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Cooking Utensils as Probable Source of Heavy Metal Toxicity

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Abstract: Heavy metal toxicity in food is one of alarming global menace. This study aimed at analysing the level of some heavy metals (Fe, Zn, Cd, Ni, Mn, Cr, Co, Pb, Cu and Al) in staple food, rice, cooked with different utensils (iron, old stainless steel, new stainless steel, old aluminium, new and aluminium and clay pots). Standard analytical procedures were used while ensuring good quality control processes. Results obtained were compared with raw rice (control 1) and rice cooked in glass beaker (control 2). The metals analysed were significantly higher (except Old stainless steel, Old clay pot and Old aluminium pot) in all the cooking utensils compared with both control. The highly concentrated heavy metal was Iron (Fe) which ranged between 17.30±3.45 mg/kg in rice cooked with Old Steel Pot (OSP) and 90.53±16.23 mg/kg in New Stainless Steel Pot (NSS). This was followed by Zinc (Zn), 5.01±2.10 mg/kg in Old Steel Pot (OSP) and 17.93±12.23 mg/kg in New Stainless Steel Pot (NSS). Lowest concentration of heavy metals was Cadmium (Cd) which ranged from 0.03±0.01 in rice cooked with Old Aluminium Pot (OAP) to 0.10±0.02 in New Steel Pot (NSP). The Estimated Daily Intake of some metals in the cooking utensils exceeded safe limits. Results from this study brought to light the contamination of food by various utensils.

Key words: Aluminium · Cooking utensils · Estimated Daily Intake · Food · Heavy Metal

INTRODUCTION

Metals having density not less than five times of water are called heavy metals. They occur naturally in the earth crust and are found in some locations in highly concentrated forms constituting ore deposits. Virtually all metals, at high concentrations, are toxic and some are poisonous even at very small concentration [1]. Human metabolic roles are disrupted by heavy metals as follows. To start with, the functional capacity of crucial organs and glands, like kidney, liver, brain or bone, are impaired. Secondly they remove nutrients that are essential minerals, preventing them from fulfilling their biological functions [2]. The levels of heavy metals in foodstuffs have been reported around the world, Nigeria inclusive [3]. In various developing countries, however, such data are either not readily available or scanty in detail.

Rice is a favourite staple food for over three billion people world over [4]. The average Nigerian consumes about 24.8 kg of rice /year, amounting to 9% of whole caloric intake [5, 6]. This present study was designed to determine the level of leaching of some metals into food consumed by the larger populace. This is with a view to predict likely human exposure and poisoning resulting from cooking with commonly used utensils like Clay, Ceramic wares, Stainless steel and Aluminium.

MATERIALS AND METHODS

Utensils Collection: SCOT brand rice produced by American Rice Company Limited was purchased from a major food market in Ibadan, South-west Nigeria. The different types of cooking utensils used for this study included New Aluminium Pot (NAP), Old

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Aluminium Pot (OAP), New Clay Pot (NCP), Old Clay Pot (OCP), New Steel Pot (NSP), Old Steel Pot (OSP), New Stainless Steel Pot (NSS), Old Stainless Steel Pot (OSS), uncooked rice and Glass beaker (Pyrex) which were used as control 1 and 2 respectively. The new cooking utensils were purchased from the local markets while the old ones (previously used) were randomly collected from different households in different areas within the city. The experiment using each utensil was carried out in triplicates. Three (3) pots were used for each set of cooking utensils (i.e. 3 new pots, 3 old pots). The pots were cleaned with detergents and thoroughly rinsed with distilled water, dried and then labelled.

Sample Preparation: Each utensil containing 600ml of distilled water was placed on an electric cooker, 50g of rice was poured in the water and covered and boiled for 20 minutes. The water was then drained and the rice transferred into a clean crucible and later dried in an oven at temperature of 70-80°C for about 2 hours. It was then put in a desiccator and left to cool after which it was pulverised to powder.

Determination of Metal Content of Samples: About 100 ppm stock solutions of the Al, Ni, Mn, Cr, Co, Pb, Fe, Cd, Cu, Zn were prepared. The samples were digested according to perchloric-acid digestion method [7]. In brief a mixture of about 250 mg of cooked rice samples and 6.5 mL of mixed acids solution was boiled. Presence of white fumes signified complete digestion. The Digested solutions of the samples were filtered with filter paper (Whatmann, No 42). The Metal concentrations in the filtrate of the samples were determined using Shimadzu AA-670 Atomic Absorption Spectrophotometer.

Estimated Daily Intake (EDI) of Heavy Metals: The EDI was calculated from the following equation:

$$EDI = \frac{Conc\ metalxCons\ rice}{Bwt}$$

where EDI- Estimated daily intake, Conc. metal = concentration of the metals in rice, Cons rice = daily average consumption of rice in this region, Bwt = average body weight. The average adult body weight was assumed to be 55.9kg [5].

Quality Control: Appropriate quality assurance and control measures were taken to prevent contamination and ensure reliability of data. Care was exercised in handling samples to prevent contamination. Also, glasswares were properly washed. Reagents were of analytical grade and double distilled deionized water was used all through. Correction of instrument reading was through reagents blank determinations. Pre-analyzed samples were spiked and homogenized with different amounts of metals' standard solution for a recovery study of the analytical procedures. Dry ashing method and reanalysis (described above) were employed to process the spiked samples for analysis. The coefficients of variation of replicate analysis were observed to be lower than 10%.

Statistics: Results are mean ± SEM of triplicate determination. Independent sample t-test @ $p < 0.05$ was used to access the differences between each test and the control group. Analyses were performed using SPSS version 16.0.

RESULTS

The mean concentrations of heavy metals and aluminium in rice cooked in glass beaker were lower than those of the rice cooked in the other cooking utensils. For aluminium, the concentration was 0.01±0.01 and 0.02±0.01 mg/kg in control samples while it was 440±60mg/kg in the NAP and 259±35mg/kg in the OAP.

The concentration of Pb was 0.01±0.01mg/kg in the control samples, the concentrations in all the other cooking utensils was in the range of 0.35±0.05mg/kg and 3.22±0.25mg/kg with the NSS cooked rice having the highest level. Cd level was in the range of 0.03±0.01 mg/kg in OAP and 0.10±0.02 mg/kg in NSP (0.10±0.02 mg/kg) while the value in control samples was 0.01±0.01mg/kg. The highest value of Fe was observed in the NSS cooked rice (90.53±16.23 mg/Kg). For all the cooking utensils, the concentrations of the metals on a general basis from the highest to the lowest followed the trend Fe > Zn > Cu > Mn > Pb > Ni > Cr > Co > Cd. Aluminium (Al) was present at a very high concentration of between 132±24 mg/kg in OCP and 440±60 mg/kg in NAP cooked rice. Some of these metals exceeded the expected standard limit recommended by WHOM (Figure 1 and 2).

The Estimated Daily Intake (Table 2) of these metals in the rice cooked with some of these utensils exceeded standard safe limits except for Mn (2.4-4.3 mg/Kg), Co (0.1-0.2 mg/Kg) and Zn (6.1-21.8 mg/Kg).

Table 1: Mean concentration (mg/kg) of metals in rice cooked in different cooking utensils

	Cooking Utensils/ Heavy Metals	NAP	OAP	NCP	OCP	NSP	OSP	NSS	OSS	C1	C2
Heavy Metals	Nickel (Ni)	0.89±0.26^{a,b}	0.78±0.13^{a,b}	0.80±0.05^{a,b}	0.72±0.06^{a,}	1.80±0.10^{a,b}	1.10±0.31^{a,b}	2.02±0.70^{a,b}	1.70±0.52^{a,b}	0.01±0.001	0.01±0.001
	Manganese (Mn)	2.92±0.61^{a,b}	2.10±0.53^{a,b}	3.04±0.92^{a,b}	2.11±0.10^{a,}	2.80±0.50^{a,b}	2.01±0.40^{a,b}	3.53±1.25^{a,b}	2.60±0.05^{a,b}	0.02±0.001	0.03±0.002
	Chromium (Cr)	0.28±0.01^{a,b}	0.13±0.03^{a,b}	0.15±0.01^{a,b}	0.13±0.01^{a,b}	0.18±0.05^{a,b}	0.14±0.04^{a,b}	0.50±0.40^{a,b}	0.31±0.10^{a}	0.01±0.001	0.02±0.001
	Cobalt (Co)	0.15±0.01^{a,b}	0.05±0.01^{b}	0.14±0.02^{a,b}	0.05±0.02	0.16±0.01^{a,b}	0.09±0.05^{a,b}	0.15±0.01^{a,b}	0.13±0.03^{a,b}	0.03±0.002	0.02±0.001
	Lead (Pb)	0.85±0.18^{a,b}	0.58±0.03^{a,b}	0.73±0.32^{a,b}	0.35±0.05^{a,b}	0.76±0.65^{a,b}	0.45±0.30^{a,b}	3.22±0.25^{a,b}	2.33±1.30^{a,b}	0.01±0.001	0.01±0.001
	Iron (Fe)	37.70±4.40^{a,b}	20.45±1.95^{a,b}	66.30±7.00^{a,}	47.80±15.10^{a,b}	21.00±11.30^{a,b}	17.30±13.45^{a,b}	90.53±16.23^{a,b}	56.01±21.25^{a,b}	0.04±0.003	0.04±0.003
	Cadmium (Cd)	0.08±0.03^{a,b}	0.03±0.01	0.08±0.01^{a,b}	0.07±0.03^{a,b}	0.10±0.02^{a,b}	0.05±0.02	0.08±0.01^{a,b}	0.07±0.01^{a,b}	0.01±0.01	0.01±0.01
	Copper (Cu)	2.91±0.09^{a,b}	2.42±0.64^{a,b}	2.92±0.42^{a,b}	2.42±0.33^{a,b}	6.54±3.10^{a,b}	4.63±0.60^{a,b}	3.35±0.50^{a,b}	2.90±0.12^{a,b}	0.03±0.002	0.02±0.001
	Zinc (Zn)	8.90±6.82^{a,b}	8.80±0.91^{a,b}	11.40±3.63^{a,b}	10.50±4.14^{a,b}	8.64±0.83^{a,b}	5.01±2.10^{a,b}	17.93±12.23^{a,b}	8.12±0.50^{a,b}	0.02±0.002	0.04±0.002
Light metal	Aluminium (Al)	440±60^{a,b}	259±35^{a,b}	195±87^{a,b}	132±24^{a,b}	241±20^{a,b}	187±75^{a,b}	295±98^{a,b}	289±65^{a,b}	0.02±0.001	0.01±0.001

Results were mean ± S.E.M. [a]significant when compared with control 1, [b]significant when compared with control 2 respectively. C1- Raw uncooked rice, C2- Beaker (Pyrex) cooked rice, NAP- New aluminium pot, OAP- Old aluminium pot, NCP- New clay pot, OCP- Old clay pot, NSP- New steel pot, OSP- Old steel pot, NSS- New stainless steel pot, OSS-Old stainless steel pot.

Table 2: Daily intake rate (g/person/day) of heavy metals through consumption of rice cooked in various cooking utensils

Cooking Utensils	Heavy Metals					Light Metal				
	Ni	Mn	Cr	Co	Pb	Fe	Cd	Cu	Zn	Al
NAP	1.1	3.5	0.3	0.2	1.0	45.8	0.1	3.5	10.8	535
OAP	1.0	2.6	0.2	0.1	0.7	24.9	0.04	2.9	10.7	314.8
NCP	1.0	3.7	0.2	0.2	0.9	80.6	0.1	3.5	13.9	237
OCP	1.0	2.6	0.2	0.1	0.4	58.1	0.1	0.5	12.8	160.4
NSP	2.2	3.4	0.2	0.2	0.9	25.5	0.1	80.0	10.5	292.9
OSP	1.3	2.4	0.2	0.2	0.5	21.0	0.1	5.6	6.1	227.3
NSS	2.5	4.3	0.6	0.2	3.9	110	0.1	4.1	21.8	358.6
OSS	2.1	3.2	0.4	0.2	2.8	68.1	0.1	3.5	10.0	351.3

NAP- New aluminium pot, OAP- Old aluminium pot, NCP- New clay pot, OCP- Old clay pot, NSP- New steel pot, OSP- Old steel pot, NSS- New stainless steel pot, OSS-Old stainless steel pot.

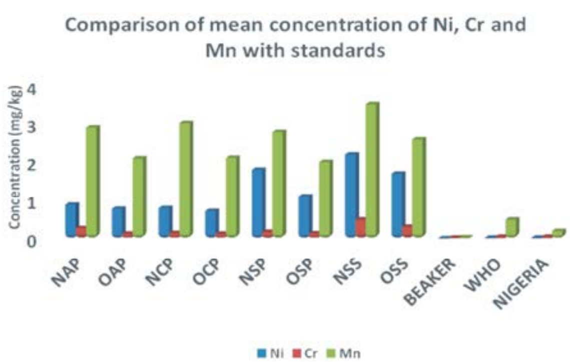

Fig. 1: Comparison of levels of Ni, Cr and Mn with standards

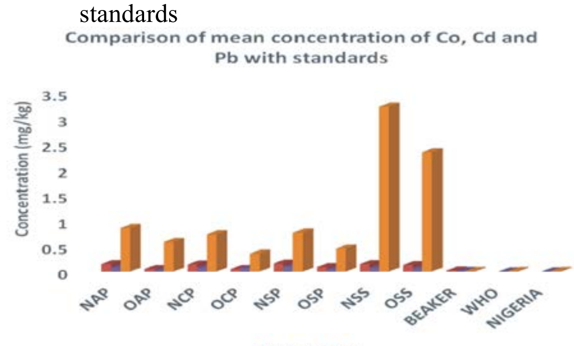

Fig. 2: Comparison of levels of Co, Cd and Pb with standards

DISCUSSION

Heavy metal toxicity in food is one of alarming global menace. In this context, this study was aimed to access the level of metals in food cooked with different cooking utensils. Excessive amount of heavy metals in food is linked to some disorders, especially of the nervous, cardiovascular and some chronic degenerative disorders [8]. High concentration of some metals exceeding the permissible limit of daily intake vis-a-vis the use of some of these cooking utensils on regular basis, as observed in this study may predispose human to some chronic diseases or disorders.

Some of the samples analysed exceeded the permissible limit of 0.01mg/kg for Pb as prescribed by WHO and Permissible level of 0.2-2.5 mg/kg for Pb in food [9]. Lead ingestion may lead to molecular mimicry of other divalent metals, Lead replaces metals like Zinc or calcium in some important protein and it then alters the protein integrity and structures and functions [10]. Chronic ingestion of this metal through food by means of cooking with some of these utensils can be detrimental to human, especially children with 40% absorption.

All the samples except OAP and OSP exceeded the permissible level of 0.05mg/kg Cd in food [11]. The results from this study showed that cadmium level in the aforementioned exceeded the daily body tolerance for adult (0.004-0.027 mg/day) [12]. This also exceeds the tolerable intake that was 1μg/kg bw/day recommended by The Joint FAO/WHO Expert Committee on Food Additives (JECFA) [9]. Cd is highly toxic and is considered to be the most severe contaminant of due to bio-persistence and bio-accumulation as a result of its slow excretion (about 0.007% of the body load everyday). The toxicological potential of cadmium is similar to zinc. Cadmium may replace zinc in some of its important enzymatic reactions hence distorting organ integrity and functions. The adverse health effect due to chronic exposure to cadmium, characterized by renal derangement/initial heightened excretion, is irreversible. The Itai-Itai syndrome is a typical of cadmium toxicity. Its main characteristics are osteomalaica and osteoporosis, creating a fragile bone easily prone to fracture. Data from animal experiments indicated that long-term *per-os* administration of Cd at relatively minimal doses caused increased arterial blood pressure and thus may be implicated in cardiovascular disorder [13].

Chromium, an indispensable trace element, is pivotal in the metabolism of protein, glucose and lipid. However, Cr (IV) is carcinogenic [14]. The observed higher than the allowable limits of Cr in the samples may therefore predispose human to the development of cancer. From table 2, the values from all the cooking utensils exceeded the daily dietary allowance.

Nickel tops the chart of the metals that possess high tendency to cause allergic reactions and cancer in humans. The World Health Organisation (WHO) tolerable daily intake (TDI) of Ni is 5μg/kg bw/day. The values of the concentration of the heavy metals of rice cooked with the various utensils exceeded the safe limit. Ni does not have a specific function in humans; however, it is an essential enzymatic co-factor for some microbiomes. Exposure to Ni above the recommended (below 0.1 mg / day) may damage cellular DNA thereby interfering with cell integrity and function [15]. The recommended dietary allowance (RDA) of Fe is 10-18 mg/day/person [16]. The values in the various cooking utensils exceeded the safe limit. The symptoms of Fe toxicity include gastro-intestinal bleeding and restlessness. Chronic Fe poisoning leads to siderosis [17].

The recommended dietary allowance of Mn is 2-5 mg/day/person [16]. The EDI of Mn for this study fall within the safe limit in all the cooking utensils so also was Cu (10 mg/kg), Co (2.5-3.0 mg/day) and Zn (50mg/kg). These suggest that food cooking utensils are not sources of copper, cobalt and Mn contamination in food. In general, this study revealed that some of these utensils may be a source of inclining heavy contamination to people.

In conclusion, Results from this study brought to light the metal contamination of food by the use various utensils. The contamination of rice cooked with various utensils suggests the leaching of some these utensils into food prepared in/with them and there is a need to educate the populace against the use of utensils that are capable of causing increased levels of heavy metals in food, as their bioaccumulation may lead to chronic health diseases and disorders.

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