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Note

Distribution of Radioactive Cesium in Ostrich (*Struthio camelus*) after the Fukushima Daiichi Nuclear Power Plant Accident

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Enormous amounts of radioactive substances were released into the environment by the Fukushima Daiichi Nuclear Power Plant (FNPP) accident. Radioactive contamination was widely observed and food inspection of radioactivity becomes indispensable. In this paper, we examined radioactive contamination in ostriches (Struthio camelus) after the FNPP accident. Cesium-137 (^{137}Cs, half-life: 30.07 y) and ^{134}Cs (half-life: 2.065 y) were observed in the skeletal muscles of the ostriches located in Kanto region (^{137}Cs: 19.2 ± 11.7, ^{134}Cs: 18.3 ± 11.3 Bq/kg in the muscles, 150 km from FNPP), while no contamination was observed in those located in Tokai region (450 km from FNPP), Tohoku region (180 km from FNPP), and Hokuriku region (140 km from FNPP). We confirmed that detectable radioactive cesium was not found in the liver before the FNPP accident (obtained 2010 November, in Kanto region). Other radioactive nuclides such as ^{129m}Te and ^{110m}Ag were not detected in all samples examined. It was considered that the radioactive materials transported in March 2011 were major contributors to the low level contaminations in ostriches located in Kanto region.

Key words: Fukushima Daiichi Nuclear Power Plants; Ostrich (*Struthio camelus*); radioactive Cesium

1. Introduction

Large amounts of radioactive nuclides such as ^{129m}Te, ^{132}Te/I, ^{131}I, ^{133}I, ^{134}Cs, and ^{137}Cs were released from the damaged reactors to the atmosphere after the accident of the Fukushima Daiichi Nuclear Power Plant (FNPP) on March 11, 2011 [1, 2, 3]. The Nuclear Safety Commission of Japan preliminarily estimated the amount of radioactive materials released in the atmosphere to be 1.5 X 10^{17} Bq of ^{131}I and 1.2 X10^{16} Bq of ^{137}Cs [4, 5]. After FNPP accident, radioactive contamination was detected at the first stage in water, vegetables, fruits, and milk and then tea leaves in May, beef in July and rice in September,

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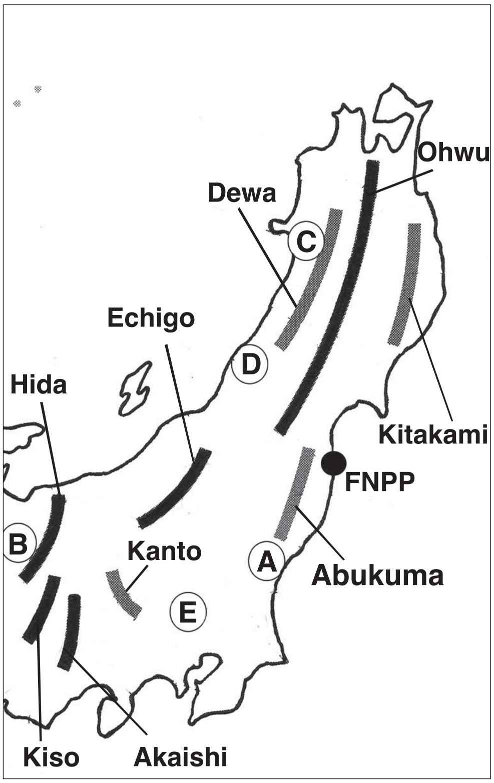

Fig. 1. Sampling areas (A, B, C, D, E) of ostriches and mountain range (black bar), intermountain area and high altitude (gray bar).

particularly in the Kanto and Tohoku regions[6]. The evacuation zone has been set within a 20-km radius surrounding the FNPP, and approximately 3,400 cows, 30,600 pigs, and 630,000 chickens were left behind in this area. Under the new standard that revised the maximum permissible dose to be 1 mSv/year from 5 mSv/year for foods, the upper limit of radiocesium in general food was set at 100 Bq/kg [6]. We detected the radioactive cesium (Cs) which exceeded the standard limit (100 Bq/kg) in skeletal muscles of cattle in the area[7]. There has been no information of the distribution of radioactive Cs and the other radioactive nuclides in ostriches.

Ostrich meat is known as a healthy alternative to other meat products because it is low in fat and cholesterol and 10,000 ostriches (from 2001 to 2004) are fed from Okinawa to Hokkaido (www.nohken.or.jp/dachoumanual1.pdf, The Nippon Agricultural Research Institute). However, the number of ostriches decreased to 3000-3500 (personal communication from Japan Ostrich Industry Network), after the south-African farm style changed to the Japanese original one. The FNPP accident also damaged on them, resulting in further decrease in the number. Commercial farming for feathers (1.4–1.8 kg), skins (1.1–1.3 m^2) and meat (34–41 kg) per an ostrich became widespread from the 1995. Ostrich has found a place on the world's menu and ostrich is poised to become "the premier red meat of the next century"(Amrican Ostrich Association. http://www.ostriches.org/meat.html). Thus, ostrich meat (including liver) is important in the new Japanese meat market.

In this report, we examined contamination levels of radioactive cesium, especially ^{134}Cs and ^{137}Cs, in ostriches located in 4 areas in Japan.

2. Materials and Methods

Collection of samples

Sampling areas from A to E were shown in Fig.1 with mountain range, intermountain area and high altitude. We collected skeletal muscles (pelvic limb: PL and pectorali major: PM) and blood from ostriches. They were collected in batches of 5 from A in Kanto region (2011, December and 2012 January, 150 km from FNPP) and 5 from B in Tokai region (2012 February, 450 km from FNPP), respectively. Skeletal muscles (PL and PM), liver and blood were also obtained from C in Tohoku region (3 ostrich, 180 km from FNPP, 2012 May) and D in Hokuriku region (2 ostriches, 140 km from FNPP, 2012 May). One liver sample (before FNPP accident, collected in November 2010, E in Kanto region, 270 km from FNPP) was kindly provided by an ostrich farm, and it should be a background sample before the accident.

Individual farm management focuses on radioactive-free feeding (transport-mixed food including seeds), shrubs, housing facilities, ventilation systems, temperature and other environmental controls. The ostriches were reared on the arms and then sent to the slaughterhouse for ostrich meat. The fresh meat and liver was treated in the slaughterhouse, packed immediately, and frozen at -20℃. The blood was taken from the carotid arteries, put into plastic tubes and frozen at -20℃. The samples were homogenized, put into U8 tube and measured the radioactivity.

Measurements of radioactivity

Radioactivity of the samples was determined by gamma-ray spectrometry using three HPGe detectors (Ortec Co., USA), as previously described[7]. A nuclide was identified when its characteristic photopeaks greater than 3 σ above the baseline were observed in the spectrum. Based on the count rate from each sample, the concentration of the radionuclides was calculated (Bq/kg sample). Efficiency curves for the detectors were obtained by using standard gel sources containing known amount of ^{152}Eu and ^{137}Cs[7]. Time for the measurements ranged from 10,000 to 100,000 s. The measurements were carried out from January to March, 2012. All data were shown at decay-corrected to the day of major release, March 15, 2011. Briefly, the activity after decay correction, X_0, is given by

Table 1. Distribution of radioactive cesium and ^{40}K

Area (No.of sample)	Samples	Date obtained	Radioactive Cs (Bq/kg)			^{40}K (Bq/kg)
			^{137}Cs	^{134}Cs	Radioactive Cs total	
A	PM	2011.Dec	23 ± 2	25 ± 2	48	70 ± 14
No.1	PL	2011.Dec	24 ± 2	22 ± 3	26	52 ± 19
A	PM	2011.Dec	41 ± 3	37 ± 3	76	87 ± 21
No.2	PL	2011.Dec	32 ± 2	32 ± 3	64	76 ± 19
A	PM	2012.Jan	12 ± 1	8 ± 1	20	77 ± 13
No.3	PL	2012.Jan	7 ± 1	7 ± 1	14	85 ± 13
A	PM	2012.Jan	12 ± 1	15 ± 1	27	82 ± 12
No.4						
A	PM	2012.Jan	15 ± 2	13 ± 2	27	94 ± 22
No.5	PL	2012.Jan	7 ± 1	6 ± 2	13	55 ± 20
	PM & PL	2012. Feb~April	ND	ND	ND	59 ± 13 ~104 ± 13

a. Data were expressed as concentration ± statistical error (1σ)
b. ND: not detected (ND level means 3σ, 0.6-1.4 for ^{137}Cs and 1.0-1.7 for ^{134}Cs)

$$X_0 = X \times 2^{t/T} \qquad (1)$$

where X is the activity at t (elapsed time (days) after March 15, 2011), T is half-life : 754 d for ^{134}Cs, 11,016 d for ^{137}Cs.

Statistics

The difference between the radioactive Cs level of two groups was found to be significant in case $P < 0.05$ with unpaired *t*-test (Microsoft Excel statistics 2012).

3. Results

Cesium-137 (^{137}Cs, half-life: 30.07 y) and ^{134}Cs (half-life: 2.065 y) were observed in the skeletal muscles (PL and PM) of the ostriches located in A, while none was observed for the samples from the areas located in B, C and D (Table 1). In A, the levels of ^{137}Cs and ^{134} Cs ranged from 7 to 41 (mean ± SD: 19.2 ± 11.7) and from 6 to 37 (18.3 ± 11.3) Bq/kg, respectively. There were significant differences in levels of ^{137}Cs and ^{134}Cs between A and B ($P < 0.01$). In contrast, radioactivity of ^{40}K shows roughly constant. The mean level of ^{40}K was 75.3 ± 14.2 Bq/kg in A and 76.3 ± 17.1 Bq/kg in B, respectively. There were no significant differences of ^{40}K concentration between A and B. Radioactive Cs was not detected in the liver of ostriches from C and D. The nuclides could be hardly detected in all the blood samples with the determination limit of ^{137}Cs around 1 Bq/kg. As for the background liver sample from the E area (before the FNPP accident), no photo-peaks from radioactive cesium was found in the gamma-ray spectrum.

Other radionuclides, such as ^{129m}Te and ^{110m}Ag, were not detected in all samples examined, although those nuclides were often observed in the organs of cattle[6] after the FNPP accident.

4. Discussion

From the view point of food safety[6], we examined the contamination of radioactive cesium in the muscles of ostriches. Radioactive cesium was detected in the muscles of all ostriches only from the A area. The levels of total radioactive Cs ranged from 20 to 76 in PM and 13 to 64 Bq/kg in PL, respectively. There were significant differences of mean level of radioactive Cs between skeletal muscles in 4 ostriches. The PM values seem to be slightly higher than the PL. The reason why the PM values showed higher than the PL is not clear, but may be explained by the age, metabolism. It has been reported that unequal distribution of Cs in the muscle of goat after 30 min intravenous administration[8]. In contrast, equal distribution has been reported in Japanese Black beef heifer after FNPP accident[9]. It might be important to know how to get contaminated Cs in livestock.

The activity concentration ratios of meat to feed were reported for various fatting periods, with mean values of about 0.3 (leg), 0.4 (breast), and 0.2 (liver) in chicken after Chernobyl accident[10]. Mitorovic *el al.* reported that ^{137}Cs was accumulated in breast meat, liver and gizzard [11]. Our previous study showed that radioactive Cs was distributed in the several organs of cattle, especially in muscle tissues with the highest deposition[7]. Commonly, skeletal muscles among the other tissues of vertebrate accumulate effectively radioactive Cs. It is true for the present case of ostriches.

It may be strange that all ostriches (from A) were slightly contaminated by radioactive Cs although they did not receive contaminated foods from the farmers. Ostriches occasionally eat soils and insects. After 4 months-old, ostriches were out of house for their management. It is plausible that they might eat soils or insects contaminated with radioactive Cs. Radioactive Cs was mainly spread in areas of eastern and northeastern

Japan on a large scale, whereas the western part of Japan sheltered by mountain ranges had no detectable levels of contamination[12]. We speculate that the concentration of radioactive Cs in soils is quite low in other areas (B,C, and D), because those regions may be far enough from the FNPP and partly blocked from the contamination by mountains (Fig.1).

The Japanese standard limit for radioactive Cs in general foods is 100 Bq/kg[6]. We did not observe the samples beyond the limit. Thus, ostrich meat found in Japanese markets could be safe for human consumption.

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