Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 25-26, 2012

Comparative Measurement of Inorganic Elements in Korean Space Foods using Instrumental Neutron Activation Analysis

Yong Sam Chung [a*], Sun Ha Kim [a], Sung Ryel Baek [a], Gwang Min Sun [a], Jong Hwa Moon [a], Jong Il Choi [b], Joo Eun Lee [b]
[a]*Korea Atomic Energy Research Institute, 989 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea.*
[b]*Korea Atomic Energy Research Institute,1266 Shinjeong-dong, Jeongeup-si, 580-185, Korea.*
[*]*Corresponding author: yschung@kaeri.re.kr*

1. Introduction

In April 2008, Korea's first astronaut became a crew member of the international space station and she brought special space versions of traditional Korean dishes such as kimchi, boiled rice, hot red pepper paste, soybean paste soup, ginseng tea, green tea, and ramyun. To date, seventy kinds of Korean space foods (KSFs) have been developed by KAERI.

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 nutrition, as well as a quality control of food and diet. In particular, special food created for consumption by astronauts in outer space may differ with common food on the earth to compensate a decrease in taste and nutrition by hygienic sterilization processing as well as strong cosmic rays, a state of non-gravitation, low pressure, and an enclosed space environment.

An accurate quantitative analysis of trace elements in various kinds of biological samples is serious work for analytical data quality. An neutron activation analysis is a sensitive, non-destructive, multi-elemental analytical method without loss and contamination of a sample by chemical pre-treatment.

The aim of this study is to identify and to compare the distribution of concentrations for essential and functional inorganic elements in six kinds of Korean space foods developed by KAERI in 2011 using INAA.

2. Methods and Results

2.1 Sampling and sample preparation

Among the developed Korean space foods, six kinds of samples, sweet pumpkin porridge, Manila clam porridge, ginseng-chicken porridge, dakgalbi (spicy grilled chicken), chicken curry rice, and ox leg bone-cabbage soup were selected for a quantitative elemental analysis. All ingredients in the food samples are edible and approved by the KFDA,Korea, and microbiological safety and sensory evaluations are performed.

The typical preparation procedure for the samples is as follows: raw material; boiling, cooking or adding additives; mixing with sauce; freezing or freeze drying; lyophilization; vacuum packaging; dehydrated and sterilized food by gamma-ray irradiation.

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

Fig. 1. Several kinds of Korean Space foods.

2.2 Analysis of sample by INAA

The prepared samples were irradiated with thermal neutrons using a 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 a ^{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 the gamma spectra and a peak analysis[2,3]

The optimum analytical conditions are used for the elemental analysis of the biological samples.

2.3 Analytical quality control by CRM

After the optimum analytical conditions, such as the neutron flux, irradiation facilities, irradiation time, cooling time, counting time, etc., were pre-estimated according to previous procedures.[1], 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, and 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.[5,6]

Table 1. 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

In previous work, the analytical results of 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 reported[1]. In this study, a comparative analysis of samples treated with and without gamma-ray irradiation was performed to check the content variations. The elemental concentrations range, mean value, and standard deviation, and the detection limits of six additional Korean space foods are summarized together with the analytical results of a commonly reported Korean diet.[4]

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 due to both inhomogeneity, loss, and contamination in the sample preparation.

3. Summary

A comparison of the elemental contents in six kinds of Korean space food samples using an instrumental neutron activation analysis was performed to check the effect of content variation and to compare the analytical results of a previous study and the common Korean diet reported by Cho, et al. [4]

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 food samples, measurement uncertainty, and detection limits of the elements measured were evaluated.

The content distributions for the essential and functional elements were compared with the reported values considering the aspects of human health and nutrition. These experimental results may be applied to control the amount of food intake and estimating the metabolic parameter of uptake and deposition of inorganic nutriment from foodstuffs.

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.

Acknowledgements

This project has been carried out under the nuclear research and development program by the Ministry of Education, Science and Technology, Republic of Korea.

REFERENCES

[1] Y. S. Chung, S. H. Kim, G. M. Sun, J. M. Lim, J. H. Moon, K. H. Lee, Y. J. Kim, J. I. Choi, J. W. Lee, *J. Radioanal. & Nucl. Chem.*, **291,** 1 (2012) 223-229,

[2] G. Erdtmann, 'Neutron Activation Tables', Vol.6, New York, 1976.

[3] IAEA, 'Handbook on Nuclear Activation Analysis Data', IAEA Tec. Rep. No. 273, 1987.

[4] S. Y. Cho, J. K. Lee, S. H. Kang, Y. S. Chung, J. Y. Lee, *J. Radioanal. Nucl. Chem.*, **249**, 1 (2001) 39-45.

[5] L. A. Currie, *Anal. Chem.*, 40 (1968) 586.

[6] URACHEM/CITAC, 'Quantifying Uncertainty in Analytical Measurement', 1999.