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Levels of Heavy Metals in Pasta Available in the Nigerian Market: Assessing the Human Health Implications

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KEYWORDS

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Target hazard index

ABSTRACT: The concentrations of some heavy metals were determined in some pasta consumed in Nigeria, with a view to providing information on their dietary intake and exposure of consumers. The metals were determined by atomic spectrometry after acid digestion. The results (μg/g) were in the following ranges: locally manufactured pasta: Ni (0.005 - 0.738); Mn (0.2 - 1.938); Cd (Nd to 0.015); Cu (nd - 0.456); Zn (0.071 – 2.902); Pb (0.278 - 0.692); Cr (nd - 0.206) while imported pasta concentrations were: Ni (0.039 – 1.301); Mn (Nd - 1.515); Cd (Nd – 1.059); Cu (nd - 0.333); Zn (nd - 2.024); Pb (0.313 – 1.085); Cr (Nd - 0.233). The estimated daily intakes of these pastas were below the tolerable daily intake limits of the metals stipulated by FAO/WHO and JECFA. The hazard quotient and total hazard index (THI) values were less than 1 indicating no adverse health effect. However, THI in imported macaroni was appreciable.

INTRODUCTION

Pastas are hard wheat product formed from dough, but not leavened and are formed into different shapes (such as thin strips, tubes, or shells) and usually boiled. Pastas commonly consumed in Nigeria include noodles, macaroni and spaghetti and they have become quite popular because of the short time required to prepare them, ease of preparation and low cost. These commodities serve as quick foods for children and adults in more than one third of homes in Nigeria and beyond [1]. The import ban, changing consumption patterns, increasing demand for more nutritious and easy-to-cook food and the more expensive local substitutes, all have also contributed to the growing demand of pasta products [2]. The high food demand, due principally to the increasing population and urbanization, the severe shortage of time on part of bachelors, spinsters and the working mothers and the change in feeding habits and way of life have combined to make the eating of pasta very popular.

Wheat (*Titicum*) is a type of cereal which is widely consumed [3]. It is often refined into wheat flour which is used as a raw material in making pastries, bread, cakes etc [3]. The pastas produced in Nigeria are wheat-based. This commodity is mainly produced by processing wheat which involves sorting and milling of dry grains, and addition of some adjuncts; sugar, honey and dried raisins [3]. Minerals constitute 1 to 3 percent of the weight of a cereal grain and concentrate more in the external areas of the wheat grain [3]. However, the metallic content in wheat varies depending on the variety, the type of land where it has been cultivated, the fertilizer that has been used and the weather conditions [3].

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As a result of rapid industrial development across the world, there has been an increase in environmental pollution; and consequently in agricultural raw materials. This has lead to high levels of food contamination across the world. Cases of environmental pollution confronted very frequently and threatening food safety is due to heavy metals. Heavy metals are persistent in the environment and are subject to bioaccumulation in food chains. Monitoring the concentrations of various metals in food is critical because these contaminants have deleterious effects on humans. Many illnesses and diseases such as hypertension, cancer, depression and metal disorders have been associated with increased concentrations of heavy metals such as cadmium, lead, copper, chromium, nickel, manganese and zinc in human organs [4, 5].

Food safety is an important aspect of a nation's economic stability and several reports have shown cases of heavy metal contamination in pasta products in some countries. For example, in Taiwan, an examination of 129 packets of seasoning oil and vegetable flavours of 67 instant noodles revealed the presence of arsenic, lead and copper at elevated concentration [6]. In India, the Uttar Pradesh Food Safety and Drug Administration prosecuted Nestle India as samples of their Maggi noodles were found to contain high levels of lead beyond the permissible level [7]. In Bangladesh, some brands of commercial noodles were found to contain varying concentrations of different heavy metals [8]. Little or no study has been reported on heavy metal and health risk assessment on pastas consumed in Nigeria. Hence, this study aimed at assessing some heavy metal (Cr, Cd, Cu, Mn, Ni, Pb, and Zn) levels in locally produced and imported pastas (noodles, spaghetti and macaroni). This study also reports the daily intakes of metals and potential health risk implications using the hazard quotient and total hazard index.

MATERIALS AND METHODS

Sample Collection

Sixty packets of locally produced and imported pasta were collected from some cities in Nigeria (Lagos, Abuja and Enugu) to reflect the kinds of pasta commonly retailed to consumers in November 2014. The identified products were categorized into three (3): noodles, macaroni and spaghetti.

Sample preparation and digestion

Each sample was crushed with wooden mortar/pestle and about 50.00g of the crushed samples were further pulverized into powder with porcelain mortar and pestle, sieved through a thin fine cotton (muslin) cloth and stored in a dessicator prior to digestion. A 2.00 g mass of the ground sample was weighed with a digital weighing balance (Ohaus Corporation Shanghai, China, Model No: Cp 413) into a conical flask and 20mL of 1:1 HNO_3:$HClO_4$ was added. The mixture was heated on a heating mantle (Labtech Technology, India) for 20–30 minutes until a clear colourless digest was obtained. The digest was transferred to a 50 mL standard flask and made up to the mark with de-ionized water. Analyses were carried out using an Agilent Technology (USA) model: 240FS Atomic Absorption Spectrophotometer. Sample blanks were analyzed for Cd, Cr, Mn, Zn, Cu, Pb and Ni by taking 20 mL of the digestion mixture through the same procedure.

Quality assurance procedure

Precision and accuracy of the analytical procedure were investigated by carrying out recovery experiments. This was done by determining the metal concentrations in triplicate samples of un-spiked and spiked pasta samples. Spiking was done by adding various standard concentrations of the heavy metal solution to 2 g of ground pasta, which was later subjected to the digestion procedure. The percent recovery was calculated as:

$$\% \text{ Recovery} = a - b / c \times 100$$

where a = concentration of the spiked sample

b = concentration of the un-spiked sample

c = concentration of the metal ion added

The limit of detection (LOD) for the AAS procedure was determined empirically by measuring progressively more dilute concentrations of the analyte, while the limit of quantification (LOQ) was calculated statistically using Association of Analytical Communities [9] method: LOQ = Xb+10Sb. Table 1 presents the recoveries obtained via spiking of the samples with the different metals at different concentrations. Recoveries ranging from 92 to 98.7% were obtained. This validates the analytical procedure used.

Table 1. % Recovery for Pb, Zn, Ni, Mn, Cu, Cd and Cr in Pasta samples.

Element	Spiking (added) conc. (μg/mL)	Conc. of spiked sample (μg/mL)	Conc. of unspiked sample (μg/mL)	Recovered conc. (μg/mL)	% Recovered	% Precision	LOD (μg/mL)	LOQ (μg/mL)
	0.100	0.526	0.427	0.099	99			
Pb	0.100	0.384	0.284	0.100	100			
	0.100	0.436	0.345	0.091	91	5.09	0.004	0.048
Mean±S.D					**96.67±4.93**			
	0.100	0.744	0.651	0.093	93			
Zn	0.100	0.866	0.780	0.086	86		0.05	0.098
	0.100	2.228	2.131	0.097	97	6.05		
Mean±S.D					**92.00±5.57**			
	0.100	0.202	0.094	0.108	108			
Ni	0.100	0.191	0.094	0.097	97		0.02	0.078
	0.100	0.191	0.099	0.091	91	8.74		
Mean±S.D					**98.67±8.62**			
	0.100	0.522	0.448	0.096	96			
Mn	0.100	0.633	0.532	0.101	101			
	0.100	1.538	1.439	0.099	99	2.55	0.01	0.032
Mean±S.D					**98.67±2.52**			
	0.100	0.158	0.062	0.096	96			
Cu	0.100	0.227	0.128	0.099	99		0.02	
	0.100	0.136	0.036	0.100	100	2.12		0.037
Mean±S.D					**98.33±2.08**			
	1.00	2.456	1.559	0.089	89			
Cd	2.00	3.399	1.559	0.092	92			
	3.00	4.804	1.559	0.108	108	10.60	0.002	0.027
Mean±S.D					**96.33±10.21**			
	2.00	2.182	0.233	0.974	97.4			
Cr	2.00	1.827	0.012	0.907	91			
	3.00	3.537	0.425	1.037	103.7	6.52	0.02	0.042
Mean±S.D					**97.37±6.35**			

Health risk assessment

Estimation of daily intake

Estimated daily intakes of the metals (EDI) were calculated as follows:

$$EDI = \frac{MI \times MC}{BW}$$

Where MC is the mean concentration of metal in the pasta consumed (mg/kg), MI is the estimated quantity of pasta consumed (g/person/day), BW is the average body weight of adult (70kg) and children (27kg) respectively [10].

Hazard Quotient (HQ)

HQs was determined following the US EPA Region III Risk-based Concentration Table [11] described by

$$HQ = \frac{Efr \times EDtot \times MI \times MC}{RfDo \times BW \times ATn} \times 10^{-3}$$

where E_{fr} is the exposure frequency (350 days/year); ED_{tot} is exposure duration, total (70 years); MI is pasta ingestion (g/person/day); MC is metal concentration in pasta (µg/g); Rf_{Do} is the oral reference dose (mg/kg/day); BW is the average bodyweight adults and children, AT_n is averaging time for non-carcinogens (365 days/year ED_{tot}).Oral reference dose for different metals (mg/kg per day; Ni = 0.02, Mn = 0.14, Cd = 0.001, Cu = 0.04, Zn = 0.3, Pb = 0.004, Cr = 1.5

Total Hazard Index (THI)

THI was calculated to evaluate the potential risk of adverse health effects from a mixture of chemical constituent in each pasta.

$$THI = HQ_1 + HQ_2 + \ldots + HQ_n$$

The magnitude of the total hazard index is assumed to be

proportional to the extent of adverse effects or toxicities of the pasta consumed.

STATISTICAL ANALYSIS

One way analysis of variance (ANOVA) was used to compare the levels of the heavy metals in locally produced and imported pasta. All statistical analysis were performed with SPSS 16.0 for windows

RESULTS AND DISCUSSION

The mean concentrations for Cd, Pb, Ni, Cr, Cu, Mn, and Zn in both locally produced and imported pasta available in the Nigerian market are presented in Table 2. The highest concentration of nickel, cadmium, copper and zinc in the locally produced pasta were recorded in macaroni. Spaghetti has the highest lead and chromium concentrations while noodles recorded the highest concentration of manganese. However, in the imported pasta products, macaroni recorded the highest of all the metals except chromium which was highest in noodles. The Ni concentrations were consistent with (0.35 - 0.43) µg/g reported by Jothi and Uddin [8] on commercial noodles in Bangladesh but higher than (0.010 – 0.004) µg/g reported by Onyeama et al [12] on instant noodles in Nigerian market. All the analysed pasta products have nickel concentration lower than the permissible limit of 4µg/g by Food and Nutrition Board [13].

Table 2. Mean concentration of metals (µg/g) in different Nigerian and imported pasta.

Metal	Local produced Pasta			Imported Pasta		
	Noodles (n = 16)	**Spaghetti (n = 8)**	**Macaroni (n = 8)**	**Noodles (n = 8)**	**Spaghetti (n = 8)**	**Macaroni (n = 12)**
Ni						
Range	0.11 - 0.446	0.050– 0.182	0.186 – 0.738	0.099 – 0.250	0.084 – 0.152	0.039 – 1.301
Mean ± S.D	0.253±0.111	0.138±0.054	0.427±0.202	0.181±0.055	0.127±0.021	0.684±0.567
Mn						
Range	0.200 – 0.895	1.018 – 1.83	0.724 – 1.938	n.d – 0.220	0.008 – 1.217	0.448 – 1.515
Mean ± S.D	0.527±0.245	1.461±0.327	1.347±0.426	0.103±0.092	0.417±0.508	0.787±0.316
Cd						
Range	n.d – 0.009	n.d – 0.007	0.001 – 0.015	0.000 - 0.007	n.d – 0.005	n.d – 1.059
Mean ± S.D	0.003±0.002	0.003±0.002	0.008±0.005	0.002±0.003	0.002±0.001	0.263±0.401
Cu						
Range	0.093 – 0.340	0.240 – 0.283	n.d – 0.456	nd – 0.115	0.02 – 0.185	0.030 – 0.333
Mean ± S.D	0.191±0.071	0.263±0.016	0.225±0.123	0.064±0.043	0.095±0.069	0.129±0.118
Zn						
Range	0.077 – 0.780	0.071 – 0.298	2.404 – 2.902	n.d – 1.626	n.d – 0.230	1.089 – 2.024
Mean ± S.D	0.459±0.234	0.230±0.07	2.643±0.163	0.855±0.599	0.084±0.091	1.419±0.297
Pb						
Range	0.280 – 0.468	0.278 – 0.692	0.358 – 0.513	0.313 – 0.493	0.318 – 0.394	0.403 – 1.085

Table 2. Continued

Mean ± S.D	0.390±0.062	0.480±0.148	0.414±0.089	0.406±0.091	0.347 ±0.027	0.608±0.233
Cr						
Range	n.d – 0.190	0.021 – 0.148	n.d – 0.206	nd – 0.233	n.d – 0.048	n.d – 0.064
Mean ± S.D	0.041±0.063	0.106±0.051	0.104±0.078	0.063 ±0.088	0.015±0.016	0.031±0.026

The mean concentrations of Mn were 0.527µg/g in Nigeria noodles, 1.461µg/g in Nigerian spaghetti and 1.347µg/g in Nigerian macaroni. These concentrations were higher than 0.103µg/g in the imported noodles, 0.147µg/g in the imported spaghetti and 0.787µg/g in the imported macaroni. The concentrations of Mn in this study were lower than the permissible limit of Mn (5.5µg/g) in food [14]. The concentration of Cd (Nd-0.015) in this study for locally produced pasta were lower than (0.01 – 0.09) µg/g reported in some wheat based snacks in Akure [15]. However, the Cd concentration (0.058±0.033µg/g) reported in pasta from Poland [16] and (0.127±0.04µg/g) reported in pasta from Egypt [17] were within the range reported in this study for imported pasta. Only the imported macaroni sample exceeded the WHO standard (0.003µg/g) [14] and FDA standard (0.005mg/kg) for Cd [15]. Cd is present as a pollutant in phosphate fertilizers that are used in cereal grains like wheat, which is a major raw material for pasta [12]. Cadmium has no known biological functions. It interferes with some essential function of Zn, thereby inhibiting enzyme reactions and nutrient utilization. It catalyzes oxidation reactions, generating free-radical tissue damage [18]. The mean concentration of Cu in Nigerian noodle was 0.191µg/g, 0.263µg/g in Nigerian spaghetti and 0.225µg/g in Nigerian macaroni. These values were higher than the concentrations in imported noodles (0.064µg/g), imported spaghetti (0.095µg/g) and imported macaroni (0.129µg/g). The Cu concentrations were lower than mean value (0.816±0.01µg/g) reported for pasta in Egypt [17]. The Cu concentrations in this study were far below the permissible level of Cu in foods (10µg/g) according to FDA [15]. The mean Zn concentration varied from 0.230 - 2.39 µg/g in locally produced pasta to 0.084-1.419 µg/g in imported pasta. These values were lower than 5.127±0.29µg/g reported in Egypt [17]. All the zinc concentrations reported were within the permissible level of Zn in foods (50mg/kg) according to FDA [15]. Cu and Zn are essential elements for human health. Cu serves as an antioxidant and helps the body to remove free radicals and prevent cell structure damage while Zn functions as a co-factor for many enzymes in the body. The mean concentration of Pb in all the pasta samples ranged from 0.347 – 0.608 µg/g. The Pb concentrations in the samples were lower than 1.17 – 1.67 mg/kg found in four commercial brands of noodles in Bangladesh [8], but were higher than 0.089 and 0.299 mg/g reported in pasta in Poland and Egypt respectively [16,17]. The possible sources of Pb are from the raw materials used in pasta production. Wheat flour being the main raw material; the possible sources for Pb in wheat include irrigation with contaminated water, application of fertilizer and metal based pesticides, industrial emissions, transportation as well as the method of harvesting and storage [8]. All the pasta samples in this study had lead levels above WHO permissible limit (0.025 mg/kg) in food [15]. Lead primarily affects the peripheral and central nervous systems, renal functions, blood cells, metabolism of vitamins D. It is associated with hypertension, reproductive toxicity, developmental effects and neurological disorders, some of which may be irreversible [19]. The concentration of Cr in this study ranged from (nd – 0.190) µg/g. This was higher than the findings of Onyema et al (0.063 – 0.118) µg/g in a study of noodles in Nigerian market [12]. The mean concentration of Cr in locally produced spaghetti and macaroni exceeded the WHO standard for Cr (0.050mg/kg) [20].

There was no significant difference ($p>0.05$) in metal content among noodles, spaghetti and macaroni produced in Nigeria. However, significant difference was recorded among imported noodles, spaghetti and macaroni ($p<0.05$). The difference could be attributed to the various country of manufacture. The imported pasta used in study was produced in Turkey, Thailand, France and Italy.

Heavy-metal contamination of food is generally associated with environmental pollution, accidental inclusion during processing and contamination during processing or storage of food [21]. Also, Gholam and Jahead [22] have attributed food processing equipment and containers as sources of metals in processed food. Wheat is the major raw material for pasta production and could be contaminated by heavy metals in various ways. The possible sources of heavy metals in wheat include irrigation with contaminated water, application of fertilizer and metal based pesticides, industrial emissions, transportation as well as method of harvesting, storage, industrial production processes, road traffic with leaded petrol, the smoke and dust emissions of coal and gas-fired power stations as well as the use of paints and anti-rust agents. Water and other minor ingredients added during production may contain heavy metals such as arsenic, lead, cadmium etc. During the different stages of pasta production like mixing, kneading, resting, sheeting, rolling and cutting; the dough has direct contact with metal surface, thus metal could be mixed with pasta dough during production. Figure 1 shows a sketch of possible contamination stages in pasta production.

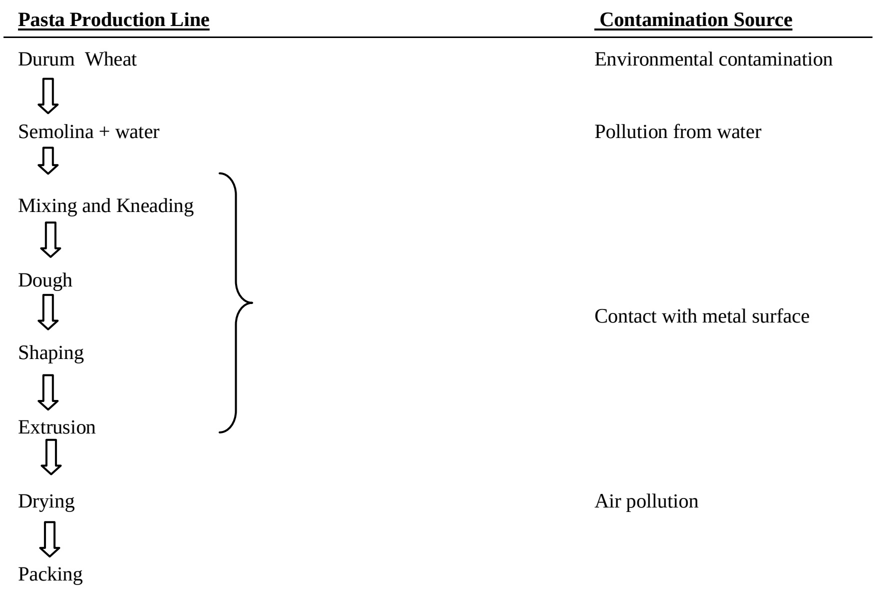

Figure 1. Possible contamination sources during pasta production

Estimation of Dietary Intake and Potential Health Risk

In estimating the dietary intake of pasta products, the consumers were hypothetically grouped into two; generally exposed and typically exposed individuals. The generally exposed individuals were taken as those who consume half of the net weight of packaged pasta (70-125g) daily while the typically exposed were those who consume a full package of pasta (120-250g) daily. According to the report of US EPA, the dose calculations were made using the standard assumption for an integrated US EPA risk analysis, including exposure over an entire 70-year lifetime and a 70kg body weight for an adult and 27kg body weight for children. In addition, it was assumed in accordance with the US EPA [23] guideline that the ingested dose is equal to the absorbed contaminant dose and that cooking has no effect on the contaminants. The EDI of the heavy metals for generally and typically exposed eaters of locally produced pasta is presented in Table 3. Manganese recorded the highest EDI in noodles and spaghetti while Zn was recorded in macaroni. All the EDI of the studied metals were below the provisional tolerable daily intake (PTDI). However, Mn has an appreciable level (62.4%) of the PTDI for children eating macaroni. Zinc recorded the highest level of EDI in noodles and macaroni for generally and typically exposed eaters of imported pasta (Table 4) while Mn has highest EDI in spaghetti. To assess the level of concern arising from metal concentration, HQ values were calculated using the measured metal concentration in the samples for seven (7) heavy metals in these pastas. The HQ is a ratio between the measured concentrations and the oral reference dose, weighted by the length and frequency of exposure; amount ingested, and body weight [27]. The total hazard index (THI) is a sum of the individual hazard quotients of each product. The HQ and THI obtained for all the metals were less than 1.0 in both locally and imported pasta (Tables 5 and 6). For HQ and THI exposures below 1.0 will likely not result in adverse non-cancer health effects over a lifetime of exposure. However, a THI greater than 1.0 does not necessarily suggest a likelihood of adverse effects. Horiguchi et al [28] has suggested that ingested dose is not equal to the absorbed pollutant dose because a fraction of the ingested toxicant maybe excreted, leaving a smaller portion to accumulate in body tissues. Therefore, it is likely that the ingested amount among the pasta consumers could be lower.

CONCLUSIONS

Heavy metals are considered particularly dangerous to human health because of the danger of bioaccumulation. In this study, the concentration of Pb was above permissible in all the samples, while the Cd and Cr levels were above permissible limits in some samples. There was no significant difference between locally manufactured noodles, spaghetti and macaroni but, there was significant difference between imported noodles, spaghetti and macaroni. The estimated dietary intakes of metals from the consumption of these pastas were less than the provisional tolerable weekly intake. From the estimated target hazard values, no lifelong health concerns of metals were associated with the consumption of these pastas.

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Table 3. Estimated daily intake (EDI) of heavy metals in Nigerian pasta

Metals	PTDI (μg/kg body weight/day)	Locally produced pasta											
		EDI (μg/kg body weight/day) for Generally Exposed						**EDI (μg/kg body weight/day) for Typically Exposed**					
		Children			**Adult**			**Children**			**Adult**		
		Noodles (70)*	**Spaghetti (125)***	**Macaroni (125)***	**Noodles (70)***	**Spaghetti (125)***	**Macaroni (125)***	**Noodles (120)***	**Spaghetti (250)***	**Macaroni (250)***	**Noodles (120)***	**Spaghetti (250)***	**Macaroni (250)***
Ni	5[a]	0.656	0.319	0.988	0.253	0.123	0.381	1.12	0.246	1.977	0.434	0.246	0.762
Mn	10[d]	1.366	3.382	3.118	0.527	1.304	1.203	2.342	2.609	6.236	0.903	2.609	2.405
Cd	0.83[a]	0.008	0.007	0.018	0.003	0.003	0.007	0.01	0.005	0.037	0.005	0.005	0.014
Cu	500[b]	0.495	0.467	0.521	0.191	0.180	0.201	0.85	0.361	1.042	0.327	0.361	0.402
Zn	1000[a]	1.190	0.532	6.118	0.459	0.205	0.234	2.04	0.411	12.236	0.787	0.411	4.719
Pb	3.57[a]	1.011	1.111	0.958	0.390	0.428	0.369	1.73	0.857	1.917	0.668	0.857	0.739
Cr	150[c]	0.365	0.245	0.241	0.041	0.095	0.093	0.18	0.189	0.481	0.07	0.189	0.186

*Portion size (g), [a]-JECFA [24] , [b]-WHO [10], [c]-EVM [25], [d]-NRC [26]

Table 4. Estimated daily intake (EDI) of heavy metals in imported pasta

Metals	PTDI (μg/kg body weight/day)	**Imported pasta**											
		EDI (μg/kg body weight/day) for Generally Exposed						**EDI (μg/kg body weight/day) for Typically Exposed**					
		Children			**Adult**			**Children**			**Adult**		
		Noodles (125)*	**Spaghetti (125)***	**Macaroni (125)***	**Noodles (125)***	**Spaghetti (125)***	**Macaroni (125)***	**Noodles (250)***	**Spaghetti (250)***	**Macaroni (250)***	**Noodles (250)***	**Spaghetti (250)***	**Macaroni (250)***
Ni	5[a]	0.503	0.294	1.585	0.194	0.113	0.612	1.005	0.587	3.171	0.388	0.227	1.223
Mn	10[d]	0.289	0.965	1.851	0.110	0.372	0.702	0.572	1.930	3.702	0.221	0.744	1.405
Cd	0.83[a]	0.005	0.004	0.609	0.002	0.002	0.234	0.011	0.009	1.217	0.004	0.003	0.469
Cu	500[b]	0.178	0.219	0.299	0.068	0.085	0.115	0.355	0.439	0.597	0.137	0.169	0.230
Zn	1000[a]	2.375	0.194	3.285	0.916	0.075	1.267	4.75	0.39	6.569	1.832	0.15	2.534
Pb	3.57[a]	0.751	0.803	1.407	0.870	0.309	0.543	1.128	1.606	2.815	0.435	0.619	1.086
Cr	150[c]	0.35	0.116	0.072	0.135	0.044	0.028	0.175	0.231	0.143	0.067	0.089	0.055

*Portion size (g), [a]-JECFA [24] , [b]-WHO [10], [c]-EVM [25], [d]-NRC [26

Table 5. Hazard Quotient and Total Hazard Index of Heavy metals in Nigerian Pasta

Metals	Locally produced pasta											
	HQ (Generally Exposed)						**HQ (Typically Exposed)**					
	Children			**Adult**			**Children**			**Adult**		
	Noodles	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**
Ni	0.031	0.015	0.047	0.012	0.006	0.018	0.054	0.031	0.095	0.021	0.012	0.036
Mn	0.009	0.023	0.021	0.004	0.009	0.008	0.016	0.046	0.043	0.006	0.018	0.016
Cd	0.007	0.007	0.018	0.003	0.002	0.007	0.012	0.013	0.035	0.005	0.005	0.013
Cu	0.012	0.011	0.012	0.004	0.004	0.005	0.02	0.022	0.025	0.008	0.009	0.009
Zn	0.004	0.002	0.019	0.001	0.001	0.007	0.006	0.003	0.039	0.002	0.001	0.015
Pb	0.242	0.266	0.229	0.093	0.103	0.088	0.415	0.532	0.459	0.160	0.205	0.177
Cr	$7x10^{-5}$	$2x10^{-4}$	$1x10^{-4}$	$3x10^{-5}$	$6x10^{-5}$	$6x10^{-5}$	$4x10^{-5}$	$3x10^{-4}$	$3x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$
THI	**0.305**	**0.324**	**0.346**	**0.117**	**0.125**	**0.133**	**0.523**	**0.647**	**0.696**	**0.202**	**0.250**	**0.266**

Table 6. Hazard Quotient and Total Hazard Index of Heavy metals in Imported Pasta.

Metals	**Imported pasta**											
	HQ (Generally Exposed)						**HQ (Typically Exposed)**					
	Children			**Adult**			**Children**			**Adult**		
	Noodles	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**	**Noodles**	**Spaghetti**	**Macaroni**
Ni	0.020	0.014	0.076	0.008	0.005	0.03	0.04	0.028	0.152	0.015	0.011	0.06
Mn	0.016	0.007	0.012	0.001	0.002	0.005	0.033	0.013	0.025	0.001	0.005	0.01
Cd	0.004	0.004	0.001	0.002	0.002	0.225	0.009	0.009	0.032	0.003	0.003	0.450
Cu	0.003	0.005	0.007	0.001	0.002	0.003	0.007	0.01	0.014	0.003	0.004	0.005
Zn	0.006	$6x10^{-4}$	0.01	0.002	$2 x10^{-4}$	0.004	0.013	0.001	0.021	0.005	$5x10^{-4}$	0.008
Pb	0.225	0.192	0.337	0.087	0.074	0.130	0.450	0.385	0.675	0.173	0.148	0.260
Cr	$1x10^{-4}$	$7x10^{-5}$	$5x10^{-5}$	$3x10^{-5}$	$3x10^{-5}$	$2x10^{-5}$	$2 x10^{-4}$	$1x10^{-4}$	$1x10^{-4}$	$7x10^{-5}$	$6x10^{-5}$	$3x10^{-5}$
THI	**0.274**	**0.223**	**0.443**	**0.101**	**0.085**	**0.397**	**0.552**	**0.446**	**0.919**	**0.2**	**0.171**	**0.793**

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