Efficiency of Excess Monitoring for Beef after the Fukushima Accident

Tsutomu Shimura\textsuperscript{a}, Ichiro Yamaguchi\textsuperscript{a}, Hiroshi Terada\textsuperscript{a}, Toshihiko Yunokawa\textsuperscript{a}, Erik Robert Svendsen\textsuperscript{b}, Naoki Kunugita\textsuperscript{a}\textsuperscript{*}

\textsuperscript{a}Department of Environmental Health, National Institute of Public Health, Minami, Wako, Saitama, Japan
\textsuperscript{b}Department of Public Health Sciences, Critical Care, and Sleep Medicine, Medical University of South Carolina, Charleston, SC, USA

Herein we analyzed food monitoring data regarding the Fukushima accident. The Japanese government ordered local governments to implement food monitoring after the Fukushima nuclear accident. This protective action for food safety contributed to the reduction of internal radiation exposure derived from the Fukushima accident. According to the food monitoring data collected from March 2011 to March 2015, more than 70% of the samples were beef. One hundred fifty-four samples from a total of 776,310 beef samples that were above provisional regulation values or new standard limits were restricted from market distribution. Most of the beef samples were below the detection limits by regulation of consumption of contaminated rice straw. Two hundred forty one from a total of 251,510 beef samples were above the detection limit during fiscal year 2014. The mean committed effective dose due to annual beef consumption was estimated to be 1 µSv. The 99.9 percentile committed effective dose was 20 µSv. Thus, internal exposure due to beef consumption is limited. However, local governments continue regular monitoring for beef in response to social concerns. It should be noted that continuous staff effort and high costs are required to maintain this food surveillance program. A formal evaluation may help to assist in the development of a more effective and efficient food monitoring system.

Key words: Food safety, Fukushima, Nuclear disaster, Food monitoring, Radiation exposure, Beef

1. Introduction

The incidence of thyroid cancer increased about five years after the Chernobyl nuclear crisis among public people who consumed $^{131}$I-contaminated milk during childhood\textsuperscript{1,2}. From this lesson learned, the Japanese government prepared a food safety manual for the measurement and protection of foods from radiation contamination, along with Indices for Food and Beverage Intake Restriction before the Fukushima accident related the Great East Japan Earthquake and Tsunami occurred on March 11, 2011\textsuperscript{3}. Thus, food safety was one of the top priorities for governmental action to protect the public from radiation exposure after the nuclear disaster. Immediately after the accident, Ministry of Health, Welfare and Labour (MHWL) adopted Indices for Food and Beverage Intake Restriction posted by the Nuclear Safety Commission (NSC) of Japan as provisional regulation values (PRVs) during radiological emergency situations, (until March 2012). For the long-term recovery phase, new standard limits were enacted on April 1, 2012. The basic concept of the PRV and new standard limits for food control in the Fukushima accident were described in our previous paper\textsuperscript{4}. The PRV was based on protective action guides (PAGs) of a 50 mSv/year of thyroid equivalent dose for radioactive iodine.
and tellurium and 5 mSv/year for the effective dose by radioactive cesium and strontium. The new standard limits for radioactive cesium were established with the goal that the effective dose of radionuclides would not exceed 1 mSv/year in affected populations. The food samples which exceeded the PRV or new standard limits were restricted from market distribution. Herein we analyzed food monitoring data regarding the Fukushima accident. Evaluation of food monitoring data is helpful to improve the monitoring systems and to offer important lessons learned for disaster preparedness.

2. Materials and Methods

2-1. Food Monitoring

Local governments implemented food monitoring using NaI- and CsI-scintillation detectors or Ge gamma-ray detector. There were difficulties in beef monitoring with Ge gamma-ray detectors because the limited number of available Ge gamma-ray detectors. In July 2011, MHLW instructed the simple-survey method with either NaI- or CsI-scintillation detectors for rapid surveillance to allow to test all beef, as precisely described. In this instruction, radioactive cesium contamination below 250 Bq/kg is not necessary further detailed examination. Thus, all cattle were eligible for testing. The MHLW compiled the results of radioactive materials testing for foods as the prefecture units. Food monitoring data are available on the MHLW’s websites (http://www.mhlw.go.jp/stf/kinkyu/0000045250.html). The data set from March 2011 to March 2015 was used to calculate percentage of samples exceeding regulatory standards in total food tested in each food category. Most data were listed by the day of sample collection. If these date were unavailable, the individual date are treated with the day of the monitoring.

2-2. Distribution of the Number of Beef Samples

Monitoring data for beef samples during 2014 were used. The data of the total number of beef samples in each prefecture were divided into seven groups (less than 800, 800–1599, 1600–3199, 3200–6399, 6400–12799, 12800–35600 and 35600 or more). The data were shown on the graphic by a light to dark shades of green (Figure 5). The darker colors represented a higher number of beef samples.

2-3. Detection Limits

Reported detection limits ranged from 1 to 50 Bq/kg depending on the type of detector and measurement conditions. Ge gamma-ray detectors, rather than NaI- or CsI-scintillation detectors showed lower detection limits for the measurements. For internal radiation dose estimation due to beef consumption, concentrations of non-detected samples were set to be the detection limits for each measurement or 10 Bq/kg for $^{131}$I, $^{134}$Cs and $^{137}$Cs, respectively. However, when 60% of beef were below the detection limits during a month, concentrations in the beef were set to be half of these values for that month. When 80% of beef were below the detection limits during a month, concentrations in the beef were set to be a quarter of these values for that month.

3. Results

According to the MHWL estimation of effective dose from radioactive cesium based on the monitoring data of the radionuclides in foods, internal exposure to contaminated food due to the Fukushima accident would result in the radiation exposure below 0.1 mSv/year in many cases. Natural background radiation has been estimated at 2.4 mSv/year worldwide and 2.09 mSv/year in Japan. Of these, 0.98 mSv/year is from internal natural radiation exposure via ingestion of foods containing radioactive potassium ($^{40}$K) and radioactive polonium ($^{210}$Po) in Japan. Thus, internal radiation exposure from ingestion of contaminated foods due to the Fukushima accident was 10 times lower than that from natural radiation exposure (Figure 1).

According to the MHLW, 0.88% of samples (1,204 of 137,037 total samples) exceeded the PRV among the samples that were collected by March 2012 (Table 1). Details on radioactive food contamination for each category were well documented in the papers described by others. The following is a brief description of these data. During the early stage of the event, $^{131}$I concentrations were as high as 2000 Bq/kg in many leafy vegetables and 300 Bq/kg in raw milk.
Therefore, the central nuclear emergency response headquarters (NERHQ) issued a declaration to Fukushima and the neighboring regions ordering restrictions on the distribution of contaminated foods. In May 2011, the number of samples that exceeded the PRV increased mainly for tea buds ready for harvest. For the safety of the rice crop, restrictions on planting were implemented in April 2011 in areas where radioactive materials in the resulting rice crop would likely exceed the PRV. In other regions and municipalities where the concentration of radioactive cesium in the soil had been relatively high, surveys of radioactive materials in the rice crops have been conducted both before and after harvest. If the results indicated radioactive contamination in the crop over the PRV, the distribution has been restricted for all rice harvested from the corresponding area. Fukushima Prefecture decided to survey all rice for radiation safety, and continues to do so. Under this surveillance, contaminated food has been restricted from entering the market. After setting new standard limits on April 1, 2012, by March 2015 only 0.43% of the samples (3,962 of 928,351 total samples) exceeded the new food monitoring standard limits (Table 2).

**Table 1** Food monitoring data among the samples which were collected by March of 2012

<table>
<thead>
<tr>
<th>Food Group</th>
<th>Number of food samples tested</th>
<th>Number of foods positive at levels exceeding PRV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meat-Egg</td>
<td>94,157</td>
<td>286</td>
</tr>
<tr>
<td>Vegetable</td>
<td>21,121</td>
<td>451</td>
</tr>
<tr>
<td>Fishery Products</td>
<td>9,408</td>
<td>245</td>
</tr>
<tr>
<td>Grain</td>
<td>5,553</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>3,808</td>
<td>197</td>
</tr>
<tr>
<td>Milk-Dairyproducts</td>
<td>2,991</td>
<td>23</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td><strong>137,037</strong></td>
<td><strong>1,204</strong></td>
</tr>
</tbody>
</table>
Beef containing radioactive cesium in excess of the PRV was found on July 8, 2011, because some beef cattle were fed with rice straw which had been left outdoors to dry after the Fukushima accident. Ministry of Agriculture, Forestry and Fisheries (MAFF) instructed farmers not to feed cows with grass, hay, grass, silage, etc. covered by radioactive nuclides immediately after the accident, on March 19, 2011. Unfortunately, contaminated rice straw had already spread among various farmers, including those in Fukushima Prefecture, neighboring prefectures and others (Hokkaido and Shimane). Some beef cattle were fed with contaminated rice straw. Therefore, MAFF set the provisional tolerable radioactive cesium levels for feed including rice straw as 300 Bq/kg. The value was revised to 100 Bq/kg as a new standard limit on February 3, 2012. According to the monitoring data for rice straw, one sample that was planted before the Fukushima accident and harvested after the accident exceeded 300 Bq/kg (1 of 23 total samples). All samples (933 total samples) were below 300 Bq/kg for forage crops planted after the accident. MHLW ordered the local government to trace shipment destinations of contaminated beef that were suspected to have been from cattle fed with contaminated rice straw and to recall contaminated beef that exceeded the PRV. The beef containing radioactive cesium in excess of the PRV was mostly detected from July 2011 to November 2011 and 0.16% of samples (152 of 92,175 total samples) exceeded the PRV by March 2012 (Figure 2 A and B). We selected the monitoring data only in Fukushima Prefecture and neighboring prefectures (Iwate, Miyagi and Tochigi) where the shipment for beef was restricted by law (Figure 2 A and B, right panel). In 2012, only two beef samples exceeded new standards limits (0.001% of samples exceeded the standards: 2 of 190,753 total samples) (Figure 2A, left panel). The last sample that exceeded the new standard limits was reported on October 26, 2012, in Gunma Prefecture. After reporting beef contamination, the amount of beef purchased dramatically dropped in 2011, as it previously dropped after the bovine spongiform encephalopathy (BSE) event in 2001 (Figure 3). Therefore, the Japanese government supported the local government to conduct the beef monitoring. The local government in Fukushima Prefecture and the neighboring prefectures decided to monitor all cattle. MHLW advised the reconsideration of that monitoring plan in the case that the local government confirms proper feeding and management at the farm. MHLW advised the necessity of regular monitoring at each farm only once every three months in Fukushima prefecture and the neighboring prefectures (Iwate, Miyagi and Tochigi). More than 70% of the monitoring samples were shared with beef among the one million total samples monitored by May 2015 (Figure 2B, left panel). Most of the beef samples have been below the detection limits, even in areas with restricted shipment for beef (Figure 4). Location of each prefecture and distribution of the number of beef samples were shown in Figure 5. Beef monitoring is still be carried out not only in Fukushima Prefecture and the neighboring prefectures but also in other areas in 2014.

4. Discussion

The World Health Organization (WHO) estimated that the effective doses in this most affected region of Namie town and Iitate village would have been 12 to 25 mSv during the first year following the Fukushima accident. The
Fig. 2. Sample size and contamination ratio regarding beef
(A) Number of beef samples exceeded standards was shown in all prefectures on the left panel and in Fukushima, Iwate, Miyagi and Tochigi Prefectures on the right panel for fiscal year 2011-2014. Number of beef sample was shown in the graph and the percentage was indicated in parenthesis. (B) Number of beef samples and others except beef was shown in all prefectures on the left panel and in Fukushima, Iwate, Miyagi and Tochigi Prefectures on the right panel for fiscal year 2011-2014. Percentage of beef sample in total samples was shown in each bar.

Fig. 3. Trend for beef purchased
The amount of beef purchased was shown from 1996 to 2012. The purchase amounts were remarkably dropped in 2001 and 2011 (indicated by arrow).
United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated radiation doses to the public by assuming more realistic scenarios than that which WHO adapted and reported effective doses to adults of up to about 50 mSv and absorbed doses to the thyroid of one-year-old infants of up to about 750 mGy if they had not been evacuated within the 20-km evacuation zone\textsuperscript{15). Although the scale of the Fukushima accident was beyond our imagina-
tion, the preparation of manuals for monitoring food contamination worked well in preventing the distribution of contaminated food and water after the Fukushima accident.

Herein we demonstrated that the ratio of samples over the limits did not dramatically increase after introduction of the new standard limits (0.88% before and 0.43% after). The distribution of radio-contaminated food has been well-controlled even by using the previous PRV even though considering decay of $^{134}\text{Cs}$ and $^{137}\text{Cs}$. However, new standard limits contributed to mitigate internal radiation exposure from contaminated food at relatively high levels.

The Japanese public paid attention to these food protection measures, especially since beef safety is a socially significant topic. Consumers avoided purchasing beef following the Fukushima accident in 2011 and 70% of consumers in Japan still have a tendency for concern about growing area of cattle even though food is below the standard limits$^{[16]}$. This is reflected in the testing of all cattle to build up a confidence between the government and the public. Therefore, the local governments still continue the complete monitoring approach due to social pressures even though most of the samples are now below the detection limits (as of July 6, 2015). Many Japanese people also remembered the experience of the BSE crisis in 2001$^{[17]}$. It was thought that BSE outbreak might not occur in Japan. However, the first BSE case was detected in 2001. Then surveillance systems for all cattle were urgently set within about one month since then directed by the central government. At that time, there was serious confusion between the central and local government due to lack of proper instructions for BSE diagnosis. Consumers had strong belief that surveillance such as testing all cattle was the only effective method to prevent disease. Consumers distrusted the government due to the lack of sufficient explanation regarding this problem. The concern for food safety may cause serious risk communication issues among the Japanese public. Recently, the Food Safety Commission of Japan (FSCJ) re-evaluated BSE risk based on the most current scientific knowledge. FSCJ agreed to revise the minimum age for BSE testing of domestic cattle to 20 months in 2004, then to 30 months in 2012, and to 48 in 2013$^{[18]}$. Thus, a quantitative evaluation may help to establish more effective and efficient food monitoring systems.

It is compulsory to remove the head, spinal cord and distal ileum as specific risk material from cattle according to law in order to reduce BSE risk. Regarding measures to fight BSE in Japan, cattle cake was prohibited to control feeding. Feeding control by checking radioactive contamination of livestock feed was also significantly reduced contamination in cattle. Ingestion doses due to beef consumption were estimated by the Monte Carlo method randomly picking up radioactive concentration data of beef and consumption amount of beef. Among 251,510 beef samples during fiscal year 2014, 241 samples were above the detection limit. The mean concentration of radioactive cesium was 16.4 Bq/kg and the maximum concentration was 47.0 Bq/kg. On the other hand, the mean consumption amount of beef was 34.1 g/d for male in twenties$^{[19]}$. The mean committed effective dose due to annual beef consumption was estimated to be 1 µSv. The 99.9 percentile committed effective dose was 20 µSv. Thus, internal exposure due to beef consumption is limited. Comprehensive sampling in the surveillance of radionuclides in beef led to increased measurement time and monitoring cost. This issue was also expected in rice monitoring because the all backs of rice were tested. In spite of this, even though consumption decreased, radioactive concentration of food tended to be higher in other foodstuffs such as a freshwater fish, wild mushrooms and game meat$^{[20, 21]}$. Regulation of feed intake is possible among livestock, while wild vegetables and animals are difficult to control. Instead of beef alone, it is extremely important to monitor other foodstuffs to best prevent radiation exposure from contaminated food and for renewing consumer trust regarding social justice and optimization of radiological protection. The food contamination issues faced in radiation disasters should be discussed to establish more effective and efficient food monitoring systems. Our present data may help to reconsider the efficiency of beef monitoring after the Fukushima accident.

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References


