EXTRACTION OF RADIOCESIUM FROM REINDEER MEAT

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INTRODUCTION

The Chernobyl nuclear reactor accident in 1986 has renewed the interest for methods of foodstuff decontamination. Unfortunately, as in the sixties in connection with the fallout from nuclear weapons tests work on such methods is mostly of a pilot character with only single observations and often published in limited spread languages.

Radiocesium is very loosely bound in mammalian muscle tissue (Szentkuki & Giese, 1974). Thus, radiocesium in meat can in practice be completely removed by extraction in aqueous media (Gernon & Bell, 1964; Kreuzer et al., 1970). In accordance with this, various curing and marinating procedures give substantial reduction in radiocesium (Hecht, 1987; Wagner, 1988). Some authors claim that addition of salts would facilitate the extractability of radiocesium (Wahl & Kallee, 1986). We here studied the effect of sodium chloride and potassium chloride on the aqueous extraction of radiocesium from reindeer meat. We also investigated the reduction of radiocesium in reindeer meat in various process steps of four traditional Norwegian curing procedures.

MATERIALS AND METHODS

Meat. Carcasses of domesticated Norwegian reindeer were obtained at the regular slaughter in the autumn 1986 from the Røros area, Sør-Trøndelag county, Norway, a district which received substantial amounts of radioactive fallout from the Chernobyl accident. The mean slaughter weight was 24.2 kg (range 16.1-35.1) and the mean content of radiocesium (cesium-134 + cesium-137) was 22.5 kBq/kg meat (range 10.0-38.2). Frozen carcasses were divided into legs, shoulders, ribs, etc., packed in shrinking plastic film and stored at -30°C until use.

Incubation experiments. The meat of one carcass (10.0 kBq/kg) was thawed, deboned, trimmed for visible fat and connective tissue and cut into approximately 0.5-1 cm pieces in a meat-mincer. Portions (250 g) of thoroughly mixed pieces were incubated in glass beakers during slow shaking for 120 min with 187.5 ml (=meat water content) of deionized and distilled water, or solutions of 0.9 %(W/W) NaCl, 1.15 %(W/W) KCl and 9.0%(W/W) NaCl, respectively. The salts were of analytical grade and the complete procedure was performed at +4°C. The liquid phase was separated by filtering the incubate through a piece of cotton cloth ("cheese cloth").

Cured products. The meat cuts were thawed at +3°C for 2-4 days prior to curing. The salts used were of food grade and the water was ordinary tap water.

Bone-in legs (left side) of mean weight 3.7 kg (range 2.9-5.2) were dry-cured in NaCl (25% by weight) for 24 days at +4°C.

Bone-in legs (right side) from the same carcasses were cured in 5 parts by weight of brine (25 %(W/W) NaCl) for 24 days at +4°C.

Deboned shoulders (left side) of mean weight 1.2 kg (range 0.9-1.7) were immersed in 25 %(W/W) NaCl (5 parts by weight) for 4 days at +4°C and watered down in 5 parts of water for 4h at +4°C. Finally the shoulders were put in nets, smoked for one day and dried for 13 days at +18°C and 75% relative humidity.

Deboned shoulders (right side) from the same animals were treated similarly except that the brine contained 19%(W/W) NaCl and 6%(W/W) KCl.

Ribs (both sides, including loin) with a mean weight of 1.1 kg (range

0.6-1.8) were cured in 5 parts by weight of 25%(W/W) NaCl for 48h at +4°C, watered down in 5 parts of water for 2h at +4°C, smoked for one day and dried for 9 days at +18°C and 75% relative humidity. The ribs were watered down as before and steam-boiled on grates for 3h using 1.5 kg of water per rib.

Radioactivity measurements. Samples were measured for gamma-activity of radiocesium (cesium-134 + cesium-137) with a Bequerel Monitor LB200 (Bertold, Wildbad, GFR) or a Scorpio 2000 mulichannel analyzer (Canberra Industries, Inc., U.S.A.).

RESULTS AND DISCUSSION

Effect of salts on the extraction of radiocesium from reindeer meat

In preliminary incubation experiments with reindeer meat the activity concentration of radiocesium increased rapidly to a constant value after about 80 min in all the aqueous media tested (Berg et al., 1988). The activity concentrations at 120 min showed no differences between four different fluids (Table 1). Thus, isotonic solutions of NaCl and KCl or a solution of 9% NaCl had the same capability as water to extract radiocesium from meat. This indicates that diffusion is more important than ion exchange for the mobility of radiocesium in raw meat. The results confirm the concept that radiocesium in meat is mainly in a water soluble, unbound form (Gernon & Bell, 1964; Szentkuti & Giese, 1974). The somewhat higher extraction of radiocesium in acid marinades (Hecht, 1987) can be explained by Donnan equilibrium (Heien, 1988).

Reduction of radiocesium in traditional curing procedures

The content of radiocesium in reindeer meat was reduced to various degrees in four Norwegian cured meat products (Table 2). Dry curing gave the smallest reduction, only about 30%. This corroborated with the amount of radiocesium assumed to be present in the losses of meat fluid. Brine-curing combined with several dewatering steps (as with ribs) gave the highest reduction of radiocesium, up to about 85%. However, a much higher reduction would be possible if the treatment times in the various steps were long enough: the partition of radiocesium between the water phase of the meat and the process liquids was far from concentration equilibrium in the present procedures (Table 2, last two coloumns). As in the incubation experiment substitution of Na+ for K+ did not significantly influence the extent of radiocesium reduction (Table 2, lines 3-4).

The main part of the cured products investigated are in Norway made from lamb. The 1987 consumption of mutton and lamb was 5.7 kg per capita or 11% of the total meat consumption (Statens ernæringsråd, 1988). Only a small part of the meat consumption is reindeer meat but the action level for radiocesium is higher than for sheep meat (6000 vs. 600 Bq/kg). Therefore, certain groups of the population, especially among the Sami people, which consume large quantities, receive up to 90% of their total intake of radiocesium from reindeer meat after the Chernobyl fallout (Statens næringsmiddeltilsyn, 1988). In situations where preslaughter measures to reduce the transfer of radioactivity to humans are not sufficient the production of the present cured products could be increased severalfold. However, a too high intake of salt is not desirable and the curing procedures, in addition to extract radiocesium, also remove water-soluble nutrients. Experiments are now under way to select specific binders which preferentially remove radiocesium and which are compatible with foodstuffs.

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TABLE 1 Effect of salts on the extraction of radiocesium from reindeer meat

Incubation liquid	Radiocesium in incubation liquid after incubation (kBq/kg, mean ± SD, n=5)*
H_2O	5.50 ± 0.02
0.9 % NaCl	5.53 ± 0.08
1.15 % KCl	5.60 ± 0.06
9 % NaCl	5.42 ± 0.17

*) Differences between means are not significant (P>0.05, analysis of variance).

TABLE 2 Distribution of radiocesium in process steps of curing methods

Procedure	(n)	Radiocesium activity in per cent of original activity in meat excluding bones (mean ± SD)				
		Brine	Water	Water (100°C)	Product	(A)
Legs (dry curing)	(10)	-	-	-	69.4 ± 2.0	(67.5[B])
Legs (brining)	(6)	66.8 ± 4.5	-	-	33.2 ± 4.5	(12.7)
Shoulders (NaCl)	(5)	64.0 ± 1.4	4.2 ± 0.4	-	31.8 ± 1.7	(2.3)
Shoulders (NaCl + KCl)	(5)	69.0 ± 3.3	3.5 ± 0.8	-	27.5 ± 3.2[C]	(2.3)
Ribs	(5)	64.0 ± 4.2	13.8 ± 1.2	8.8 ± 0.8	13.4 ± 3.1	(0.1)

[A] Theoretical minimum residual radiocesium in product if diffusion equilibrium between meat and the processing liquids had been reached.
[B] Calculated for assumed radiocesium equilibrium between the meat water inside and outside the product.
[C] Not significantly different from shoulders (NaCl) ($P>0.05$, analysis of variance).