Nucl. Sci. and Tech, Vol.4, No. 1 (2014), pp. 76-83

Nuclear Science and Technology

Journal homepage: https://jnst.vn/index.php/nst

Some results of NAA collaborative study in white rice performed at Dalat Nuclear Research Institute

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Abstract: White rice is a main food for Asian people. In the framework of Forum for Nuclear Cooperation in Asia (FNCA), therefore, the eight Asian countries: China, Indonesia, Japan, Korea, Malaysia, the Philippines, Thailand and Vietnam selected white rice as a common target sample for a collaboration study since 2008. Accordingly, rice samples were purchased and prepared by following a protocol that had been proposed for this study. The groups of elements that were analyzed by using neutron activation analysis in the white rice samples were toxic elements and nutrient elements, including: Al, As, Br, Ca, Cl, Co, Cr, Cs, Fe, K, Mg, Mn, Na, Rb and Zn. The analytical results were compared between the different countries and evaluated by using the Tolerable Intake Level of World Health Organization (WHO) and Recommended Dietary Allowance or Adequate Intake (AI) of the U.S. Institute of Medicine (IOM) guideline values. These data will be very useful in the monitoring of the levels of food contamination and in the evaluation of the nutritional status for people living in Vietnam and other Asian countries.

Keywords:*White rice, neutron activation analysis, FNCA,tolerable intake level, dietary reference intakes, adequate intake.*

I. INTRODUCTION

FNCA (Forum for Nuclear Cooperation in Asia) was formally established in March 1999 at the 10th session of the International Conference on Nuclear Cooperation in Asia region ICNCA (International Conference for Nuclear Cooperation in Asia) initiated and funded by the Japanese government. FNCA is supposed to enhance mutual understanding, exchange of information and experience to social and economic development in Asia through research, collaboration, technology applications initiatives for peaceful purposes. Up to 2012, FNCA has 12 member countries, including: Australia, Bangladesh, China, Indonesia, Malaysia, Japan, Kazakhstan, Korea, Mongolia, the Philippines, Thailand and Vietnam.

NAA (Neutron Activation Analysis) is one of the projects under the ResearchReactor Utilization in the framework of the forum FNCA. Vietnam has participated in the FNCA since 2000.

In the FNCA workshop held in Dalat, Vietnam, in 2008, the eight among twelve member countries of the FNCA which are China, Indonesia, Malaysia, Japan, Korea, the Philippines, Thailand and Vietnam, agreed to participate in a collaborative study on the analysis of food samples as a sub-project thematic in NAA. White rice has been selected as research subjects for this work because of its importance as the basic staple food for people wholives in Asia. Specifically, the major rice producing countries in Asia are China, India, Indonesia, Malaysia, Bangladesh, Thailand,

https://doi.org/10.53747/jnst.v4i1.217
Received 5 March 2014, accepted 14 March 2014

Vietnam, etc. These countries accounts for over 80% of production and consumption of rice in the world. This highlights the importance of the information gained from the study because rice is the staple food as well as providing a large portion of the calories in the Asian diet [1].

The objective of this study was to determine the inorganic elements in the white rice of Vietnam and compared it with seven Asian countries by NAA method, these results are preliminary by the level of nutrients and toxic elements in rice for safety.

II. EXPERIMENTS

A. Sample collection and preparation

Eighteen samples were collected from the Department of Agriculture and Rural Development Centre Tiengiang province agricultural seed wherein rice is the most common type on the market which are presented in Table I.

Table I. The information sampling of Vietnam's rice samples at Department of Agriculture and Rural Development Centre Tiengiang province

No.	Type
1	Ham Chau Rice
2	IR 50404 Rice
3	Japan 504 Rice
4	Jasmine 85 Rice
5	Jasmine Rice
6	OM 4218 Rice
7	OM 4900 Rice
8	OM 5451 Rice
9	OM 5472 Rice
10	OM 5976 Rice
11	OM 6162 Rice
12	OM 6377 Rice
13	OM 6976 Rice
14	Otim Rice
15	Seri Rice
16	Tai Nguyen Rice
17	Taiwan Fragrant Rice
18	Thom Lai Rice

The collected rice samples were brought to the lab and washed with distilled water and then dried in a drying oven at a temperature of 60 ^{0}C for 4 hours, then ground into fine particles using an agate mortar in order to prevent contamination. Rice samples were repeatedly ground until a particle size of 60 meshes. Finally, the samples were subdivided into subsamples weighing from 100-300 mg prior to analysis by INAA.[1]

B. Analysis

The rice samples were analyzed by INAA in Dalat Nuclear Research Institute. The analytical procedures are followed with ISO/IEC 17025 [2]. A concurrent analysis of reference standard samples for quality control was made for each batch of analysis. Analyses were made using a combination of both short and long irradiations. The HPGe detector with

multichannel analysis system was used to measure the gamma rays from the sample after irradiation. The concentration of the elements was calculated using the relative method and/or k-zero method.

III. RESULTS AND DISCUSSION

A. The content of elements in white rice samples

The result of standard reference material was shown in Table II and the result of fifteen elements concentrations in eighteen samples of white rice are in Table III.

In Table II, The average result are caculated through 3 times analysis, it's not much different to the value of certificate. The Z-score of all elements is lower than 2, that mean this results are satisfactory.

Table II. Result of standard reference material IAEA-V-10

No.	Ele.	Aver.	Sd.	Cert.	Z-score	Ana/Cert
1	Mg	1579	121	1360	1.81	1.161
2	Ca	20865	2892	21600	-0.25	0.966
3	Cl	7360	100	-	-	-
4	Mn	46	5	47	-0.20	0.979
5	Na	507	9	500	0.78	1.014
6	K	20119	3530	21000	-0.25	0.958
7	Br	7.3	0.5	8	-1.40	0.913
8	Sc	0.016	0.002	0.014	1.00	1.143
9	Cr	6.6	0.5	6.5	0.20	1.015
10	Fe	196	21	186	0.48	1.054
11	Co	0.15	0.03	0.13	0.67	1.154
12	Zn	25.5	2.2	24	0.68	1.063
13	Rb	7.7	0.5	7.6	0.20	1.013

Aver: Average result;
Sd: Standart deviation
Cert: Certificate

In Table III, the concentration of Mg element are not analyzed in all samples, elements concentration of Al, Ca and Fe are not obtained and reported limit of detection, the result of other elements are included concentration and uncertainty. The highest concentration are K element, the lowest come from Co and Cs. The other elements have no significant differences between all samples except Rb.

B. Comparing the elements concentration in white rice of 8 countries

Results of fifteen elements: Al, As, Br, Ca, Cl, Co, Cr, Cs, Fe, K, Mg, Mn, Na, Rb and Zn in rice samples determined by eight participating countries are summarized in Table 4. The results of quality control analysis for fifteen elements are summarized as a relative error (%) with absolute value and are shown in Fig. 1. The relative error of most of the elements evaluated in Fig. 1 were less than 15%, except for some few elements such as Al of Malaysia; Co of Vietnam; Mg of China, Korea and Vietnam, Mn and Na of Korea rice samples.

Table III. The analytical results of eighteenwhite rice samples in Vietnam

No.	Type	Al		As		Br		Ca		Cl		Co		Cr		Cs		Fe		K		Mg		Mn		Na		Rb		Zn	
		C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.	C.	U.
1	Ham Chau Rice	<3		0.12	0.02	0.43	0.05	<165		294	11	0.031	0.006	<0.4		0.026	0.007	<14		518	10	NA.		8.0	0.2	22.6	0.3	1.5	0.3	23.0	0.5
2	IR 50404 Rice	<8		0.16	0.04	0.17	0.05	<160		242	11	0.026	0.008	<0.5		0.061	0.010	<10		1649	17	NA.		15.9	0.2	11.5	0.2	11.4	0.6	21.3	0.6
3	Japan 504 Rice	<4		0.06	0.02	0.78	0.07	<120		407	14	0.022	0.008	<0.4		0.019	0.008	<14		527	11	NA.		5.1	0.1	48.5	0.3	1.0	0.3	21.7	0.8
4	Jasmine 85 Rice	<5		0.13	0.03	0.31	0.07	<185		235	30	0.028	0.008	<0.5		0.056	0.012	<18		1543	17	NA.		19.1	0.1	18.2	0.3	10.3	0.7	22.8	0.8
5	Jasmine Rice	<4		0.12	0.02	0.22	0.04	<100		192	10	0.030	0.008	<0.5		0.052	0.007	<20		453	9	NA.		3.5	0.1	9.0	0.2	1.9	0.4	19.2	0.6
6	OM 4218 Rice	<5		0.15	0.04	0.22	0.06	<130		282	25	0.031	0.008	<0.6		0.045	0.009	<17		1548	16	NA.		12.8	0.1	17.1	0.3	8.3	0.6	22.2	0.7
7	OM 4900 Rice	<7		0.10	0.03	0.34	0.07	<140		346	31	0.043	0.008	<0.5		0.044	0.010	<19		1780	18	NA.		16.0	0.1	14.8	0.3	5.9	0.5	26.2	0.7
8	OM 5451 Rice	<7		0.15	0.03	0.29	0.06	<120		199	23	0.036	0.007	<0.6		0.046	0.008	<16		1254	16	NA.		11.8	0.1	18.8	0.3	11.4	0.7	22.6	0.7
9	OM 5472 Rice	<4		0.11	0.03	0.26	0.06	<100		293	22	0.034	0.007	<0.5		0.047	0.011	<22		1414	15	NA.		11.9	0.1	14.9	0.2	9.7	0.6	24.8	0.7
10	OM 5976 Rice	<5		0.11	0.03	0.18	0.05	<110		186	11	0.031	0.009	<0.6		0.043	0.011	<17		1227	14	NA.		12.7	0.1	11.3	0.2	10.7	0.6	24.0	0.7
11	OM 6162 Rice	<10		0.08	0.03	0.17	0.05	<120		307	13	0.043	0.009	<0.4		0.039	0.011	<16		1509	16	NA.		13.9	0.2	12.6	0.2	8.3	0.6	23.7	0.7
12	OM 6377 Rice	<7		0.14	0.03	0.23	0.06	<120		266	27	0.058	0.009	<0.6		0.063	0.011	<13		1636	16	NA.		16.8	0.1	13.1	0.2	15.7	0.7	23.4	0.8
13	OM 6976 Rice	<6		0.11	0.03	0.34	0.05	<100		382	14	0.027	0.007	<0.5		0.038	0.009	<19		1487	16	NA.		6.7	0.3	13.5	0.2	4.8	0.5	25.0	0.7
14	Otim Rice	<4		0.17	0.03	0.47	0.04	<100		225	11	0.044	0.009	<0.3		0.051	0.013	<28		568	11	NA.		7.5	0.1	14.4	0.2	2.8	0.5	21.4	0.7
15	Seri Rice	<4		0.22	0.02	0.18	0.04	<135		236	11	0.041	0.009	<0.4		0.074	0.011	<21		501	9	NA.		5.4	0.1	13.5	0.2	8.2	0.7	21.1	0.7
16	Tai Nguyen Rice	<3		0.06	0.02	0.65	0.07	<100		378	12	0.039	0.009	<0.5		0.016	0.007	<16		470	9	NA.		5.2	0.1	40.9	0.3	1.0	0.3	17.5	0.7
17	Taiwan Rice	<5		0.11	0.03	0.23	0.04	<110		330	12	0.024	0.010	HL		0.066	0.010	<22		842	13	NA.		5.9	0.1	10.5	0.2	7.5	0.6	24.8	0.9
18	Thom Lai Rice	<3		0.08	0.02	0.40	0.04	<110		208	9	0.031	0.008	<0.5		0.029	0.007	<14		463	8	NA.		3.9	0.1	7.8	0.2	1.2	0.4	19.8	0.6
Average		**<5**		**0.12**		**0.33**		**<124**		**278**		**0.034**		**<0.5**		**0.045**		**<18**		**1077**		**NA.**		**10.1**		**17.4**		**6.8**		**22.5**	

Unit: mg/kg; C. : Concentration; U. : Uncertainty; NA. : Not Applicable

Table IV. The analytical results of white rice (unit: mg/kg) [1]

Ele.	[a]China	Indonesia	[b]Japan	Korea	[c]Malaysia	[d]Philippine	Thailand	[e]Vietnam (This work)
Al	<4.46	<20.52	<1.66	<1.38	<2	<2.82	<2.33	<5
As	0.55	0.08	0.1	0.13	0.11	0.07	0.09	0.12
Br	0.35	0.45	0.5	0.19	13.6	5.35	0.43	0.33
Ca	N.A	<4.53	49.5	53.9	<10	39.1	<15	<124
Cl	264	210	239	193	225	236	239	278
Co	<0.3	0.77	N.A	0.005	0.026	N.A	0.022	0.034
Cr	0.25	0.38	N.A	<0.01	<0.08	N.A	<0.4	<0.5
Cs	<0.07	0.09	N.A	0.009	0.016	N.A	N.A	0.045
Fe	N.A	4.65	N.A	1.58	<5	N.A	<16	<18
K	977	739	611	660	573	637	620	1077
Mg	379	131	149	241	<150	90	59	N.A
Mn	9.25	9.95	7.66	9.06	6.19	7.89	9.23	10.1
Na	10.3	7.7	5.69	4.1	13.7	5.17	4.58	17.4
Rb	<3.35	7.64	N.A	1.39	2.1	3.24	1.34	6.8
Zn	15.3	24.2	18.5	15.3	10.1	15.4	21.4	22.5

N.A: not applicable; (a) Mean values are derived from four different samples; (b) Mean values from a sample of known origin and two samples of unknown origin; (c) Mean values are derived from two different samples; (d) Mean values from four samples of unknown origin; (e) This work, average value of eighteen samples from known origins.

As can be seen from Table 4, the Al concentrations in rice saples from all participating countries were below the detection limit, hence only the limit of detection (LOD) were reported. Indonesia had an LOD value of 20.52 for Al, highest compared to other countries. Korea and Japan had the lowest LOD values in the eight countries. K concentration range is from 553 to 1077 mg/kg. K in Vietnam rice samples had the highest value which is 1077 mg/kg. Cl and Mg have similarly eminent values. Seven elements of As, Br, Cl, K, Mn, Na and Zn were determined by all participating countries, but LODs were not reported. As content of China had the highest value, 0.55 mg/kg and the other countries have equivalent levels of As, 0.1 mg/kg. Br concentrations of Malaysia, Indonesia and the Philippines were more than a dozen times higher than those of other countries. Five elements Cl, K, Mn, Na and Zn did not differ significantly and the average content of the standard deviation were 236±27, 737±178, 8.67±1.32, 8.58±4.84 and 17.8±4.7 mg/kg respectively. Concentrations of Mg were reported by six countries excluding Malaysia and Vietnam. Thailand showed the lowest levels of Mg, 59 mg/kg, while the Mg content of China was the highest at 379 mg/kg. Only three countries namely Japan, South Korea and the Philippines reported Ca data which were 49.5, 53.9 and 39.1 mg/kg respectively. In addition, the levels of Cr, Cs and Fe in Indonesian rice were higher compared to those of other countries.

C. Dietary intake level of the toxic elements and nutrition elements of 8 countries

To estimate the dietary intake level of inorganic constituents on consumption of white rice, it was necessary to conduct a survey of daily consumption of rice. For example, the amount of the average daily consumption of rice in Korea in 2000 was 256 grams, or in Vietnam in 2010 is 360 gram [3, 4]. However, rice consumption varies in different countries, and therefore a consensus value of 300 grams/day was set, to be able to compare the intake of As, Cl, K, Mn, Na and Zn from rice consumption in all participating countries. This is to assess whether or not, the ingested levels of the elements can be considered as harmful or beneficial to human health. Data are shown in Table 5.

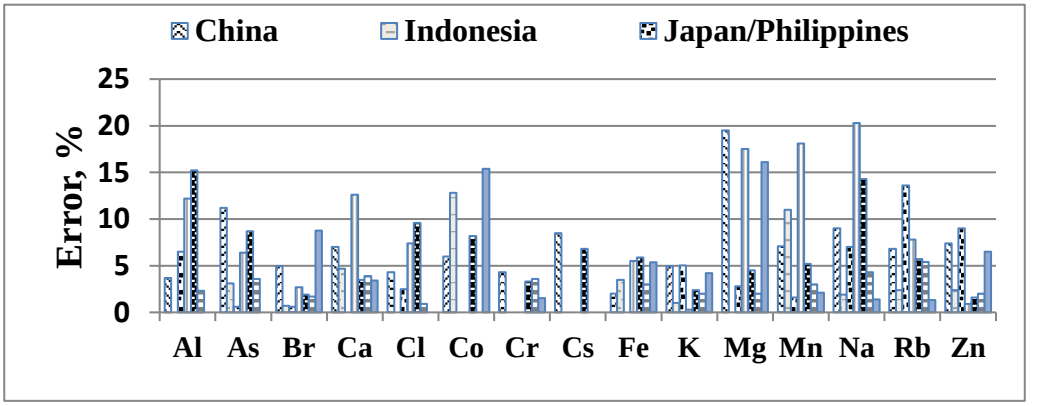

Fig. 1. The absolute value of the relative error (%) of the value analysis to value certification/reference.

Table 5. The RDA value of 6 elements each day through white rice, assuming consumption of 300 grams /day for adults[1]

Ele.	China	Indonesia	Japan	Korea	Malaysia	Philippine	Thailand	Vietnam (This work)
As (µg)	165	24	30	39	33	21	27	36
Cl (mg)	79.2	63	71.7	57.9	67.5	70.8	71.7	83.4
K (mg)	293	222	183	198	172	191	186	323
Mn (mg)	2.78	2.99	2.30	2.72	1.86	2.37	2.77	3.03
Na (mg)	3.09	2.31	1.71	1.23	4.11	1.55	1.37	5.22
Zn (mg)	4.59	7.26	5.55	4.59	3.03	4.62	6.42	6.75

The WHO has established a Tolerable Intake Level for weekly consumption, which is 15 mg/kg of body weight for As [5]. Assuming a body weight of 70 kg of an adult, the Tolerable Intake Level for As daily consumption will be 150 microgram As. In addition, the Institute of Medicine (IOM) in the United States has established the value of the Recommended Dietary Allowance (RDA) or adequate intake (AI) for the necessary elements [6, 7]. Zn has the highest RDA of 11 mg/day for men. AI highest values for Cl, Mn defined by the IOM is 2.3 g/day for all adults, for Na and K, the highest AI values are respectively 1.5 and 4.7 g/day.

Calculations for the RDA or AI for the elements As, Cl, K, Mn, Na, Zn are shown in Figure 2.Tolerable Intake Level of As in China is higher than Tolerable Intake Level of WHO which was about 10%, for the other countries. The level of Mn is almost equal to the value of the RDA of IOM. This shows just rice consumption of 300 g/day may provide sufficient Mn necessary for the human body. The intake level for the remaining elements (Cl, K, Na and Zn) were below the RDA or AI. In the case of Zn, the range of daily consumption from 21.6% (Malaysia, Indonesia) to 51.9% (Indonesia) can only supply approximately 21.6% to 51.9% Zn necessary for the human body. Similarly, consumption of Cl at 2.5% to 3.6%, K at 3.7% to 6.2% and 0.3% Na were below the recommended values. These essential elements can be obtained anyway, from other foods such as meat, fish, vegetables, eggs, milk, etc. which are eaten together with the rice.

IV. CONCLUSIONS

A collaborative study on the determination of elemental abundance in rice using NAA was participated in by eight countries namely China, Indonesia, Japan, Korea, Malaysia, the Philippines, Thailand and Vietnam. A total of fifteen elements in thirty five samples of white rice collected from eight countries were determined by INAA method. Within the framework of project participants FNCA/NAA, NAA laboratory of Vietnam has collected and analyzed fifteen elements in eighteen samples of white rice types. Results of Vietnam's rice has been compared with the results of the seven countries participating members.

The analytical data were compared between the participating countries and assessed according to the daily intake using the guideline values set by the WHO and IOM. The results showed an elevated amount of As in Chinese rice which exceeded by approximately 10%, the RDA recommended by WHO. In addition the research gave an overview of the levels of nutritional elements Na, Mn, Cl, K and Zn in rice consumed in the eight countries. Information on the intakes of Mn (of approximately 100%), Zn, Na, Cl (21.6÷51.9) % and K (lower than 10%) in comparison to the requirements of IOM was obtained from the study.

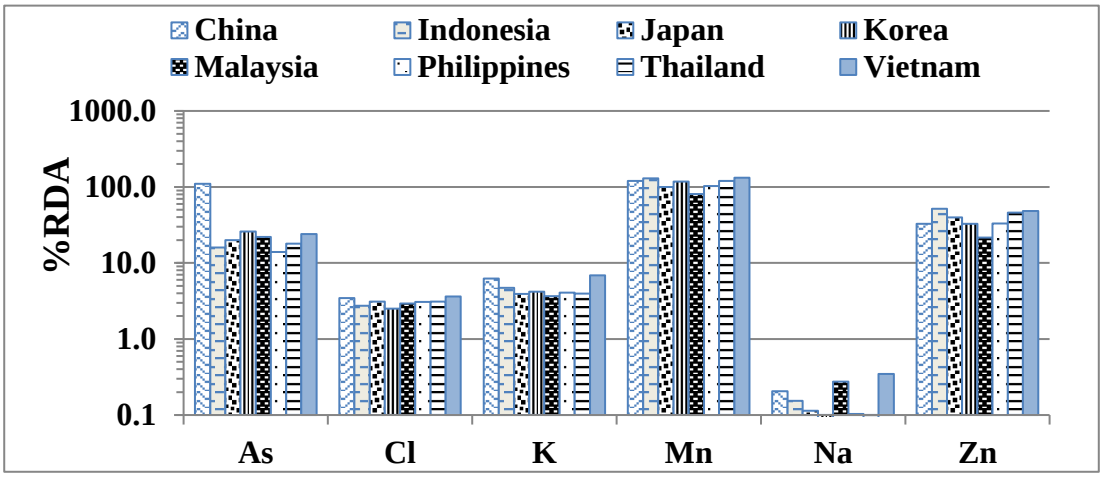

Fig. 2. Assess daily nutrient consumption (%) for the six elements through white rice.

In future, FNCA will carry on to expand the scope of research in elemental abundance in food samples to strengthen the collaboration between Asian countries for the continued application of NAA in the assessment for contamination and mineral potentiality in the basic foodstuffs.

ACKNOWLEDGEMENTS

We would like to thank the MEXT of Japan for support of this research.

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