



Concentrations of Selected Metals In Some Ready-To-Eat-Foods Consumed in Southern Nigeria: Estimation of Dietary Intakes and Target Hazard Quotients

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ARTICLE INFO

Article history:

Received 24 April 2013

Accepted 19 September 2013

Available online, ISSN: 2148-127X

Keywords:

Metal ions,
Dietary intake,
Target hazard quotients,
Ready-to-eat-foods,
Nigeria

ABSTRACT

Concentrations of selected metals (Cu, Cd, Ni, Pb, Mn, Fe, Zn, Cr and Co) in some ready-to-eat-foods consumed in southern Nigeria were investigated with a view to providing information on the risk associated with the consumption of these products. The concentrations of metals (mg kg⁻¹) in these ready-to-eat-foods are in the ranges of 2.4 – 5.2 for Cu; 0.1– 0.8 for Cd; 0.7 – 4.0 for Ni; 8.1 – 53.7 for Fe; 8.9 – 20.0 for Zn; 0.1 – 3.8 for Pb; 5.1 – 14.4 for Mn; 0.83 – 21.4 for Cr and 0.20 – 1.32 for Co. The concentrations and estimated intakes of Cd, Ni and Pb in some of these food types exceeded the permissible limits and tolerable daily intake respectively. The target hazard quotients (THQ) for the individual metals indicate levels of concern for Ni, Cd, and Co in some of the ready-to-eat-foods. The combined THQ values for the metals in the examined samples ranged from 1.7 to 10 with significant contributions from Cd, Ni and Co.

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Introduction

Ready-to-eat foods can be described as foods being ready for immediate consumption at the point of sale. It could be raw or cooked, hot or chilled and can be consumed without further heat treatment including reheating (Clarence et al., 2009; Mahakarnchanakul et al., 2010). There are certain appealing factors that make street foods popular as food sources. These include familiarity, taste, low cost and convenience (Mahakarnchanakul et al., 2010). Our society shows a social pattern characterized by increased mobility, large number of itinerant workers and less family or home centred activities. This situation, however, has resulted in more ready-to-eat foods taken outside the home. Thus, food vendor services is on the increase and the responsibility of good manufacturing practices of food such as good sanitary measures and proper handling have been transferred from individuals/families to the food vendors who rarely enforce such practices (Musa and Akande 2002; Clarence et al., 2009).

In Nigeria, most of these products are stored under non-hygienic conditions. They are often displayed in open trays or container in the market or are hawked along the street and major runways. Contamination of food can occur at any point in the production chain (i.e. from the raw materials, processing, packing, transportation, storage or marketing) to consumption. Because of improper processing, handling and storage of these foods could be subject to contamination by micro organism, metals as well as pesticides. Obviously, data on the concentrations of metals in food items at the point of consumption are necessary for estimation human exposure to metals (Iwegbue, 2011).

The levels of metals in foods are of great importance because of the wide role of metal ions in health and diseases which include the requirement for intake of essential trace elements to the toxicity associated with metal overload (Hague et al., 2008). Certain metals (e.g. Cd, Pb) cannot be tolerated at low concentrations because they are exceptionally toxic to human (Suppin et al.,

2006). For example, the toxicity of heavy metals could be by the displacement of physiologically appropriate metal: Cd can replace Cu and Fe in cytoplasmic and membrane proteins. Especially in divalent form, the free metal ions can promote the generation of superoxide and hydroxyl radical which, in turn, can lead to oxidative damage of lipids, nucleic acids and proteins (Marias and Blackhurst, 2009). Cd has been linked to skeletal damage (Jarup, 2003). Cd and Pb are known to harm the reproductive system and embryonic development.

The physiologic roles of essential metals are well known e.g. Fe (haem moieties of hemoglobin and cytochromes), Cu (amine oxidases, caeruloplasmin, dopamine hydrolase and collagen synthesis), Mn (superoxide dismutase), Zn (protein synthesis, stabilization of DNA and RNA) with low requirement of Cr (glucose homeostasis) (Marias and Blackhurst 2009). The physiologic roles of essential metals are due to the fact that these metals are components of enzymes and proteins. The deficiency of these elements could induce disease conditions e.g. Cu deficiency is known to induce hypertension, increase blood cholesterol (hypercholesterolemia) and low density lipoproteins fraction increment in blood which add to the conditions favouring heart attack. Deficiency of manganese has been associated with chronic disease like osteoporosis, epilepsy and diabetes mellitus. The intake of essential metals above threshold limits could cause toxicity problems. For example, epidemiological studies have shown that there is a link between excessive intake of dietary Zn and increase in prevalence of obesity and associated diseases (Singh and Taneja, 2010).

As in Nigeria and many other countries, ready-to-eat foods (meat pie, sausage rolls, burger, moin-moin (black eyed pea cake) etc) make up a significant proportion of the daily food intake. A survey of literature reveals only a few studies of Nigerian foods for metal contents and these studies are limited in the scope of the elements and foods surveyed (Okoye 1994; Onianwa et al., 1999; Onianwa et al., 2001; Iwegbue 2011). For example, Onianwa et al. (2001) examined the levels and daily intake of Cu and Zn from confectioneries (sweets, biscuits and breads). At present, there is paucity of information on the elemental composition of ready-to-eat foods consumed in southern Nigeria and no study has reported the individual and combined target hazard quotient values for common confectioneries. This study give a comprehensive evaluation of the concentrations, daily intake and long life exposure to metals from consumption of ready-to-eat foods with a view to providing information on the risk associated with consumption of these items.

Materials and Methods

Reagents

Nitric acid 'AnalaR' (69%), Perchloric Acid AnalaR (60%) and hydrochloric acid 'Aristar' (36%) (BDH, Poole, UK). The working standard of Cu, Cd, Ni, Pb, Mn, Fe, Zn, Cr and Co were prepared by diluting concentrated stock solution (Merck, Darmstadt, Germany) of 100 mg/L with 0.25 mol/L.

Sample Collection

A total of 180 different samples of ready-to-eat food (Beans cake, sponge cake, egg roll, hot dog, queen cake, pudding, sausage roll, buns, doughnut, bread, puff-puf (a type of doughnut), chin-chin (fried doughnut), burger, fish pie and meat pie) were collected from different sale outlets in Abraka, Warri, Agbor and Benin-City (southern Nigeria) between the months of July to September, 2010. The samples were packed in polyethylene bags and conveyed to the laboratory. In laboratory, the samples were dried in the oven at 60°C for 1 h and ground into fine powder using a stainless steel blender. 2 g of the samples were weighed into a 50 mL beaker, and then 20 mL 69% (v/v) of HNO₃, 4 mL 60% (v/v) of HClO₄ and 4 mL 36% (v/v) of HCl were added into the sample and heated to 120°C for 2 h. The digest was cooled to room temperature, filtered and made up to 25 mL with 0.25 mol L⁻¹ nitric acid.

Chemical Analysis

All digested samples were analysed in triplicate using a flame atomic absorption spectrophotometry (Perkin Elmer Analyst 200, USA). Blanks and calibration standard solutions were analysed in the same way as the samples.

Quality Control

For all metal determinations, analytical blanks were prepared in a similar manner. All digested glassware's were soaked in a solution of 10 % nitric acid for 48 h followed by thorough rinsing with deionized water. The instrument was re-calibrated after every 10 samples analysis. The accuracy of the analytical procedure was checked by introducing known metal standards into already analysed samples and re-analysed. Spiked recoveries were 98.5% for Cu, 93.2% for Cd, 98.2% for Ni, 89.5% for Fe, 98.6% for Zn, 99.4% for Pb, 96.4% for Mn; 101.3% for Cr and 94.8% for Co. The procedural blanks were used to correct calculated sample concentrations for contamination from reagent and procedural manipulation. The relative standard deviation between replicate analyses was < 4%. The detection and quantification limits (LODs and LOQs) were evaluated on the basis of noise obtained with the analysis of blank sample (n=4). The LOD and LOQ were defined as the concentration of the analyte that produced signal-to-noise ratio of 3 and 10, respectively. The detection limits (mg kg⁻¹) of the metals were Cu (0.01), Cd (0.001), Ni (0.005), Fe (0.02), Zn (0.05), Pb (0.001), Mn (0.02), Cr (0.03) and Co (0.001). The estimated limits of quantification for the studied metals (mg kg⁻¹) were Cu (0.13), Cd (0.01), Ni (0.06), Fe (0.25), Zn (0.63), Pb (0.01), Mn (0.38), Cr (0.25) and Co (0.01).

Estimation of Dietary Intake and Target Hazard Quotient

Intake of heavy metals can be assessed in various ways; acceptable daily intakes (ADI), no observed effect levels (NOEL) or no observed adverse effect levels (NOAEL). A provisional weekly intake (PTWI) has been used to serve as guide for exposure to individual metals. Another method proposed to evaluate lifelong exposure to

heavy metals is the largest hazard Quotient (THQ). It is necessary to estimate the combined effects of frequently ingestion of multiple metal ions which can be expressed as a function of the quantified level of concern in the form of THQ values arising from individual or combined metal concentrations. THQ was developed by the United State Environmental Protection Agency (EPA) for estimation of potential health risk associated with long term exposure to chemical pollutants (EPA, 1989).

A consumption rate of 80 g day⁻¹ and average weight of 60 kg adult were assumed for the estimation of dietary exposure to metals.

The target hazard quotient is given by the expression (Naughton and Petroczi, 2008a, b).

$$THQ = \frac{EFr \times ED_{Total} \times SFI \times MCS_{inorg}}{RfD \times BWa \times ATn} \times 10^{-3}$$

Where

EFr=the exposure frequency (days/year)

EDtot=the exposure duration

SFI=Mass of selected dietary ingestion (g day⁻¹)

MCSinorg=concentration of inorganic species in the dietary component (mg kg⁻¹ wet weight)

RfD=oral reference dose (mg kg⁻¹ day⁻¹)

BWa=average adult body weight (kg)

ATn=average time for non-carcinogen (days) and 10⁻³ is the conversion factor.

For this project, length of exposure was set to 16,936 days for Nigerian based on the average life expectancy of 48.4 years, from 2 years of age. For the oral reference dose (mg kg⁻¹), the figures used were Cu (4.0 × 10⁻²), Cd (1 × 10⁻³), Ni (2 × 10⁻²), Fe (7.0 × 10⁻¹), Zn (3.0 × 10⁻¹), Pb (1.5), Mn (1.4 × 10⁻¹), Cr (1.5) and Co (3.0 × 10⁻⁴).

Results and Discussion

The concentrations of selected metals in ready-to-eat foods are displayed in Table 1. Analysis of Variance (ANOVA) (p<0.05) indicates significant difference in the concentrations of metals in these products. These differences may be attributed to the ingredients, the processing, packing and transportation.

Copper is an essential metal and serves as anti-oxidant and help the body to remove free radicals, prevent cell structure damage (Salama and Radwan, 2005) and plays an important role in bone formation and skeletal mineralization (Mariam et al., 2005). The mean concentrations of Cu in these ready-to-eat foods ranged from 2.4 to 5.2 mg kg⁻¹. The highest mean level of Cu was observed in the spongy cake. Most of these products have similar mean level of Cu. The limit for Cu in food is 10 mg kg⁻¹ (European Commission, 2006). The values of Cu reported in the present study were lower than the values reported in the literature for snacks samples (Cabrera et al., 2003; Salaman and Radwan, 2005; Soyлак et al., 2006). However, similar Cu levels have been recorded in confectionaries; for example, Gopalani et al. (2007) reported Cu levels ranging from not detected to 4.699 mg kg⁻¹ in biscuits, Nagpur India and Saracoglu et al. (2004) reported mean concentrations of Cu in biscuits in Turkey as <1.0 to 4.2 mg kg⁻¹.

The mean concentrations of Cd ranged from 0.14 mg kg⁻¹ in queen cake to 0.83 mg kg⁻¹ in pudding. Higher concentration of Cd was observed in pudding in comparison to other types of ready-to-eat foods examined. Within the same type of ready-to-eat food, the concentrations of Cd observed were significantly different (p<0.05). The Codex Committee on Food Additives and Contamination draft guideline for Cd in foods is 0.05 mg kg⁻¹ (CCFAC 2001; European Commission, 2006). These food types have Cd concentrations above the drafted guideline. There is the need for caution on the consumption of these products since there is a contamination of risk of Cd. The levels of Cd we observed in the present study were higher than the levels reported in the literature for confectioneries (Karavoltosos et al., 2002; Salama and Radwan, 2005; Gopalani et al., 2007).

The minimum and maximum concentrations of Ni in the analysed samples were 0.7 and 44.1 mg kg⁻¹ respectively. The maximum Ni concentration was found in the sausage roll and minimum concentration was observed in buns. The concentrations of Ni in these products are elevated. The differences in the concentrations of Ni within the same type or group are significant. Higher concentrations of Ni in these products are due to the processing of the foods. The processing of these foods is done in stainless steel container, where Ni contamination is possible. In addition, Ni contamination is possible from the catalyst used in preparation of hydrogenated vegetable oil (Dahiya et al., 2005; Iwegbue, 2011). Hydrogenated vegetable oil is a key component of these products. The concentrations of Ni reported in this study were similar to Ni levels found in snacks and appetizer in Turkey (Soyлак et al., 2006) and confectioneries (Gopalani et al., 2007). The high levels of Cd and Ni in these food types could be due vehicular emission since these foods are usually hawked along the major run ways without proper packaging.

Iron is a mineral essential for life and for our diets. Results of Fe concentrations for all analysed samples are in the ranges of 8.1 to 53.7 mg kg⁻¹. The maximum level of Fe was observed in puff-puff while the minimum level is observed in bread. Iron levels in the range of 44.6 to 113.4 mg kg⁻¹ have been reported for appetizers and snacks in Turkey (Soyлак et al., 2006). These food items are potential source of Fe for both children and adults. Deficiency of Fe in the body could result into anaemia.

The mean concentrations of Zn in the analyzed samples are in the range of 8.9 to 20 mg kg⁻¹. The highest mean level of Zn was observed in burger while the lowest mean level of Zn was observed in fish pie. Demirezen and Uruc (2005) reported mean Zn concentration in sausage as 0.6 mg kg⁻¹. Soyлак et al. (2005) reported mean concentration ranging from 6.8 to 20.4 mg kg⁻¹ as concentrations of Zn in the appetizers and snacks. Salaman and Radwan (2005) reported in the ranges of 2.347 to 13.70 mg kg⁻¹ as Zn concentrations in cereal products. Zinc levels in the ranges of 3.1 and 16.1 mg kg⁻¹ in biscuits in Turkey (Saracoglu et al., 2004), and not detected to 13.4 mg kg⁻¹ in biscuits from India (Gopalani et al., 2007) have been reported. The concentrations of Zn observed in these foods were below the guideline value of

150 mg kg⁻¹ for Zn in foods. The recommended dietary allowance for Zn is 10 mg day⁻¹ for growing children and 15 mg day⁻¹ for adult (Saviparumal and others 2007). Zinc deficiency is marked with retarded growth and hypogonadism, leading to decreased fertility.

Lead is well known for its toxic and adverse effects on human. Absorption of ingested Pb may constitute a serious risk to public health. Some chronic effects of Pb poisoning are colic, constipation and anaemia (Bolger et al., 2000; Uluozlu et al., 2007). The average mean concentration of Pb in the analysed samples ranged from 0.09 to 3.8 mg kg⁻¹. The highest mean concentration of Pb was observed in sausage roll (3.8 mg kg⁻¹) while the lowest mean level of Pb was observed in bread (sugar free). The main source of Pb in these foods may possibly come from contamination during production and foods handling. These foods are usually displayed in trays without cover or hawked along the major roads. Contamination with Pb and other metals from automobile emission cannot be ruled out in these foods. The concentrations of Pb in these products were above the guideline value for lead in foods (1 mg kg⁻¹) except for puff-puff, buns, doughnut and meat pie.

Manganese contents in the analysed samples were in the ranges of 5.1 to 14.4 mg kg⁻¹. The bread samples showed significant higher concentrations of Mn concentrations ($p < 0.05$) than any other types of ready-to-eat foods analysed. The levels of Mn observed in this study were lower than values reported for appetizers and

snacks (Soylak et al., 2006). However, similar levels of Mn have been reported in biscuits in Nagpur, India (Gopalani et al., 2007).

Chromium is an essential trace element and the biological usable form of Cr (Cr³⁺) potentiates insulin action and, plays a significant role in glucose, lipid and protein metabolism. However, Cr (IV) is carcinogenic (Ikem and Egiebor, 2005; Iwegbue, 2011). It has been estimated that humans require nearly 1 µg day⁻¹. The mean concentrations of Cr in these samples were in the ranges of 0.8 to 21.4 mg kg⁻¹. The highest Cr concentration was observed in spongy cake, while the lowest concentration of Cr was observed in fish pie. The sources of Cr contamination in food are mainly from raw materials used, manufacturing processes and leaching of Cr from the vessel in which these are stored.

Cobalt is a component of vitamin B12 and has a low oral toxicity. However, excessive intake of Co could result into cardiomyopathy (Hokin et al., 2004). Normal daily intake of Co is reported to be in the range 2.5 to 3.0 mg day⁻¹ poisoning occurs within the range of greater than 23–30 mg Co day⁻¹ (Hokin et al., 2004). The average concentrations of Co in this study ranged between 0.2 and 1.6 mg kg⁻¹. The highest concentration of Co was observed in spongy cake while the lowest concentration of Co was observed in buns. Similar ranges of values have been reported for confectionaries in the literature (Gopalani et al., 2007).

Table 1. Mean concentrations (±SD) of selected metals (mg kg⁻¹) in some ready-to-eat foods.

Sample Type	Cu	Cd	Ni	Fe	Zn	Pb	Mn	Cr	Co
Beans Cake	2.8 ± 1.0 (1.7-3.8)	0.2 ± 0.1 (0.1-0.2)	3.6 ± 2.3 (1.5-2.4)	27.6 ± 27.4 (10.7-60.3)	12.7 ± 3.5 (9.0-16.2)	1.6 ± 1.8 (0.2-4.1)	6.2 ± 1.4 (4.9-7.8)	0.9 ± 0.3 (0.5-1.1)	0.4 ± 0.2 (0.3-0.6)
Egg roll	2.7 ± 0.6 (1.9-3.1)	0.2 ± 0.2 (0.0-0.6)	3.9 ± 2.9 (1.5-8.0)	24.1 ± 11.5 (9.6-37.4)	12.3 ± 2.8** (8.9-14.6)	0.6 ± 0.5 (0.1-1.1)	6.7 ± 0.7** (5.9-7.4)	1.5 ± 0.8 (0.7-2.7)	0.7 ± 0.2 (0.5-0.9)
Hot dog	2.5 ± 0.3 (2.1-2.8)	0.2 ± 0.2 (0.0-0.3)	15.7 ± 17.7 (1.5-38.2)	19.76 ± 4.79 (15.1-26.1)	16.1 ± 7.8 (12.1-27.8)	1.2 ± 0.7 (0.5-2.1)	6.8 ± 1.3** (5.5-8.1)	1.4 ± 0.8 (0.6-2.2)	0.7 ± 0.1** (0.6-0.8)
Queen cake	2.6 ± 0.6 (1.7-3.0)	0.1 ± 0.1 (0.0-0.3)	3.4 ± 2.8 (0.7-7.2)	27.0 ± 8.7 (14.7-35.3)	12.1 ± 17.6** (9.6-13.6)	2.1 ± 0.4 (1.7-2.6)	6.6 ± 1.5 (4.9-8.1)	1.9 ± 0.6 (0.9-2.5)	0.8 ± 0.2 (0.6-1.0)
Pudding	3.1 ± 0.2 (2.9-3.3)	0.83 ± 0.32 (0.6-1.3)	15.8 ± 10.0 (3.4-25.5)	8.1 ± 5.1 (12.2-20.5)	13.3 ± 0.9** (12.4-14.4)	3.0 ± 0.2 (2.6-3.2)	6.4 ± 0.2** (6.2-6.6)	2.4 ± 0.7 (1.5-3.0)	0.8 ± 0.1** (0.7-0.9)
Burger	3.0 ± 0.8 (2.3-4.1)	0.6 ± 0.2 (0.4-0.9)	3.6 ± 2.6 (1.7-7.4)	21.0 ± 13.2 (3.9-35.9)	20.0 ± 3.9 (17.2-24.5)	2.56 ± 0.26 (2.3-2.9)	6.3 ± 0.6** (5.8-7.2)	1.3 ± 0.6 (0.8-2.2)	0.5 ± 0.1** (0.4-0.6)
Sausage roll	4.5 ± 2.5 (2.1-5.0)	0.5 ± 0.2 (0.1-1.1)	44.0 ± 40.2 (0.8-111.2)	49.4 ± 40.2 (12.2-126.3)	16.0 ± 5.5 (7.9-29.6)	3.8 ± 2.4 (1.7-8.4)	8.4 ± 2.5 (5.7-15.4)	15.1 ± 16.2 (0.6-66.7)	1.3 ± 0.9 (0.3-4.2)
Puff – puff	3.0 ± 0.3 (3.0-3.3)	0.5 ± 0.4 (0.2-1.1)	13.9 ± 15.8 (0.03-36.6)	53.7 ± 48.4 (27.6-126.3)	15.7 ± 1.6** (14.8-16.9)	0.6 ± 0.5 (0.04-1.2)	6.0 ± 2.6 (2.4-8.1)	2.0 ± 1.2 (1.0-3.5)	0.4 ± 0.1 (0.3-0.4)
Buns	2.6 ± 0.3 (2.2-2.9)	0.5 ± 0.3 (0.3-0.9)	0.70 ± 0.41 (0.1-0.9)	24.8 ± 4.0 (21.0-30.3)	9.9 ± 1.3 (8.1-11.0)	0.9 ± 0.3 (0.5-1.1)	6.7 ± 1.6 (5.2-8.6)	1.1 ± 0.9 (0.5-2.4)	0.2 ± 0.1 (0.1-0.3)
Doughnut	3.1 ± 0.3 (2.8-3.4)	0.7 ± 0.5 (0.4-1.2)	0.9 ± 0.1 (0.8-1.0)	26.5 ± 7.3 (19.7-32.9)	14.3 ± 2.5 (11.4-17.5)	0.7 ± 0.4 (0.2-10.1)	6.7 ± 1.6 (4.3-7.8)	1.6 ± 0.6 (0.7-2.2)	0.3 ± 0.1 (0.1-0.5)
Chin-chin	3.3 ± 0.5 (2.6-3.7)	0.6 ± 0.4 (0.3-1.2)	17.1 ± 18.6 (1.1-38.7)	45.0 ± 29.8 (18.8-87.1)	19.9 ± 12.9 (12.9-39.3)	3.2 ± 2.1 (1.6-6.2)	8.5 ± 3.2 (6.3-13.1)	2.5 ± 1.6 (0.3-4.9)	0.5 ± 0.2 (0.3-0.7)
Fish pie	2.4 ± 0.4 (1.3-3.5)	0.1 ± 0.2 (0.01-0.1)	0.9 ± 1.1** (0.1-2.5)	22.8 ± 9.5 (14.2-36.2)	8.9 ± 3.7 (4.9-13.7)	1.9 ± 1.1 (0.8-3.4)	5.1 ± 2.1 (2.8-7.8)	0.8 ± 0.2 (0.6-1.0)	0.4 ± 0.2 (0.2-0.6)
Meat pie	2.5 ± 0.5 (2.1-2.9)	0.3 ± 0.2 (0.03-0.4)	0.9 ± 0.7 (0.1-1.8)	16.3 ± 2.4 (12.9-18.5)	12.5 ± 4.6 (8.1-18.94)	0.7 ± 0.3 (0.4-1.1)	6.3 ± 1.0** (5.2-7.7)	1.1 ± 0.5 (0.6-1.5)	0.4 ± 0.1 (0.3-0.6)
Bread (Sugar free)	2.8 ± 0.7 (2.0-3.4)	0.3 ± 0.2 (0.1-0.5)	10.5 ± 19.5 (0.5-39.8)	19.2 ± 10.2 (11.9-33.8)	12.85 ± 1.55 (9.64-15.40)	0.1 ± 0.1 (0.01-0.2)	14.4 ± 2.2** (12.5-17.0)	1.0 ± 0.8 (0.5-2.2)	0.1 ± 0.1 (0.04-0.1)
Bread (Flour)	2.9 ± 0.6 (1.7-3.6)	0.2 ± 0.2 (0.1-0.6)	1.4 ± 1.3 (0.3-4.8)	14.4 ± 5.2 (7.8-21.8)	12.2 ± 3.1 (8.1-15.5)	1.9 ± 0.7 (1.0-3.2)	12.7 ± 4.6 (6.1-19.1)	1.1 ± 0.5 (0.6-2.4)	0.6 ± 0.2 (0.01-0.6)
Spongy Cake	5.2 ± 5.7 (1.8-12.7)	0.1 ± 0.1 (0.1-0.2)	33.4 ± 51.1 (3.5-109.7)	48.0 ± 52.5 (12.4-125.6)	16.0 ± 9.1 (8.6-28.6)	1.9 ± 2.6 (0.2-5.8)	6.3 ± 3.1 (3.8-10.8)	21.4 ± 10.9 (0.5-82.8)	1.6 ± 2.1 (0.4-4.8)

**Not significant ($P < 0.05$)

Dietary Intakes and target hazard quotients

The computed daily intakes and target hazard quotients (THQ) for the individual and combined metals in each group of the ready-to-eat food are provided in Tables 2&3 respectively. The daily intakes of Cu in this study are in the ranges of 3.3 to 6.9 $\mu\text{g kg}^{-1}$ bw day⁻¹. The Joint Expert Committee on Food Additives (JECFA)

Provisional Maximal Tolerable Daily Intake (PMTDI) of Cu is 500 $\mu\text{g kg}^{-1}$ bw day⁻¹; and Safe Upper Level recommended by EVM (2003) is 160 $\mu\text{g kg}^{-1}$ bw day⁻¹. The estimated dietary intake of Cu from these food types constitutes maximally 1.4% and 4.3% of the PMTDI and SUL values respectively.

Table 2. Estimated Daily intake of metal ($\mu\text{g/kg}^{-1}$ bw day⁻¹) from ingestion of 80 g of these products per day

Sample Type	Cu	Cd	Ni	Fe	Zn	Pb	Mn	Cr	Co
Beans Cake	3.8	0.2	4.7	36.7	16.9	2.1	8.2	1.2	0.6
Egg roll	3.5	0.2	6.2	32.1	16.4	0.8	8.9	2.0	1.0
Hot dog	3.3	0.2	20.8	26.3	21.4	1.6	9.0	1.8	0.9
Queen cake	3.4	0.2	4.5	35.9	16.2	2.8	8.7	2.2	1.0
Puddings	4.1	1.1	20.9	10.8	17.6	4.0	8.6	3.2	1.0
Burger	4.0	0.8	4.7	27.9	26.6	3.4	8.4	1.8	1.1
Sausage roll	6.0	0.6	58.6	65.9	21.3	5.1	11.2	20.1	1.8
Puff – puff	4.1	0.7	18.5	71.5	20.8	0.56	8.0	2.6	0.5
Buns	3.5	0.7	0.9	33.0	13.1	1.2	9.0	1.4	0.3
Doughnut	4.2	1.0	1.3	35.3	19.1	1.0	9.1	2.2	0.4
Chin-chin	4.4	0.2	22.8	59.8	26.4	4.3	11.0	13.4	0.7
Fish pie	3.1	0.2	1.1	30.3	11.8	2.6	6.8	1.1	0.5
Meat pie	3.3	0.3	1.2	21.6	16.7	0.7	8.4	1.4	0.5
Bread (Sugar free)	3.7	0.4	14.0	25.5	17.1	0.1	19.2	1.3	0.1
Bread (Flour)	3.9	0.3	1.9	19.2	16.2	2.54	17.0	1.4	0.3
Spongy Cake	6.9	0.2	44.0	63.9	21.2	2.5	8.4	28.4	2.2

Table 3. Estimated Target Hazard Quotient of metal ion

Sample Type	Cu	Cd	Ni	Fe	Zn	Pb	Mn	Cr	Co	THQ*
Bean Cake	0.09	0.2	0.24	0.05	0.06	0.001	0.06	0.001	2.0	3.2
Egg roll	0.08	0.2	0.31	0.05	0.05	0.001	0.06	0.001	3.3	4.1
Hot dog	0.08	0.2	1.04	0.03	0.07	0.001	0.06	0.001	3.0	4.5
Queen cake	0.09	0.2	0.23	0.05	0.05	0.002	0.06	0.001	3.3	4.9
Puddings	0.10	1.1	1.05	0.02	0.06	0.003	0.06	0.002	3.3	5.7
Burger	0.10	0.8	0.24	0.04	0.09	0.002	0.06	0.001	3.6	4.9
Sausage roll	0.15	0.6	2.93	0.09	0.07	0.003	0.08	0.013	6.0	9.9
Puff – puff	0.10	0.7	0.93	0.10	0.07	0.001	0.06	0.002	1.6	3.6
Buns	0.09	0.7	0.05	0.05	0.04	0.001	0.06	0.001	1.0	2.0
Doughnut	0.10	1.0	0.06	0.05	0.06	0.001	0.06	0.001	1.3	2.7
Chin-chin	0.11	0.8	1.14	0.09	0.09	0.003	0.08	0.009	2.3	4.0
Fish pie	0.08	0.2	0.06	0.04	0.04	0.002	0.05	0.001	1.6	2.1
Meat pie	0.08	0.3	0.06	0.03	0.06	0.001	0.06	0.001	1.6	2.2
Bread (Sugar free)	0.09	0.4	0.07	0.04	0.06	0.001	0.14	0.001	0.3	1.7
Bread (Flour)	0.10	0.3	0.10	0.03	0.05	0.002	0.12	0.001	1.0	1.7
Spongy Cake	0.17	0.2	2.20	0.09	0.07	0.002	0.06	0.019	7.3	10.1

*Combined THQ value

The dietary intake of Cd from these confectioneries spanned between 0.2 and 1.1 $\mu\text{g kg}^{-1}$ bw day⁻¹. The JECFA tolerable daily intake (TDI) of Cd is set at 1 $\mu\text{g kg}^{-1}$ bw day⁻¹. The estimated dietary intake of Cd for consuming pudding or doughnut exceeded the tolerable intake limit. Again, in the other types, dietary contribute of Cd to TDI from this source ranged between 20 and 80%.

The estimated daily intakes of Ni in this study ranged between 0.9 and 58.6 $\mu\text{g kg}^{-1}$ bw day⁻¹. The World Health Organization (WHO) tolerable daily intake (TDI) of Ni is 5 $\mu\text{g kg}^{-1}$ bw day⁻¹. Higher dietary intakes of Ni are expected from the consumption of egg roll, hot dog, sausage roll, puff, chin-chin, bread and spongy cake. Similar intake values of Ni have been reported for confectionaries in India (Dahiya et al., 2005). Higher

dietary Ni contributions, ranging from 200 to 900 $\mu\text{g day}^{-1}$ have been reported (Myron et al., 1978; Clemente et al., 1984; Nielson and Flyvholm, 1984; Smart and Sherlock, 1987; Larsen et al., 2002). Krishnamurti and Puspha (1991) reported Ni intake as high as 240–3900 $\mu\text{g day}^{-1}$ in Indian foods. The dietary intake of Ni does not lead to any health risk in the general population but could be troublesome to some sensitized individuals (Dahiya et al., 2005; Saracoglu et al., 2007; Duran et al., 2009).

The estimated dietary intake of Fe from consumption of the product ranged between 10.8 to 71.8 $\mu\text{g.kg}^{-1}$ bw day⁻¹. The upper tolerable intake of Fe in children (0 months – 8 years) and males/female (14–70 years) is 40 and 45 mg day⁻¹ respectively (Institute of Medicine, 2003). The recommended dietary allowance (RDA) of Fe is 10–18 mg day⁻¹ person (Demirezen and Uruc, 2006).

The estimated intake of Fe in this study constitutes 0.5% of the recommended dietary allowance for Fe.

The Joint Expert Committee on Food Additives (JECFA) Provisional Maximal Tolerable Daily Intake (PMTDI) for Zn is $1000 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ (WHO, 1982). The Expert Group on Vitamins and Minerals (EVM) safe upper level (SUL) is 42mg day^{-1} (equivalent to $700 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ in a 60 kg adult) for total dietary intake (EVM, 2003). The estimated dietary intake of Zn in this study are in the ranges of 11.8 to $26.6 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ which is equivalent to 1.6 to 3.8% of the EVM safe upper level.

The daily intake of Pb varies from 0.1 to $4.3 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ through the consumption of any of these food types. The JECFA Provisional Tolerable Daily Intake for Pb is $3.6 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ (WHO, 2000). Only puddings and chin-chin have intake exceeding the JECFA PTDI. However, spongy cake, beans cake, fish pie, burger and queen cake have estimated dietary intake of Pb greater than 50% of JECFA PTDI.

Daily intake of small amounts of Mn is needed for growth and good health in humans otherwise deficiency of Mn can cause serious nervous system problems (Demirezen and Uruc, 2006). The recommended dietary allowance for Mn is 2–5 mg day^{-1} person (which is equivalent to $33.3\text{--}83.3 \mu\text{g kg}^{-1} \text{bw day}^{-1}$) (WHO 1993; Demirezen and Uruc, 2006). The estimated daily intake of Mn from consumption of any of these foods ranged from 6.8 to $19.4 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ which is below the recommended dietary allowance.

The vast majority of Cr found in food is the trivalent form (Anderson, 1994; Iwegbue et al., 2010) and so comparison of total Cr level in food with guidance levels for trivalent Cr is appropriate. To prevent deficiency, the Committee on Medical Aspect of Food Policy (COMA) has recommended that Cr should be above 0.25 mg day^{-1} for adults and 0.1 and $1.0 \mu\text{g.kg}^{-1} \text{bw day}^{-1}$ for children and adolescents respectively (Ministry of Agriculture, Fisheries and Food (MAFF) 1999). The RDA for Cr is $130 \mu\text{g d}^{-1}$ person ($2.2 \mu\text{g kg}^{-1} \text{bw day}^{-1}$). The EVM guidance value for trivalent Cr is $150 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ (EVM 2003). The estimated daily intake of Cr in this study ranged between 1.1 and $28.4 \mu\text{g kg}^{-1} \text{bw day}^{-1}$. The estimated dietary intakes of Cr from these food types constituted 0.7 to 18.9% of the guidance level.

The recommended dietary allowance (RDA) value for Co is $100 \mu\text{g/day}$ (Nutrition Data 2000; Amidzic Klaric et al., 2011). The estimated daily intake of Co is in the range of 0.1 to $2.2 \mu\text{g kg}^{-1} \text{bw day}^{-1}$ which is higher than the recommended dietary allowance.

Target Hazard Quotients

The interpretation of the THQ value is binary: THQ is either > 1 or < 1 , where $\text{THQ} > 1$ indicates a reason for health concern (Sharma and Agrawal, 2005; Hague et al., 2008; Naughton and Petroczi, 2008a,b) It must be noted that THQ is not a measure of risk (Chien et al., 2002; Wang et al., 2005; Hague et al., 2008) but indicates a level of concern and while the THQ values are additive, they are not multiplicative; e.g. the level of concern at THQ of 20 is larger but not tenfold of those at $\text{THQ} = 2$ (Hague et al., 2008). The estimated target hazard quotient for the individual metals in the ready-to-eat foods were

less than 1 except for Cd in pudding ($\text{THQ} = 1.1$), doughnut ($\text{THQ} = 1.0$) and nickel in pudding ($\text{THQ} = 1.1$), sausage roll $\text{THQ} = 2.9$, Hot dog ($\text{THQ} = 1.0$), chin-chin ($\text{THQ} = 1.1$) and spongy cake ($\text{THQ} = 2.2$). The THQ values for Co in different types of the ready-to-eat foods are greater than 1 except for bread and buns. This indicates level of concern for these elements. The combined THQ values of examined metals for these food types ranged between 1.7 and 10.1 with significant contributions from Cd, Ni and Co.

Conclusion

The concentration of metals in these food types were below their respective permissible limits in food except for Cd, Ni and Pb in some of the food types. The estimated daily intakes of metals from consumption of these products were below tolerable daily intake except for Ni, Cd, Pb, and Co exceeded the recommended dietary allowance value in some types of these products. The combined target hazard quotient (THQ) for the metals never exceeded 12. Individual THQ values indicate level of concerns for Cd, Co and Ni in some of the ready-to-eat foods. Low levels of certain essential elements were observed in these foods and therefore do not contribute significantly to the dietary requirements of essential elements ($< 5\%$). Contamination of these food types arises from automobile emissions, poor packaging and storage conditions, contamination carried from the water source, poor hygiene and sanitation conditions of the processing premises. There is the need to educate and advocate for good manufacturing practices among the processors and food vendors. Also relevant agencies in Nigeria such as Consumer Protection Rights, National Agency for Food, Drug Administration and Control (NAFDAC) and Standard Organization of Nigeria (SON) need to ensure and enforce strict compliance to the desired levels of essential elements in foods and hazard analysis critical control point (HACCP) in all food production.

Acknowledgements

The authors are grateful to Miss B.O Ogiemwonyi and Mr. P.O Afebuamhe for the assistance during sampling and analysis, and the Central Research Laboratory, University of Ibadan, Ibadan, Nigeria for atomic absorption analysis.

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