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$^{230, 232}$Th in milk, meat, and grain in Korea

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The concentrations of natural radioisotopes ^{230}Th and ^{232}Th in Korean foods were measured by the method of calcium oxalate co-precipitation in addition to the conventional anion-exchange method and alpha spectroscopic measurement. The ^{230}Th concentrations(mBq/kg-fresh) in Korean foods were found to be as follows: milk 0.14~2.45, pork 2.98~8.97, beef 1.94~9.80, chicken 1.22~13.0, rice 0.43~2.35, wheat 0.53~14.4, and soybeans, 8.44~91.6. The ^{232}Th concentrations(mBq/kg-fresh) in Korean foods were found to be as follows: milk 0.01~2.46, pork 0.28~9.32, beef 1.02~5.34, chicken 0.56~4.98, rice 0.32~2.54, wheat 0.53~20.0, and soybeans, 2.30~42.2. The annual internal dose of Th was also estimated. The annual internal dose of ^{230}Th and ^{232}Th in milk was about 0.006 μSv/yr and much lower than that of other countries because of the low intake of milk in Korea compared to other countries. The annual internal dose of ^{230}Th and ^{232}Th in the rice was about 0.043 μSv/yr and highest because rice is the staple food of Koreans.

KEYWORDS: thorium, concentration, annual internal dose, Korean foods.

I. Introduction

Natural radioisotopes belonging to thorium and uranium series enter the human body mainly through dietary ingestion, except Rn which is absorbed by inhalation, and those radioisotopes give rise to the internal dose. The internal dose can be evaluated from intake of the radionuclides in food. Thus it is very important to assess the concentration of natural radioisotopes in foods and the internal dose by dietary ingestion. According to the report of UNSCER (2000) [1], the total annual dose for a person was 2.4 mSv, of which 0.38 mSv is from the cosmic rays and 2.03 mSv (0.48 for external, 1.55 for internal) is from natural radioisotopes.

In South Korea, the concentrations of artificial radionuclides in the environmental samples, which include many kinds of food samples, have been investigated by the Korean Institute of Nuclear Safety for many years. However, there have been no studies thorium isotopes concentrations in Korean foods to our knowledge [1].

The purpose of this study is to investigate concentrations of ^{230}Th and ^{232}Th in Korean foods such as milk, meat (pork, beef and chicken), and grain (wheat, soybean and rice), and to estimate the annual internal dose from ^{230}Th and ^{232}Th for a Korean adult man.

II. Materials and Methods

The food samples were collected in ten major cities of Korea in 1998 and 1999 as shown in **Figure 1**. The collected food samples were milk, meat (pork, beef and chicken) and grain (rice, wheat, and soybeans).

The collected samples were oven dried at 80°C for 24 hours and then ashed at 450°C until the samples become white to remove organic matter completely. The ashed samples was homogenized and weighed. 10g of ashed sample was dissolved with concentrated nitric acid and 10ml of hydrogen peroxide after adding ^{229}Th tracer. The dissolving process was performed three or four times repeatedly until the solution became clear and then the solution was filtered by a glass fiber filter. The Th isotopes

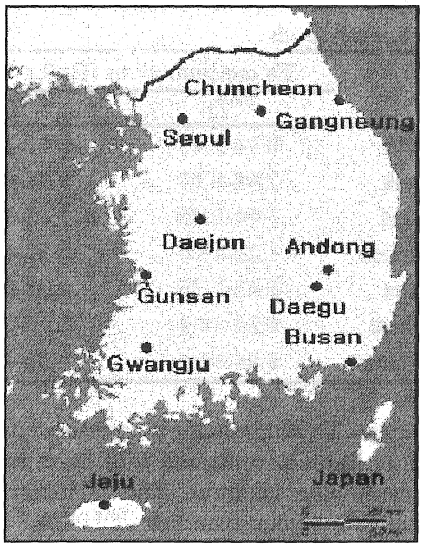

Fig. 1 The sampling cities in Korea.

in the filtered solution were co-precipitated with calcium oxalate at pH 1.5. The purpose of calcium oxalate co-precipitation process was to remove all phosphorus content in the samples, which decreases markedly the distribution coefficient of Th for anion exchange resin. The precipitate was dissolved by 7.8 M HNO_3 after 24h of calcinations at 550°C and the Th isotopes were co-precipitated with iron

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hydroxide at pH 8.0. The separated iron hydroxide precipitation was dissolved with 7.8 M nitric acid and the resultant solution was passed through an anion exchange resin column (Dowex 1×8, 100-200 mesh), which is equilibrated with 120 ml 7.8 M nitric acid. The column was washed with 7.8 M nitric acid and the thorium isotopes retained in column were eluted with 200 ml of 8 M hydrochloric acid. The elute was evaporated to dryness, the residue was dissolved in special electrolyte [2], and Th isotopes were electrodeposited on stainless steel disc with 0.75 A for 2 h. The electrodeposited disc was measured using an alpha spectrometer (Canberra 7401) for 300,000 seconds.

III. Results and Discussion

The obtained Th concentrations in Korean foods are shown in **Table 1**. The ^{228}Th concentrations were obtained with alpha spectrometry, but they were not reported in this study. The ^{228}Th concentrations were much higher than ^{230}Th and ^{232}Th in overall food samples, especially in grain samples. This might be caused by the ingrowth of ^{228}Th from parent ^{228}Ra and ^{228}Ac taken by plants, in addition to the direct uptake of ^{228}Th from the soil [3]. Because there was no information about ^{228}Ra and ^{228}Ac of the initial sampling time, the ^{228}Th concentrations in foodstuff could not be evaluated accurately. Additionally, the amount of the ingrowing ^{228}Th depends on the elapsed times from sampling, which are not same for each sample in this study. So, in this work, we do not estimate the activity of ^{228}Th.

Table1. The range of Th concentrations in Korean foods

	Th concentrations (Bq/kg-fresh)	
	^{230}Th	^{232}Th
Milk	0.14-2.45	0.01-2.46
Pork	2.98-8.97	0.28-9.32
Beef	1.94-9.80	1.02-5.34
Chicken	1.22-13.0	0.56-4.98
Rice	0.43-2.35	0.32-2.54
Wheat	0.53-14.4	0.53-20.0
Soybean	8.44-91.6	2.30-42.2

The average Th concentrations measured in this study are shown in **Table 2** compared with those reported from studies done in other countries. The ^{230}Th concentration of milk was slightly higher than that of U.S.A.[4] and slightly lower than that of Poland [5] . The ^{232}Th concentrations in milk was close to those of U.S.A.[4] and Japan [6], whereas it was about a half of value in China [7] and Poland [5].

For meat samples, as shown in **Table 1**, the ^{230}Th and ^{232}Th concentration in beef was close to those of pork and chicken. Both of ^{230}Th and ^{232}Th concentration in meat were same level of those of Poland [5, 8], whereas they were higher than those of U.S.A.[4] and Japan [9].

For grain samples, a relatively large local variation in Th concentration was found even within the same kind of food. The maximum and minimum concentrations for soybeans appeared in Chuncheon province and Jeju Island, respectively. As shown in **Table 1**, the Th concentrations in soybeans were much higher than rice and wheat, which may indicate that there is a different degree of Th uptake by plant in growth process.

As shown in **Table 2**, the Th concentration of wheat is the same level of that in central Poland [5, 8] and Brazil [10]. The Th concentrations in soybean were considerably higher than wheat and rice, and were close to that of U.S.A. [4], while they were larger than Poland [5, 8]. The differences in Th concentrations of soybeans in Korea from other countries may be attributable to Th concentrations in soil. According to report of UNSCER (2000) [1], the average ^{232}Th concentrations of soil in U.S.A. and Poland were 35 Bq/kg and 21 Bq/kg, respectively. Although the report for Th concentrations in Korean soil has not been published yet, the Th concentrations in Korean soybeans and other countries suggest that the Th concentrations in Korean soil may be relatively high compared with other countries.

In most food samples, the ^{230}Th concentrations were higher than those of ^{232}Th. The average ratio of ^{230}Th/^{232}Th was 1.6 in whole food samples. Additionally it was 1.2 in grain samples, which suggests that the level of ^{230}Th may be higher than those of ^{232}Th in Korean soils.

With the measured Th concentrations, annual consumption of Korean foods [12] and dose per unit intake coefficients given by ICRP (1996) [13], the annual internal dose for Korean adult men was estimated and presented in **Table 3**. The total annual internal doses due to Th in milk, meat and grain were estimated to be 0.006, 0.030, and 0.059 μSv, respectively. Although the Th concentration in rice was relatively low compared to wheat and soybeans, the annual internal dose due to rice was much higher than wheat and soybeans, because rice is staple food for Korean. However, rice consumption has shown a tendency to decrease because of change of eating habits. The consumption of chicken is increasing, whereas pork and beef consumption are at a standstill. On the other hand, the annual internal dose due to Th in milk was lower than that of Poland, which were in the range of 0.058~0.112 μSv/year [5, 8], because the annual consumption of milk for Korean adult is much less than Poland.

V. Conclusion

In this study, the concentrations of ^{230}Th and ^{232}Th in Korean foods were estimated. The average concentration of ^{232}Th in milk was significantly lower than Poland and China, while ^{230}Th concentration was similar to other countries. The ^{230}Th and ^{232}Th concentrations in beef were close to those of pork and chicken. For grain samples, Th concentrations in soybeans were considerably higher than wheat and rice. The total annual internal doses due to Th in milk, meat and grain were estimated to be 0.006, 0.030 and 0.059 μSv, respectively. The annual internal dose due to milk was lower than in Poland and that due to rice was higher than for other foods because rice is the staple food of Koreans.

In the present study, the daily intake of Th could not be evaluated for lack of food categories such as drinking water, vegetables, and fish. The Th concentration in vegetables (including fruit) and fish (including shellfish) will be estimated in the 2nd year and 3rd year, respectively.

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Table 2. Comparison of Th concentration in Korean foods with the other's (mBq/kg-fresh)*

	Country	Foodstuff							Ref.
		Milk	Pork	Beef	Chicken	Rice	Wheat	Soybean	
^{230}Th	Korea	0.64±0.71	5.13±2.15	4.05±2.39	4.29±3.33	1.24±0.53	4.82±4.21	34.7±23.0	Present study
	Poland	0.76-1.15	0.74-2.68	2.90-3.04	1.95-2.06		1.53-16.0	3.41-4.14	5, 8
	U.S.A	0.4		3.00±0.17	0.47±0.33	0.93±0.17	0.9-10	31.7±2.5	4
^{232}Th	Korea	0.39±0.77	2.18±2.73	2.51±1.63	2.41±1.64	1.26±0.87	6.38±6.45	17.3±13.4	Present study
	Poland	0.61-1.19	0.52-1.82	2.40-3.61	1.31-1.65		2.13-21.14	2.16-2.58	5, 8
	U.S.A	0.27				0.10±0.13	0.1-28	27.0±2.2	4
	Brazil					0.7-7.9	0.51-4.3	1.9-54	10
	U.K.						12	12	11
	Japan	0.29	0.40±0.02	0.40±0.02	0.40±0.02				6, 9
	China	0.93							7

* Mean ± S.D.

Table 3. Annual consumption of Korean foods and annual internal dose due to thorium for Korean adult man.

Foodstuff	Annual consumption	Internal dose (μSv/year)		
		^{230}Th	^{232}Th	Total
Milk	25.8 L	0.0035	0.0023	0.006
Pork	8.1 kg	0.009	0.004	0.013
Beef	7.4 kg	0.006	0.004	0.010
Chicken	4.8 kg	0.004	0.003	0.007
Wheat	1.9 kg	0.002	0.003	0.005
Soybean	1.0 kg	0.007	0.004	0.011
Rice	78.9 kg	0.020	0.023	0.043

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