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Comparison of Elemental Composition in Korean Irradiated Foods using Instrumental Neutron Activation Analysis

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1. Introduction

The information and role of trace mineral elements from an intake of created and processed foodstuff are important as a indicator of human health and nutritional parameter, as well as a quality control of food and diet. Particularly, special food created for consumption by astronauts in outer space may differ with common food on the earth in order to compensate a decrease of taste and nutrition by strong cosmic rays, a state of non-gravitation, low pressure, and enclosed space environment. In April 2008, Korea's first astronaut became a crew member of the international space station and she was brought special space versions of Korea's national dishes such as Kimchi, boiled rice, hot red paste, green tea, ramyun, and so on.

Accurate quantitative analysis of trace elements in various kinds of biological samples is also important for data quality. Neutron activation analysis is a sensitive, non-destructive, multi-elemental analytical method, and is proper for tracing elements in a biological sample in order to avoid loss and contamination by chemical pre-treatment.

This study analyses the distribution of concentrations for both essential and toxic elements in six kinds of Korean space foods developed by KAERI. The quantitative analytical results from instrumental neutron activation analysis are presented.

Fig. 1. Irradiated Korean Space foods.

2. Methods and Results

2.1 Sampling and sample preparation

Six kinds of Korean space foods, bulgogi (marinated barbecued beef), kimchi, bibimbap (mixed rice with hot pepper paste), ramyun, a mulberry beverage and a fruit punch were prepared. The typical preparation procedure for the samples is as follows: raw material; cooking or adding additives; mixing with sauce; vacuum packaging; freezing or freeze drying (-20 to 70ºC) and gamma-ray irradiation (10 to 40 kGy).

The samples were weighed in a range of 10 to 200 mg in polyethylene vials for short and long-term irradiation. To remove the blank effect, the irradiated samples were transferred to new vials after irradiation.

2.2 Analysis of sample by INAA

The prepared samples were irradiated with thermal neutrons using the Pneumatic Transfer System (PTS, Φ_t = 3.75 x 10^{13} n/cm^2·s, R_{cd} ~ 205) at the HANARO research reactor at the Korea Atomic Energy Research Institute. The samples were irradiated at the same position to minimize geometric errors. For neutron flux monitoring, activation wires (Reactor Exp. Inc., R/X activation wire, 99.99% purity) such as Au-Al, Co, Fe and Mn were used. Analytical conditions were optimized after considering the preliminary results.

The measurements were carried out using a high purity Ge detector of 25% relative efficiency and 1.9 keV resolution (FWHM) at 1332 keV of ^{60}Co and peak-to-Compton ratio of 45:1, which was coupled to a personal computer and 8k-multichannel analyzer (919A MCB, EG&G ORTEC, USA). Energy and efficiency calibrations were conducted using multi-nuclide reference sources (NEN Products Inc., NES-602, 1" diameter disc type) certified by NIST. GammaVision software (EG&G ORTEC) for energy and efficiency calibrations, was used for the acquisition of gamma spectra and peak analysis.[1,2] The analytical conditions used for the elemental analysis of the biological samples are presented in Table 1.

Table 1. Analytical conditions of biological samples by INAA.

Categories	Irradiation time	Decay time	Measurement time	Measured Nuclides
Short lived nuclides I	1 ~ 2 min.	5 ~10 min.	300 ~ 500 sec.	^{28}Al, ^{80}Br, ^{49}Ca, ^{38}Cl, ^{66}Cu, ^{27}Mg, ^{37}S, ^{51}Ti, ^{52}V
Short lived nuclides II	1 ~ 2 min.	1 ~ 2 hr.	1000 ~ 1500 sec.	^{139}Ba, ^{82}Br, ^{165}Dy, ^{42}K, ^{56}Mn, ^{24}Na, ^{87m}Sr, ^{69m}Zn
Medium lived nuclides	3 hr.	5 ~ 7 da.	4000 sec.	^{110m}Ag, ^{76}As, ^{198}Au, ^{131}Ba, ^{82}Br, ^{60}Co, ^{134}Cs, ^{181}Hf, ^{42}K, ^{140}La, ^{24}Na, ^{86}Rb, ^{46}Sc, ^{153}Sm, ^{175}Yb, ^{65}Zn
Long lived nuclides	3 hr.	10 ~ 15 da.	20000 sec.	^{141}Ce, ^{60}Co, ^{51}Cr, ^{134}Cs, ^{59}Fe, ^{153}Gd, ^{177}Lu, ^{99}Mo, ^{147}Nd, ^{122}Sb, ^{124}Sb, ^{46}Sc, ^{75}Se, ^{85}Sr, ^{182}Ta, ^{239}Np(U), ^{233}Pa(Th), ^{187}W, ^{169}Yb, ^{65}Zn

2.3 Analytical quality control by CRM

After the optimum analytical conditions, such as neutron flux, irradiation facilities, irradiation time, cooling time, counting time, etc., were pre-estimated according to previous procedures.[3], Five kinds of standard reference material (NIST, the National Institute of Standards and Technology, U.S.A., SRM 1547, Peach Leaves; SRM 1548, Total Diet; SRM 1566b, Oyster tissue; SRM 1567a, Wheat Flour; SRM 1568a, Rice Flour) were used for analytical quality control. The concentrations of 30 elements in the certified reference materials were determined. The concentrations of measured elements were statistically compared with the certified values. The relative errors were in agreement with the certified values within 10%, and the relative errors of As, Fe, Zn were in agreement within 10%. The concentrations of some elements were compared with the recommended values. The relative standard deviations were within 15% except for Au, As, Ca, Cu, Dy, Sc, Ti and Se. In addition, the results of the combined uncertainty at a 95% confidence interval and the detection limit for each element under analytical conditions were evaluated.[4,5]

Table 2. Analytical results of certified reference material (NIST SRM-1547) by INAA.

Element	Concentration, mg/kg		Relative Error, %
	Measured Values	Certified Values	
Al	287 ± 10	249 ± 8	15.3
Au	0.0089 ± 0.0032		
Ba	128 ± 8	124 ± 4	3.23
Br	11.6 ± 0.45	11	5.45
Ca	16990 ± 361	15600 ± 200	8.91
Ce	10.03 ± 0.32	10	0.3
Cl	414 ± 36	360 ± 19	15.0
Co	0.072 ± 0.014	0.07	2.85
Cr	1.65 ± 0.30	1	
Dy	4.25 ± 0.58		
Eu	0.21 ± 0.03	0.17	23.5
Fe	205 ± 6	218 ± 14	5.96
Hf	0.08 ± 001		
K	27100 ± 6600	24300 ± 300	11.5
La	9.72 ± 0.35	9	
Lu	0.039 ± 0.004		
Mg	4260 ± 940	4320 ± 80	1.41
Na	42.6 ± 0.29	24 ± 2	77.5
Nd	8.36 ± 0.33	7	
Rb	20.1 ± 1.02	19.7 ± 1.2	2.03
Sc	0.044 ± 0.002	0.04	
Sm	1.24 ± 0.11	1	
Sr	43.1 ± 3.55	53 ± 4	18.7
Tb	0.11 ± 0.01	0.1	
V	0.41 ± 0.06	0.37 ± 0.03	10.8
Yb	0.145 ± 0.019		
Zn	16.3 ± 1.03	17.9 ± 0.4	8.94

2.4 Data comparison and interpretation

A comparison of samples treated with and without gamma-ray irradiation was performed to check the content variations. Elemental concentrations of Korean space foods are summarized together with the analytical results of a commonly reported Korean diet.[3] Most of the elemental concentrations are equivalent in both samples before and after gamma ray irradiation, but the elemental concentrations of some elements in non-irradiated food samples are different with those of irradiated foods. A comparison of elemental contents analyzed using a short lived radionuclide between Kimchi samples with and without gamma ray irradiation is shown in Fig. 2.

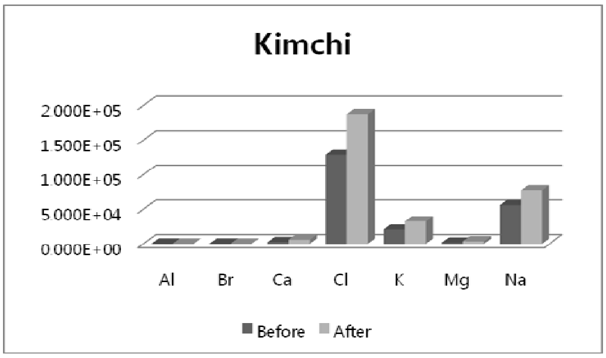

Fig. 2. Comparison of elemental contents between food samples (Kimchi) with and without gamma ray irradiation.

3. Conclusion

The comparison of irradiated Korean food samples was performed to check the effect of contents variation and to compare the analytical results of a commonly reported Korean diet. Five certified biological reference materials (NIST SRM) were used for analytical quality control of the method. The optimum analytical conditions, measurement uncertainty, and detection limit of the measured elements were pre-evaluated. Under the given analytical conditions, the chemical composition of the irradiated foods, measurement uncertainty, and detection limits of the elements measured are evaluated. The content distributions for the essential and toxic elements were compared with reported values considering the aspects of human health and nutrition. Comparisons of the elemental composition between food samples treated with and without gamma-ray irradiation were investigated. These results may be applied toward the identification of irradiated foods.

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