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Determine of heavy metal contents in fresh vegetable by using nuclear activation analysis technique

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Abstract

Vegetables may contaminate with heavy metals that are toxic to the body. Those of them come from soil, water and air, which are the cultivation of plants. In addition, each vegetable has the capacity to accumulate heavy metals or elements of various kinds. This study aimed to compare the results of analyzing heavy metal by two techniques that were Neutron Activation Analysis (NAA) and Atomic Absorption Spectrometry (AAS) techniques. Both of them were used to analyze heavy toxic metals (Cd, Co, Fe, Pb, Cr, Zn) and others in vegetable samples. The study found that heavy metals concentration were Co, Fe, Cr that could be analyzed by NAA. Co, Fe, Zn were found by AAS. The results showed that both techniques had the same results of heavy metals that Co and Fe were different in Cr and Zn.

Keywords: Neutron Activation Analysis, Atomic absorption Spectrometry, Heavy metals

1. Introduction

Heavy metals are toxic when accumulating in human body. The toxic substances come from the environment such as soil, water, air, food, cosmetics or household appliances. Accumulation of heavy metals in human tissue through consumption of contaminated vegetables can cause hazardous impacts on health. Each vegetable has the absorption capacity to accumulate heavy metals or element of various kinds. Heavy metals in vegetables are called traces to ultra-trace elements. Therefore, the determination of heavy metals in vegetables is essential. In addition, to allow consumers to get the information of the safety food, analyzing of the amount and type of heavy metals are necessary. There are a few techniques to determine the elements in food such as flame atomic absorption spectrometry (FAAS), inductively coupled plasma atomic emission spectrometry (ICP-AES),

inductive couple plasma mass spectrometry (ICP-MS) etc. Besides those mentioned above, neutron activation analysis has also been shown as excellent tool for trace and ultra-trace analysis [1].

Neutron Activation Analysis (NAA) is a nuclear process for determining the type and the concentrations of materials. The technique of analyzing is very high sensitivity. It can be used to analyze chemical composition with a concentration of the sample in ppm to ppb without the amount for sample quantities [2]. The method is based on neutron activation, and therefore requires a source of neutrons. The sample is bombarded with neutrons, causing the elements to form radioactive isotopes. The radioactive emission and radioactive decay paths for each element are well known. Using this information, it is possible to study spectra of the emissions of radioactive sample, and determine the concentrations of the elements within it. A particular advantage of this technique is that it does not destroy the samples, and thus has been used for analysis of works of art and historical artifacts. NAA can also be used to determine the activity of a radioactive sample. There are 2 approaches of activation analysis: Destructive or radiochemical activation analysis (RNAA) and Non-destruction or Instrument Neutron activation analysis (INAA) [3].

Atomic absorption spectrometry (AAS) is an analytical technique that measures the concentrations of elements. Atomic absorption is so sensitive that it can measure down to ppb. in a sample. The technique makes use of the wavelengths of light specifically absorbed by an element. They correspond to the energies needed to promote electrons from one energy level to another, higher energy level. A detector measures the wavelengths of light transmitted by the sample, and compares them to the wavelengths which originally passed through the sample [4].

The objective of the study is to develop agricultural production value. For the safety of consumers, then determine techniques to measure contaminants in agricultural productivity without damaging the samples. The measurement values with high resolution and precise objectives of the study were as follows: 1) to obtain information on the amount and type of heavy metals in the popular edible vegetables, and 2) to compare the results from measurements by INAA and AAS.

2. Materials and Methods

Sample Preparation for INAA

By random selection, the sample of vegetables, lettuce and gotu gola, were selected from a large market in the middle area of Bangkok Thailand. Samples were dried in an oven as far as possible, and then each of samples was blended into the smallest pieces. Weighing and packing them into polyethylene bag, and then heat-sealed. The code of the samples was written down and recorded the weight. The reference material (US Department of Commerce National Institute of Standard and Technology Gaithersburg, Standard Material 1573a Tomato Leave) was used as a comparator standard for gamma spectrum evaluating using the relative method of standardization for neutron activation analysis.

Element Analysis

The samples and standard material were irradiated in turn at one of the inner radiation chambers of nuclear research reactor (PP-1), Bangkok, Thailand. Neutron flux, neutron activation of samples was irradiated for short-lived and long-lived radioisotopes, as shown in Table 1.

Table 1 The conditions for analyzed in INAA

Neutron flux	Time for irradition	samples	elements
2.74×10^{12} n/cm^2	10 sec	lettuce	Al, Mn, Ca, Br, Mg, Na, Cl
		goto gola	Al, Mn, Ca, Br, Mg, Na, Cl
	10 hr	lettuce	Co, Fe, Cr, La
		goto gola	Co, Fe, Cr, La

3. Results and Discussion

Result of INAA

After each successive irradiation, the samples and standard were counting time. Characteristic gamma rays belonging to the produced radionuclides were recorded by a high-purity germanium detector (HPGe) coupled with a computer-based multichannel analyzer. The radionuclides, half-lives and gamma-ray to calibrate energies were Cs-137: 661.7 keV and Co-60: 1173.24, 1332.5 keV. The peak area of gamma ray spectrum of samples and standard were evaluated using HPGe semiconductor detector. The gamma-ray spectroscopy accumulated by program computer. The area under the peaks of spectrum after neutron activation of materials were integrated and converted into concentration using the relative method of standardization for neutron activation analysis. The results of concentration of elements in the selected samples are shown in Table 2.

Table 2 The concentration of elements in the samples at decay time 10 sec

Samples	Al(ppm)	Mn(ppm)	Ca(%)	Br(ppm)	Mg(%)	Na(%)	Cl(%)
Lecttuce	3524±318	68.81±0.22	1.33±0.06	20.36±3.49	0.36±0.07	0.29±0.7	1.79±0.04
Gotu gola	427.49±18.92	625.53±17.41	1.42±0.08	127.58±4.02	1.32±0.07	1.09±0.05	2.62±0.00

Preparation of AAS

The same samples of vegetables were dried in an oven as far as possible. Then each of them was blended in to the smallest pieces and weighed, burnt the same samples of vegetables to ash, and digested by concentrated nitric acid for 24 hours and filter.

The Process Preparation of Standard Solution for AAS

Standard Solution, Cd, Co, Fe and Pb The standard solution prepared from stock solution at a concentration of 0.5, 1.0, 3, 10.0, 15.0 ppm, using micropipette of stock solution 1000 ppm, and adjust volume with 0.01 M of nitric acid (0.01 M HNO_3) until 10 ml. The solutions contain various concentrations respectively, taking a total solutions to analyze by calibration with the standard curve. The results of concentration of heavy metals in lettuce, gotu gola are shown in Table 3-5. Moreover, Table 6 and 7 showed the comparison of heavy metals in lettuce and gotu gola by INAA and AAS

Table 3 The concentration of element in samples (ppm.) at decay time 10 hours

Samples	Co	Fe	Cr	La
Lettuce	1.01±0.16	1506±54.34	0.57±0.13	4.36±0.30
Gotu gola	0.61±0.16	458.81±87.44	1.2±0.06	1014±0.45

Table 4 Concentration of heavy metals in lettuce

Heavy metal	Cd	Co	Fe	Pb	Cr	Zn
ppm	<0.001	7.2	530.4	<0.001	<0.001	67.8

Table 5 Concentration of heavy metals in gotu gola

Heavy metal	Cd	Co	Fe	Pb	Cr	Zn
	<0.001	8.3	865.3	<0.001	-	110.4

Table 6 Comparing heavy mental in lettuce by INAA and AAS

technique/heavy metal (ppm)	Cd	Co	Fe	Pb	Cr	Zn
INAA	-	1.01±0.16	1506±54.34	-	0.57±0.13	-
AAS	<0.001	7.2	530.4	<0.001	<0.001	67.8

4. Conclusion

Determination of heavy metals by the Neutron Activation Analysis technique (NAA) method using a specific tool (Instrument Neutron Activation Analysis: INAA) showed that lettuce and gotu gola had the same heavy metals: Co, Fe, Cr, Sc and La. The quantitative analysis of heavy metals from the technical Atomic Absorption spectrometry (AAS) method used Flameless (Flame Atomic Absorption Spectrometry.). They were the same heavy metals: Co, Fe, and Zn in lettuce and gotu gola.

By comparison of both techniques, the toxic heavy metals which was harmful to the body were the same type of Co, Fe, but different in Cr and Zn. Whereas, Cr could be analyzed by INAA, and Zn could be analyzed by

AAS. Zn could not be analyzed by INAA due to the spectra emission energy of Zn, and Br was quite the same [5, 6]. In consequence, the spectrum energy of Br would be overlapped to Zn. The finding of t - test for independent samples found that for the same results of heavy meals, two techniques showed the less of standard deviation and no significant difference at 0.05. Thus, vegetables (lettuce and gotu gola) could be analyzed for elements using INAA. Generally, the results showed that Al, Mn, Ca, Br, Mg, Na, Cl, Co, Fe, Cr and La were established in two vegetables. Moreover, by comparison to the standard value of Thailand National food Institute indicated that Fe and Cr are the toxic heavy metal concentration found in sampling vegetables which is higher than standard (TNFI) [7]. This data should be used to build database for vegetables' growth and consumption in Thailand.

Table 7 Comparing heavy mentals in gotu gola by INAA and AAS

technique/metal (ppm)	Cd	Co	Fe	Pb	Cr	Zn
INAA	-	0.61±0.16	458.81±87.44	-	1.2±0.06	-
AAS	<0.001	8.3	865.3	<0.001	-	110.4

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