

An Autoradiogram of Skeletal Muscle from a Pig Raised on a Farm within 20 km of the Fukushima Daiichi Nuclear Power Plant

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ABSTRACT. We utilized autoradiography to visualize radioactive contamination in the skeletal muscles of a pig raised within 20 km of the Fukushima Daiichi nuclear power plant following the nuclear accident. The autoradiogram of control muscle showed relatively homogenous exposure. In contrast, the autoradiogram of affected muscle showed a heterogeneous and sporadically dense imaging pattern. Photo luminescence densities of the affected and control muscles were 3.89 ± 0.67 and 2.13 ± 0.43 PSL/mm², respectively. This difference indicated that radioactive cesium was distributed in the skeletal muscle of the affected pig.

KEY WORDS: autoradiography, cesium, potassium, radioactive contamination.

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Radioactive fallout from the Fukushima Daiichi nuclear power plant contaminated areas within 20 km of the plant with high radioactive levels. As a result, livestock raised in the exposed area were contaminated by radionuclide [5]. Beef with radioactive cesium was widely distributed all over Japan in July 2011 (www.mhlw.go.jp/stf/houdou/2r985200001jc5x.html). Similar to potassium ions, cesium ions distribute in skeletal muscle [2–4]. Radioactive potassium denoted as ⁴⁰K, constitutes 0.0119% of naturally occurring potassium; therefore, the biodistribution of potassium ions can be visualized using autoradiography (ARG) for ⁴⁰K [3]. Therefore, the biodistribution of radioactive cesium can also be detected by comparing autoradiograms between affected and control animals.

The present study focused on a mixed-breed male pig that was born and raised on a farm within 20 km of the Fukushima Daiichi nuclear power plant. The pig was moved to an uncontaminated area 17 days after the accident (March 29, 2011), and it was slaughtered 41 days later (May 10, 2011). Another male pig was raised in an uncontaminated area and slaughtered on the same day as a control. Skeletal muscle (ham, 100 g) from each pig was sampled in a polystyrene container for radionuclide detection. Each sample was measured with a germanium (Ge) semiconductor detector (GMX-10180; Ortec, Oak Ridge, TN, U.S.A.) for 12 hr. The detection limits for ⁴⁰K (1.461 MeV), ¹³⁴Cs (0.605 MeV) and ¹³⁷Cs (0.662 MeV) were 0.468, 0.055 and 0.063 Bq/100 g, respectively. The muscle of the affected pig was

measured with ⁴⁰K, ¹³⁴Cs and ¹³⁷Cs at levels of 110.3, 48.2 and 67.9 Bq/kg, respectively (measured on the day of ARG exposure). This pig had been fed complete imported feed before movement, so the internal contamination might be led by intake of contaminated water or inhalation of contaminated air. The control pig contained only ⁴⁰K, which was detected at a level of 123.2 Bq/kg. Our findings indicate that the ⁴⁰K radioactive level was higher than ¹³⁴Cs and ¹³⁷Cs levels.

Potassium is naturally present in ham levels 350 mg/100 g (http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu3/toushin/05031802.htm). Therefore, 1 kg ham contains 3.5 g potassium, including 0.42 mg of radioisotope ⁴⁰K naturally, which is equivalent to approximately 100 Bq of ⁴⁰K. Therefore, the ⁴⁰K level detected in the affected and control muscles in this study was almost the same as the theoretical value. Our findings indicated that radioactive levels in the contaminated muscle were around 2-fold higher than those in the control muscle. In general, vegetables are naturally abundant in potassium. For example, spinach contains 690 mg/100 g of potassium (http://www.mext.go.jp/b_menu/shingi/gijyutu/gijyutu3/toushin/05031802.htm) naturally, which is equivalent to approximately 200 Bq of ⁴⁰K. The natural concentration of ⁴⁰K in spinach is almost twice that in ham. Therefore, the contaminated ham contains almost the same amount of radioactivity per unit weight as natural spinach.

ARG was performed using an imaging plate (SR; Fujifilm, Tokyo, Japan) and the BAS-5000 imaging system (Fujifilm). Freeze-dried sections of 5-mm thickness were covered with plastic wrap and exposed on the imaging plate for 31 days. The resolution of the imaging plate was 25 μm. The photo stimulated luminescence density (PSL/mm²) was measured for regions of interest marked on each sample. Statistical analysis was performed using the Student's *t*-test, and a

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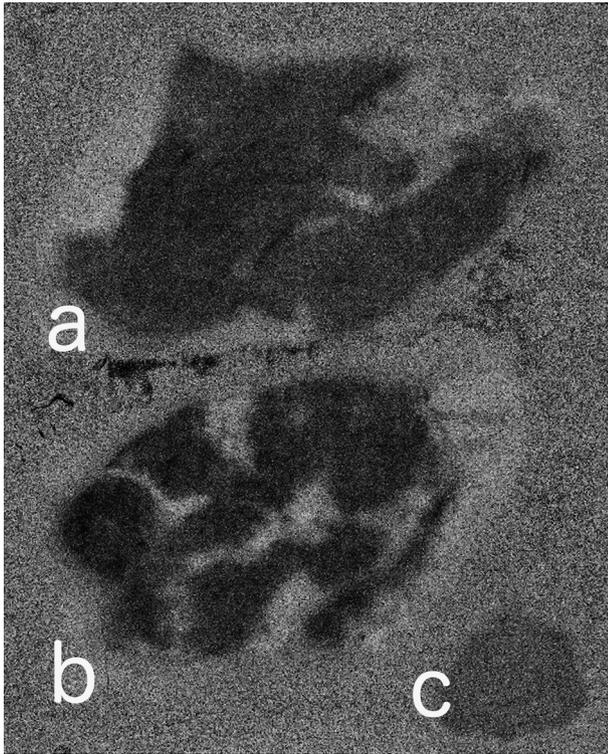


Fig. 1. Autoradiogram of control (a) and the sampled (b) skeletal muscle of pig and positive control (c) ginger exposed for 31 days.

P -value of <0.01 was considered statistically significant. Autoradiograms showed the density of the skeletal muscle but not fat (Fig. 1), which was visualized using β -rays of ^{40}K (1.33 MeV, 89.3%), ^{134}Cs (0.658 MeV, 70.2%; 0.415 MeV, 2.5%; 0.089 MeV, 27.3%) and ^{137}Cs (0.512 MeV, 94.6%; 1.174 MeV, 5.4%) [1]. However, autoradiogram of muscle from the control pig showed a relatively homogenous expo-

sure, whereas that of muscle from the affected pig showed a heterogeneous and sporadically dense imaging pattern. The relatively homogeneous image of the control muscle was probably due to the uniform distribution of ^{40}K [3]. Photo luminescence densities on the autoradiograms, which represented the radioactivity in the affected and control muscle samples, were 3.89 ± 0.67 and 2.13 ± 0.43 PSL/mm², respectively, which was statistically significant. Contaminated hams are exposed to approximately 2 times the radiation that individuals who eat uncontaminated hams are exposed to. The different imaging patterns between the affected pig and the control pig indicated that radioactive cesium was distributed in the skeletal muscle of the contaminated pig.

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