Analysis of Gamma Radioactivity Concentration of Coffee and Investigation of Harmfulness using High Purity Germanium Detector

Sangbok Lee[*a,c], Donghyeok Choi[b], Jeongsoo Park[a], Seokhwan Lee[a], Kwanggyun Choi[a], Seunggeon An[a], Haeun Seok[c], Yongsuk Jang[c]

[a] Department of Radioactivity Test & Analysis center, Sunkwang T&S Co. Ltd., Seoul 08298, South Korea
[b] Department of Radiation Oncology, Yonsei University College of Medicine, Seoul, Republic of Korea
[c] Department of Radiological Science, Gachon University, Incheon 21936, South Korea

Introduction

Coffee Consumption per adult in Korea is 353 cups per year, about 2.7 times the average of 132 cups in the world. According to the National Nutrition Statistics of the Korea Health Industry Development Institute, coffee ranks second in the national consumption index with 54.41% This is higher than rice, which is a staple food and it is known that these coffee release radionuclides. That means they are unconsciously exposed to the risk of internal exposure. Coffee in Korea is mostly imported rather than directly produced and consumed due to climate differences. The main producers of such coffee are in developing countries such as South America, Central America and Africa. It is needed analysis of radioactivity in coffee.

In this study, the harmfulness of coffee beans in 10 countries in Brazil, Colombia, Honduras, Mexico, Guatemala, Vietnam, India, Indonesia, Ethiopia and Uganda among these countries were being reviewed. If possible, food monitoring measures can be established to become a basic material.

Materials & Methods

1. Sample & Analysis method selection

High purity germanium detector (Canberra Co. U.S) was used an analysis equipment for measuring radioactivity by nuclide. The equipment is P-type, which has a range of measuring within 50~2,000 keV and has a relative efficiency of 30%. Marinelli Beaker was used as the measuring vessel, which was to increase the reliability of the analysis by measuring in the same form as the calibration standard source for the equipment.

As target nuclides for measuring coffee radioactivity, K-40, U-238, Th-232, which are expected to be widely distributed and I-131, Cs-134, Cs-137 were analyzed to see the harmfulness. Since common natural radioactive indicator nuclides, U-238 and Th-232 are difficult to measure directly, radioactive equilibrium was performed to measure offspring radionuclide (U-238 is Bi-214, Th-232 is Pb-212).

2. Sample preparation

After drying the coffee bean samples for each country of origin in the natural breeze for 1 to 2 days, crush them finely using a grinder. Because the pulverization not only minimizes the air layer between the samples but also increases the surface area of the sample to increase the measurement efficiency of the sample. In order to increase the homogeneity of the sample, it was filtered and collected using a sieve. To dry it again, it was dried at 105 ℃ for 3 hours using a hot air dryer to minimize the effect of moisture.

(a) (b) (c)

Fig 1. Equipment used for preparation

(a) A coffee mill
(b) Filter net
(c) Hot-air dryer

Dry samples are compressed to have a uniform distribution on the Marinelli Beaker for measure filled, weighed and sealed. At this time, the sample is in powder form the upper surface is filled and sealed to prevent voids. After sealing, it was stored for about 3 weeks for radial equilibrium.

3. Radioactivity measurement

The sealed sample was measured using a High Purity Germanium detector. Genie 2000 basic was used as the measurement was performed based on Marinelli Beaker to increase the reliability of the relative measurement. The measurement time of the sample was measured as 30,000 seconds, which is more than the time specified in the Food & Food Additives Code.

For the analyzed sample, the measurement value and measurement uncertainty were calculated by applying the relative measurement equation as in Eq. 1 using the results of the spectrum analysis for each nuclide.

$$A = \frac{N}{m \times \varepsilon \times \gamma \times t_s \times K_1 \times K_2 \times K_3 \times K_4 \times K_5}$$

A is radioactivity (Bq/kg), N is the net coefficient, m is the weight of the sample (kg), ε is the counting efficiency, r is the gamma-ray emission rate, ts is measurement time, K is the correction factor for time(K_1, K_2), sample(K_3), the properties of the nuclide(K_4, K_5).

Results

✓ In order to compare the harmfulness of coffee to radiation, we compared the regulatory recommendations for each country. The recommended values are based on the radioactivity values for I-131, Cs-134 and Cs-137. This is shown in Table 1.

✓ Table 1. Radiation standards among food products

Nation	Nuclide	Activity (Bq/kg)			
		Drink	Dairy	Vegetable	other
Japan	I-131	-	-	-	-
	Cs-134, 137	10	50	100	100
U.S.	I-131	170	170	170	170
	Cs-134, 137	1,200	1,200	1,200	1,200
China	I-131	-	33	160	800
	Cs-134, 137	-	330	210	900
Codex	I-131	100	100	100	100
	Cs-134, 137	1,000	1,000	1,000	1,000
EU	I-131	300	300	2,000	2,000
	Cs-134, 137	200	200	500	500

✓ Table 2 shows the radioactivity measurement results for coffee by country of origin. The average radioactivity for each nuclide was 6.47×10^{2} Bq/kg for K-40, 1.77×10^{1} Bq/kg for U-238, 7.93×10^{-1} Bq/kg for Th-232. The detection results of I-131, Cs-134 and Cs-137 were less than the minimum detectable activity. It was verified that less than 3.85×10^{-1} Bq/kg for I-131, 4.06×10^{-1} Bq/kg for Cs-134, 4.67×10^{-1} Bq/kg for Cs-137.

✓ Table 2. Result of radionuclide analysis in coffee (Bq/kg)

No.	Origin	K-40	Bi-214	Pb-212	Artificial Radionuclides	No.	Origin	K-40	Bi-214	Pb-212	Artificial Radionuclides
1	India	6.66×10^{2}	1.23×10^{1}	6.85×10^{-1}	<MDA	6	Ethiopia	5.64×10^{2}	1.00×10^{1}	6.44×10^{-1}	<MDA
2	Honduras	6.22×10^{2}	1.82×10^{1}	8.24×10^{-1}	<MDA	7	Uganda	6.66×10^{2}	<MDA	6.85×10^{-1}	<MDA
3	Guatemala	5.74×10^{2}	1.14×10^{1}	4.32×10^{-1}	<MDA	8	Vietnam	7.04×10^{2}	1.39×10^{1}	7.74×10^{-1}	<MDA
4	Mexico	6.32×10^{2}	1.06×10^{1}	7.49×10^{-1}	<MDA	9	Colombia	6.26×10^{2}	1.47×10^{1}	6.50×10^{-1}	<MDA
5	Indonesia	6.93×10^{2}	2.69×10^{1}	9.68×10^{-1}	<MDA	10	Brazil	7.18×10^{2}	4.09×10^{1}	1.51×10^{0}	<MDA

Discussion & Conclusion

As a result of conducting radioactivity analysis on beans in 10 countries, some natural radionuclides were detected, but not artificial radionuclides. For natural radionuclides, the highest concentration was measured in Brazil and the lowest in Ethiopia. As a result of comparing with the international radiation regulation value, the radioactivity concentration of coffee beans is judged to be very insignificant.

Reference

[1] Yongjeong Park, Jeongwon Lee, Jaejin Han, "Changes and Prospects of 5 Trends in the Coffee Industry", Hyundai Industry Laboratory, 2019
[2] Korea Health Industry Development Institite, "National Nutrition Statistics Food intake", 2017
[3] Jeongseok Chae, Jongin Byen, Seokwon Yoon, Heeyeol Choi, Changsoo Park, Jooyong Yoon, "Study on the radiation concentration of K-40 and Cs-137 among domestic foods and the internal exposure dose due to food intake", The Korean Association for Radiation Protection, p.236-237, 2010
[4] Canberra, "HPGe Product Spectrometer" Neosiskorea, 2017
[5] Ministry of Food and Drug Safety, "Food and Food additives Revolution", Chapter 8. General test method. 9.9 Radioactivity, 2019
[6] Ministry of Food and Drug Safety, "Food Standard to Food Sanitation Act", 2019

E-mail address : lsbguy87@sktns.co.kr

Sunkwang T&S 선광티앤에스