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Comparative study on the heavy metal content of domestic rice (*Oryza sativa* L) brands common in Awka, Nigeria.

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Abstract: *The incident of heavy metal intoxication and its antecedent health effect are on the rise, owing mainly to anthropogenic activities that severely perturb the natural distribution of heavy metals. The level of select heavy metals (Hg, As, Pb and Cd) were assayed in three popular brands of locally farmed (Nigerian), Thai, Indian and Chinese rice commonly consumed in Awka, Nigeria. The heavy metal analysis was conducted using atomic absorption spectrometry of digested, parboiled rice samples. The findings showed a combined mean level (in mg/kg) of heavy metals as follows: Hg, 0.270; As, 1.373; Pb, 0.131 and Cd, 0.138. All the values were below the maximum allowable concentration (MAC) values stipulated by JECFA/EPSA for heavy metals in cereals and vegetables, except that of Cd which was marginally higher than the recommended JECFA value of 0.1mg/kg. The high mean Cd value observed was mainly contributed by the Chinese brands whose mean Cd level was 0.21 mg/kg. Although the combined mean Cd level was higher than the recommended MAC level, its estimated daily exposure mean level of 0.156 µ/kg bw/day was much lower than the Permissible Tolerable Daily Intake (PTDI) of 0.8 µ/kg bw/day recommended by JECFA. This result shows that there is no serious risk of heavy metal poising (acute or chronic) when these rice brands are consumed at the national average per capita level of 24.8 kg per annum.*

Keywords: *Arsenic, Cadmium, heavy metals, Lead, Mercury, Rice*

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I. Introduction

The global importance of rice as stable food crop, especially in Asia, the Caribbean and Sub-Saharan Africa cannot be overstated. Rice accounts for over 20% of global calorie intake, and in Sub-Saharan Africa, rice consumption has seen a steady rise especially amongst urban settlers; with per capita consumption having doubled since 1970 [1].

Although there has been an upward trend in rice production in Nigeria [2-3] with Nigeria accounting for 44% of total output in West Africa [4], the demand for rice still surpasses local production, thereby necessitating rice importation. Nigeria imports mainly from China, India and Thailand, with the former two countries accountable for about 50% of global rice output [5].

Heavy metals are often classified as those metal with specific density greater the 5 g/cm^3 [6]. Although these metals play vital roles in maintaining biological functions by mostly acting as cofactors in enzymes, at high concentrations they become noxious and can pose serious health risks.

As a result of massive industrialization, use of inorganic fertilizers and pesticides and poor environmental policies, heavy metal pollution of arable land is increasingly becoming a serious threat to food safety and health. China and India, two of Nigeria major rice import destinations, are particularly culprit in cultivating rice in paddies that are contaminated with heavy metals. Several reports have found toxic levels of heavy metals in rice produced in certain regions of China and India [7-10].

Indubitably, exposure to high concentrations of heavy metals in foods poses serious health threat [11]. The aim of this research effort was to evaluate the heavy metal content of rice brand commonly consumed in Awka, Anambra State Nigeria, to see if they fall within the permissible range stipulated by the major regulatory agencies and organizations. For this effort, three brands of rice farmed in Nigeria, and three other brands imported from Thailand, China and India were assayed for their heavy metal contents.

II. Materials And Method

2.1 Sample collection and preparation.

Three different brands each of locally farmed rice (Adarice®, Ebonyi Gold®, Marvel Rice®,) Thai rice (PJS®, Mama Africa® and Sweet Mama®), Indian Rice (Golden Eagle®, Big Bull® and Sungold®) and Chinese rice (Carlrose®, Nishiki®, and Hakubai®) were purchased from market and shopping malls in Awka, Anambra State Nigeria.

100 grams of each of the rice sample was ground using mortar and pestle, after which it was further ground with an electrical blender to obtain a finer powder. The powdered rice samples were sieved with 5nm mesh to remove any large debris left. The powdered samples were kept in air-tight containers until used for analysis.

2.2 Metal analysis

Metal analysis was conducted using atomic absorption spectrometry (Varian AA 240, Agilent, USA) according to the method described by the American Public health Association [12]. Two grams (2g) of the rice sample was put in a crucible and heated in a furnace at 550^oC to ash the sample. The ash obtained thereafter was diluted with 20 mL of 20% H_2SO_4 and filtered. The filtrate obtained was transferred to a 100 ml conical flask, and further diluted with distilled water to the 50 mL mark. The solution was then used for the metal analysis.

2.3 Statistical Analysis

Collected data were subjected to one-way analysis of variance (ANOVA) for comparison using the SPSS software (Version 15, SPSS Inc, Chicago, USA). Results were expressed as mean ± SD and variations were considered significant when $P < 0.05$.

III. Results

Table 1: showing mean concentration of heavy metals for the rice brands from different countries analyzed and the MAC level set JEFCA.

Metal	Concentration (mg/kg)					MAC[a] (mg/kg)
	Type of Rice					
	Nigerian rice	Thai rice	Indian rice	Chinese rice	*Mean (NTIC)	
Hg	0.23 ± 0.02	0.22± 0.06	0.32 ± 0.03	0.31 ± 0.07	0.270 ± 0.052	0.5
As	1.13 ± 0.38	1.02 ± 0.29	1.72 ± 0.48	1.63 ± 0.22	1.374 ± 0.351	1.4
Pb	0.16 ± 0.04	0.21 ± 0.03	0.19 ± 0.01	0.13 ± 0.02	0.131 ± 0.035	6.0
Cd	0.15 ± 0.05	0.09 ± 0.03	0.10 ± 0.02	0.21± 0.04	0.138 ± 0.055	0.1

n=15

Table shows the mean concentration of heavy metals in three rice brands from different countries. Each value is the mean± SD of five samples each of three different brands obtained from a particular country; for instance, 'Nigerian rice' values are mean values for Adarice, Ebonyi Gold and Marvel rice. *Mean (NTIC) = mean for all four brands of rice, i.e, Nigerian, Thai, Indian and Chinese rice. [a]MAC = Maximum allowable concentration of contaminants in cereals and vegetables set by JEFCA [13].

Table 2: Showing Recommended safe exposure levels to heavy metals in food against estimated level of exposure to consumers of the rice brands sampled.

Metal	Safe value µg/kg bw/day	*Mean daily exposure value (µ/kg bw/day) for the brands sampled
As	3.0[a]	0.155
Cd	0.8[b]	0.156
Hg	0.14 (adults)[c] 0.57 (children)[c]	0.306
Pb	1.5[d]	0.148

[a]The provisional tolerable weekly intake (PTWI) of 21 µg/kg bw (equivalent to 3 µg/kg bw/day) according to JECFA(2010[a]) . [b]PTMI 0.025 mg/kg bw on a monthly basis according to JECFA [14] . [c]For adults (1 µg/kg bw per week) and for children (4 µg/kg bw per week) according to JECFA [14]. [d]Based on cardio-vascular effects according to EFSA [15]

* This was calculated with the average per capita rice consumption of 24.8 kg per annum in Nigeria [16]

IV. Discussion

The contamination and bioaccumulation of heavy metals in foods and its antecedent health implications have been extensively investigated. In the present research, the heavy metal (Hg, As, Pb, Ni and Cd) content of rice brands commonly consumed in Awka was investigated.

Mercury (Hg)

Mercury is very toxic and has high capacity for bioaccumulation. Main sources of Hg pollution include municipal wastes discharges, mining and industrial waste water [17]. Methylmecury the organic form of the metal has been implicated in neurotoxicity (Minamata disease being a classic example), microtubule damage, lipid peroxidation to mention a few [18].

In the present study, the highest mean concentration of mercury (0.32± 0.03 mg/kg) was observed in the Indian rice brands assayed (Table 1). However, the value is well below the Maximum allowable concentration (MAC) of 0.5 mg/kg for cereals and vegetable set by Joint FAO/WHO Expert Committee on Food Additives [13]. The mean mercury concentration (0.270 ± 0.052) for all the rice brands assayed in the present study differ markedly from that of Huang *et al.*,[19], who recorded mean mercury values of 0.05 mg/kg for rice harvested in from Zheijiang province of China. The variation may be as a result of farming method employed, as use of inorganic fertilizers in rice farming generally increases Hg contamination.

Arsenic

Anthropogenic sources of arsenic include mining and processing of ores, use of certain pesticides and fertilizers. Toxicity is often associated with the inorganic forms of the metal such as arsenate and arsenite. Arsenic has been implicated in various kinds of cancers [11, 20]. Population exposure to arsenic is mostly via drinking water and food. For this study, the mean arsenic concentration was 1.374 ± 0.351 (Table 1), although smaller than the MAC value of 1. Mg/kg recommended by JECFA [13], the average values for arsenic in both the Chinese and Indian brands were marginally higher than the JEFCA recommended value. This however does not necessarily imply that consumption of these brands will lead to arsenic poisoning. Again, JECFA recommends a safe level of daily arsenic intake of no more than 3μ/kg b.w (Table 2) for both children and adults. We estimated the mean daily exposure to arsenic as 0.155 μg/kg bw (Tab 2) for the rice brands we sampled, using an average body weight of 60 kg (adults), and estimated yearly consumption of 24.8 kg. This implies that there is no real danger of arsenic poisoning in consuming any of the rice brands sampled, unless the amount is far greater than the national average rice consumption of 24.8 kg per annum.

Lead

The widespread use of lead in industrial and domestic processes has led to serious environmental risks. Some of the major sources of the metal include paints, plumbing materials, and automobile batteries [21]. Lead has been implicated in both plant and animal diseases; it causes lipid peroxidation and loss of photosynthetic capacity in plants [22]. Humans-especially children are also susceptible to lead-induced brain damage because of its ability to transverse the blood-brain-barrier [23].

For all the rice samples assayed in this study, the mean level of lead (0.13 mg/kg) was far below the MAC level of 6mg/kg recommend by JECFA [13]. Also, the estimated daily mean intake (0.148μ/kg) calculated from the mean lead concentrations of the rice brands sampled, fall below the provisional tolerable daily intake (PTDI) of 1.5 μg/kg set by EFSA [15].

Furthermore, the result of this study is reinforced by that of Huang *et al.*, [24] who obtained a mean lead concentration of 0.171 mg/kg for rice cultivated along the Yangtze River basin. However Fu *et al.*, [7] obtained a much higher mean Pb level of 2.04 mg/kg for rice cultivated in Southeast China. The large difference may be accounted for by the fact that the rice they assayed was cultivated near an E-waste recycling plant.

Cadmium

Cadmium is a major component of batteries (rechargeable cadmium-Nickel batteries), and is also present in phosphate fertilizers as impurities. Exposure to cadmium may cause nephritis, evidenced by excretion of low molecular weight proteins in urine [25-26].

In the present study, the mean cadmium levels of the Nigerian and Chinese rice brands exceeded the MAC level of 0.1 mg/kg set by JEFCA; with the average of the Chinese brands (0.21 mg/kg) being twofold the MAC concentration. However, the estimated cadmium daily exposure obtained using the mean Cd concentration of Chinese brands (upper limit), was 0.238 mg/kg/bw per day, which is quite lower than the PTDI of 0.8 mg/kg bw per day set by JECFA [13]. The high cadmium level observed particularly in the Chinese brands is supported by the result of Fu *et al.*, [7] who obtained mean cadmium level of 0.244 mg/kg in rice planted in an E-recycling area in China.

V. Conclusion

This study investigated the heavy metal content of rice brands commonly consumed within Awka, Anambra State Nigeria. The findings indicate that the rice brands have heavy metals at tolerable concentrations that mostly do not exceed the MAC levels set by JECFA [13-14] for heavy metals in cereals and vegetables. Although the level of cadmium was twofold the MAC value set by JECFA in the Chinese brands studied, this does not pose any serious health risk as the estimated PTDI was within the acceptable level set by JEFCA/EFSA. We recommend that further work be done in this area that will be of broader scope, as this research was limited to rice brands common in markets and malls in Awka, Nigeria.

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