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SHORT COMMUNICATION

Cadmium and lead contents and potential health risk of brown rice (NSIC Rc222 *Tubigan 18*) cultivated in selected provinces in the Philippines

Marjorie Anne Abratique Layosa, Liezl Marinay Atienza* & Angelina delos Reyes Felix

Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Banos, Los Banos, Laguna, Philippines

ABSTRACT

Introduction: Brown rice is promoted for a healthier rice-consuming population as it renders numerous nutritional benefits due to its fiber and germ, yet may contain high concentrations of metal elements from environmental effluents. The purpose of this study is to identify the potential health risk of brown rice cultivated in different major islands in the Philippines. **Methods:** Concentrations of heavy metals cadmium (Cd) and lead (Pb) were investigated on brown rice of a popular modern rice variety (NSIC Rc222) cultivated from top rice-producing provinces in Luzon, Visayas and Mindanao, namely Nueva Ecija, Iloilo and Bukidnon, respectively, through non-probability sampling. Total Hazard Quotient (THQ) and Combined Total Hazard Quotient (CTHQ), as developed by US EPA, were used to calculate the potential hazard. **Results:** Cd levels of brown rice from different sites were found to be below the maximum level of 0.1 mg/kg. However, Pb content from all sites exceeds the 0.2 mg/kg allowable level as recommended by the Joint FAO/WHO Food Standards Programme. Brown rice from Ilo-ilo had the highest Pb content while Nueva Ecija the lowest. THQ values were all below 1.0 but contribution of Pb to CTHQ was higher than that for Cd. **Conclusion:** The findings suggest consuming brown rice from the studied sites has low probability of inducing carcinogenic effects in the long run, but Pb has a greater contribution in the hazard risk as compared to Cd. Further studies on heavy metals especially Pb in brown rice consumed in the Philippines are suggested.

Keywords: Brown rice, cadmium, lead, hazard identification, total hazard quotient

INTRODUCTION

Rice, aside from being the staple food in the Philippines, is also one of the country's major agricultural products. Rice is consumed by 94.8% of the population at 290 g per capita; the richest household has relatively lower consumption at 264 g, as compared to poor households at 309 g (FNRI, 2013). It is the major source of energy due to its high carbohydrate content.

There are two common types of available rice in the market, namely, white rice and brown rice. The difference between the two is in the degree of polishing. In brown rice, only the outer covering is removed, leaving the bran intact whereas white rice is milled and

*Corresponding author: Dr Liezl M Atienza
Institute of Human Nutrition and Food, College of Human Ecology, University of the Philippines Los Banos, Los Banos, Laguna 4031 Philippines
Telefax: +6349-536-2445; E-mail: lmatienza@up.edu.ph

polished leading to the removal of husk bran and germ. Due to polishing, white rice loses most of its nutritional content and health promoting activities from fiber, antioxidants, minerals, vitamins and phenolic compounds (Yang *et al.*, 2016). Thus, brown rice is being promoted for a healthier rice-consuming population.

However, rice is also prone to different environmental hazards from water, soil and air. Solidum (2014) showed that all rice varieties sold in Metro Manila market contained lead, and the regular *Malagkit* and NFA rice exceeded the permitted limit for lead. Concern for this matter was raised by the Department of Agriculture – Philippine Rice Research Institute (DA-PhilRice) due to the alarming increase of levels of heavy metals in rice. Further, different rice samples from Asia and Europe were reported to be contaminated with such heavy metals too (Oplas, 2013).

Human exposures to heavy metals have increased dramatically (Cherfi *et al.*, 2016) and it has been reported that the main route of exposure to heavy metal of most people is through the diet. It is important to identify hazards in rice, as it constitutes a major part of the diet among Filipinos.

The general objective of this study was to identify the potential health risk of brown rice cultivated in the Philippines. Specifically, the study aimed to determine concentrations of cadmium (Cd) and lead (Pb) of brown rice of NSIC Rc222 (*Tubigan 18*) cultivated in three major rice producing islands in the country, namely Nueva Ecija in Luzon, Ilo-ilo in Visayas, and Bukidnon in Mindanao.

MATERIALS AND METHODS

Raw materials and sample preparation

Inbred NSIC Rc222 raw rice paddies grown during the 2016 wet season were collected from Munoz, Nueva Ecija, Pototan, Ilo-ilo and Musuan, Bukidnon. Rice growing procedure followed the protocols of National Cooperative Test (NCT) for Rice (BPI, 2014). Briefly, seedlings aged 18 to 21 days old were transplanted at 1-2 seedlings per hill in each plot. Fertilizer (N, P2O5, K2O) were applied at 7 days, 21 days and 28 days after transplanting at a rate of 120-60-60. Crop management practices followed the PalayCheck® (Cruz *et al.*, 2005) recommendations. Thirty days after 50% heading date, the paddies were harvested, and amounts from the three plots (except border rows) were combined as sample source. The composite samples were dried under the sun in net bags until a paddy moisture content of 14% is reached. The rice samples were then cleaned and winnowed properly to remove impurities and dirt.

A hand-operated wooden dehuller with polyurethane rubber was used to remove rice bran from the grain, assisted with a ceramic pincher. The equipment was cleaned and sterilized after every sample manual dehulling to prevent contamination. The brown rice was triple washed, as normally done during household cooking and allowed to dry at room temperature. Rice samples were ground and dried overnight (12 hours) at 60°C. This procedure was adapted from Al-Saleh and Shinwari (2001). The dried and ground samples were weighed at 40 g each and were packed in coin envelopes which were properly labeled, sealed and sent at the Central Analytical Services Laboratory of the National Institute of Molecular Biology and Biotechnology, University of the Philippines Los Baños for Cd and Pb analysis.

Chemical analyses

Cd analysis was done using the protocol of AOAC 965.05 19th edition, while Pb analysis was done using the modified AOAC 972.25 19th edition using Atomic Absorption Spectrophotometry.

Data processing and analysis

Heavy metal concentrations of the investigated rice samples were reported as mean ± standard deviation (SD), as purchased weight. One-way Analysis of Variance (ANOVA) was employed in determining significant differences among the heavy metal concentrations from the three sites of cultivation using the software IBM SPSS Statistics 20.

Further, the estimated daily intake (EDI) and target hazard quotient (THQ) were calculated using the following formulas as developed by the US Environmental Protection Agency (US EPA):

$$\boldsymbol{EDI_i} = \left(\frac{E_f \times E_d \times F_{ir} \times C}{W_{ab} \times T_a}\right) \times 10^{-3}$$

$$\boldsymbol{THQ_i} = \left(\frac{E_f \times E_d \times F_{ir} \times C}{R_fD \times W_{ab} \times T_a}\right) \times 10^{-3}$$

where C is the average concentration of heavy metal (mg/kg, as purchased weight); F_{ir} is the rate of rice consumption (the average F_{ir} for adults is 290 g/day/person as reported on FNRI's FCS), E_f is the exposure frequency (365 days/year), E_d is the exposure duration (68 years, Filipino's life expectancy), R_fD is the oral reference dose (mg/kg/day) (0.1 mg/kg/day for Cd and 0.2 mg/kg for Pb), W_{ab} is the average adult body weight (52.5 and 60.5 kg for women and men, according to the Philippine Dietary Reference Intake 2015, respectively), T_a is the averaging time for non-carcinogens (E_d×365 days/year); and 10^{-3} is the unit conversion factor (Fang *et al.*, 2014).

The Combined Target Hazard Quotient (CTHQ) was calculated using the equation:

$$\boldsymbol{CTHQ} = \sum_{j=1}^{3} THQ_j$$

where j represents the individual heavy metal content namely Cd and Pb. The CTHQ evaluates the risks of the two studied metals together in the brown rice samples. Exposure to two or more pollutants may result in additive effects (Wang *et al.*, 2005 in Cherfi, 2016).

RESULTS AND DISCUSSION

Heavy metal content

Among the three samples, brown rice from Nueva Ecija has significantly highest amount of Cd at 0.037 ppm, whereas Bukidnon brown rice has 0.015 ppm, while no Cd was detected in brown rice from Ilo-ilo (Table 1). Ilo-ilo is a geographic island surrounded by multiple bodies of water with different wetlands as well as coasts and rivers. The abundance of water source in the island could be one factor for the non-detectable quantity of Cd in the brown rice grown in the said area. Nonetheless, the Cd content from all three sites were below the maximum allowable levels for cereals, according to the Joint FAO/WHO Food Standards Programme (FAO/WHO, 2001).

Table 1. Heavy metal content (cadmium and lead) of sampled brown rice (*N*=3)

Rice sample	*Heavy metal content*[†] *(mg/kg, AP wt.)*	
	Cadmium	*Lead*
Nueva Ecija	0.037±0.000[a]	1.510±0.475[a]
Ilo-ilo	*ND*[c]	1.863±0.478[a]
Bukidnon	0.015±0.018[b]	1.705±0.241[a]

[†]Maximum Allowable Levels: Cd – 0.1 mg/kg; Pb – 0.2 mg/kg

ND – not detectable

[a, b, c] Different alphabets denote significant difference at $p<0.05$.

On the other hand, all brown rice samples showed Pb contents that exceeded the maximum allowable level for cereals (FAO/WHO, 2001). Brown rice from Nueva Ecija, Ilo-ilo and Bukidnon contained 1.510 ppm, 1.863 ppm and 1.705 ppm, respectively, which were not significantly different. Xie and colleagues (2016) revealed that rice has high adsorption capacity for Pb suggesting that the high concentration of Pb identified from the samples were sourced from the contamination of each cultivation sites with Pb.

As the three brown rice samples had the same cultural management, the differences in the amounts of heavy metals found could be attributed to different locations, sources and quality of water, soil and air quality. Xie *et al.* (2016) reported that the bio-concentration ability of Pb and Cd had no difference between conventional and hybrid rice, suggesting soil quality is an important consideration for producing contaminant-free rice.

Another interesting observation from the result is the brown rice from Ilo-ilo for it contained non-detectable amounts of Cd but the highest concentration of Pb among the samples. This indicates that the presence of heavy metals may be independent of one another

Estimated daily intake

The EDI of heavy metals for both men and women were calculated and compared to the maximum levels recommended by FAO/WHO (2001). The values were obtained by assuming that brown rice is consumed regularly as a result of promotion for its consumption. Thus, EDIs was calculated to estimate daily intake of Cd and Pb from brown rice consumption.

EDI of Cd for both men and women were 0.2 μg/kg/day, ND and 0.04 μ/kg/day from Nueva Ecija, Ilo-ilo and Bukidnon, respectively, which accounts for 0.2%, 0.0% and 0.04% of the oral reference dose (R*f*d). EDI for both men and women from different sources are approximately similar due to the low concentration of Cd. However, the EDI of Pb, men were 7.2 μ/kg/day, 8.9 μ/kg/day and 8.2 μ/kg/day, which accounts for 3.6%, 4.45% and 4.1% of the R*f*d, from Nueva Ecija, Ilo-ilo and Bukidnon, respectively. In comparison, women were observed to have higher EDI at 8.3 μ/kg/day, 10.3 μ/kg/day and 9.4 μ/kg/day, accounting for 4.15%, 5.15% and 4.7% of the R*f*d, from Nueva Ecija, Ilo-ilo and Bukidnon, respectively. It is thus observed that women were more likely to have higher intake of these heavy metals. This is a concern in relation to the physiological attribute especially during time of pregnancy since these contaminants can penetrate through the placenta (Zhu *et al.*, 2014), thus can affect the pre-natal environment and development of the fetus.

The estimated daily intake of Cd and Pb showed that daily intakes were lower than the R*f*d, both for women and men. This suggests that consuming brown rice at 290 g, as purchased, is generally safe on a daily basis.

Total hazard quotient (THQ)

Heavy metals are accumulated in the body through chronic consumption, such as a staple food like rice. Thus the THQ was calculated to determine its hazard from chronic consumption. The THQ values for Cd were 0.002 for men and 0.003 for women, and 0.0004 both for men and women, from Nueva Ecija and Bukidnon, respectively. There is a higher THQ value for Pb as compared to Cd due to its higher heavy metal concentration (mg/kg). Specifically, THQ values were 0.036 for men and 0.042 for women, 0.044 for men and 0.051 for women, and 0.044 for men and 0.047 for women from Nueva Ecija, Ilo-ilo and Bukidnon, respectively. It is observed that the calculated THQ were far below the hazard indicator value of 1.0, thus considered generally safe (Figure 1). The Pb content of brown rice poses a higher health hazard risk, as compared to the Cd contaminant.

Combined total hazard quotient (CTHQ)

In consideration of the additive effects of the heavy metals under study, the CTHQ values among three cultivation sites were estimated to be below 1.0, which

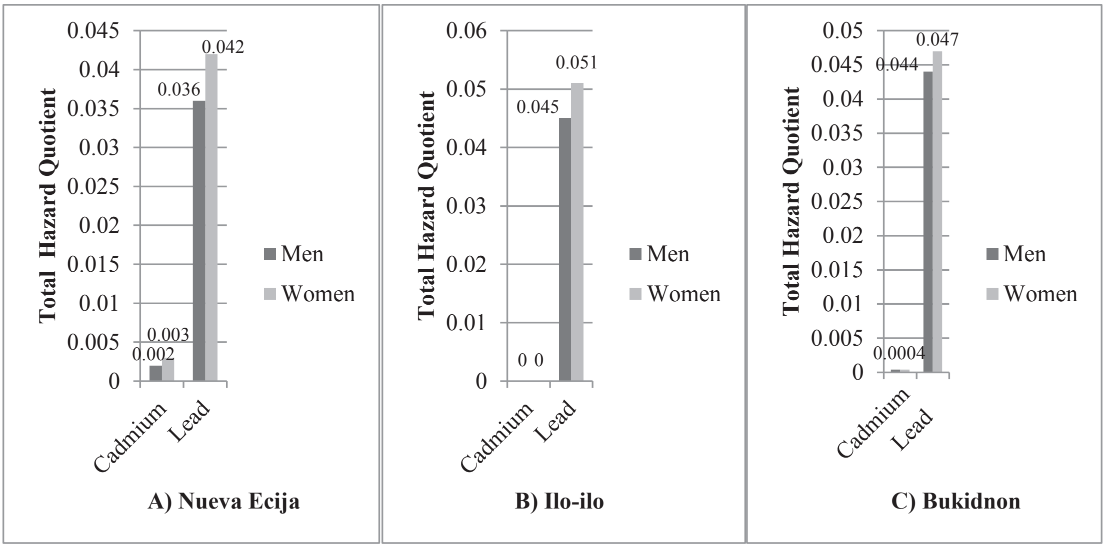

Figure 1. Target hazard quotient (THQ) of brown rice from Nueva Ecija, Ilo-ilo and Bukidnon for men and women.

is considered as generally safe. However, Pb has the greatest contribution in the hazard risk as compared to Cd, and women showed higher CTHQ than men for both metals.

In analyzing the concentration of heavy metals of brown rice from three major producing rice sites in the country, results revealed that Cd concentration was below the maximum level of 0.1 ppm; however, Pb concentration of brown rice from the three cultivated sites was relatively higher, exceeding the maximum level of 0.2 ppm. Nevertheless, based on calculation of EDI, THQ and CTHQ, sampled brown rice is considered as generally safe for consumption.

CONCLUSION

The results showed that the sampled brown rice contain heavy metals but at levels that is still considered generally safe for consumption. It is suggested that analysis for other possible heavy metals such as mercury and arsenic be determined in brown rice consumed in the Philippines.

Authors' contributions

MA Layosa collected the data, wrote the manuscript and conducted the study; LM Atienza supervised the study; ADR Felix helped in the conceptualization and data collection.

Conflict of interest

The authors declare they have no conflict of interest.

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