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Quantification of Heavy Metals in White Rice and Brown Rice from Thapaung Township

Phyo Wai Zin[*]*, Khin Phyu Phyu, San San Htwe, Mya Marlar, Tin Tin Han, Khin Moe Latt, Ohnmar Win, Aye Thida Tun & Thet Htet Aung*

Department of Medical Research

Rice is the major staple food of Myanmar. In general, there are two kinds of rice as white and brown rice. The evidence suggested that brown rice may contain more heavy metals especially arsenic than white rice. When the permissible concentration of heavy metals in the body becomes exceeded, they can cause serious health disorders. This cross-sectional study was aimed to determine the concentrations of heavy metals in white and brown rice from four villages of Thapaung Township, Ayeyawady Region. Six milled rice and six un-hulled rice samples were collected as white rice and brown rice samples, respectively. The concentration of ten kinds of heavy metals was determined by inductively coupled plasma-optical emission spectrometry (ICP-OES) (Perkin Elmer) Optima 8000. In brown rice samples, lead (Pb), zinc (Zn), copper (Cu), nickel (Ni), iron (Fe) and manganese (Mn) were detected above their respective maximum allowable concentration (MAC). However, arsenic (As), chromium (Cr) and cobalt (Co) were below their MAC. In white rice samples, Pb, Zn, Cu and Mn were above their respective MAC. However, these concentrations were lower than those of brown rice samples. Cadmium (Cd), As, Cr and Co in white rice samples were below their MAC as in brown rice samples. Among the highly toxic metals, As was not detected in both samples. However, one of the toxic metals, lead (Pb) was present above MAC in all samples of brown rice and white rice except one sample of white one and these concentrations were much lower than those of brown rice. Cd was present in all samples of brown and white rice but only one sample of brown rice had the concentration above MAC. Therefore, it can be highlighted that the studied white rice contained less heavy metals concentration than the studied brown rice.

Key words: White rice, Brown rice, Heavy metals, ICP-OES, MAC

INTRODUCTION

Rice, the seed of the monocot plants (*Oryza sativa*), is the major staple food of Myanmar. In general, there are two kinds of rice as white and brown rice; white rice is the result of milling process in which it removes the outer bran layer of the brown rice.[1] As it is claimed that brown rice contains many nutritional contents, some people prefer to eat brown rice than white rice. However, large amount of heavy metals in rice can cause serious health problems in people. Moreover, evidence suggests that brown rice may contain more heavy metals especially arsenic than white rice.[2, 3]

In Ayeyawady Region of Myanmar, Thapaung Township plays a dominant role in cultivation of rice in rich alluvial soil. The uptake of heavy metals depends on the plant species and bioavailability of the metal in the soil.[4] Rice has been identified as one of the major sources of cadmium (Cd) and lead (Pb) intakes for humans especially in Asia.[5] Up to 50% of the ingested Cd was from rice and its products in Asian countries.[6] Malidareh and colleagues reported that the value of arsenic (As), Cd and Pb concentration in rice in Iran were <0.005-

*To whom correspondence should be addressed.
Tel: +95-1375447, Ext: 507
E-mail: phyowaizin@gmail.com

0.051 mg/kg, <0.05-0.113 mg/kg and <0.05-0.135 mg/kg, on dry weight, respectively. They also stated that in all samples of polished white rice, Cd and Pb contents were lower than the maximum permitted level for rice compared with Standard Codex/EU/WHO and lower than the maximum permitted level Standard of Iran. However, arsenic contents in white rice were not compared because standard for arsenic in the polished white rice had not been determined yet. Moreover, the weekly intake of As, Cd and Pb from rice was lower than that of total dietary As, Cd and Pb intake, and the maximum weekly intake recommended by WHO/FAO.[7] The total arsenic concentrations in white rice were 0.501, 0.19, 0.25, 0.21, 0.07, 0.08 and 0.14 μg/g as dry basic weight in China, Japan, Vietnam, India, Bangladesh and Thailand, respectively.[8]

Heavy metals can reach into the body system through food, air and water and bioaccumulate over a period. When the permissible concentration becomes exceeded, they can cause serious health disorders; immunological defenses, intrauterine growth retardation, disabilities associated with malnutrition and a high prevalence of upper gastrointestinal cancer.[4] Metals such as Cd, Pb, Cr and Ni are considered as adverse effect to human and environment, thus receiving global attention for environmental contamination.[9] Although brown rice consumption is less significant than white rice consumption in Myanmar, the increased amount of heavy metals in brown rice becomes important in considering the safety for brown rice consumers.

Therefore, the quantification and comparison of ten heavy metal (As, Co, Cd, Pb, Cr, Zn, Cu, Ni, Fe and Mn) contents in white and brown rice from Thapaung Township, Ayeyawady Region, were carried out.

MATERIALS AND METHODS

A cross-sectional study with one year duration was done. White rice samples are meant to be milled rice grains. Brown rice samples are meant to be un-hulled rice grains and these are pounded to remove the husk in order to get brown rice. A total of 12 samples (6 milled rice and 6 un-hulled rice grain samples) were collected from 4 villages of Thapaung Township in Ayeyawady Region from October to December, 2016 after harvesting the paddy crops. Two milled rice grain and two un-hulled rice grain samples were collected from Konetangyi (ကုန်းတန်းကြီး) and Yaylegyi (ရေလဲကြီး) villages, each; one milled rice grain and one un-hulled rice grain samples from Daleet (ဒလယ်အဲ) and Shannkwin (ရှမ်းကွင်း) villages, each. The samples collected belong to 3 varieties of rice grain namely Yaysintheehtat (ရေဆင်းသီးထပ်), Mheekaut (မီးကောက်) and Shwe-thweyin (ရွှေသွယ်ရင်).

Twenty primary samples of rice were taken from about 50 bags of rice from warehouses of respective villages. These 20 samples were mixed thoroughly to get the one composite sample, the representative one. The composite sample was analyzed triplicately for heavy metal concentrations in the laboratory. The same procedure was done for un-hulled and milled rice of different varieties of rice from different villages.[10] Each sample was kept into each plastic bag with concise label, sent to the laboratory, Chemical Toxicology Research Division, Department of Medical Research and stored at room temperature until analysis.

For digestion of sample before analysis, 30 ml of concentrated nitric acid were mixed with 5 gm of rice sample and it was gently boiled until 3-6 ml of digest remained. Then, 25 ml of concentrated hydrochloric acid were added and heated gradually until 10-15 ml of volume remained. After cooling, the residue was filtered with 45 μm size Whatman filter paper. The sample was diluted to 50 ml with deionized water. The blank digestion was carried out as described previously.[11] ICP-OES (Perkin Elmer) Optima 8000 was used for measurement by applying the standard operating condition, including ICP-OES multi-element-standard-solution, nitric acid (69%), hydrochloric acid and deionized water.

Statistical analysis

Data were analyzed by using Microsoft Excel. Concentrations of ten heavy metals were presented as mean±SD and compared with maximum permissible level according to codex/WHO.

RESULTS AND DISCUSSION

Toxic elements

Table 1 shows that As was not present in all samples of brown and white rice. The finding was contradict to the fact that brown rice may contain especially arsenic than white rice.[2, 3]

Arsenic level in rice depends on irrigated water which comes from arsenic contaminated source.[12] The absence of As in the samples of the study may be due to the fact that the water used for rice cultivation is rainwater and water from the Gawon river (one of the branches of Ayeyawady River) but not from the deep well. Cadmium was present above the MAC (Cd=0.2 µg/g, CODEX standards) in one sample of brown rice but below in all samples of white rice.[13] The milling process reduces Cd concentration in grain.[14] In general, Cd in plants may relate to the fertilizer used and it reduces the growth both in roots and stems. This effect is partly due to the suppression of the elongation growth rate of cells, especially in the stem.[15]

Khairiah, *et al.*[16] found that the application of various types of pesticides and fertilizers served as contributor to increasing toxic metal contamination of crop. All samples of brown rice and except one sample of white rice had lead (Pb) concentration above MAC (Pb=200 ηg/g, CODEX standards).[13] However, the levels of Pb in white rice were much lower than that of brown rice. Shabbir, *et al.*[17] described that the lead content was found significantly higher in brown rice than in white rice. Lead contamination in long term may lead to anemia and brain damage.[4]

Chromium was present in all samples of brown rice and 3 samples of white rice, which were below MAC (Cr=1 µg/g, CODEX standards).[13] On milling of the grain, Cr was lost to the extent of 57%.[18]

Diet is the primary route of Cr entry into humans though humans can absorb Cr by inhalation or dermal contact.[19] Nickel ranged from 4.03±0.01 to 59.04±1.09 µg/g in brown rice samples and from 0.55±0.01 to 2.69±0.02 µg/g in white rice samples. Nickel concentration was above MAC (Ni=1.5 µg/g) in all samples of brown rice and one sample of white rice.[13] Dermatitis due to nickel toxicity is not uncommon.

Table 1. Distribution of concentrations of toxic elements (mean±SD) in brown and white rice grains

	Rice	As	Cd	Pb	Cr	Ni
Konetangyi						
Yaysintheehtat	Brown	ND	205.8±9.33	7.50 ±0.03	0.25±0.00	4.03±0.01
	White		49.27±2.18	0.66±0.01	0.01±0.01	1.58±0.00
Mheekaut	Brown	ND	78.06±1.38	3.88 ±0.03	0.11±0.00	5.00±0.07
	White		43.59±0.64	0.05±0.00	0.15±0.18	1.48±0.01
Yaylegyi						
Mheekaut	Brown	ND	104.6±0.24	5.26 ±0.05	0.24±0.01	10.57±0.07
	White		55.00±1.43	0.67±0.00	ND	0.91±0.02
Shwethweyin	Brown	ND	59.91±1.43	6.58 ±0.05	0.23±0.01	10.88±0.14
	White		61.79±1.04	1.40±0.00	0.55±0.02	1.50±0.02
Daleet						
Shwethweyin	Brown	ND	81.46±0.71	4.03 ±0.04	0.13±0.00	4.82±0.09
	White		29.76±0.40	0.26±0.01	ND	0.55±0.01
Shannkwin						
Shwethweyin	Brown	ND	188.4±4.39	98.29 ±0.86	0.51±0.01	59.04±1.09
	White		78.93±0.14	3.86±0.03	ND	2.69±0.02
Reference value		200 ηg/g	200 ηg/g	0.2 µg/g	1 µg/g	1.5 µg/g

As=Arsenic, Cd=Cadmium, Pb=Lead, Cr=Chromium, Ni=Nickel, ND=Not detected

Table 2. Distribution of concentrations of microelements in brown and white rice grain samples

	Rice	Zn	Cu	Fe	Mn	Co
Konetangyi						
Yaysintheehtat	Brown	371.4±1.44	223.10± 2.03	5.51±0.29	16.24±0.37	ND
	White	71.98±0.15	41.87±0.18	2.40±0.05	19.75±0.13	ND
Mheekaut	Brown	239.8±5.45	117.2±1.03	8.86±0.43	27.11±0.35	ND
	White	65.64±1.10	20.69±0.11	1.98±0.08	25.89±0.36	ND
Yaylegyi						
Mheeka ut	Brown	303.5±8.10	181.60±2.84	139.0±2.34	23.73±0.00	ND
	White	67.53±1.48	29.72±0.48	1.75±0.10	21.03±0.22	ND
Shwethweyin	Brown	329.80±6.15	199.10±3.72	8.11±0.11	9.21±0.08	ND
	White	80.74±1.47	49.66±1.09	6.16±0.34	14.18±0.17	0.005±0.0008
Daleet						
Shwethweyin	Brown	212.10±6.40	120.90±1.87	9.02±0.4	11.78±0.07	ND
	White	50.53±1.73	22.21±0.17	0.67±0.3	18.65±0.19	ND
Shannkwin						
Shwethweyin	Brown	4170±30.35	421.1±1.69	14.20±0.61	18.38±0.07	ND
	White	158.3±3.62	121.0±1.28	ND	9.61±022	ND
Reference value		50 µg/g	10 µg/g	5 µg/g	5 µg/g	0.01 µg/g

ND=Not detected, Zn=Zinc, Cu=Copper, Fe=Iron, Mn=Manganese, Co=Cobalt (mean±SD)

Microelements

Table 2 indicates that apart from one sample of white rice, cobalt (Co) was not detected in both brown and white rice samples. Cobalt is a natural element that is essential for the healthy functioning of many plants and animals. Rice contained only small amount of Co.[20]

Zinc (Zn), copper (Cu) and manganese (Mn) levels in brown rice samples ranged from 212.1±6.40 to 4170±0.35 µg/g, from 117.2±1.03 to 421.1±1.69 µg/g and from 9.21±0.08 to 27.11±0.35 µg/g, respectively. Zn, Cu and Mn levels in white rice samples ranged from 50.53±1.73 to 158.3±3.62 µg/g, from 20.69±0.11 to 121.0±1.28 µg/g, from 9.61±0.22 to 25.89±0.36 µg/g, respectively. These were above their respective MAC (Zn=50 µg/g, Cu=10 µg/g, Mn=5 µg/g) in both brown rice and white rice.[13]

Iron (Fe) ranged from 5.511±0.29 to 139.0±2.34 µg/g in brown rice samples and from 0.67±0.3 to 6.16±0.34 µg/g in white rice samples. Fe concentration was above MAC (Fe=5 µg/g) in all samples of brown rice and one sample of white rice.[13]

Zn was found to be the most abundant microelement, followed by Cu, Fe, Mn, Ni and Co in the brown rice samples, and followed by Cu, Mn, Fe, Ni and Co in white rice samples. The metal ions distribution in the rice grain is still not definitely known. Some studies found out that microelements (Cu, Fe, Mn, and Zn) were probably to be equally distributed in the grain.[21-23] Some authors reported that there was much of iron concentration in the outer layers (aleurone and pericarp) of rice. Milling reduced the iron concentration of the white rice.[24]

Conclusion

In this study, among toxic elements (As, Cd, Pb, Cr), Pb was found in all brown rice and white rice but except one. Zn, Cu and Mn were found in all brown and white rice. Most of the Ni and Fe were found in brown rice only. Cobalt was not found in all brown rice. It was found in one white rice sample, but it was very much lower than that of MAC limit.

Microelements, as well as toxic elements, were more contaminated to a certain extent in brown rice grains than those in white rice grains in this study. Although the increased concentration of microelements required for nutrition in brown rice may be pleasant for health, the increased concentration of toxic metals may concern the safety for brown rice consumers. In this study, there was no consideration on estimated daily intake (EDI) of metals and daily consumption of rice. Therefore, further study should be performed for assessing the risks of white and brown rice consumers by applying the reference values for estimated daily intake of metals and daily consumption of rice.

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