Communication in Physical Sciences 2020, 5(2): 210-222 https://journalcps.com

Health Risk Assessment of Heavy Metals in some Rice Brands Imported into Nigeria

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Received 29 April 2020/Accepted 26 May 2020/Published online: 28 May 2020

Abstract Rice is a major staple food in Nigeria and currently, the production capacity of the country cannot meet consumers; demand. Therefore, large quantities of rice are imported into the country without recourse to their heavy metal contents. Several research reports indicated that there is a likely possibility of heavy metal contamination of foreign rice and associated health hazards. Therefore, this study seeks to analyse foreign rice in Nigeria markets and identified their health implications. The result obtained indicated that mean concentrations of the heavy metal ions were Cd (0.0014 ± 0.00005 to 0.4322 ± 0.00005), Cr (0.0010 ± 0.00005 to 0.1080 ± 0.00005), As (0.0006 ± 0. 0001 to 0.1711 ± 0.0008), Ni (0.0007 ± 0.00001 to 0.8865 ± 0.00005), Hg (0.0024 ± 0.0001 to 0.0935 ± 0.001), Cu (0.0052 ± 0.00001 to 0.3208 ± 0.00005), Pb (0.0047 ± 0.00001 to 0.3974 ± 0.00001). Most of the imported rice brands have mean concentration (mg/kg) of the heavy metals below their maximum permissible limit (MPL) as set by FAO/WHO and Codex Alimentarius Commission (CAC). The hazard quotient (HQ) for the heavy metals in the imported rice brands range from 0.0006 (6×10^{-4}) to 5.0 while their hazard index (HI) range from 1.2 – 9.31. Most of the imported rice brands (62.5 %) and all the rice brands (100 %) had HQ and HI for the heavy metals greater than one respectively pointing to the, likelihood and high potential for non-carcinogenic risks. The cancer risk assessment value ranged from 8×10^{-6} to 1×10^{-3} which suggest probability of cancer risks.

Keywords: *Rice, heavy metals, hazard index, hazard quotient, cancer risk.*

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1.0 Introduction

Rice is a cereal grain eaten by most countries of the world by more than 50 percent of the world's population (Muthayya et al., 2014; FAO Rice publication). Rice like most cereal grain belongs to the grass family known as *Gramineae* and of the genus *Oryza*. Generally cereal grains are rich in carbohydrate, fat and even protein can produce energy called calories but carbohydrates produce more energy than others. Rice provides more energy to humans than most cereal and crop plants (Nayar, 2014). According to Juliano, *et al.* (2019) oat grain has more energy than rice.

The nutritional value of food can be assessed based on its proximate, mineral, and toxicants compositions (Abdul-Hamid *et al.* 2007; Eddy and Ekop, 2005; Eddy and Udoh, 2005). Oko *et al.* (2012) investigated the chemical composition of some fifteen different varieties of rice and reported that carbohydrate content ranged from 51. 50 to 86.90 %, maximum ash content was 2.0 % while the energy value ranged from 262.94 to 398.82 %. Fat content (0.5 to 3.5 %), fibre content (1.0 to 2.5 %) and moisture content (5.00 to 9.60%) were found to be relatively low. Highest concentrations of calcium, magnesium, potassium and sodium ions were 0.13, 0.26, 0.55, 0.23 and 0.17 % respectively. However, they did not analyze heavy metal contents. According to Juliano *et al.* (2019), 100g of brown rice contain moisture (14%), energy (358 kCal), crude protein (7.4 g), total lipid (3.1 g), ash (1.2 g), carbohydrate (73.5 g), dietary fibre (3.5 g) and sugar (0.6 g). They compared the chemical composition of brown rice with some grains (barley grains, corn white, oat grain, rye grain, sorghum grain, triticale grain and wheat flour). The results indicated that rice is richest in energy (apart from oat grain), lowest in protein, third in total lipid, lowest in ash content, richest in carbohydrate and least in fibre and sugar (apart from wheat flour). Raw, long-grain white rice is a relatively good source of energy, carbohydrates, calcium, iron, thiamine, pantothenic acid, folate and vitamin E, compared to maize, wheat and potatoes. It contains no vitamin C, vitamin A, beta-carotene, or lutein+zeazanthin, and is notably low in fiber (Chaudhari *et al.,* 2018). Due to their rich and selective nutrient contents, ease of availability and relatively low cost, rice is the prefer choice of food for several rich and poor populace. Rice is mostly consumed in Asia, Latin America, the Caribbean and Africa (Muthayya *et al*, 2014). However, Asia is the largest producer and consumer of rice with about 90% global rice production and consumption (Muthayya *et al*., 2014).

In spite of its useful nutrient contents of rice, one of the greatest environmental problems that can confront the nutritional benefits of rice is the presence of heavy metals (Ali *et al.,* 2019). Rice acquired heavy metals ions through absorption from the soil (Zeng *et al*., 2015). Heavy metals are those elements whose density is greater than 5 g/cm^3 (Ivica, 2015). The worst recorded incident of heavy metal pollution (i.e itai itai) which occurred in Japan due to cadmium poisoning was heavily associated with rice farm due to irrigation of the farm with water from the Cd-polluted Jinzu River basin of Toyama (Aoshima, 2016). Mao *et al.* (2019) had reported the accumulation of heavy metal in rice. Their results indicated that heavy metal levels in soil decreased with increasing soil pH, while rice shoots accumulated heavy metals more readily under low soil pH conditions. The non-carcinogenic hazard quotients (HQ) of heavy metals show that health risks for humans were primarily due to Pb and As and that ~76% and ~15.7% of cancer risk was caused by Cd and As levels, respectively. Chen *et al*. (2018) investigated cadmium content of rice in China and reported that 88% of rice grain samples, exceeded the Chinese maximum permissible limit for Cd (0.1 mg fresh weight kg^{-1} for rice) and expressed fear of possible health risk that can results from this contamination. Chi *et al.* (2018) also reported that rice can easily absorbed cadmium and arsenic from the soil. They found that the rate of uptake of this heavy metal depends on seasons and vary with different soil. Liu *et al.* (2013) has also reported the dependence of lead absorption by rice on genotype. World leading producers of rice (oryza sativa) are China, India, Indonesia, Bangladesh, Vietnam, Thailand, Myanmar, Philippines, Brazil and Japan (FAOSTAT, 2018) United States, Pakistan, Korea and Egypt, with China and India alone accounting for 50 percent of global rice production while the entire Asian countries account for 90 % of global rice production and supply (Muthayya, 2014) Rice is imported into Nigeria from Thailand, India, China, Indonesia, Pakistan, United States of America, Vietnam and Brazil. Rice and other food crop grown in some regions of these countries have been implicated with heavy metal contamination, as well as, the soil and water on which rice is grown and water used in growing the rice respectively (Satpathy *et al*, 2014; Zarcinas *et al*, 2004; Simmons *et al.*, 2003; *Simmons et al., 2005*; Shabbir *et al.,* 2013, Nawaz *et al.,* 2003 and (Zeng *et al.*, 2015).

Due to the documented facts on the tendency of rice plant to accumulate heavy metals and the fact that most of the imported rice in Nigeria comes from some of those countries that have reported the presence of heavy metals in their rice, the need to investigate the heavy metal (Cd, Cr, As, Ni, Hg, Pb and Cu) contents of imported rice can yield results that can form a baseline information on importation control. Therefore, this study is aimed at analyzing some samples of foreign rice in the Nigerian market.

2. Materials and methods

2.1 Sample collection

Eight (8) rice brands imported into Nigeria were purchased from Wuse and Karimu markets located in the Federal Capital Territory (FCT), Abuja, Nigeria. The samples were purchased between August 2019 to September 2019, stored in properly labelled polyethene bags and taken immediately to the laboratory. They were sieved through a ThermoFisher scientific sieve of 100 mesh to remove impurities and stored again in well labelled polyethene bags.

2.2 Sample preparation and analysis

2 g of the sample was weighed into a beaker and twelve milliliters (12 ml) mixture of HNO_3/HCl (aqua regia) in a ratio of 1:3 (prepared from ultrapure HNO_3 and HCl from Merck, Darmstadt, Germany) was added to each sample and heated on a hot plate inside a fume cupboard. The temperature was increased gradually, starting from 100 ^{0}C and increasing up to 200-300 ^{0}C. The digestion was completed with the appearance of white fumes. The mixture (after cooling) was filtered into a 50 ml standard volumetric flask and made to mark with deionized water. The digest was used for heavy metal determination using both atomic absorption spectrophotometer (AAS) and inductively coupled plasma - optical emission spectrometry (ICP-OES). Cd, Cr, Cu, Ni and Pb were analysed using Buck 210VGP atomic absorption spectrophotometer (Buck Scientific, Inc. East Norwalk, U.S.A) with detection limits of 0.01, 0.04, 0.005, 0.10, 0.04 $mgkg^{-1}$ for Cd, Cr, Cu, Ni and Pb respectively. The wavelengths of maximum absorption for the metals were 228.9, 357.9, 324.8, 232 and 217 nm respectively. Buck Puro – graphic™ stock standard solution (1000ppm) of Cd, Cr, Cu, Ni and Pb were used for preparation of calibration curve of the respective metal ion. Certified reference material (GBW (E) 080684 for rice flour) of the National Research Center for Certified reference materials, China (NRCCRM) was used to verify the accuracy of the analytical result. The percentage recoveries ranged from 91 to 117%. Mercury and arsenic were analysed using Agilent 720 ICP-OES (Agilent Technology, Inc, USA) with megapixel CCD detector which provides simultaneous measurement while the Agilent SPS3 autosampler was used for sample introduction. Agilent Expert II Software was used to control the instrument and acquire data. Calibration and Quality Control (QC) solutions were prepared from AccuStandard QCSTD-27 multi-element solution. Ultrapure Merck Lichrosolv water was used for dilution of standards and QC solutions. These were also stabilized in high purity 2% v/v concentrated nitric acid (HNO_3). The analysis was performed in triplicate n equals 3 and results presented as mean ± standard deviation.

2.3. Human health risk assessment

2.3.1 Estimation of average daily dose (ADD) exposure to heavy metals in rice

The average daily dose (ADD, $kg^{-1}\ day^{-1}$) is the amount of chemical at the exchange boundary $mg\ kg^{-1}\ day^{-1}$ (USEPA, 2005), it is used to evaluate the oral exposure dosage to deleterious chemical compounds by a receptor. The average daily dose (ADD) of heavy metals in this study were estimated using USEPA equation for estimating ADD, which is as follows; (USEPA, 2005; USEPA, 2014; Gerba, 2019)

$$\text{ADD} = \frac{C.\ IR.\ EF.\ ED}{BW.\ AT} \qquad (1)$$

Where C = average concentration over the period ($mg\ kg^{-1}$ for food or soil, $mg\ L^{-1}\ for\ water$, $mg\ m^3\ day^{-1}$ for air), IR = Ingestion rate, the amount of contaminated medium ingested or contacted per unit time ($kg\ day^{-1}$, $l\ day^{-1}$ or $m^3\ day^{-1}$), EF= Exposure frequency (days/ year), according to USEPA 365 days/year, ED = Exposure duration (years), 30 years (standard exposure duration for adult exposed to a non-carcinogenic, and 70 years for carcinogenic (USEPA, 2005; Gerba, 2019). According to World Bank the life expectancy of an adult Nigerian is 54 years (World Bank, 2018), AT is the average time – the period over which exposure is averaged (days); for carcinogens the average time is 25,550 days (365 days/year x 70 years) based on a lifetime exposure of 70 years; for non-carcinogens, averaging time equals ED years multiplied by 365 days per year and BW is the average body mass over the exposure period (Kg). In Nigeria the average body mass of an adult as determined by Onyedum *et al*, (2020) is 61 Kg, which is in close correlation with that (60. 94 Kg) determined by Ogunlade *et al*, (2015), while that by Innocent et *al*, (2016) is 68.68 Kg. In this study the average 63 Kg was used. AT the average time (19710 days) was obtained by multiplying the life expectancy of an adult Nigerian 54 years by 365 days/year. Based on World Health Organisation (WHO) Global Environmental Monitoring System (GEMS)/Food consumption cluster diets, Nigeria belongs to the cluster 13 (G13) nations. According to the estimated daily consumption contained in the WHO/GEMS database (2012), Nigeria consumes an average of 330.5 g/day (0.3305 Kg/day) of cereal grains and flours.

2.3.2 Non – carcinogenic risk

The human non – carcinogenic risk assessment for Nigerians who consume the rice under study was calculated using the equation; (USEPA, 2005; USEPA, 2014; Gerba, 2019)

$$HQ = \frac{ADD}{RFD} \qquad (2)$$

HQ the hazard quotient characterizes the health risk of non – carcinogenic adverse effects due to exposure to a single toxicant. RFD is the reference dose is the estimated maximum permissible dose through daily exposure to human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious (non-cancer) effects during lifetime. If HQ < 1, adverse health effects would unlikely not occur, potential non – carcinogenic effects would occur when HQ ≥ 1 (USEPA, 2005; USEPA, 2014; Gerba, 2019). The hazard index (HI) which evaluates the potential risk of adverse health effects from a mixture of chemical elements (multiple substances) was calculated for the rice samples using the equation: (USEPA, 2005; USEPA, 2014; Gerba, 2019).

$$HI = \sum HQ \qquad (3)$$

HI is the sum of HQ (assuming additive effects). If HI < 1, chronic risks are assumed to unlikely happen, while non-cancer risks are likely to occur if HQ ≥ 1.

2.3.3 Carcinogenic Risk

Cancer risk (CR) is the incremental probability for developing cancer for individuals exposed to a given chemical over a lifetime (USEPA, 2014). It can be calculated using equation 4

$$CR = ADI \times SF \qquad (4)$$

where SF is cancer slope factor (mg/kg day^{-1}) for a substance. A cancer risk of 10^{-4} to 10^{-6} are considered acceptable US EPA (2014). Cancer risk of 10^{-4} and 10^{-6} indicates a probability of 1 in 10,000 individuals and 1 in 1,000000 individuals developing cancer during a lifetime.

3.0 Results and Discussion

The result of the heavy metal concentration (mg/kg) of some rice brands imported into Nigeria is presented in Table 1. The concentration (mg/kg) of cadmium, chromium, arsenic, nickel, mercury, copper and lead range as follows: Cd ion concentration ranged from 0.0014 ± 0.00005 to 0.4322 ± 0.00005 mg.kg (with highest and lowest concentrations in mama gold (Thailand) and diamond (India) rice respectively). Chromium concentrations ranged from 0.0010 ± 0.00005 to 0. 1080 ± 0.00005 mg/kg (lowest concentration was recorded for tomato (Thailand) rice while highest concentration was recorded for diamond (India) rice). Highest and lowest concentrations of arsenic were found in Crown (Indian) brand of polished rice, except cadmium concentration in Diamond rice (0.4322 ± 0.00005 mg/kg. Although the observed concentrations of cadmium in the rice while highest was in Diamond rice, which is also an Indian rice. The range for the measured concentrations of arsenic was As 0.0006 ± 0. 0001 to 0.1711 ± 0.0008 mg/kg. Nickel concentrations ranged from 0.0007 ± 0.00001 to 0.8865 ± 0.00005 mg/kg (lowest concentration was measured for crown (India) rice while the highest concentration was found in Diamond (India) rice). Mercury concentration was lowest in Basmatic rice (0.0024 ± 0.0001 mg/kg) while highest concentration (0.0935 ± 0.001 mg/kg) was found in the Thailand Tomato branded rice. Mean concentration of copper in the rice samples ranged from 0.0052 ± 0.00001 to 0.3208 ± 0.00005 mg/kg with highest and lowest concentrations measured for Diamond (Indian rice) and Mama gold (Thailand rice). Mean concentrations of lead ions ranged from 0.0047 ± 0.00001 to 0.3974 ± 0.00001 mg/kg (with lowest concentration in Prince (India) rice and highest in Tomato (Thailand) rice). From Table 3, most of the imported rice brands have mean concentration of Cd, Cr, As, Ni, Hg, Cu, and Pb below their maximum permissible limit (MPL). Only one (11 %) has mean concentration above the maximum permissible limit for cadmium in polished rice, while, the remaining eight (89 %) rice brands have mean concentration below the maximum permissible limit for cadmium. Similarly, one (11%) of the rice brands has mean concentration above the maximum permissible limit for chromium in cereal grains, whereas the remaining eight (89 %) rice brands have mean concentration below the maximum permissible limit for chromium. The mean concentration of arsenic and copper in all (100%) of the rice brands are below the maximum permissible limit for arsenic and copper in paddy, brown and polished rice.

Six (representing 67 %) and two (22%) of the rice brands have mean concentrations of mercury and lead respectively below the maximum permissible limit for mercury and lead in white rice and cereal grains respectively, while, three (33 %) and 7 (78 %) of the rice brands have mean concentration of mercury and lead respectively above the maximum permissible limit for mercury and lead. The concentration (mg/kg) of cadmium in the different brands of rice imported into Nigeria is below the maximum permissible (MPL) of FAO/WHO (2017) for cadmium (0.4 mg/kg) in other rice samples are within the safety range, most rice contaminated by cadmium are product of cadmium contaminated irrigation water and application of cadmium rich fertilizers or waste (Satpathy *et al*, 2014 ; Zarcinas *et al*, 2004; Simmons *et al*, 2003 and Nawaz *et al,* 2003). According to Nawaz *et al* (2003).

Table 1: Heavy metal concentrations (mg kg^{-1}) of some rice brands imported into Nigeria and their maximum permissible limit (MPL) in polished rice by regulatory agencies.

Rice brand and MPL	Cd	Cr	As	Ni	Hg	Cu	Pb
Mama Gold (Thailand)	0.0014 ± 0.00005	0.0698 ± 0.00005	0.0707 ± 0. 0008	0.1165 ± 0.00005	0.0340 ± 0.00111	0.0052 ± 0.00001	0.3553 ± 0.00001
Tomatoes (Thailand)	0.0015 ±0.00005	0.0010 ± 0.00005	0.1704 ± 0.00007	0.0043 ± 0.00005	0.0935 ± 0.001	0.0371 ± 0.0001	0.3974 ± 0.00001
Smile (Thailand)	0.0273 ± 0.0005	0.0211 ± 0.00003	0.0418 ± 0.0005	0.0794 ± 0.00577	0.0104 ± 0.00013	0.0343 ± 0.0002	0.3081 ± 0.0001
Mr (Pakistan)	0.0023 ± 0.00005	0.0032 ± 0.00002	0.0006 ± 0.0001	0.0025 ± 0. 00004	0.0095 ± 0.00005	0.2146 ± 0.00005	0.2090 ± 0.00004
Basmati (India)	0.0103 ± 0.0003	0.0625 ± 0.0002	0.0195 ± 0.00004	0.1140 ± 0.00005	0.0024 ± 0.0001	0.1646 ± 0.0001	0.3811 ± 0.00005
Crown (India)	0.1004 ± 0.00005	0.0321 ± 0.00005	0.0118 ± 0.00141	0.0007 ± 0.00001	0.0082 ± 0. 0003	0.2481 ± 0.00005	0.0085 ± 0.00005
Diamond (India)	0.4322 ± 0.00005	0.1080 ± 0.00005	0.1711 ± 0.0008	0.8865 ± 0.00005	0.0711 ± 0.00006	0.3208 ± 0.00005	0.2766 ± 0.00005
Prince (India)	0.0031 ± 0.01721	0.0028 ± 0.00005	0.0402 ± 0.00005	0.0199 ± 0.00001	0.0101 ± 0.0003	0.2074 ± 0.00005	0.0047 ± 0.00001
MPL ([a]FAO/WHO,[b]CAC))	0.4	_	0.2	__	_	_	0.2
MPL ([c]NFSS)	0.2	0.1	0.2	__	0.02	10	_

Pakistan is located in arid and semi-arid zones and does not have sufficient water to meet the water requirement of crops including rice. Consequently, irrigation water may contain heavy metals since options are limited. According to Aoshima (2016), the most popular sources of heavy metals in rice is irrigation water, some of which may originate from mining activities. The process of foliar absorption transfers heavy metal from the soil to the plant including rice and by their characteristics, heavy metals have the tendency to bioaccumulate but the danger is through the food chain when it is transported to other organism including man. Consumption of rice with high cadmium content can cause adverse health effect; chronic cadmium poisoning was experienced by consumers who consumed food in the 1950s from cadmium polluted areas in Japan where cadmium levels in unpolished rice from the contaminated regions were ≥ 0.3 mg (Fowler *et al*, 2015). The consumers came down with itai – itai disease, exhibiting symptoms of disturbed calcium metabolism, osteoporosis, and osteomalacia. Cadmium has the potential to displace divalent metal ions from the body and the target organs for cadmium in the human body are the kidney, the skeletal and the respiratory system, and is classified as a human carcinogen (WHO, 2010, Fowler *et al*, 2015). The maximum permissible limit of chromium in rice is 0.1 mg/kg (NFSS, 2012); apart from diamond rice with chromium concentration (0.1080 ± 0.00005) mg/kg slightly above the MPL for Cr in cereal grains, the other rice brands have MPL for Cr below 0.1 mg/kg. Therefore, the rice is not contaminated with chromium ion. Chromium as pure metal has no adverse effect. Little toxic effect is attributed to trivalent chromium when present in very large quantities; trivalent chromium is an essential trace element in humans and in animals. Both acute and chronic toxicity of chromium are mainly caused by hexavalent compounds. The most important toxic effects after ingestion of hexavalent chromium compounds are bronchial carcinomas, gastro enteritis and hepatocellular deficiency (Deng *et al.,* 2019). Cchromium (VI) is classified as a human carcinogen by the International Agency for Research on Cancer (IARC, 1987). Mean concentrations of arsenic in the various rice brands are less than FAO/WHO (2017) and NFSS (2012) MPL for arsenic in polished rice. Hence, the rice is not contaminated by arsenic. Arsenic is associated with integumentary, nervous, respiratory, cardiovascular, hematopoietic, immune, endocrine, hepatic, renal, reproductive system and development health issues as well as genetic mutations. Arsenic and arsenic compounds is classified as a human carcinogen by the International Agency for Research on Cancer (IARC, 1990). There is no permissible limit for Ni in polished rice or other forms of rice (paddy and brown rice), therefore nickel concentration in the imported rice brands could not be compared with MPL for nickel in polished rice, however, the MPL for Ni in hydrogenated vegetable oils and hydrogenated vegetable based products is 1.0 mg /kg. This value is higher than the concentration of Ni in all the rice brands. Therefore, nickel does not constitute health risk to consumers of these rice brands. Humans may experience acute toxicity of nickel when taken orally in large doses (Daldrup *et al*, 1983; Sunderman *et al*, 1988). Signs and symptoms of nickel includes lung fibrosis, cardiovascular and kidney diseases and cancer of the respiratory tract (Oller *et al*, 1997, Mcgregor *et al*, 2000, Seilkop and Oller, 2003). Mean concentrations of mercury in smile, Mr, basmati, crown, and prince rice are less than 0.02 mg/kg MPL of mercury in polished rice as set by the National Food Safety Standard of the People's Republic of China (2012). However, mean concentrations of mercury in mama gold (0.0340 mg/kg), tomatoes (0.0935 mg/kg) and Diamond (0.0711 mg/kg) rice are greater than MPL for mercury. The mean concentration of Hg in brown rice cultivated in Hunan province of China were 0.043 mg/kg and 0.047 mg/kg, these were in excess of 0.02 mg/kg of the Chinese standard, and was attributed to the presence of the mining and processing of Pb – Zn ores in Hunan Province which contain mercury, the use of explosive in mining processes which releases Hg, Cd and other heavy metals that eventually spread to nearby fields, background soil concentration as well as soil physicochemical reactions (Zeng *et al*, 2015). Mercury has profound cellular, cardiovascular, haematological, pulmonary, renal, Immunological, neurological, endocrine, reproductive, and embryonic toxicological effects (Rice *et al,* 2014). Due to the adverse health effect of mercury, the rice brands with mercury concentrations higher than MPL for mercury are not recommended for consumption. Copper is essential for good health, however, exposure to higher doses can be harmful. High intakes of copper can cause liver and kidney damage and even death (ATSDR, 2004). The concentrations of copper in all the imported rice brands are below the MPL for Cu (National Food Safety Standard of the People's Republic of China, 2012). Hence, the rice is not contaminated by copper. However, lead concentrations in crown and prince rice samples, (Table 1) are greater than FAO/WHO (2017) MPL for lead (0.2 mg/kg) in cereal grains. Exposure to lead ion above tolerance limit can lead to coma, convulsions and even death because lead attacks the brain and central nervous system. It also causes renal impairment, immunotoxicity and toxicity to the reproductive organs, hypertension, and anaemia (WHO, 2019).

Mean ± standard deviation. [a]Food and Agricultural Organization/World Health Organization, [b]Codex Alimentarius Commission, National Food Safety Standard of the People's Republic of China.

The average daily dose (mg/kg) exposure to Cd, Cr, As, Ni, Hg, Cu and Pb is presented in Table 2, the highest ingestion per day of each of the heavy metals from the imported rice is as follows: Cd (2 x 10^{-3} mg/kg) from consumption of diamond (India) rice, Cr (6 x 10^{-4} mg/kg) from consumption of diamond (India) rice, As (1 x 10^{-3} mg/kg) from consumption of tomatoes

(Thailand) rice, Ni (5 x 10^{-3}) from consumption of diamond (India) rice, Hg (5 x 10^{-4} mg/kg) from consumption of tomatoes (Thailand) rice, Cu (1 x 10^{-3} mg/kg) from consumption of Mr (Pakistan), crown (India), diamond and Prince rice (both India rice), Pb (2 x 10^{-3} mg/kg) from consumption of mama gold (Thailand), tomatoes (Thailand) and smile (Thailand) rice.

The acceptable daily intake (ADI) is the maximum amount of a chemical that can be ingested daily over a lifetime with no appreciable health risk, and is based on the highest intake that does not give rise to observable adverse effects. The Joint FAO/WHO Expert Committee On Food Additives (JECFA, 2000 and JECFA 2010) put the oral daily intake of cadmium and arsenic through food, for adults as 10-35 µg/kg (0.01 mg/kg – 0.035 mg/kg) and 3.0 µg/kg (0.03 mg/kg) respectively. The average daily dose (mg/kg) (Table 2) of cadmium range from 7 x 10^{-6} (0.000007 mg/kg) to 2 x 10^{-3} (0.002 mg/kg) while that of arsenic range from 3 x 10^{-6} (0.000003 mg/kg) to 1 x 10^{-3} (0.001 mg/kg). These values are below and within the standard values set by JECFA. Currently there is no standard value for oral daily intake of chromium through food by WHO or FAO, however, the UK Committee on Medical Aspects of Food Policy calculated a theoretical safe and adequate level of intake requirement of chromium which lies above 25 µg/kg bw/day (0.025 mg/kg bw/day) for adults and between 0.1 µg/kg bw/day and 1.0 µg/kg bw/ day for children and adolescents, respectively (COMA, 1991).

Table 2: Average daily doses (mg kg^{-1}) exposure to heavy metals in some rice brand imported into Nigeria.

Brand	Pb	Cd	Cr	As	Ni	Hg	Cu
Mama gold (Thailand)	7 x 10^{-6}	4 x 10^{-4}	4 x 10^{-4}	6 x 10^{-4}	2 x 10^{-4}	3 x 10^{-5}	2 x 10^{-3}
Tomatoes (Thailand	8 x 10^{-6}	5 x 10^{-6}	1 x 10^{-3}	2 x 10^{-5}	5 x 10^{-4}	2 x 10^{-4}	2 x 10^{-3}
Smile (Thailand)	1 x 10^{-4}	1 x 10^{-4}	2 x 10^{-4}	4 x 10^{-4}	5 x 10^{-5}	2 x 10^{-4}	2 x 10^{-3}
Mr (Pakistan	1 x 10^{-5}	2 x 10^{-5}	3 x 10^{-6}	1 x 10^{-5}	5 x 10^{-5}	1 x 10^{-3}	1 x 10^{-3}
Basmati (India)	5 x 10^{-5}	3 x 10^{-4}	1 x 10^{-4}	6 x 10^{-4}	1 x 10^{-5}	8 x 10^{-4}	1 x 10^{-3}
Crown (India	5 x 10^{-4}	2 x 10^{-4}	6 x 10^{-5}	4 x 10^{-6}	4 x 10^{-5}	1 x 10^{-3}	4 x 10^{-5}
Diamond (India)	2 x 10^{-3}	6 x 10^{-4}	8 x 10^{-4}	5 x 10^{-3}	4 x 10^{-4}	1 x 10^{-3}	1 x 10^{-3}
Prince (India)	2 x 10^{-5}	1 x 10^{-5}	2 x 10^{-4}	1 x 10^{-4}	5 x 10^{-5}	1 x 10^{-3}	2 x 10^{-5}

The average daily doses of Cr in the imported rice brands range from 5 x 10^{-6} (0.000005) mg/kg to 6 x 10^{-4}(0.0006) mg/kg, which are below the standard value for adults highlighted.

Oral daily intake through food for adult for Hg, Ni, Cu and Pb are; PTWI 4 µg/kg equivalent to 0.57 µg/kg per day i.e 0.00057 mg/kg per day Hg (FAO/WHO , 2011) and 0.0016 mg/kg bw Hg for (ENHIS, 2007), Ni < 300 µg/kg, i.e.< 0.3 mg/kg (WHO, 2000), Cu 0.5 mg/kg bw per day (FAO/WHO, 1982) and Pb 0.025 mg/kg bw (ENHIS, 2007). The average daily doses of Hg, Ni, Cu and Pb as presented in Table 2 are lower than their standard values. This suggests that these heavy metals in the imported rice brands may be ingested over a lifetime with no appreciable health risk.

Table 3 shows the hazard quotient (HQ) and hazard index for Cd, Cr, As, Ni, Hg, Cu and Pb for consumers exposed to these heavy metals through consumption of the imported rice brands, The hazard quotient for arsenic, mercury and lead for mama gold rice; arsenic, mercury and lead for tomatoes rice; lead for smile rice, lead for basmati rice, cadmium, arsenic and mercury for diamond rice exceeded one. On the other hand, the hazard quotient for Cd, Cr, As, Ni, Hg, Cu, Pb, for Mr, crown and prince are less than one. The hazard index (HI) for Cd, Cr, As, Ni, Hg, Cu, and Pb of each rice brand is: mama gold rice (4.33), tomatoes rice (9.31), smile rice (2.5), Mr rice

(1.14), Basmati rice (2.0), crown (1.2), diamond rice (10) and prince rice (1.3). These hazard indices are greater than one.

The hazard quotient for both As, Hg and Pb of mama gold and tomatoes rice as well as Pb of basmati rice, and Cd, As and Hg of diamond rice exceeded one. This implies likelihood of potential non carcinogenic risks to consumers of these rice brands. However, the hazard quotients for Cd , Cr, As, Ni, Hg, Cu, Pb, for the following imported rice brands; Mr, crown and prince are less than one, indicating that non carcinogenic adverse health effects may not occur through the consumption of these rice brands. The hazard index (HI) for Cd, Cr, As, Ni, Hg, Cu, and Pb of each rice brand is greater than one indicating that exposure to the heavy metals simultaneously pose high potential for non-carcinogenic risk.

Table 3:Hazard quotient (HQ) and hazard index (HI) from individual heavy metal exposure to rice brands imported into Nigeria.

Rice brands				**HQ**				
	Cd	**Cr**	**As**	**Ni**	**Hg**	**Cu**	**Pb**	**HI**
Mama gold (Thailand)	7 x 10^{-3}	0.12	1.23	3 x 10^{-2}	1.7	6 x 10^{-4}	1.25	4.33
Tomatoes (Thailand)	8 x 10^{-3}	2 x 10^{-3}	3.00	1 x 10^{-3}	5.0	5 x 10^{-3}	1.4	9.31
Smile (Thailand)	0.14	4 x 10^{-2}	0.7	2 x 10^{-2}	0.5	4 x 10^{-3}	1.11	2.5
Mr (Pakistan)	1 x 10^{-2}	5 x 10^{-3}	1 x 10^{-2}	7 x 10^{-4}	0.5	3 x 10^{-2}	0.60	1.14
Basmati (India)	5 x 10^{-2}	0.11	0.33	3 x 10^{-2}	0.1	2 x 10^{-2}	1.3	2.0
Crown (Thailand)	0.5	5 x 10^{-2}	0.2	2 x 10^{-4}	0.4	3 x 10^{-2}	3 x 10^{-2}	1.2
Diamond (Thailand)	2.2	0.2	2.7	0.2	3.7	4 x 10^{-2}	0.9	10
Prince (Thailand)	1 x 10^{-2}	3 x 10^{-3}	0.6	5 x 10^{-3}	0.5	3 x 10^{-2}	0.13	1.3

Table 4 shows the carcinogenic risk for Cd, Cr, As and Ni; these four heavy metals were used to calculate cancer risk because they are carcinogenic whereas Hg, Pb, and Cu are non-carcinogenic. The cancer risk for these heavy metals in each imported rice brand range from 3 x 10^{-6} (Cd) to 1 x 10^{-3} (As and Ni) for mama gold rice; 2 x 10^{-6} (Cd) to 1 x 10^{-3} (As) for tomatoes rice; 4 x 10^{-6} (Cd) to 3 x 10^{-3} (As) for smile rice; 4 x 10^{-6} (Cd) to 2 x 10^{-5} (Ni) for Mr rice; 2 x 10^{-5} (Cd) to 2 x 10^{-3} (As) for basmati rice; 3 x 10^{-6} (Ni) to 2 x 10^{-4} (Cd) for crown rice and 3 x 10^{-4} (As) to 5 x 10^{-3} (Ni) for prince rice. The cancer risk for all the heavy metals in all the imported rice brands exceeds US EPA regulatory value of 1 x 10^{-6} to 1 x10^{-4}. The cancer risk for Cd, Cr, As and Ni for all the imported rice brands exceeds USE PA, 2014 regulatory value of 1 x 10^{-6} to 1 x10^{-4}. This implies that there is probability of cancer risk with intake of these heavy metals in the imported rice brands, over an adult Nigerian's lifetime. Ingestion of high dose level of heavy metals over a short term or low-level concentrations of heavy metals over prolonged period may cause health issues. Some heavy metals are easily assimilated and they bioaccumulate; they build up over time either because they are taken up faster than they can be used or they cannot be broken for use by the organism. Cadmium is a cumulative toxin which has no useful function in human body (ATSDR, 2008). Once ingested passes through the gastrointestinal tract unchanged and about 6 % of the ingested Cd is absorbed by healthy persons while about 9 % may be absorbed in those with iron deficiency (ATSDR, 1999).

The rate of excretion (through urine, the main source of excretion) is low due to the strong bond that may be formed between cadmium and metallothionein (MTN), which is almost completely reabsorbed in the renal tubules. Due to slow excretion, cadmium can accumulate in the body over a lifetime with a biological half-life of about 38 years (ATSDR, 2008).

Table 4: Incremental lifetime cancer risk (ILCR) for consumers of rice imported into Nigeria.

Rice brands	Incremental lifetime cancer risk			
	Cd	**Cr**	**As**	**Ni**
Mama gold (Thailand)	3×10^{-6}	2×10^{-4}	1×10^{-3}	1×10^{-3}
Tomatoes (Thailand)	2×10^{-6}	3×10^{-6}	1×10^{-3}	2×10^{-5}
Smile (Thailand)	4×10^{-6}	6×10^{-5}	3×10^{-3}	3×10^{-4}
Mr (Pakistan)	4×10^{-6}	8×10^{-6}	5×10^{-6}	2×10^{-5}
Basmati (India)	2×10^{-5}	2×10^{-4}	2×10^{-3}	6×10^{-4}
Crown (Thailand)	2×10^{-4}	8×10^{-5}	9×10^{-5}	3×10^{-6}
Diamond (Thailand)	8×10^{-4}	1×10^{-3}	3×10^{-4}	5×10^{-3}
Prince (Thailand)	6×10^{-6}	7×10^{-6}	3×10^{-4}	9×10^{-5}

****Notes:[a] United States Environmental Protection Agency, [b]New York State Department of Health, United States,[c] Environmental Protection Division of the Georgia Department of Natural Resources, United States, [d]Agency for Toxic Substances and Disease Register, U.S. Department of Health and Human Services, [e]Risk Assessment Information System, U.S. Department of Energy.**

Most of the chromium leaves the body in the urine within a week, although some may remain in the cells for several years or longer (ATSDR, 2012). 70% of the arsenic is excreted mainly in urine, for soluble trivalent arsenic compounds approximately 95% of the ingested dose is absorbed from the gastrointestinal tract (Rossman, 2007). Absorbed arsenic is widely distributed by the blood throughout the body after absorption through the lungs or gastrointestinal tract (ATSDR, 2007). Most of the arsenic remain in hair, nails, skin and to a lesser extent in the bones and teeth after two to four weeks exposure when the other tissues of the body would have cleared the arsenic in them (Yip and Dart, 2001). When nickel is ingested greater proportion of it is quickly eliminated in faeces, while the remaining amount that finds its way into the blood leaves in the urine (ATSDR, 2005). 1 to 10 % of dietary nickel is absorbed by humans and animals (EPA, 1986). Nickel is not destroyed in the body, but its chemical form may be altered. The metabolism of nickel is most appropriately associated with its binding ability to form ligands and its transport throughout the body (Das *et al.,* 2008). The toxicity of nickel-containing substances is considered to be related to the bioavailability of the metal ion (Ni^{2+}) at systemic or local target sites (Goodman *et al*., 2011).

4.0 Conclusion

Concentrations of most of the studied heavy metals are below their MPL. Mr (Pakistan) rice has Pb concentration at the same level as its MPL while concentrations of other heavy metals are below their MPL. Smile (Thailand) and basmati (India) rice both have Pb concentrations higher than its MPL while the concentrations of the other heavy metals are lower than their MPL. Mama gold and tomatoes rice both imported from Thailand have mercury and Pb in concentrations higher than their MPL whereas, the concentrations of the other heavy metals are lower than their MPL. The mean concentrations of all the heavy metals assessed are below their maximum permissible limit for polished, brown, paddy rice and cereal grains for both crown and prince rice, whereas they are above for diamond. From the results and findings of this study, there is need for routine analysis of samples from each batch of rice that are imported into Nigeria.

5.0 References

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Appendix 1: Reference doses (RfD) and Slope factors (SF) for oral exposure to chemicals

Elements	RfD mg/kg/day	Source	SF mg/kg/day	Source
As	3×10^{-4}	US EPA	1.5	US EPA[a]
Hg	1×10^{-4}	US EPA	-	
Cd	1×10^{-3}	US EPA	0.38	RAI, US DOE[e]
Cr vi	3×10^{-3}	US EPA,	0.5	RAI, US DOE
Cu	4×10^{-2}	US EPA, NY Dept. of Health, EPD Georgia[c] ATSDR[d], EPD Georgia	-	
Ni	2×10^{-2}	EPD Georgia	0.91	EPD Georgia
Pb	0.00143		0.0085	EPD Georgia

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