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RESEARCH ARTICLE

Candy consumption may add to the body burden of lead and cadmium of children in Nigeria

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Abstract
The affordability of candies and chocolates makes their consumption common especially in children. Heavy metal contamination of these candies is well known. This study has estimated health risks associated with heavy metals (HM; Pb, Cd, Cr, Ni, and Zn) in commonly consumed candies in Nigeria. Fifty candies/sweets and chocolates/chewing gums bought from different stores in Port Harcourt and Uyo in Niger Delta, Nigeria, were processed and digested in perchloric acid. The filtrate was analyzed for these heavy metals using atomic absorption spectroscopy (AAS). Pb/Zn and Cd/Zn ratios were calculated. Daily intake, the target hazard quotient (THQ), the hazard index (HI), and the cancer risk were estimated for children. About 80% of the samples exceeded the 0.1 mg/kg permissible lead level in candies. Milk sweet had the highest Pb:Zn and Cd:Zn ratios of 0.99 and 0.40 respectively. For chocolates, the Emperor had the highest Pb:Zn (0.50) ratios and Trident had the highest Cd:Zn (0.57) ratios. The calculated percentage provisional tolerable weekly intake (%PTWI) of cadmium from consumption of chocolates and candies was higher than the Joint Expert Committee for Food Additives (JECFA) standard, and the cancer risk of lead, cadmium, and chromium ranged between 10^{-7} and 10^{-3}. Consumption of some candies by children in Nigeria may pose significant health risks.

Keywords Confectioneries · Health risk assessment · Potential toxic metals · Public health

Introduction

Background of study

Candies are a popular food consumed by Nigerian kids between the ages of 1 and 10 years, who snack on it almost on a daily basis. This sweet food is primarily made of sugar and/or chocolate and is often eaten between meals. It usually encompasses any sweet confectionary ranging from chocolates, chewing gum, and sugar candy. Common ingredients in candies are sugar, water, cocoa, honey, milk, and sweeteners (aspartame), most of which are gotten from plant or animal sources. Recently in 2016, Scan Holdings described any fruit, vegetable, or nut which has been glazed and coated with sugar as being candied (Scan Holdings 2016). The affordability of these sweet foods in Nigeria has made craving and consumption high.

The different ingredients used in the preparation of candies and chocolates are likely to increase the risk of contamination (Devi et al. 2016). There is also a high risk of heavy metals, such as Pb, Cr, Ti, Zn, Al, Cd, and Cu migrating from the printed surface to the contact surface (Bradley et al. 2005). However, most heavy metals are introduced during the preparation and also during the packaging process when the candies' surfaces are sticky, allowing the surface of the candy to adhere to the inner cover of the package (Adebola et al. 2015), thereby increasing the risk of contamination and heavy metal exposure.

Food is the most common non-occupational source of exposure to heavy metals for humans (WHO 1996; Ihedioha et al. 2014). The study of heavy metal concentration in foods is of great importance, as there is a growing concern about imported foods from different parts of the world (Maxwell and

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Neumann 2009). Children are the most vulnerable age group to any kind of contamination in the food chain as a result of their body weight (Samsuddin et al. 2016). Although an earlier study we carried out in 2015 on imported herbal teas showed low-level contamination of lead (Pb) and PAHs in the studied samples (Orisakwe et al. 2015), this does not however represent the contamination profile of numerous foods imported into the country. In the science of toxicology and risk assessment, low-level contamination does not necessarily translate to low risk; rather, the frequency of exposure and dose define the potential risk. Reports of heavy metal toxicity even in trace concentrations make it necessary to calculate the estimated intake among children who are the most susceptible population to toxic metal intake from such type of food items (Jalbani et al. 2009). This present study is aimed at monitoring contaminant levels of Pb, Cd, Ni, Cr, and Zn in the candy samples and assessing the safety and health hazards associated with the consumption by Nigerian children.

Materials and methods

Samples

A wide variety of 50 candy samples with code numbers S_1 to S_{50} ranging from chocolates, solid sweets, and chewing gum were obtained in no specific order by a random sampling method.

Collection of the samples

A total of 50 candy samples were randomly collected from different parts of Akwa-Ibom and Rivers State. The candies were either imported or locally produced. The collected samples were packed in clean zipped polythene bags and brought to the laboratory for further analysis.

Sample preparation

The candy samples were digested using the hot-block digestion procedure. For each sample, 1–2 g was measured with a weighing balance using plastic materials to prevent further contamination with metals. After that, approximately 9 mL of 65% concentrated nitric acid (HNO_3) and 3 mL of perchloric acid was added in a ratio of 3:1 prior to heating. The solution was then transferred to a hot plate were it was heated to a temperature of 120 °C for about 5 h. Afterwards, the sample was introduced into an oven under a temperature that was gradually increased by 10 °C every 60 min until the final temperature of 450 °C was reached 18 h after, and white ashes were obtained. Following this, the samples were left to cool, and the white ash was then dissolved in 5 mL of 1.5% nitric acid (HNO_3) and a final volume of 25 mL was made by addition of distilled water. The resulting solution was filtered using a Whatman filter paper no. 42 fitted into a Buchner funnel to avoid residues from getting into the beaker before transferring it into a tightly sealed plastic container. The samples were automatically detected as they emerged from the column (at a constant flow rate) by the flame ionization detector (FID) whose response is dependent upon the composition of the vapor. Metal concentrations were assayed with atomic absorption spectroscopy (Model 205, Buck Scientific, East Norwalk, CT, USA). Samples were analyzed in triplicates.

Quality control

The instrument was recalibrated after every ten runs. The analytical procedure was checked using the spike recovery method (SRM). A known standard of the metals was introduced into already-analyzed samples and re-analyzed. The results of the recovery studies for Pb, Cd, Cr, Ni, and Zn were more than 95%. The relative standard deviation between replicate analyses was less than 4%. The limit of detection (LOD) for Pb, Cd, Cr, Ni, and Zn was 0.005 ppm, with blank values reading as 0.00 ppm for all the metals in deionized water with an electrical conductivity value of less than 5 μS/cm. The limit of quantification (LOQ) for Pb, Cd, Cr, and Ni was 0.04, and for Zn, it was 0.06 ppm.

Health risk assessment calculation

In order to evaluate the daily or long-term potential health risk of hazardous exposure to heavy metals via consumption of candies by the exposed population, the estimated daily intake (EDI) and target hazard quotient (THQ) which is defined as the ratio of the body intake dose of a pollutant to the reference dose that was first proposed by the United States Environmental Protection Agency (USEPA) for assessing the potential health risks of pollutant exposure to human health were calculated. If THQ > 1, there could be a potential health risk associated with the pollutant. On the other hand, if THQ < 1, then there will be no obvious risk. Also, to assess the overall potential for non-carcinogenic effects posed by more than one heavy metal, a hazard index (HI) approach had been applied.

- Estimated daily intake (EDI)

The daily intake of metals was calculated using the equation below:

$$\mathrm{EDI} = \frac{C_{\mathrm{metal}} \times \mathrm{IR} \times \mathrm{EF} \times \mathrm{ED(US\ EPA\ 2010)}}{B_{\mathrm{average\ weight}} \times \mathrm{AT}_n} \quad (1)$$

- Target hazard quotient (THQ)

The target hazard quotient was calculated using the following equation:

$$\text{THQ} = \frac{\text{EDI(US EPA 2013)}}{\text{RfD}} \quad (2)$$

- Hazard index (HI)

The hazard index was calculated using the formula below:

$$\text{HI} = \Sigma\text{THQ (US EPA 1989)} \quad (3)$$

where C is the mean concentration of a particular metal in candies; IR is the daily candy intake by the exposed population (children) assumed to be 20 g (Devi et al. 2016); EF is the exposure frequency given as 350 days; ED is the exposure duration of 53 years as the average life expectancy rate for a Nigerian adult according to World Bank Statistics (https://data.worldbank.org/indicator/SP.DYN.LE00.IN.); BW is the average weight of local residents which is 16 kg for children; AT is the average exposure time for non-carcinogens (exposure days within the whole lifetime), 20,440 days = 365 × 56; and RfD is the chronic oral reference dose for the heavy metals Cd, Cr, Pb, Ni, and Zn which is 0.001, 1.5, 0.0035, 0.02, and 0.3 mg/kg/day, respectively (USEPA 2015). The Pb:Zn and Cd:Zn ratios were also calculated. In this study, all ratios that skewed to unity "1" indicate lower nutritional value or high levels of lead and cadmium (Plessi et al. 2001; Olmedo et al. 2013).

Results

Concentration of heavy metals in candies and chocolate samples

The concentration of heavy metals in the candies and chocolate samples collected from Port Harcourt and Uyo in Niger Delta, Nigeria, was in the order Cd < Cr < Pb < Ni < Zn across all samples as shown in Tables 1 and 2. The mean concentrations of heavy metals were as follows: Cd ranged between < 0.001 and 2.06 mg/kg, Cr varied within < 0.001–3.093 mg/kg, Pb ranged from 0.07 to 3.69 mg/kg, Zn ranged between < 0.001 and 11.91 mg/kg, and Ni ranged from 0.07 to 7.46 mg/kg, with all the samples (candies, chocolates, and chewing gum) showing wide variations with respect to the diverse samples. The average concentrations of heavy metals in the candy samples were Pb = 0.76 mg/kg, Cr = 0.79 mg/kg, Cd = 0.59 mg/kg, Ni = 1.29 mg/kg, and Zn = 5.8 mg/kg), while the average concentrations in the chocolate samples were Pb = 1.46 mg/kg, Cr = 0.39 mg/kg, Cd = 0.73 mg/kg, Ni = 2.29 mg/kg, and Zn = 7.25 mg/kg; also, the average concentrations of heavy metals in chewing gum samples were Pb = 1.04 mg/kg, Cr = 0.31 mg/kg, Cd = 0.36 mg/kg, Ni = 1.54 mg/kg, and Zn = 5.21 mg/kg. Similarly, some of the heavy metal concentrations in the candies, chewing gum, and chocolate samples were seen to be above the maximum permissible limit for heavy metals in food substances when compared to the standards set by Joint FAO/WHO Expert Committee on Food Additives (JECFA) www.fao.org/3/a-i2358e.pdf (Cd − 0.05; Cr − 0.5, Pb − 0.2, and Ni − 0.6). The Pb:Zn and Cd:Zn ratios of the candies and chocolates are also shown in Tables 1 and 2 respectively. Milk sweet had the highest Pb:Zn and Cd:Zn ratios of 0.99 and 0.40 respectively. For chocolates, the Emperor had the highest Pb:Zn (0.50) and Trident had the highest Cd:Zn (0.57) ratios.

Estimated daily intake of heavy metals in candy and chocolate samples

The estimated daily intake (mg/kg day^{-1}) of heavy metals by the exposed population from consumption of candies and chocolates is presented in Tables 3 and 4. Although the total intake rate of Cd, Cr, Pb, Zn, and Ni was calculated for only children, the contribution of heavy metals through ingestion of candies to the daily dietary intake decreased in the following order: Cd < Cr < Cu < Pb < Ni < Zn. The calculated EDI were compared with the provisional tolerable daily intake (PTDI). The TDI for lead (0.004 mg/kg day^{-1}) set by the WHO/JECFA was used for comparison in the present study, and it was observed that the calculated EDI were lower than the TDI. There is no JECFA PTDI for Cr in foods; however, the EDI was calculated and ranged between 0 and 0.0015 mg/kg day^{-1}. The EDI of Cd in the samples when compared with the PTDI (0.001 mg/kg day^{-1}) was seen to be slightly higher especially in chocolate samples. The estimated daily intake of most of the chocolate samples was less than the recommended daily intake of 0.005 mg/kg day^{-1} set by FAO/WHO for nickel. Only Safa chocolate had an estimated daily intake (0.0062 mg/kg day^{-1} of Ni) higher than the standard set by JECFA. The maximum tolerable daily intake of zinc had been set at 0.3–1 mg/kg day^{-1} by JECFA accordingly, this safe range when compared with the calculated EDI had 100% of the samples within the safe limit.

The estimated weekly intake (EWI) and percentage tolerable weekly intake (%PTWI) of heavy metals are shown in Tables 5, 6, 7, and 8. The calculated %PTWI of cadmium from consumption of chocolates and candies was higher than the JECFA standard (http://www.inchem.org/documents/jecfa/jeceval/jec_2411.htm.). For cadmium, it was as high as 162% and lowest in nickel with a %PTWI value of 0.002%.

Table 1 Concentrations of heavy metals (mg/kg) and Pb:Zn and Cd:Zn ratios in candies/sweets collected from Port Harcourt and Uyo metropolis

Samples	Pb	Cr	Cd	Ni	Zn	Pb:Zn	Cd:Zn
Ceramel sweet	1.06	1.02	1.41	0.32	5.71	0.19	0.25
Ook-pop sweet	0	0.87	0	1.49	7.06	0	0
Fanta sweet	1.33	0.07	0.27	0.07	9.31	0.14	0.03
Parego chewing candy	0.72	1.24	0.11	2.43	4.32	0.17	0.03
Rola cola mint sweet	2.11	0	0.09	1.01	7.06	0.30	0.01
Milk lolo pop sweet	0	1.44	0	2.71	5.11	0	0
Galactic sweet	1.32	2.07	0.3	1.54	3.07	0.43	0.10
Tom tom sweet	0.43	0.43	1.32	0	6.34	0.07	0.21
Splash sweet	0.61	2.12	0.43	2.69	11.91	0.05	0.04
Nana sweet	1.21	0.69	1.01	1.43	7.32	0.17	0.14
Ice mint sweet	0	0	0.96	0.57	2.03	0	0.48
Kona café sweet	1.03	1.41	1.42	0.63	4.06	0.26	0.35
Vick blue sweet	2.03	0.33	0.39	1.42	5.61	0.36	0.07
Milk sweet	1.71	0.38	0.69	0.71	1.73	0.99	0.40
Milkose sweet	1.32	1.07	1.42	2.41	9.68	0.14	0.15
Milk topper sweet	0	0.03	1	1.91	4.3	0	0.23
Milk quell sweet	1	0	0.78	0.73	2.78	0.40	0.28
Milk chewing candy sweet	0.22	1.42	0	1.04	6.1	0.04	0
Cauger sweet	0	0.37	0	0.69	3.12	0	0
Buttermint sweet	1.07	0.07	0.07	1.03	4.72	0.23	0.02
Kahh drops sweet	0.29	1.83	0.32	1.67	3.44	0.08	0.09
Love (milk & white)	0.59	3.093	1.11	0.53	7.86	0.08	0.14
N-joy sweet	0.22	0.04	0	2.01	7.34	0.03	0
Pin pop sweet	0.89	0	2.06	0.59	4.41	0.20	0.47
Menko's mint sweet	0	0.89	0.23	1.41	9.19	0	0.03
Real taste fruit sweet	0	0.69	0	2.17	6.31	0	0
Cola sweet	1.43	0	0.63	1.69	8.96	0.16	0.07

Discussion

There is epidemiologic evidence that regular consumption of candies and chocolates is likely to cause a hypercholesterolemic effect (Wan et al. 2001) and weight gain, since chocolate consumption may increase the proportion of fat in the diet (Mursu et al. 2004). On the other hand, there are facts in literature that strongly suggest the flavonoid integral components of chocolate candies are beneficial in cardiovascular disease, with lower incidences of coronary heart disease (CHD) and stroke (Djoussé et al. 2011; Ariefdjohan and Savaiano 2005; Engler and Engler 2006). There is a need therefore to study the overall dietary exposure and human health risk assessment to trace metals and potential toxic metals. The presence of heavy metals in candies and chocolates reported by various researchers in recent times across the globe with varying levels of contamination in different countries (Rehman and Husnain 2012; Jalbani et al. 2009; Kim et al. 2008b; Ortiz et al. 2016; Dahiya et al. 2005) validates the growing evidence that heavy metal contamination is one of the major problems mitigating against food safety around the world.

This study has estimated the heavy metal risk associated with consumption of candies, chewing gum, and chocolates which are mainly imported into Nigeria. The detection of the following potential toxic metals in these confectioneries may be of public health importance. Lead interacts with calcium in the nervous system to impair cognitive development. Cadmium interacts with calcium in the skeletal system to produce osteodystrophies. Lead replaces zinc on heme enzymes and cadmium replaces zinc on metallothionein.

Lead has been shown to induce cognitive and behavioral deficits in adults and children with elevated levels of exposure (Lanphear et al. 2005; Toscano and Guilarte 2005). Lead has no useful biological role in the body, and certain levels in the blood can damage the nervous, skeletal, circulatory, enzymatic, endocrine, and immune systems of those exposed to it (Zhang et al. 2012). According to a study based in Mexico, candy ingestion is associated with elevation of the blood lead level in 13.72% and 29.32% of children that consume 5 or 10 mg of lead through candy (y Ortiz et al. 2016). Most of the candies in this study exceeded the 0.1 mg/kg permissible level of lead in candies (US FDA 2006a, b). With high levels of lead

Table 2 Concentrations of heavy metals (mg/kg) and Pb:Zn and Cd:Zn ratios in chocolates/chewing gums collected from Port Harcourt and Uyo metropolis

Samples	Pb	Cr	Cd	Ni	Zn	Pb:Zn	Cd:Zn
Chocolates							
Safa	1.94	0	0.35	7.46	11.31	0.17	0.03
Snickers	0.72	0	0.84	1.73	5.25	0.14	0.16
X-one	3.69	0	1.49	3.57	8.49	0.44	0.18
Emperor	3.63	0	0	4.08	7.28	0.50	0
Eclairs	0	0.51	0.19	3.19	0	0	0
Cocos	1.26	1.64	0	2.67	9.38	0.13	0
My love	2.61	0	1.4	1.72	5.97	0.44	0.24
Twrx	1.17	0	1.46	0.903	10.08	0.12	0.15
Derive	0.83	1.53	1.58	0.61	8.42	0.10	0.19
Camellia	1.61	0	0.03	1.06	3.94	0.41	0.01
Tuyo - bon bon	1.27	0	1.23	2.36	10.33	0.12	0.12
Mars	1.38	0.35	1.67	0.45	9.36	0.15	0.18
Tiffany	0	1.32	0.07	0.32	8.12	0	0.01
Ochore Choco cube	0.35	0.04	0	2.02	3.7	0.10	0
Chewing gums							
Super stars	1.07	0.31	0.03	3.03	4.69	0.23	0.01
Double mind	2.14	0.26	0.61	2.18	6.42	0.33	0.10
Kelito	1.13	0.55	0	0.81	2.42	0.47	0
Trident	0.49	0.24	0.89	0.3	1.56	0.31	0.57
Centre fruit jelly	0.31	1.21	1.61	0.31	5.81	0.05	0.28
Orbit	1.61	0.01	0.02	2.48	9.44	0.17	0
Long stick	0.07	0.12	0.04	0	4.48	0.02	0.01
Fruit Banana	0.49	0	0	1.75	5.58	0.09	0
Super	2.12	0.13	0	3.03	6.56	0.33	0

Table 3 Estimated daily intake (EDI) of heavy metals (mg/kg day^{-1} bw) from consumption of candies/sweets from Port Harcourt and Uyo metropolis

Samples	Pb	Cr	Cd	Ni	Zn
Ceramel sweet	0.0009	0.0008	0.00117	0.0003	0.0047
Ook - pop sweet	0	0.0007	0	0.0012	0.0059
Fanta sweet	0.0011	6E−05	0.00022	6E−05	0.0077
Parego chewing candy	0.0006	0.001	9.1E−05	0.002	0.0036
Rola cola mint sweet	0.0018	0	7.5E−05	0.0008	0.0059
Milk lolo pop sweet	0	0.0012	0	0.0022	0.0042
Galactic sweet	0.0011	0.0017	0.00025	0.0013	0.0025
Tom tom sweet	0.0004	0.0004	0.0011	0	0.0053
Splash sweet	0.0005	0.0018	0.00036	0.0022	0.0099
Nana sweet	0.001	0.0006	0.00084	0.0012	0.0061
Ice mint sweet	0	0	0.0008	0.0005	0.0017
Kona café sweet	0.0009	0.0012	0.00118	0.0005	0.0034
Vick blue sweet	0.0017	0.0003	0.00032	0.0012	0.0047
Milk sweet	0.0014	0.0003	0.00057	0.0006	0.0014
Milkose sweet	0.0011	0.0009	0.00118	0.002	0.008
Milk topper sweet	0	2E−05	0.00083	0.0016	0.0036
Milk quell sweet	0.0008	0	0.00065	0.0006	0.0023
Milk chewing candy sweet	0.0002	0.0012	0	0.0009	0.0051
Cauger sweet	0	0.0003	0	0.0006	0.0026
Kahh drops sweet	0.0002	0.0015	0.00027	0.0014	0.0029
N-joy sweet	0.0002	3E−05	0	0.0017	0.0061
Love (milk & white)	0.0005	0.0026	0.00092	0.0004	0.0065
Pin pop sweet	0.0007	0	0.00171	0.0005	0.0037
Butter mint sweet	0.0009	6E−05	5.8E−05	0.0009	0.0039
Menko's mint sweet	0	0.0007	0.00019	0.0012	0.0076
Real taste fruit sweet	0	0.0006	0	0.0018	0.0052
Cola sweet	0.0012	0	0.00052	0.0014	0.0074

seen in the present study, even moderate consumers of candy can attain or even exceed levels reported in Mexican children. Lead (Pb) poisoning is ranked as the most common environmental health hazard (Hosseini et al. 2015), making Pb exposure a public health concern. Pb is a well-known neurotoxicant and especially dangerous to child neurodevelopment, with significant toxic outcomes even at a very low concentration (Kim et al. 2013; Nigg et al. 2010). The levels of Pb in the present study are not detectable in few but present in most of the studied samples and were found to be > 0.2 mg/kg which is higher than the recommended maximum limit of 0.1 mg/kg (US FDA 2005) for Pb in candies. Most of the samples were made of splendidly colored polyethylene and polypropylene films. These very colorful packages are mostly produced in China with a poor record of environmental pollution and therefore could be a source of Pb contamination (Kim et al. 2008a, b). Lead contamination in candies tends to be associated with aerosol and atmospheric emissions of leaded gasoline since cocoa bean shells have high affinity for the absorption of lead (Rankin et al. (2005). Also, leaded gasoline emissions tend to occur during the fermentation and sun-drying of unshelled beans at cocoa farms. Some researchers have also reported migration of heavy metals from packaging to foodstuff by direct or indirect contact (Kim et al. 2008a, b). The co-occurrence of lead and chromate in candies and chocolates has serious public health implication, as lead could combine with Cr(VI) to form ($PbCrO_4$), an inorganic salt known to be associated with increased oxidative stress and cancer induction (bronchial carcinoma and lung cancer) (IARC 1990).

The chronic health effects of low-level exposure to cadmium in man include lung cancer, pulmonary adenocarcinomas, prostatic proliferative lesions, hypertension, obstructive pulmonary disease, emphysema, a renal tubular disease, and osteodystrophy (Żukowska and Biziuk 2008). Cadmium accumulates in the kidney and liver and according to IARC is a human carcinogen linked with increased risk of various forms of cancer. Chronic dietary exposure to high levels of cadmium in man is associated with nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury

Table 4 Estimated daily intake (EDI) of heavy metals (mg/kg day^{-1} bw) from consumption of chocolates/chewing gums from Port Harcourt and Uyo metropolis

Samples	Pb	Cr	Cd	Ni	Zn
Chocolates					
Safa chocolate	0.0016	0	0.00029	0.0062	0.0094
Snickers chocolate	0.0006	0	0.0007	0.0014	0.0044
X-one chocolate	0.0031	0	0.00124	0.003	0.007
Emperor chocolate	0.003	0	0	0.0034	0.006
Eclairs chocolate	0	0.0004	0.00016	0.0026	0
Cocos chocolate	0.001	0.0014	0	0.0022	0.0078
My love chocolate	0.0022	0	0.00116	0.0014	0.005
Twrx chocolate	0.001	0	0.00121	0.0007	0.0084
Derive chocolate	0.0007	0.0013	0.00131	0.0005	0.007
Camellia chocolate	0.0013	0	2.5E−05	0.0009	0.0033
Camellia chocolate	0.0013	0	2.5E−05	0.0009	0.0033
Mars chocolate	0.0011	0.0003	0.00139	0.0004	0.0078
Tiffany chocolate	0	0.0011	5.8E−05	0.0003	0.0067
Ochre choco cube chocolate	0.0003	3E−05	0	0.0017	0.0031
Chewing gums					
Supestars chewing gum	0.0009	0.0003	2.5E−05	0.0025	0.0039
Double mind chewing gum	0.0018	0.0002	0.00051	0.0018	0.0053
Kelito chewing gum	0.0009	0.0005	0	0.0007	0.002
Trident chewing gum	0.0004	0.0002	0.00074	0.0002	0.0013
Centre frit jelly	0.0003	0.001	0.00134	0.0003	0.0048
Orbit gum	0.0013	1E−05	1.9E−05	0.0021	0.0078
Long stick chewing gum	6E−05	1E−04	3.3E−05	0	0.0037
Fruit banana chewing gum	0.0004	0	0	0.0015	0.0046
Super gum	0.0018	0.0001	0	0.0025	0.0054

convulsions, shocks, and kidney-related problems (Rajappa et al. 2010). The cadmium concentration in the different samples ranging from 0 to 2.60 mg/kg is an indication that the level of heavy metal contamination in these candies and chocolates is relatively higher than the result of a similar study in Nigeria (Iwegbu 2011). Long-term exposure to cadmium may cause oxidative stress of the cell tissues thereby damaging target organs in the body (Aziz et al. 2014).

Nickel is an essential trace element in man, although the functional importance of nickel has not been clearly demonstrated. Nickel seems to be implicated in allergic reactions, chronic bronchitis, emphysema, pulmonary fibrosis, and impaired lung function (ATSDR 2005). Dietary exposures are considered the main sources of nickel in the general population (Barceloux 1999); consumption of chocolates and chocolate-based products was identified as the main contributor to dietary exposure to nickel (EFSA 2014). Nickel is the main known contaminant resulting from the manufacturing process of chocolate, when its hardening is done by hydrogenation of unsaturated fats using nickel as catalyst (Selavpathy and Sarala Devi 1995). Exposure of the general population to dietary intake of nickel does not lead to any health risk (Duran et al. 2009), but a recent study reported that a population of children had exacerbated acute generalized dermatitis after ingestion of chocolates (Bergman et al. 2016). Until 2015, there was no acceptable limit for Ni in food, but the new tolerable daily intake of 2.8 mg/kg adopted by the CONTAM panel (EFSA 2014) has helped in assessing the risk of Ni exposure to the general population. Dahiya et al. (2005) in an Indian-based study reported Ni levels in candies which ranged from 0.041 to 8.29 mg/kg are similar to our data in the present study which ranged from 0.3 to 7.46 mg/kg but lower than Turkey candies' Ni levels with an average of 0.85 mg/kg (Duran et al. 2009).

Chromium (Cr) is listed by the Environmental Protection Agency as one of the 129 priority pollutants and one of the 14 most noxious heavy metals (ATSDR 2001). The potential of Cr(VI) to induce carcinogenesis via chronic oral exposure makes it necessary to always investigate the level of this metal in frequently consumed foods to minimize the risk of oral exposure especially to kids (Xu et al. 2015). The concentration of Cr varied across the studied samples which is similar to the result of an initial study in Mexico (Martinez et al. 2010) and also in Korea (Kim et al. 2008a, b) but higher than the result

Table 5 Estimated weekly intake (EWI) of children exposed to heavy metals via consumption of candies/sweets

Samples	Pb	Cr	Cd	Ni	Zn
Ceramel sweet	0.006	5.60E−03	8.19E−03	0.002	0.033
Ook - pop sweet	0	4.90E−03	0.00E+00	0.008	0.041
Fanta sweet	0.008	4.20E−04	1.54E−03	4E−04	0.054
Parego chewing candy	0.004	7.00E−03	6.37E−04	0.014	0.025
Rola cola mint sweet	0.013	0.00E+00	5.25E−04	0.006	0.041
Milk lolo pop sweet	0	8.40E−03	0.00E+00	0.015	0.029
Galactic sweet	0.008	1.19E−02	1.75E−03	0.009	0.018
Tom tom sweet	0.003	2.80E−03	7.70E−03	0	0.037
Splash sweet	0.004	1.26E−02	2.52E−03	0.015	0.069
Nana sweet	0.007	4.20E−03	5.88E−03	0.008	0.043
Ice mint sweet	0	0.00E+00	5.60E−03	0.004	0.012
Kona café sweet	0.006	8.40E−03	8.26E−03	0.004	0.024
Vick blue sweet	0.012	2.10E−03	2.24E−03	0.008	0.033
Milk sweet	0.01	2.10E−03	3.99E−03	0.004	0.01
Milkose sweet	0.008	6.30E−03	8.26E−03	0.014	0.056
Milk topper sweet	0	1.40E−04	5.81E−03	0.011	0.025
Milk quell sweet	0.006	0.00E+00	4.55E−03	0.004	0.016
Milk chewing candy sweet	0.001	8.40E−03	0.00E+00	0.006	0.036
Cauger sweet	0	2.10E−03	0.00E+00	0.004	0.018
Kahh drops sweet	0.001	1.05E−02	1.89E−03	0.009	0.020
N-joy sweet	0.001	2.10E−04	0	0.012	0.043
Love (milk & white)	0.004	1.82E−02	6.44E−03	0.003	0.046
Pin pop sweet	0.005	0	1.20E−02	0.004	0.0259
Butter mint sweet	0.006	4.20E−04	4.06E−04	0.006	0.027
Menko's mint sweet	0	4.90E−03	1.33E−03	0.008	0.053
Real taste fruit sweet	0	4.20E−03	0	0.013	0.036
Cola sweet	0.008	0	3.64E−03	0.009	0.052

reported in Zaria, Nigeria (Ochu et al. 2012). The primary source of oral exposure to Cr in non-occupational human populations remains food and drinking water (Sun et al. 2015). Basically, Cr exists in two stable states: trivalent chromium [Cr(III)] and hexavalent chromium [Cr(VI)], with the latter generally considered more toxic than the former (Nickens et al. 2010). The current tolerable daily intake (TDI) of Cr in food adopted by the CONTAM panel (EFSA 2014) is 0.3 mg/kg day^{-1} for Cr(III) under the assumption that all Cr in food is Cr(III). Also, the adult population showed lower exposure to Cr(III) than the younger population. These reports by the CONTAM panel in 2014 placed children at higher risk of Cr(III) contamination and toxicity. The calculated daily intake was significantly lower when compared with the TDI. This indicates a low risk of toxicity to the exposed population.

Zinc (Zn) is essential for growth and development but in particular is required during the early years of life when the body is growing rapidly (Kambe et al. 2015). Although Zn is an essential metal and its deficiency widely reported in literature (Prasad 2013; Wong et al. 2013; Suzuki et al. 2016), chronic oral exposure to this metal can result in neurological disorders (Hedera et al. 2009). Also, studies with experimental animals have shown that high levels of dietary zinc can cause anemia as well as decreased levels of copper and iron absorption, and reduction in the activities of several important enzymes in various tissues. There is a wide margin between nutritionally required amounts of zinc and toxic levels. The content of Zn in the present study is significantly higher than the concentrations reported in chewing gums and candies in Korea (Kim et al. 2008a, b). The PMTDI of 0.3–1.0 mg/kg falls within the acceptable when compared with the calculated daily intake.

Human health risk assessment calculation from the pathway of the food chain is of major significance in a country like Nigeria, where heavy metal exposure is on the rise and still unchecked. Target hazard quotient (THQ) is defined as the ratio of the body intake dose of a pollutant to the reference dose. If THQ > 1, there could be a potential health risk associated with the pollutant. On the other hand, if THQ < 1, then there will be no obvious risk. The following notably cadmium-contaminated candies: x-one chocolate, my love chocolate, Twrx chocolate, pin pop sweet, derive chocolate,

Table 6 Estimated weekly intake (EWI) of children exposed to heavy metals via consumption of chocolates/chewing gums

Samples	Pb	Cr	Cd	Ni	Zn
Chocolates					
Safa	0.011	0	2.03E−03	0.043	0.065
Snickers	0.004	0	4.90E−03	0.009	0.031
X-one	0.022	0	8.68E−03	0.021	0.049
Emperor	0.021	0	0	0.024	0.042
Eclairs	0	2.80E−03	1.12E−03	0.018	0
Cocos	0.007	9.80E−03	0	0.015	0.055
My love	0.015	0	8.12E−03	0.009	0.035
Twrx	0.007	0.00E+00	8.47E−03	0.005	0.059
Derive	0.005	9.10E−03	9.17E−03	0.004	0.049
Camellia	0.009	0	1.75E−04	0.006	0.023
Tuyo - Bon bon	0.008	0	7.14E−03	0.014	0.060
Mars	0.008	2.10E−03	9.73E−03	0.003	0.055
Tiffany	0	7.70E−03	4.06E−04	0.002	0.047
Ochre Choco cube	0.002	2.10E−04	0.00E+00	0.012	0.022
Chewing gum					
Supestars	0.006	2.10E−03	1.75E−04	0.018	0.027
Double mind	0.013	1.40E−03	3.57E−03	0.013	0.037
Kelito	0.006	3.50E−03	0	0.005	0.014
Trident	0.003	1.40E−03	5.18E−03	0.001	0.009
Centre frit jelly	0.002	7.00E−03	9.38E−03	0.0021	0.034
Orbit	0.009	7.00E−05	1.33E−04	0.015	0.054
Long stick	4E−04	7.00E−04	2.31E−04	0	0.026
Fruit banana	0.003	0.00E+00	0.00E+00	0.011	0.032
Super	0.013	7.00E−04	0.00E+00	0.018	0.038

Table 7 Target hazard quotient (THQ) for children exposed to heavy metals via consumption of sweets and candies

Samples	Pb	Cr	Cd	Ni	Zn
Ceramel sweet	0.251	0.282	1.17	0.013	0.016
Ook - pop sweet	0	0.241	0	0.062	0.02
Fanta sweet	0.315	0.019	0.224	0.003	0.026
Parego chewing candy	0.171	0.343	0.091	0.101	0.012
Rola cola mint sweet	0.5	0	0.075	0.042	0.02
Milk lolo pop sweet	0	0.398	0	0.112	0.014
Galactic sweet	0.313	0.573	0.249	0.064	0.008
Tom tom sweet	0.102	0.119	1.096	0	0.018
Splash sweet	0.145	0.587	0.357	0.112	0.033
Nana sweet	0.287	0.191	0.838	0.059	0.02
Ice mint sweet	0	0	0.797	0.024	0.006
Kona café sweet	0.244	0.39	1.179	0.026	0.011
Vick blue sweet	0.481	0.091	0.324	0.059	0.016
Milk sweet	0.406	0.105	0.573	0.029	0.005
Milkose sweet	0.313	0.296	1.179	0.1	0.027
Milk topper sweet	0	0.008	0.83	0.079	0.012
Milk quell sweet	0.237	0	0.647	0.03	0.008
Milk chewing candy sweet	0.052	0.393	0	0.043	0.017
Cauger sweet	0	0.102	0	0.029	0.009
Kahh drops sweet	0.069	0.506	0.266	0.069	0.01
N-joy sweet	0.052	0.011	0	0.083	0.02
Love (milk & white)	0.14	0.856	0.921	0.022	0.022
Pin pop sweet	0.211	0	1.71	0.024	0.012
Butter mint sweet	0.254	0.019	0.058	0.043	0.013
Menko's mint sweet	0	0.246	0.191	0.059	0.025
Real taste fruit sweet	0	0.191	0	0.09	0.017
Cola sweet	0.339	0	0.523	0.07	0.025

centre fruit jelly, tuyo-bon bon, ceramel sweet, mars chocolate, tom sweet, kona café sweet, and milkose sweet had a THQ > 1. Children are always vulnerable to chronic effects of ingestion of chemical pollutants, since they (children) consume more (twice the amount) candies per unit of body weight compared to adults. The high THQs found in candies especially for cadmium are of immense public health concern considering that the diverse sources of these metals could exacerbate the body burden of these potential toxic metals (Wongsasuluk et al. 2014).

Excessive dietary intake of zinc could lead to hematological disorders and may affect the metabolic activities of the human body. However, Ieggli et al. (2011) reported that zinc levels in chocolate do not pose a health hazard. Significantly higher concentrations of Zn, Ni, and Cd were observed in the present study when compared with other studies. The higher concentration of metals in the candies and chocolates may be due to the raw materials such as cocoa beans, cocoa solids, and cocoa butter. The possible sources of heavy metal contamination include processing methods, raw materials (Duran et al. 2009), and unsafe storage conditions or during the production chain, i.e., raw materials, processing, packaging, transportation, storage, or marketing; utensils used during the preparation of candies and chocolates may also cause metal contamination (Ochu et al. 2012). Cocoa beans can accumulate Cd naturally from soil, and hence, its concentration could vary significantly in candies (Ochu et al. 2012). The ratios between Pb and Zn ranged from 0 to 0.99 and 0 to 0.57 for Cd:Zn ratio. Lower ratio levels indicate better nutritional values (Plessi et al. 2001; Olmedo et al. 2013; Orisakwe et al. 2017). High zinc levels in relation to either Pb or Cd levels tended to lower the ratio of potential toxic metals to nutritional metal levels in the candies. The favorable ratio between these elements increases the nutritional importance of the candies (Plessi et al. 2001, Olmedo et al. 2013, Orisakwe et al. 2017).

Candies may exacerbate the effects of the environmental burden of heavy metals given the contamination of the other foods consumed commonly by children in Nigeria (Maduabuchi et al. 2006; Orisakwe et al. 2006). The impact of the high cadmium and lead levels in these candies commonly eaten by children in Nigeria on childhood cancer storm in Nigeria (Vigneri et al. 2017) remains largely unknown and

Table 8 Target hazard quotient (THQ) for children exposed to heavy metals via consumption of sweets and chewing gums and chocolates

Samples	Pb	Cr	Cd	Ni	Zn
Chocolates					
Safa chocolate	0.46	0	0.291	0.31	0.031
Snickers chocolate	0.171	0	0.697	0.072	0.015
X-one chocolate	0.875	0	1.237	0.148	0.023
Emperor chocolate	0.861	0	0	0.169	0.02
Eclairs chocolate	0	0.141	0.158	0.132	0
Cocos chocolate	0.299	0.454	0	0.111	0.026
My love chocolate	0.619	0	1.162	0.071	0.017
Twrx chocolate	0.277	0	1.212	0.037	0.028
Derive chocolate	0.197	0.423	1.311	0.025	0.023
Camellia chocolate	0.382	0	0.025	0.044	0.011
Mars chocolate	0.327	0.097	1.386	0.019	0.026
Tiffany chocolate	0	0.365	0.058	0.013	0.022
Ochre choco	0.083	0.011	0	0.084	0.01
Tuyo - Bon bon	0.301	0	1.021	0.098	0.029
Chewing gum					
Supestars	0.254	0.086	0.025	0.126	0.013
Double mind	0.507	0.072	0.506	0.09	0.018
Kelito	0.268	0.152	0	0.034	0.007
Trident	0.116	0.066	0.739	0.012	0.004
Centre frit jelly	0.074	0.335	1.336	0.013	0.016
Orbit	0.382	0.003	0.019	0.103	0.026
Long stick	0.017	0.033	0.033	0	0.012
Fruit banana	0.116	0	0	0.073	0.015
Super	0.503	0.036	0	0.126	0.018

calls for further study. The presence of Pb in these commonly consumed confectioneries especially among children given the stipulation that Pb should not be found in any amount in any consumer product, especially those that children can have contact with (y Ortiz et al. 2016) places a huge responsibility on the relevant regulatory bodies.

Conclusion

The present non-cancer risk assessment of potential toxic metals in candies and chocolates consumed by children in Nigeria has important public health concern. The high levels of potential toxic metals especially lead and cadmium in these commonly consumed candies may pose health risks.

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