Essential Minerals of Rice in West Java And Its Daily Intake Estimation

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ABSTRACT

Rice (*Oryza sativa L.*) is the staple food for more than half of the world's population and a major source of essential minerals. Essential minerals such as cobalt (Co), chromium (Cr), iron (Fe), selenium (Se) and zinc (Zn) play an important role in metabolism and physiological function. Information of rice micronutrient and its quality content is limited whereas it is important for estimating daily intake and its contribution to Recommended Dietary Allowance (RDA). The research was aimed to determine the micronutrient content in rice from 12 regions in West Java by means of neutron activation analysis (NAA) and estimate the nutrient intake from rice. The samples were irradiated with thermal neutron flux of 10^{13} n.cm^{-2}.s^{-1} at the rabbit system facilites of multipurpose reactor G.A. Siwabessy. Quality control of data analysis was assessed using standard reference materials (SRM) national institute of standards and technology (NIST) Rice Flour 1568a and gave good results with %acuracy 95-105% and 0.02-8.6% relative standard deviation (RSD). The results of the content of Co, Cr, Fe, Se and Zn in rice, were in the range of 0.003 to 0.220, ≤0.001-0.679, ≤0.060-18.36, ≤0.020-0.975, 8.558-28.83 mg/kg respectively. These results were then used to estimate its daily intake status in West Java. The daily intake of Co and Cr element reported, generally are sufficient. While for Fe, Se and Zn; almost all regions observed give low contribution to the recommended dietary allowance (RDA) value, except Se in Garut which is exceeded its RDA value. It is generally concluded that rice is the main contributor of trace element intake observed.

INTRODUCTION*

Essential mineral elements plays an important role in biochemical processes due to their direct or indirect effects on human metabolism [1,2]. Essential mineral such as cobalt (Co) as a part of vitamin B12, stimulates the production of red bloods cells, related to the activities of brain and nervous system [2,3]. Chromium (Cr) is needed to help maintaining normal blood glucose levels/ insulin activity [3]. Iron (Fe) is component of hemoglobin and numerous enzymes, prevents microcytic hypochromic anemia [3,4]. Selenium plays important biological activities, especially related to hormones metabolism and the immune system [2] due to its antioxidant and anticancer properties [5] and zinc (Zn) is connected to the metalloproteinases, that are involved in processes of gene regulation [2,3].

Micronutrients content in rice in Food Composition Tables in Indonesia is still very limited, obsolete and generally are based on a compilation of nutrient data from other countries [6], so that the data can not describe representatively of nutrient composition in Indonesian rice and also nutrient status of people in some population. Therefore the latest data information about the composition of the essential mineral content in rice is indispensable.

Multi element methods for rice analysis are necessary due to the increasing needs for more detailed information of nutrient composition in food and nutrient status of a person in a population. For these purposes a wide range of instrumental analytical techniques have been used. Several methods such as flame atomic absorption spectrometry (FAAS) and inductively coupled plasma mass spectrometry (ICPMS) are rather popular and frequently used for elemental determination in rice samples by several countries [7–9]. However, these techniques imply a prior

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total destruction, which may lead to the contamination problems from the reactants employed. Moreover, the samples destruction is strongly depend on the chemical composition of the sample and on the element to be determined. The standard used in AAS is made of each element compounds, making it less effective in terms of preparation time and poses high risk due to the contamination of contaminants chemical compounds. Given the nutritional benefits and health issues associated with Se supplementation and other essential mineral, it is very important to ensure that rapid and sensitive analytical methods for simultaneous determination of multielements including Se in rice are available. Instrumental neutron activation analysis (INAA) is known as a powerful technique for the determination of various elements in food samples. It is also a non destructive, sensitive, selective, simultaneous multi element analytical technique with a very low detection limits that can be used for the investigation of rice samples [10].

Some countries are already using NAA method for the determination of minerals in rice. Moon et al undertake collaborative studies for the analysis of white rice in seven Asian countries with the results obtained some elements such as As, K, Mn, Na, Co, Cr, Fe, Zn etc and daily intake for As, K, Mn, Na, Zn [11]. Research related to the characterization of minerals on rice in Indonesia have been conducted by M.Wiyono et al which focus on several areas in Java with the results of the mineral content in rice in accordance with the seven other Asian countries [12]. It implies that rice provides important information of mineral supplement as well as a large portion of calories for Asians. As scientists have focused their research on health impacts caused by mineral nutrient deficiency and hazardous elements, public concerns about mineral intake by dietary food is rising worldwide [11].

West Java was chosen for this research because the population of this province are the highest in Indonesia [13], it is one of the main production center of rice with a contribution of 17.6% of the national rice production, capable to meet the needs of rice for 42.2 million people, and give surplus of more than 1 million tons for the population outside of the province [14].

The aim of this research was to determine the essential minerals in the rice and estimate the nutrient intake of local inhabitant observed from rice as main staple food in their diet, that is why the rice samples was taken based on the most frequently consumed in several area of West Java. The rice samples were bought in traditional markets based on mostly consumed in 12 regions of West Java. This research was also assessed the daily intake estimation of Co, Cr, Fe, Se and Zn related to nutrient status of people in West Java.

EXPERIMENTAL METHOD

Materials

Standard reference materials Typical Diet (SRM 1548a), is obtained from the National Institute of Standards and Technology, demineralized water (>18 MΩ cm^2) was used throughout this work, the multi-elements standard solutions (ICP E.Merck), tritisol standard solution (E.Merck), polyethylene vial and various types of rice such as *setra*, *kurmo*, *jembar*, and *pandan wangi*.

Sample collection

White rice samples were collected from traditional markets in Bogor (*kurmo* and *jembar*), Sukabumi (*setra* and *jembar*), Bandung (*kurmo* and *jembar*), Cirebon (*setra*), Bekasi (*setra*), Tasikmalaya (*setra* and *pandan wangi*), Indramayu (*setra*), Lembang (*setra*) , Majalaya (*setra*), Garut (*setra*, *jembar* and *kurmo*), Cianjur (*setra* and *jembar*) and Karawang (*setra*), West Java. *Setra* is trade name of *IR 64* rice variety while *jembar*, *kurmo* and *pandan wangi* are local rice variety in West Java. Fig. 1 shows the sampling locations.

Fig. 1. Sampling location in twelve regions in West Java province

Standard and sample preparation

Standard solution were prepared for 1, 1.01, 10, 10.2 and 10 µg of Co, Cr, Fe, Se and Zn, respectively from standard solution of ICP multi element standard solution VI E.Merck and additional 49.9 µg of Fe from standard solution of 1000 mg Fe, ($FeCl_3$ in 15% HCl) Tritisol E.Merck.

A representative portion from each white rice sample was crushed to a homogeneous fine powder by titanium blade-blender. About 40 mg of sample and NIST 1548a were each weighed and put into 0.3 mL polyethylene vial and then sealed by heat. Samples were then irradiated along with SRM 1548a and mix standard for two hours at 15 MW and thermal neutron flux of 10^{13} $n.cm^{-2}.s^{-1}$ in rabbit system facilites of multipurpose reactor G.A. Siwabessy [3,15]. The properties of used radionuclides, ɣ -energies, and other details of the analysis are presented in Table 1.

Table 1. Nuclear parameters of all essential elements [6,16]

Element	Radionuclide	Half-life	ɣ-ray (keV)	Irradiation time (h)
Co	Co-60	5.271 year	1332.50	2
Cr	Cr-51	27.704 day	320.08	2
Fe	Fe-59	44.496 day	1099.25	2
Se	Se-75	119.77 day	264.66	2
Zn	Zn-65	243.8 day	1115.52	2

Measurement of essential mineral

After the appropriate decay times, all elements were analyzed by ɣ-spectrometry (Canberra, Australia) using a high purity germanium (HPGe) detector with relative efficiency of 15 and 35%, and resolution of 1.9 keV for 1332.5 keV peak of Co-60. The ɣ-ray spectra were processed using the Genie 2000 software. The ɣ-ray activities of samples were counted for 6 to 13 hours for all elements.

Quality control of the results

Quality control was provided by using international standard reference materials (SRM NIST 1548a). The samples and the standard reference materials were treated in the same manner in all analytical steps. The results of SRM analysis were compared with its certificate value and evaluated its accuracy and precission by % accuracy and % RSD calculation.

Estimated daily intake of elements

The daily intake of each element is a function of the concentration of the element in the food sample as well as the amount of the food that is being consumed daily. The estimated daily intake (EDI) of each element was therefore calculated using the following equation: [2,8,17]

$$EDI = C \times M \quad (1)$$

C is the mean concentration of element in rice samples (mg/kg) and M was assumed to be consumption rate (kg/day) of people. In this research, the consumption rate were 0.290 kg /person/day for West Java [14]. The obtained values were then compared with Recommended Dietary Allowance (RDA). RDA is the average daily intake level that is sufficient to meet the nutrient requirements of nearly all (97-98%) healthy individuals in a particular life stage and gender group and it is commonly used as a standard value in assessing the adequacy of daily intake [3]

Table 2. Recommended Dietary Allowance for adult men and women >19 years old.

No	Element	RDA (mg/day)	
		men	women
1	Co [18]	0.005*	0.045*
2	Cr [19]	0.035	0.025
3	Fe [19]	8	18
4	Se [5]	0.055	0.055
5	Zn [19]	11	8

**The range biological control on Co*

Contribution of essential mineral

The estimated contribution of the various rice to the daily intake of each elements was therefore calculated using the following equation:

$$Contribution = \frac{EDI}{RDA} x100\% \qquad (2)$$

RESULTS AND DISCUSSION

Quality control

The result of the quality control assesment with SRM NIST 1548a Typical Diet is listed in Table 3.

Tabel 3. Quality control assessment using SRM NIST Rice Flour 1568a

	SRM NIST RF 1568a				Acceptable [20]	
Elements	Certified Value (mg/kg)	Result (mg/kg)	Accuracy %	Precision %RSD	Accuracy range %	Precision %RSD
Co	0.0184	0.018±0.001	102	4.6	60-105	30
Fe	7.40±0.9	7.35±0.6	99	0.1	80-110	7.3
Se	0.38±0.04	0.36±0.03	95	8.6	80-110	11
Zn	19.4±0.5	20.3±1.3	105	6.6	80-110	7.3

Table 3. showed that the results obtained are in good agreement with the certified value. Accuracy range resulted in 95-105% and precision 0.1-8.6%, while for Cr since this element is not included in the certified quality assesment, it's quality control were applied using traceable and certified ICP multi element standard solution VI Certipur.

Accuracy and precission were 96 and 9.7%, respectively.

Concentration of essential minerals in rice samples

The concentration of essential minerals in white rice samples from West Java are listed in Table 4.

Table 4. Range values of essential mineral concentrations determined in white rice from West Java

Sampling	Essential mineral content (mg kg-1 wet weight)														
Location		Co			Cr			Fe			Se			Zn	
This Study															
Bogor	0.003	-	0.004	≤0.001	-	0.120	≤0.060	-	4.12		≤0.020		12.43	-	13.57
Sukabumi	0.034	-	0.065	0.104	-	0.137	4.560	-	12.49	≤0.020	-	0.115	9.037	-	18.57
Bandung	0.013	-	0.040	0.115	-	0.143	3.55	-	11.40		≤0.020		9.830	-	14.12
Cirebon	0.044	-	0.093	≤0.001	-	0.134	10.29	-	10.32		≤0.020		8.558	-	19.16
Bekasi	0.049	-	0.139	0.092	-	0.222	12.72	-	18.15	≤0.020	-	0.088	10.62	-	28.83
Tasikmalaya	0.049	-	0.070	0.234	-	0.448		≤0.060		≤0.020	-	0.178	10.08	-	18.44
Indramayu	0.045	-	0.074	0.093	-	0.120	7.465	-	18.36	0.055	-	0.086	15.80	-	18.36
Lembang	0.054	±	0.003	0.082	±	0.004	6.623	±	1.21	0.156	±	0.023	12.64	±	0.153
Majalaya	0.032	±	0.003	0.057	±	0.007	5.567	±	0.77	0.107	±	0.011	8.674	±	0.011
Garut	0.077	-	0.110	0.086	-	0.149	11.91	-	15.64	0.048	-	0.975	12.48	-	15.64
Cianjur	0.048	-	0.220	0.102	-	0.138	7.073	-	13.10	0.129	-	0.206	12.05	-	12.64
Karawang	0.005	±	0.0002	0.679	±	0.035	17.70	±	2.34		≤0.020		22.96	±	0.303
Other Studies															

Bandung [3]	0.012	-	0.254	0.004	-	0.180	0.080	-	9.180	0.060	-	0.290	11.9	-	160
Arab [7]	0.001	-	0.116	0.010	-	0.184	1.950	-	55.10	0.007	-	0.574	1.150	-	13.50
Brisbane Australia [7]	0.013	-	0.026	0.033	-	0.390	1.750	-	6.470	0.002	-	0.150	8.440	-	18.30
Spanish [8]	0.120	±	0.090	0.110	±	0.050	6.800	±	1.500	0.200	±	0.190	13.50	±	3.400
Brazil [9]	0.011	-	0.058	2.700	-	3.300	0.600	-	6.600	0.048	-	0.090	15.70	-	26.40
Jamaica [19]	0.097	±	0.018	0.080	±	0.036	22.30	±	37.90	0.108	±	1.900	15.60	±	1.900
Indonesia (Jakarta) [11]		0.770			0.380			4.650			-			24.20	

Essential element

The elemental concentrations of rice sample taken from twelve regions measured by INAA were presented in Table 4. The concentrations of Co, Cr, Fe, Se and Zn were observed as the essential element for all studied samples. The order of the mean concentration of element was Zn > Fe > Se > Cr > Co with the concentration were in the range 8.558-28.83, ≤0.06-18.36, ≤0.020-0.975, ≤0.001-0.679 and 0.003-0.220 mg/kg, respectively. Elemental concentration in rice from Bandung in this study slightly different from previous research by Damastuti et al [3] due to the difference in rice type.

As shown in Table 4, it can be seen the variation within the element concentration obtained from the 12 regions in West Java.

Those variations are attributed to many factors such as the mineral composition of the soil, soil type, fertilizer, agricultural chemicals [21], cultivar of plant, weather conditions during the growing, the state of the plants maturity at harvest [22]. Furthermore, soil pH, cation exchange capacity, soil texture and the interaction of soil plant root microbes which play important roles in regulating movement from soil to the edible parts of plant, while the ability of a metal species in its different forms to migrate from the soil through the plant part sand makes it self available for consumption can be represented by the transfer factor [23].

The content of Co, Cr, Fe, Se and Zn on rice were generally correspond with previous reported data in other countries [7–9,11,19].

Cobalt (Co)

The cobalt concentration in white rice were range from 0.003 to 0.220 mg/kg whereas the mean concentration was found to be 0.056 mg/kg. The mean concentration of Co from twelve regions West Java were similar with those from Arab, Spanish, Brazil but higher than Brisbane and Finlandia as 0.01 mg/kg wet base [22]. Cobalt is an essential trace nutrient. As it is present in small amounts in most foods, deficiency of it is rarely found, however a lack of Co may lead to pernicious anemia which can be fatal [19].

Chromium (Cr)

The chromium element content in the white rice samples range from ≤0.001 to 0.679 mg/kg and the mean chromium content of the samples was 0.179 mg/kg. The highest value, 0.679 mg/kg, was found in Karawang rice. It can be caused by the use of phosphate fertilizers which is very intensive and continuous, and is thought to cause the accumulation of metals in soil contained in the fertilizer, so some will be absorbed by plants and partly leached into the soil.

Humans require chromium in trace amounts. Its mechanisms in the body are not well defined but it is known to enhance the action of insulin, and appears to aid in the metabolism and storage of protein, carbohydrates and fats. Chromium is present in very low levels in food and absorption rates in the body are low, between 0.4% and 2.5%. It is primarily found in two forms Cr(III), which is biologically active, and Cr(VI), which is a pollutant and potential toxic [19].

Iron (Fe)

The iron content of white rice range from ≤0.06 to 18.36 mg/kg and the mean value found in white rice was 9.712 mg/kg. The iron content of rice sample in Tasikmalaya had iron levels below the limit of detection, therefore the rice that most consumed by Tasikmalaya people had the lowest detected concentration of Fe, while the highest value was found Karawang rice samples. The mean iron content of rice sample in West Java similar with National food database; 7.3±2.5 mg/kg [8] and then the iron content in Karawang still below with those from Arab and Jamaica.

The amount of bioavailable iron in rice and other staple plants is low, and the phytic acid present in rice may add to this lack of bioavailability. This is a likely contributor to the global iron deficiency problem [19]. Iron biofortification is difficult as many beneficial Fe compounds ($FeSO_4$) are unpalatable, and less soluble Fe compounds are poorly absorbed. Increasing the Fe content of rice is a difficult task for several reasons. Although soil is abundant of Fe, plants cannot utilize it as it is mainly present as large insoluble Fe(III) compounds.

The fact that calcareous soils with a high pH account for 30% of the world's cultivated soils makes the situation getting worse. On the other hand, Fe is a transition metal that readily accepts and donates electrons. This property of Fe makes it essential for plants while, at the same time, making it toxic through the production of reactive oxygen species. Thus, plants have developed sophisticated mechanisms to absorb Fe from soil and to transport it from root to shoot and grain [24].

Selenium (Se)

The Se concentrations in rice samples from West Java ranged from ≤0.020 to 0.975 mg/kg (Table 4) which was quite higher than the results reported for the average Se content of rice which were 0.125 mg/kg in Brazil 0.048 to 0.090 mg/kg, despite 33% of the samples had lower concentrations below detection limit which are from Bogor, Bandung, Cirebon and Karawang and 67% above the detectable level of Se. The highest value was found in Garut rice samples, it is similar with the average of Se concentrations in rice samples collected from north of Iran ranged from 0.50 ppm (Langaroud) to 1.49 ppm (Gonbadkavos) [25].

These variations in Se levels may occur due to the soil availability. In addition, the concentration of Se can be different not only in samples collected in the world, but in samples from different regions of a specific country [2]. Although Se soil concentrations of the geographic origin of the crop is the main determinant of the Se content of foods, other factors such as climatic conditions and the use of Se rich fertilizers can affect Se concentrations of foodstuffs [25].

Zinc (Zn)

The average concentration of Zn in Rice from West Java was 14.994 mg/kg with ranged from 8.558-28.83 mg/kg. The lowest value, 8.558 mg/kg, was found in Cirebon rice. The content of zinc in rice sample from Cirebon similar with rice from Brisbane Australia 8.440-18.30 mg/kg [7]. It is likely that the relatively low concentrations in rice are a function of zinc deficient soils or soils with properties that make this element biologically unavailable for uptake by the plant. It is known that rice and other cereals contain phytic acid, a chelating agent of several trace elements including zinc. The low Zn concentrations found in the rice and further reduction in the bioavailability of zinc caused by phytate require special attention because of the high prevalence of zinc deficiency in the developing countries [19]. The soil factor that most affecting the availability of Zn is pH. In a study at Bhopal, desorption of adsorbed Zn decreased with increasing pH and stopped abruptly at pH 7.5. Alternate flooding and drying as obtained under irrigated rice culture also results in increased desorption of Zn [26]. The WHO lists zinc deficiency as the 5th leading cause of illness and disease in low income countries, with some estimates suggesting that up to a third of the world's population is affected [19].

Estimation of essential mineral daily intake

Dietary intake levels of essential minerals for West Javanese people were estimated. Previous research by M. Wiyono et al [12] focusses on determination of elements in rice in Pandeglang, Indramayu, Tasikmalaya, Cirebon. However, they did not calculate the mineral daily intake from rice. Therefore, this study provides the daily intake of minerals and also more number of sampling area. The estimation values and its comparison with RDA were showed in Fig. 2-6. In estimating the daily intake of inorganic constituents via white rice, a daily consumption survey of it is indispensible. Hence, by assuming that the average consumption of rice is 0.290 kg/day, daily intake values can be simply calculated for five elements such as Co, Cr, Fe, Se and Zn determined from all regions and can be compared each other. The EDI considering the average of rice consumption per capita in West Java and estimates that average value is for adults aged 19–50 years. Overall, rice can be an important dietary source of Co, Cr, Fe, Se and Zn, it can provide more than 5% of the RDA. However, the contribution of the elements is highly dependent on the type of rice.

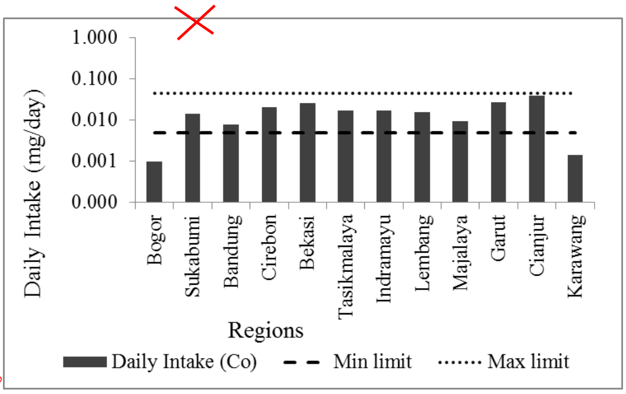

Fig. 2. Estimation of Co daily intake

The cobalt intake from rice were exceeded its minimal value (5 μg/day) for biological control on metal as shown in Fig. 2 for ten region, but all regions were below maximal value (45 μg/day) for biological control and there is no data of RDA and tolerable upper intake level (UL) of cobalt. The UL is the highest level of daily nutrient intake that do not pose a risk of adverse health effects to almost all individuals in the general population [3]. Its has still within the normal range and safe for daily intake of Co element from 0.005 to 1.8 mg/day [27]. Contribution daily intake of cobalt in rice obtained from Bogor and Karawang were 24 and 35% of the RDA values.

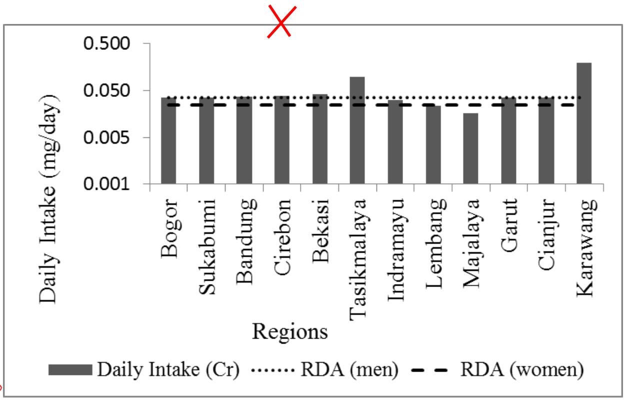

Fig. 3. Estimation of Cr daily intake

Fig. 3 showed that the results obtained of chromium daily intake. The average chromium daily intake in our study equals 0.052 mg/day, which is between those RDA for men dan women values of aged > 19 years (Fig. 3, Table 2), with the average daily intake contribution for men and women were 1.5 and 2.1 times of each RDA values respectively. The average Cr daily intake obtained were also in the range of 0,05-0,2 mg/day as recommended by National Academy of Science [18].

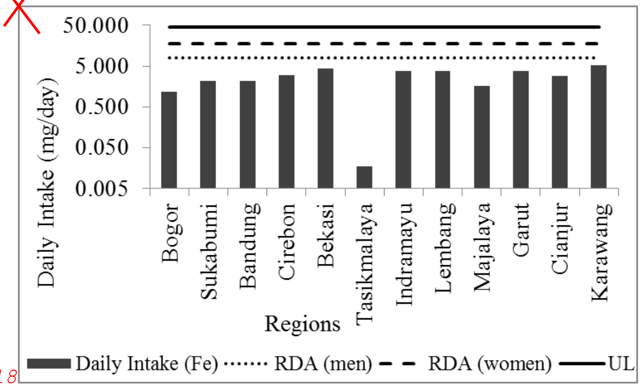

Fig. 4. Estimation of Fe daily intake

Daily intake of Fe in Fig. 4 showed that in twelve region were below RDA values and the average gives contribution of around 0.1-64% Fe intake of recommended RDA values for women and men aged >19 years, calculated from the equation 2. According to R. Kukuh normal daily input element Fe is 6-40 mg/day [27]. FAO (Food and Agriculture Organization) or WHO (World Health Organization) recommends that the amount of iron that must be consumed should be based on the amount of iron loss in the body. Therefore the RDA value of Fe for men and women, according to their need, are different [3].

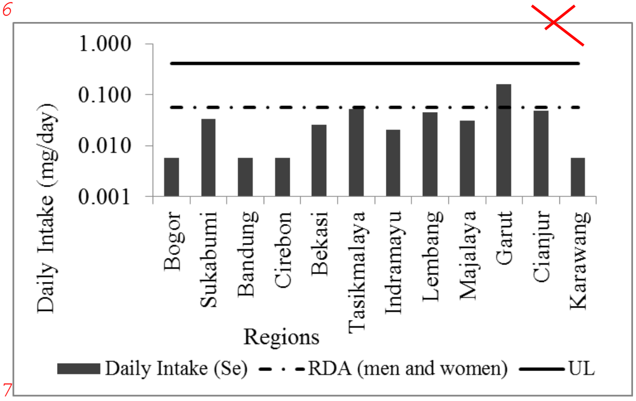

Fig. 5. Estimation of Se daily intake.

The Se daily intake of white rice ranged from 0.006 to 0.158 mg/day whereas the mean daily intake was found to be 0.040 mg/day with contribution of the RDA was 73%. Fig. 5 showed the Se daily intake of rice in Garut exceeded the RDA but still below UL (400 μg/day). Due to the essentiality of Se and its reported beneficial effects, nutritionists recommend more and more to increase Se intake, especially in regions where environmental Se levels are low [5]. Selenium plays important biological activities, especially related to hormones metabolism and the immune system.

Selenium can reduces toxic effects of As and Cd. Studies indicate that an adult biological needs, in matter of Se, may be satisfied if at least 70 µg/day is provided [2].

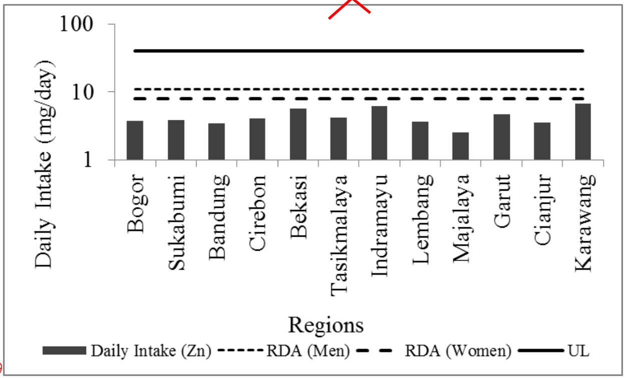

Fig. 6. Estimation of Zn daily intake

Similar to the previous elements, the average Zn intake were below RDA values as can be seen in Fig. 6 and contributed 23 to 83% of the RDA value. A daily intake of 5 to 40 mg/day is recomended, high deficiency of Zn leads to a slow development or congenital malformation [18,28]. Therefore, efforts to improve the content of Zn in rice products needs to do so that will increase nutrition and public health [28].

CONCLUSION

The high concentrations of Zn and Fe and the minor contents of Se, Cr and Co were observed for all white rice samples collected. The content of Co, Cr, Fe, Se and Zn in rice were generally correspond with previous reported data in other countries. The daily intake of Co and Cr element reported, are conveniently supplied by the diet, except for Fe, Se and Zn where almost all regions observed give low contribution to the RDA value, except the content of Se in Garut which is exceeded its RDA value. However, that the main contributor of trace element intake is rice, it is needed to be considered that a healthy diet is not just to fulfill the nutrition requirements but also should consist of balanced varied diet. Analyses for elements have provided meaningful information on the nutrient database of rice.

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