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Application of PGAA for BNCT

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Abstract

A prompt gamma-ray activation analysis (PGAA) is known as one of the powerful method for the analysis of boron in different samples. In the boron neutron capture therapy, BNCT study, accurate determination of boron content in biological sample is very important work. The PGAA facility at HANARO research reactor, KAERI was applied for the determination of boron in the tissue organ of mouse sample. The solution of boron was administered intraperitoneally in mice induced skin cancer and accumulation rate in each organ such as skin cancer, blood, spleen, liver, kidney and brain was investigated. Boron concentrations of ppm level in tissue organs of mice are measured. The analytical quality control of measurement was carried out using NIST SRM such as peach leaves, apple leaves, total diet, typical diet and oyster tissue. The analytical results for the SRM are good agreed to the certified values.

1. Introduction

Boron is known as an essential trace element for the growth of plants. It is in charge of the uracil formation and normal growth and its deficiency as well as toxicity threatens crop productivity in many areas[1]. It has been reported that boron has effects upon the metabolism of calcium, phosphorus and magnesium in animals[2]. Boron is present in animal tissue in low concentrations (about 1 ppm) and is probably an essential micronutrient for humans. Though the essentiality of boron for animals is not yet fully established[3], there is growing evidence that it may have a metabolic role in human and animal nutrition[4,5]. Its deficiency in plants may result in a reduced growth, yield loss, and even death, depending on the severity of the deficiency. In contradiction to this, an excess of boron in food products and drinking water is toxic to plants and animals, which is also considered harmful for health[6]. Boron is also used as a source for the short range alpha particles in cancer treatment using boron neutron capture therapy (BNCT)[7,8]. In the biological research by the PGAA, the boron concentrations in tumors, tissues, blood and cultured cells which were estimated from the calibration curves obtained by using standard samples containing a different 10B

concentrations were studied by Matsumoto et al.[9]. The aim of the present study is to confirm the accuracy of the boron analysis in biological samples using the PGAA system at the HANARO research reactor, KAERI.

2. Experimental

To find accumulation rate in each organ such as skin cancer, blood, spleen, liver, kidney and brain, the solution of boron was administered by i.p. injection with a dose of 1500 mg/kg body weight in mice. Three hours later, mice were sacrificed and then the samples to be analyzed were taken. These biological samples were frozen at the deep freezer for overnight and then were freeze-dried at -23℃ for seven days. Dried samples were ground into powder and then placed into a measuring polytetrafluoroethylene (PTFE) vial for boron analysis with lid and stored in desiccator. The powdered samples were re-dried using oven at 60℃ for 2 hours and then cooling at room temperature. To check the moisture content, the sample was weighed before and after drying. The moisture content of sample was less than 1.2 %. Measurements were done 5 times on each biological samples. Also, the certified reference materials used are the following; the peach leaves (NIST SRM 1547) with a weight of 12 mg, 30 mg and 85 mg, the apple leaves (NIST SRM 1515) with a weight of 5 mg, 12 mg and 27 mg, the total diet (NIST SRM 1548) with weight of 6 mg and 38 mg, the typical diet (NIST SRM 1548a) with a weight of 25 mg and 40 mg, and the oyster tissue (NIST SRM 1566b) with a weight of 5 mg and 11 mg.

The PTFE vial of cylindrical shape was 8 mm in outer diameter, 1 mm in thickness and 5 mm in height. The vial size was made to be less than the beam dimensions and then the irradiation was performed in air. The sample frame was inclined 45° with respect to the diffracted beam direction. All of the samples were measured for 3,600 second per sample at same position.

3. Results and Discussion

The boron peak was overlapped with the prompt gamma rays from ^{24}Na with 472 keV. The interference is caused by the strong 472 keV gamma-ray arising from the capture in the sodium. The region of interest is decomposed into a broad peak, interfering normal peaks and a background of low energy near the boron energy region. The statistical fluctuation of the boron peak can be neglected the sodium peak in the case of a high boron content in the samples. The combined uncertainties were in the range of about 4.0% for the boron analysis in the relevant materials. The main sources of the uncertainties are due to statistical errors (0.20~0.34%), the detection efficiency (2.8%), the background subtraction of 472 keV-Na (2.4~2.65%), and error sources including some other corrections. The boron concentration of each sample was determined from the measured count rate of the boron peak, sample mass and boron sensitivity.

The analytical quality control of measurement was carried out using certified reference materials, NIST SRM. The results are summarized in Table 1 together with the certified values. The relative errors of the measured values are 1.0~2.0 % for the apple leaves and peach leaves, 11% for the typical diet, about 25 % for the total diet and oyster tissue. The analytical results of boron using the present PGAA facility is in good agreement with the certified value of NIST SRMs in the above 10 ppm, but in the below a 3 ppm concentration, the measured values are higher than the certified values. The measured biological samples are showing in Table 2. The each weight of organ was obtained from a few mice, the boron solution was administered by i.p. injection with 1500 mg/kg body wt. per each mouse. The boron concentration of brain was detected lower than other organ.

Table 1. Comparison between the measured values and certified values for the NIST SRMs.

Sample (NIST SRM)	Present (ppm)	Certified (ppm)	Relative Error(%)
Peach(1547)	28.4±1.0	29.0±2.0	2.1
Apple(1515)	27.3±1.0	27.0±2.0	1.1
Total Diet (1548)	3.1±0.6	2.5	24
Typical Diet (1548a)	4.6±0.1	4.16±0.04	11
Oyster Tissue (1566b)	3.4±0.2	2.8±1.2	21

Table 2. Measured boron concentration from each mouse organs.

Sample(mouse organ)	Weight (mg)	Concentration (ppm)
blood	90	241
brain	76	53
skin cancer	203	214
spleen	71	314
kidney	90	484
liver	142	125

4. Conclusion

In the NIST SRM used as reference samples such as peach leaves (SRM 1547), apple leaves (SRM 1515), total diet (SRM 1548), typical diet (SRM 1548a) and oyster tissue (SRM 1566b), the measured values for the high boron concentration are in good agreement with the certified values, but in a low concentration below 5 ppm in SRM 1548 and 1566b, present values were higher than the certified values. Also the solution

of boron was administered with a dose of 1500 mg/kg body weight in a mouse to find accumulation rate in each organ. The total concentration was detected about 1430 ppm in the skin cancer, blood, spleen, liver, kidney and brain. In the biological sample, the boron concentrations in the kidney and spleen are showing higher than brain and liver.

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