Heart, liver, kidneys, lungs and rumen wall were weighed and a sample (50–200 g) was taken from each of these tissues. The central 5 cm of tibia was sampled and carefully cleaned. The whole body, except from the parts that had been weighed and sampled separately, was weighed and ground in a large grinder. The ground material was carefully mixed and 3 samples (200 g) from each animal were taken for determination of ^{137}Cs.

Tissue samples were chopped or cut into small pieces. All samples were packed in standard plastic vials for determination of ^{137}Cs activity using HPGe-detectors (Ortec, PTG) connected to multichannel analysers.

The body burden and the average body acitivty concentration of ^{137}Cs (ingesta excluded) were determinated for each animal. The ratio between the activity concentrations of ^{137}Cs in heart, liver, kidneys, lung, rumen wall, bone and blood and the average acitivity concentration in muscle samples from the same animal were calculated. The ratio between average body activity concentration of ^{137}Cs and activity concentration in muscle (body to muscle ratio) were also calculated.

The differences between groups of animals were tested with Student's t-test, using JMP Statistical Visualisation software, version 2.0.5

Table 1. Whole body weight, ingesta-free body weight and carcass weight of reindeer grazing contaminated pasture and reindeer fed uncomtaminated feed, mean ± S.D. or values from two individuals.

		Grazing reindeer	Reindeer fed uncontaminated feed	
			no caesium binder	AFCF/bentonite
Number of animals				
	calves	4	2	4
	adults	2		
Whole body weight, kg		-	55, 45	54 ± 4
Ingesta-free body weight, kg				
	calves	26 ± 2	47, 38	44 ± 4
	adults	57, 73		
Carcass weight, kg				
	calves	15 ± 1	30, 24	28 ± 3
	adults	35, 42		

from SAS Institute Inc. The significance level was set to $P<0.01$.

Results

Body weight and weight of ingesta

Reindeer calves that had been fed and kept in captivity had considerably larger body mass (carcass weights from 23 to 31 kg) than grazing reindeer of the same age (14 to 16 kg carcass weight, Table 1). The weight of carcass in relation to ingesta-free weight was also significantly higher for the fed reindeer (63 ± 2 %) than for the grazing animals (59 ± 2 %). The carcasses of the grazing reindeer appeared to be lean. The carcasses of the fed reindeer weighed 52 ± 2 % of total body weight (ingesta included). Rumen

Table 2. Number of days with reduced or no intake of radiocaesium, biological half-life of radiocaesium during these days, total activity of ^{137}Cs in the ingesta-free body (body burden) and activity concentration of ^{137}Cs in the whole body and in muscle samples from reindeer grazing contaminated pasture and reindeer fed uncontaminated feed, mean ± S.D. or values from two individuals.

		Grazing reindeer	Reindeer fed uncontaminated feed	
			no caesium binder	AFCF/bentonite
Number of days with reduced or no intake of radiocaesium		0	23, 30	23, 30[a]
Half-life or radiocaesium, days		-	19, 31	15 ± 1
Body burden of ^{137}Cs, kBq				
	calves	390 ± 70	12, 24	14 ± 8
	adults	1400, 1500		
Average act. cone. of ^{137}Cs in the body, kBq kg^{-1}				
	calves	15 ± 2	0.25, 0.63	0.34 ± 0.22
	adults	25, 21		
Act. cone. of ^{137}Cs in muscle kBq kg^{-1}				
	calves	28 ± 2	0.43, 1.11	0.61 ± 0.42
	adults	47, 35		

[a] two animals 23 days and two animals 30 days.

content and total ingesta from these animals were 13 ± 12 % and 17 ± 2 % of total body weight, respectively.

Activity concentrations of ¹³⁷Cs in tissues and blood

The average activity concentrations of ^{137}Cs in skeletal muscle from the grazing reindeer was 32 ± 8 kBq kg^{-1} (Table 2). The activity concentration in muscle from the fed reindeer was 0.67 ± 0.40 kBq kg^{-1}. The coefficients of variation for muscle samples within animal ranged from 3 to 12 %. No significant differences were found between the different parts of the body from which muscle samples were taken.

The activity concentration of ^{137}Cs in kidneys from the grazing reindeer was 1.2 ± 0.2 times higher than in skeletal muscle (Figure 1). In the two fed reindeer that had not received any caesium binder, the kidney to muscle ratios were 1.0 and 1.1, respectively, while lower ratios (0.7 ± 0.1) were found in the four reindeer that had been given AFCF or bentonite.

In other examined tissues and in blood, activity concentrations were lower than in muscle (Figure 1). The lowest ratios were found for blood (0.10 ± 0.01) and bone (0.07 ± 0.01). No significant differences between the different groups of reindeer were found for blood to muscle or bone to muscle ratios. The acitivity concentrations measured in heart, liver, lungs and rumen wall in the group of grazing animals were about half of those in muscle (average ratios from 0.44 to 0.54). The ratios were lower in the animals that had been fed uncontaminated feed prior to slaughter and particularly low (from 0.19 to 0.32) in the four animals that had had received caesium binder.

Body burden of ¹³⁷Cs and average body activity concentration

Body burden of ^{137}Cs (Table 2) ranged from 330 to 1500 kBq in the grazing reindeer and from 7 to 24 kBq in the fed animals. The average body activity concentration of ^{137}Cs relative to muscle activity concentration, the body to muscle ratio, varied very much (from 0.51 to 0.62) in the group of grazing animals and the average ratio for this group was 0.55 ± 0.04 (Figure 1). Corresponding ratio in the group of fed reindeer was 0.57 ± 0.02.

The coefficients of variation between repeated samples, taken from the mixed body of each animal, were within the range 1 to 12 %.

Discussion

In this work two groups of reindeer with very divergent levels of radiocaesium are compared. The radiocaesium is, however, most probably in balance with stable caesium that naturally occurs in living organisms. Chemically, the radiocaesium represents an insignificant part of the total caesium and thus acts only as a tracer to stable caesium. It is therefore no reason to

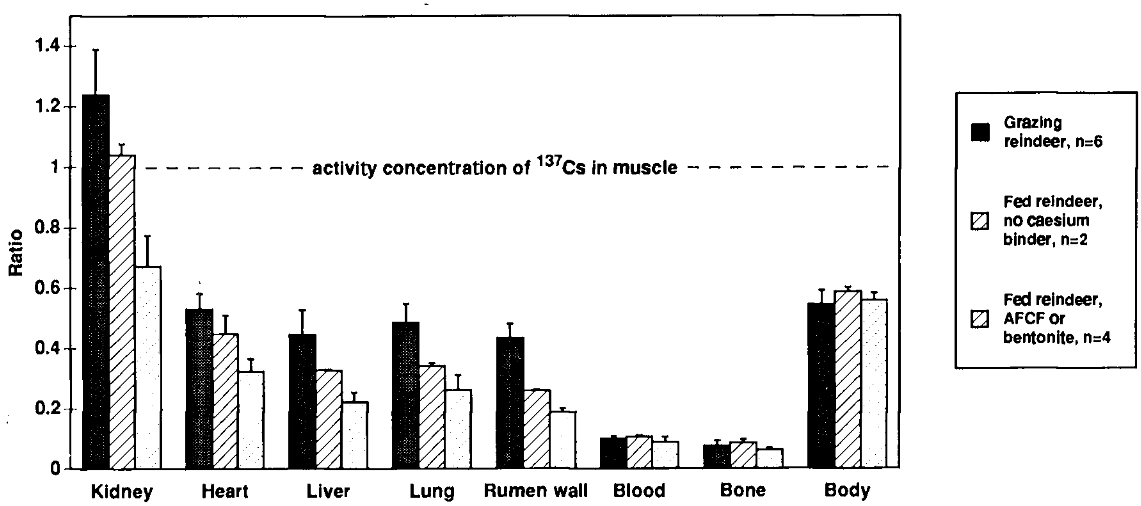

Figure 1. Activity concentration of ^{137}Cs in kidneys, heart, liver, lung, rumen wall, blood, bone and in ingesta-free body, relative to activity concentration of ^{137}Cs in muscle from the same animal, mean ± S.D. for three groups of reindeer.

believe that differences in radiocaesium distribution should occur because of generally different body contents of radiocaesium.

The high acitivity concentrations of ^{137}Cs in skeletal muscle compared to most other tissues, observed in the present work, are consistent with previous findings. It was stated already by Hamilton (1947) that, in rat, a major part of absorbed radiocaesium is located in the muscles. According to findings by Hollemann *et al.* (1971), about 80 % of the total amount of radiocaesium in the reindeer was located in skeletal muscle, after a period of continuous radiocaesium intake.

Differences in ^{137}Cs acitivity concentration between different muscles from the same animal are generally relatively small. Rissanen *et al.* (1990) found differences smaller than 10 % between skeletal muscle samples from different parts of the body of reindeer. In the present work, the variations within animal were small and the muscle samples taken from each animal, therefore, are believed to provide fairly good estimates of average muscle acitivity concentration for the single reindeer.

The kidney to muscle ratio (around 1.2), observed for grazing reindeer in the present work, was somewhat lower than corresponding ratio, around 1.5, found previously in reindeer taken from contaminated pasture (Rissanen *et al.* 1990). Andersson & Hansson (1989) found levels of ^{137}Cs in lambs, after continuos intake, giving a kidney to muscle ratio of 1.14. These authors also observed lower relative activity concentrations of ^{137}Cs in the kidneys (corresponding to a kidney to muscle ratio of 0.85), as an effect of treatment with bentonite. The effect of caesium binder can be explained by a higher fraction of radiocaesium being excreted with faeces, and thus a lower fraction with urine, in animals that are given caesium binder.

Lower activity concentrations of ^{137}Cs in kidneys, heart, liver, lung and rumen wall relative to skeletal muscle (Figure 1) in reindeer with no radiocaesium intake (and especially in those that had been fed caesium binder) compared to reindeer with continuous intake of radiocaesium (grazing animals) indicate a faster elimination of radiocaesium in these tissues than in muscle. Earlier findings in reindeer (Ekman and Greitz, 1967) support the assumption that accumulation and elimination of caesium is more rapid in kidneys, heart, liver and lungs than in skeletal muscle.

The bone to muscle ratio, around 0.07, that was observed in the present work (Figure 1), might not be typical for bone in general, since only one sample of bone (tibia) was taken from each animal.

The blood to muscle ratio around 0.10, as observed in the present work (Figure 1), is on the same level as those reported for reindeer by Åhman (1986a) and Rissanen *et al.* (1990). A higher ratio, 0.15, has been reported for lichen fed reindeer (Åhman, 1986b). These reindeer had, however, eaten contaminated food for only three weeks and had probably not reached stable radiocaesium levels in muscle.

In the present work, body burden has been defined for the ingesta-free body. In studies of a contaminant the interesting part is most often the fraction that has actually been absorbed into the body. Furthermore, the ingesta may vary considerably, in both amount and radiocaeasium content, depending on occasional variations in food composition and total intake. Around 17 % ingesta in the whole body, as observed in the fed animals of the present work, is in accordance with previous findings in reindeer (Åhman & Åhman, 1980) and is probably a good estimate for most reindeer with normal food intake.

The average body activity concentration of radiocaesium, in relation to activity concentration in muscle, is doubtless much affected by the relative amounts of bone, fat and muscle in the animal. Fat content and muscle mass in reindeer may vary considerably over the year (Huot, 1989; Rydberg, 1990; Rydberg, 1991). Bone and fat retain little caesium compared to muscle. Low body to muscle ratios are therefore expected to be found in reindeer that have endured generally poor grazing conditions or that have been eating predominantly lichens, which are very low in nitrogen content (Staaland & Sæbø, 1993). This may explain the low ratios, down to 0.51, that were found in some of the grazing reindeer in this work. Similar ratios, 0.51–0.53, can be calculated for reindeer that had been fed only lichens for over five weeks (Holleman *et al.*, 1971). Low body to muscle ratios may also be expected in very fat animals. There is, however, no documentation on reindeer to confirm this.

For reindeer in good nutritional condition, the ratio 0.57, that was observed in the group of fed reindeer, could be used to estimated average body activity concentration of radiocaesium from known activity concentration in muscle.

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