Health risk assessment of zinc, chromium, and nickel from cow meat consumption in an urban Nigerian population

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Background: Meat consumption is increasingly becoming a larger part of diets worldwide. However, the bioaccumulation of toxic metals from anthropogenic pollution is a potential health risk to human health.
Objective: To measure the daily intake of zinc, chromium, and nickel from cow meat consumption and assess the possible health risks in an urban population in Nigeria.
Methods: Dried meat samples were digested with 3 : 2HNO3 : HClO4 v/v. Zinc, chromium, and nickel concentrations were determined with atomic absorption spectrophotometer. Daily intakes of meat were obtained using a food frequency questionnaire (FFQ).
Results: The estimated daily intakes (EDI) (μg/person/day) ranges were: zinc (10 496–13 459), chromium (310.90–393.73), and nickel (26.72–34.87). Estimated daily intake for zinc was 15–30% of provisional maximum tolerable daily intake (PMTDI) and for nickel it was 8–15% of tolerable daily intake (TDI).
Conclusion: Chromium intakes were above recommended daily intake (RDI). Target hazard quotient (THQ) for nickel and zinc were within WHO/FAO limit. There was no evidence of possible health risk to consumers with regard to zinc and nickel. However, chromium intake should be of utmost concern, while disposal of tanning waste should be checked.

Keywords: Food contamination, Heavy metals, Bioaccumulation, Trace metals, Zinc, Nickel, Chromium, Beef, Cow meat

Introduction

Heavy metals occur naturally in the environment and can be found in virtually all plant, animal, and food substances.[1] Although small quantities of metals are necessary for human development, continuous and excessive exposure of heavy metals can lead to toxicity threatening human health. Previous studies have found that metal toxicity can result in pathological changes in the kidneys, liver, gastrointestinal tract, bone, pancreas, testes, and blood vessels.[2]

Zinc is an example of a heavy metal essential for normal functioning of cells including protein and carbohydrate metabolism, cell growth, and cell division.[3] However, while humans can handle proportionally large concentrations of zinc, overconsumption of zinc can cause stomach cramps, skin irritations, vomiting, nausea, and anemia. Very high exposure to zinc can damage the pancreas, disturb protein metabolism, and cause arteriosclerosis.[3] Chromium is an essential element that helps the body use sugar, proteins, and fat.[4] Human ingestion of high doses of chromium VI can result in human health problems including gastrointestinal bleeding and necrosis of the proximal and distal tubules in the kidney.[5–7] Nickel is also beneficial to human health. It is an important cofactor for various enzymes and acts to accelerate normal chemical reactions occurring in the body.[8] However, the ingestion of high levels of nickel may aggravate vesicular hand eczema and possibly eczema arising on other parts of the body, even in the absence of skin contact with nickel.[9] Very high concentrations of nickel can induce teratogenic or genotoxic effects.[9]

Food is the most common non-occupational source of exposure to heavy metals for humans.[10] Although human bodies have homeostatic mechanisms that enable them to tolerate small fluctuations in metal consumption, concentrations far above or below certain levels can result in a range of acute and chronic negative health effects.[11] Two common routes of exposure to heavy metals in the food supply are through crops grown in soil with high concentrations of metal and/or irrigated with polluted water and when animals graze in pastures with increased

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concentrations of heavy metals. The latter results in the bioaccumulation and/or biomagnification of metals in animal tissue.

Meat is an important source of essential amino acids, minerals, vitamins, and energy.[12] All the essential amino acids required for life are highly bioavailable in muscle tissue, and liver is rich in vitamins, particularly vitamin A.[12] Meat is also an important dietary source of vitamins B_1 (thiamin) and B_2 (riboflavin).[12] While meat provides an important source of nutrients, it can also be a source of heavy metal exposure for humans.

In Nigeria, cattle are free grazing and drink water from any available source including ditches, streams, rivers, and other sources that may be contaminated with heavy metals. They graze along roadways and other sites that have high contaminations of toxic substances. Previous research in Nigeria has identified high levels of some trace metals in meat. Iwegbue and Iwegbue *et al.* found levels of chromium and nickel above the acceptable limit in beef and some chicken and turkey meat from southern Nigeria.[13,14] Similarly, Okoye and Ugwu found elevated levels of zinc in Nigerian goats.[15]

This study hypothesized that when cattle are feeding and drinking in Nigeria, they may be exposed to high levels of contaminants including heavy metals, which accumulate in their organs and other tissues. This study adds to existing literature on levels of trace metal in farm animals. It is the first study in Nigeria to investigate the dietary intake of trace metals through cow meat consumption and the possible health risks involved in their consumption.

Methods

Sampling and sample pretreatment

Samples were collected from 150 *White Fulani* cows, including 30 samples of muscle, liver, kidney, intestine, and tripe. All collection took place in the abattoirs of Nsukka and Enugu, Nigeria between August 2007 and November 2008. Samples were oven-dried at 105°C to a constant weight, pulverized in a porcelain mortar, and stored in a desiccator.

Digestion

2.00 g of each meat sample was digested with 10 ml of 3 : 2 Analar grade HNO_3 (65% v/v) : $HClO_4$ (70% v/v) mixture (Riedel-de Haen, Germany) in a 100 ml polyethylene bottle. The meat samples and the digestion mixture were gently swirled and left to stand overnight. The samples were later heated at 70°C in a water bath with swirling at 30 minutes intervals for 3 hours. At cooling, the digests were transferred into 20 ml standard flask, rinsed with de-ionized water, and reconstituted to 20 ml with de-ionized water. Metal analyses were carried out using an atomic absorption spectrophotometer (GBC Avanta ver. 2.02, Australia) with air–acetylene flame. Sample blanks, prepared by taking 10 ml of the digestion mixture through the same procedure as the samples were analyzed for the same metals. The detection limit for each element was determined using the lowest possible dilution. The values were as follows: zinc=0.05 μg/g; chromium=0.03 μg/g; and nickel=0.09 μg/g.

Quality assurance procedures

The standard addition method was used for the validation of the digestion method. We determined the metal concentrations in triplicate samples of un-spiked and spiked liver samples. Spiking was performed by adding 1 ml of various concentrations of the metal standard solution (Table 1) to 2 g of ground liver sample, which was later subjected to the digestion procedure. The formula for calculating the percent recoveries was:

$$\% \text{ Recovery} = \frac{s-y}{z} \times 100$$

s is the concentration of spiked sample, y is the concentration of un-spiked sample; z is the spiking concentration (μg/ml).

Table 1 Percent recoveries of zinc, chromium, and nickel from meat samples after digestion

Metals	Spiking (added) concentration (μg/ml)	Concentration of un-spiked sample (μg/ml)	Concentration of spiked sample (μg/ml)	Recovered concentration (μg/ml)	% Recovery	% Precision
Zinc	0.100	0.475	0.578	0.103	103	4.60
	0.100	0.639	0.737	0.098	98	
	0.100	0.872	0.966	0.094	94	
Mean±SD					98±4.51	
Chromium	0.150	0.089	0.216	0.127	84.7	7.38
	0.300	0.027	0.319	0.292	97.3	
	0.450	0.029	0.459	0.430	95.6	
Mean±SD					92.5±6.83	
Nickel	0.250	0.180	0.449	0.269	107.6	9.27
	0.500	0.175	0.627	0.452	90.4	
	0.750	0.160	0.951	0.791	105.5	
Mean±SD					101.2±9.38	

Dietary intake analyses

To obtain food history information from individuals in this study, we constructed a semi-quantitative food frequency questionnaire (FFQ). Food frequency questionnaire was chosen because it can be self-administered, is easy to complete, inexpensive, and has been previously validated.[16–18]One limitation of the FFQ is that subjects often have difficulty estimating portion sizes. In order to overcome this problem, portion size estimations were achieved by providing pictures of cooked meats of different sizes (large, moderate, small, and very small). The use of pictures as portion aids in dietary assessment tools has been previously validated.[19–23]

The FFQ was face validated by experts in the field and administered to 755 subjects (adult men and women, pregnant/lactating women, undergraduate students, and school children) between 2007 and 2010.The FFQ was divided into three sections. Section A collected socio-demographic information including: age, sex, physiological condition, occupation, and educational status. Section B asked participants about preferred cuts of meat for consumption and Section C collected information on the frequency and quantity of beef consumed. The frequency categories ranged from 0 to 7 days/week. Weekly intakes of beef consumption were estimated for each subject. Participant body weight was measured using a bathroom balance.

Data analysis

Estimation of daily intake

All data from the FFQ were analyzed using SPSS version 15.0 for Windows. Estimated daily intakes (EDI) of the metals were calculated using the formula:

$$\mathrm{EDI} = \sum\nolimits_{i=1}^{5} \mathrm{MI} \times \mathrm{MC}$$

MC is the mean concentration of metal in the meat (μg/g).

MI is the estimated quantity of meat consumed (g/person/day). Subscript $i=1$–5 corresponds to different meat parts: muscle, liver, kidney, intestine, and tripe respectively.

Target hazard quotient (THQ)

Risk assessment is the process that evaluates the potential health effects of dietary exposure to a contaminant through one or more exposure pathways. The health risks from consumption of cow meat were assessed using the THQ, which is the ratio of determined dose of a pollutant to a reference dose level. If the ratio is less than 1, the exposed population is unlikely to experience obvious adverse effects.[24] Target hazard quotient has been recognized as a useful parameter for evaluation of risk associated with the consumption of metal contaminated food.[25,26]

The THQ were estimated using the U.S. Environmental Protection Agency (EPA) Region III risk-based concentration model table.[27]

$$\mathrm{THQ} = \frac{\mathrm{Efr} \times \mathrm{EDtot} \times \mathrm{EDI}}{\mathrm{RfDo} \times \mathrm{BW} \times \mathrm{AT}} \times 10^{-3}$$

where THQ is target hazard quotient; Efr is exposure frequency (350 days/year); EDtot is exposure duration, total (70 years); RfDo is the oral reference dose (mg/kg/day); BW is the average body weight for each group of the subjects, AT is averaging time for non-carcinogens (365 days/year × EDtot) and EDI is total estimated daily intake of cow meat in micrograms per person per day.

The oral reference dose (RfDo) for zinc is 0.3 mg/kg/day and 0.02 mg/kg/day for nickel.[28]

Following EPA guidelines, we assumed that the ingested dose was equal to the absorbed contaminant dose and that cooking had no effect on the presence of contaminants.[29,30] There is no RfDo for chromium.

Results

Table 1 shows the mean percent recoveries of zinc, chromium, and nickel. Mean concentrations (μg/g fresh weight, fw) are shown in Table 2. The highest concentration of zinc was observed in liver, followed by muscle. The lowest concentration of zinc was measured in intestine samples. For chromium, the highest concentration was found in liver while the lowest concentration was found in muscle. The highest concentration of nickel was found in kidney and the lowest in liver. Table 3 shows a comparison of the results of this study with other studies.

Table 4 presents the results of the FFQ, including the daily consumption rates of the different sections of cattle. The total daily consumption of cow meat by percentage fractions of various groups of subjects is also shown. The highest total daily consumption rate of cow meat was recorded for pregnant/lactating women while the lowest consumption rate was recorded for school children. For adult men, tripe was the most important source of zinc followed by intestine. For undergraduate students, muscle was the largest source of zinc and for schoolchildren it was liver. The most important source of nickel for adult men, pregnant/lactating women, undergraduate students, and school children was intestine, followed by tripe. For adult women, tripe was the largest source of nickel. As for chromium, the largest source for adults, undergraduate students, and school children was tripe. The largest source for pregnant/lactating women was intestine.

Table 5 shows that the total daily intakes (μg/person/day) of zinc, nickel, and chromium from cow meat consumption were highest for pregnant/lactating women and lowest for schoolchildren. Figure 1

Table 2 Mean concentrations (μg/g, fresh weight, fw) of zinc, chromium, and nickel in different meat parts

Metals		Muscle	Kidney	Liver	Intestine	Tripe
Zinc	Min	104.90	84.00	26.12	68.99	77.95
	Max	138.26	117.64	163.26	100.18	100.79
	Median	122.21	98.17	145.18	93.23	92.79
	Range	33.36	33.64	137.14	31.19	22.84
	Mean±SD	121.27±7.45	98.01±7.19	132.33±38.81	91.10±8.04	92.22±5.11
Chromium	Min	0.13	0.07	1.59	2.55	3.00
	Max	2.46	3.77	5.51	4.51	6.36
	Median	1.33	2.62	4.66	3.45	3.66
	Range	2.33	2.18	5.44	1.96	3.36
	Mean±SD	1.24±0.52	2.58±0.46	4.28±1.39	3.42±0.41	3.81±0.65
Nickel	Min	0.06	0.08	0.01	0.13	0.05
	Max	0.54	0.70	0.57	0.58	0.57
	Median	0.25	0.34	0.19	0.31	0.26
	Range	0.48	0.62	0.56	0.45	0.52
	Mean±SD	0.25±0.12	0.36±0.14	0.20±0.11	0.33±0.11	0.27±0.10

shows that the THQ of nickel ranges from 0.018 to 0.037 for the different groups in the study. For zinc (Fig. 2), the THQ were: adult men (0.56), adult women (0.57), pregnant/lactating women (0.47), undergraduate students (0.58), and schoolchildren (0.96).

Discussion

We found high levels of zinc in the muscle and liver of cows. This is in line with studies by Lopez-Alonso *et al.* and Miranda *et al.* that muscle and liver are the tissues where zinc is most likely to accumulate.[31,36]

We also found that kidneys contain the highest concentrations of nickel, which may be explained by the excretion function of the organ. Nieboer *et al.* has suggested that the primary excretory route for absorbed nickel is via the kidneys in the form of low-molecular-weight complexes, mainly with histidine.[37]

The Codex Alimentarium Commission has set the maximum permissible limit of zinc in meat as 50 mg/kg for muscle and 80 mg/kg fw for edible offals.[38] All zinc values reported in this study exceeded this limit. Moreover, Okoye and Ugwu have reported elevated zinc levels in goats bred in Nigeria.[15] These findings suggest that zinc contamination likely takes place in the environment where the animals feed. There are no set standards for chromium and nickel concentrations in meat by international bodies such as Codex Alimentarium and/or the WHO/FAO. However, Brazil has set a standard of 0.1 μg/g fw for chromium in meat and fish, and Russia has a permissible limit of 0.5 mg/kg fw for nickel in meat and meat products.[9,39] All chromium concentrations found in this research, ranging from 1.24 to 4.28 μg/g, exceeded the Brazilian standard. Apart from this study, high values of chromium has been reported in Nigerian cattle (2.88–4.92 mg/kg) by Iwegbue and (0.201–0.305 mg/l) in human blood by Ibeto and Okoye, suggesting considerable levels of chromium in the environment.[13,40] The nickel concentrations in this analysis were below the Russian permissible limit.

Table 3 compared levels of zinc, chromium, and nickel from this study with values reported in other studies. It was observed that the levels of zinc and chromium (dry and fresh weights, fw) in this study were much higher than those reported by others, a further indication of substantial contamination of the Nigerian environment by zinc and chromium.[32–35]

Table 3 Mean metal concentrations (μg/g, fresh weight, fw) in different cow meat parts from the present study and values from other studies

	Zinc		Chromium		Nickel	
Meat parts	Present study	Other studies	Present study	Other studies	Present study	Other studies
Muscle	121.27±7.45	46.60* 47.00* 43.09–200.20‡	1.24±0.52	0.02–2.55‡	0.25±0.12	2.64–41.4‡
Kidney	98.01±7.19	16.3–41.4† 3.87§	2.58±0.46	0.349–15.2†	0.36±0.14	0.038–6.44†
Liver	132.33±38.81	36.80* 40.20* 26.80–63.00† 20.09‡ 4.24§ 98.49‖	4.28±1.39	nd–14.9†	0.20±0.11	0.005–23.2†
Intestine	91.10±8.04	–	3.42±0.41	–	0.33±0.11	–
Tripe	92.22±5.11	–	3.81±0.65	–	0.27±0.10	–

*Miranda *et al.*;[31] † Yabe *et al.*;[32] ‡ Chowdhury *et al.*[33] (dry weight); § Akan *et al.*;[34] ‖Binkowski *et al.*[35] (dry weight).

Table 4 Results of the food frequency questionnaire (FFQ)

Characterization	Adult men	Adult women	Pregnant/non-lactating women	Undergraduate students	School children
n	186	214	96	99	165
Age range (years)	25–55	25–55	25–45	16–25	6–15
Average body weight (kg)	70±10.36	63±10.80	92±12.19	65±10.83	35±5.91
Formal education	175 (94%)	205 (96%)	93 (97%)	99 (100%)	165 (100%)
Occupation					
Civil servants	120 (65%)	131 (61%)	55 (57%)	–	–
Traders	55 (29%)	75 (35%)	35 (37%)	–	–
Artisans	11 (6%)	8 (4%)	–		
Students	–	–	6 (6%)	99 (100%)	165 (100%)
Daily meat consumption (g/day)					
Muscle					
n	169 (90.86%)	184 (85.98%)	83 (86.46%)	75 (75.76%)	134 (83.75%)
Range	1.32–197.40	1.32–215.10	1.32–140.61	1.32–140.61	1.32–131.60
Mean±SD	25.54±2.20	22.96±2.44	22.56±2.90	26.27±2.93	19.13±1.83
Liver					
n	107 (57.52%)	145 (67.75%)	57 (59.38%)	63 (63.64%)	91 (56.88%)
Range	0.68–198.66	1.16–397.32	1.16–231.77	1.16–264.88	1.16–198.66
Mean±SD	17.31±2.86	21.47±3.38	24.75±4.87	22.01±4.46	22.31±3.76
Kidney					
n	93 (50%)	132 (61.68%)	43 (44.79%)	44 (44.44%)	50 (31.25%)
Range	1.26–100.20	1.26–99.33	1.26–112.2	1.26–50.10	1.26–112.2
Mean±SD	11.42±1.61	10.77±1.44	12.86±2.68	8.36±1.34	11.07±2.45
Intestine					
n	128 (68.82%)	147 (68.69%)	59 (61.46%)	46 (46.46%)	79 (49.38%)
Range	1.29–557.47	1.29–250.86	1.29–836.2	1.29–250.86	1.29–250.86
Mean±SD	32.58±6.10	23.50±3.03	40.94±14.39	25.89±5.78	21.67±4.16
Tripe					
n	120 (64.52%)	155 (72.43%)	56 (58.33%)	54 (54.55%)	116 (72.50%)
Range	1.32–499.40	1.32–224.73	1.32–224.73	1.32–224.73	1.32–379.55
Mean±SD	29.42±5.27	26.42±2.89	22.74±4.38	26.71±5.56	23.48±4.55
Total meat intake	116.27	105.12	123.85	109.24	97.66

Most zinc enters the environment as the result of mining, zinc purification, lead and cadmium ores, steel production, coal burning, and waste burning. Chromium sources may come from waste effluents discharged from textile, pigment, leather tanning, and electroplating industries, and/or incineration of municipal refuse and sewage sludge.

We observed that pregnant/lactating women consumed more meat than the other study groups (Table 4) and thus recorded high daily intakes for all of the measured metals. Their high intakes may be due to their physiological condition as nutrient requirements increase during pregnancy to support fetal growth and maternal health.

Comparing the daily intakes reported in this study with other studies, we observed that the total dietary intake of zinc from cow meat by the different groups was higher than the 6660 μg/day reported for meat, fish, and poultry in some US cities.[41] The daily intake of zinc from meat (2430 μg/day) reported in Greece was also lower than the values in this study.[42] The total dietary intake of zinc (3186 μg/day) from muscle tissue reported for undergraduate students in this study was higher than 1800 μg/day reported for female university students in Malaysia.[43] Also, the values reported as dietary intake of zinc from liver and kidney in this study were higher than the 670 and 300 μg/day reported by MAFF from liver and kidney, respectively.[44] The dietary intakes of nickel among the different groups were lower than 9 μg/day reported for meat in Greece and 117 μg/day reported for meat in Lahore.[42,45] The total dietary intakes of chromium for the different groups were higher than 47 μg/day reported for meat (beef, mutton, and chicken) in Lahore.[45] The high intakes of zinc and chromium from this study as compared to the other studies goes further to support that there are high levels of zinc and chromium in cow tissue as low consumption rates were reported among the subjects (Table 4).

For an assessment of health risks with respect to the daily intakes, the total daily intake for each group was compared to the tolerable intake for the different metals as stipulated by international organizations. The provisional maximum tolerable daily intake (PMTDI) of zinc is 1000 μg/kg body weight.[46] It was observed that the total daily intakes of zinc from cow meat for the different groups: adult men, adult women, pregnant/lactating women, undergraduate students, and school children were: 17, 18, 15, 18, and 30% of the PMTDI, respectively. This shows considerably low exposure to zinc. This may be attributed to low consumption of meat (Table 4), since zinc concentrations in the meat samples were considerable.

World Health Organization has set a tolerable daily intake (TDI) of 5 μg/kg body weight for nickel.[47] The total daily intakes of the different groups as a percent TDI of nickel were: 10, 9, 8, 9, and 15% for adult men, adult women, pregnant/lactating women, undergraduate students, and school children, respectively. The low percent TDI obtained for the different groups indicates low exposure to nickel through cow meat consumption. Chromium evaluation was based on its recommended daily intake (RDI) of 50–200 μg by the National Academy of Science, for adults and adolescents.[48] The results show that the total daily intakes for the different groups of the subjects exceeded the RDI range as follows: 179, 65, 197, 169, and 155% for adult men, adult women, pregnant/lactating women, undergraduate students, and school children, respectively. High intake of chromium from cow meat could be connected to the fact that the studied animals were free ranging and there is widespread chromium contamination in the study region due to large-scale tanning industry where the animals were bred.

As a result of unavailability of RfDo for total chromium, this study was limited to evaluating THQ for zinc and nickel only. Chromium speciation was not performed. The THQ obtained in this study (Figs. 1 and 2) were less than 1 suggesting that the subjects were not exposed to health risks from dietary nickel and zinc through cow meat consumption.

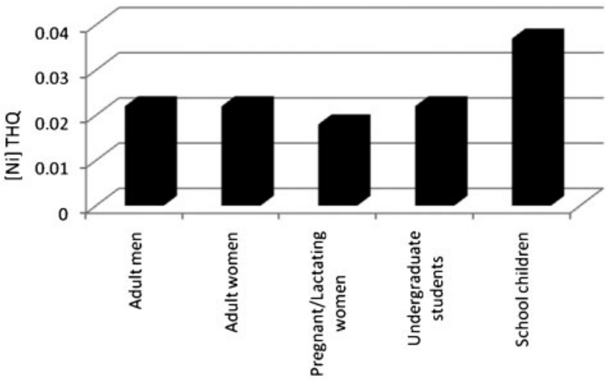

Figure 1 Target hazard quotient (THQ) for nickel.

Moreover, Horiguchi *et al.* suggested that the ingested dose is not equal to the absorbed pollutant dose because a fraction of the ingested toxicant may be excreted, leaving a smaller portion to accumulate in body tissues.[49] Therefore, it is likely that the ingested amount among the sample population is even lower.

The THQ for zinc obtained in this study was higher than the 0.089 reported for fish in Taiwan but comparable to 0.48–0.60 reported for rice in south China.[24,50] The highest THQ for zinc in this study was recorded for school children. Children are especially vulnerable to acute and chronic effects of ingestion of chemical compounds since they consume

Table 5 Estimated daily intake (EDI) of zinc, nickel, and chromium from cow meat consumption

Groups	Meat parts	Zinc daily intake (μg/person/day)	Zinc daily intake (μg/kg body weight/day)	Nickel daily intake (μg/person/day)	Nickel daily intake (μg/kg body weight/day)	Chromium daily intake (μg/person/day)	Chromium daily intake (μg/kg body weight/day)
Adult men	Muscle	3097	44	6.39	0.09	31.67	0.45
	Liver	2291	33	3.46	0.05	74.09	1.06
	Kidney	1119	16	4.11	0.06	29.46	0.42
	Intestine	2968	42	10.75	0.20	111.43	1.59
	Tripe	2712	39	7.94	0.10	112.09	1.60
	Total	12 188	174	32.65	0.50	358.78	5.12
Adult women	Muscle	2784	44	5.74	0.09	28.47	0.42
	Liver	2841	45	4.29	0.07	91.89	1.46
	Kidney	1056	17	3.89	0.06	27.79	0.44
	Intestine	2141	34	7.76	0.12	80.37	1.28
	Tripe	2436	39	7.13	0.11	100.66	1.60
	Total	11 258	179	28.81	0.45	329.18	5.17
Pregnant/lactating women	Muscle	3097	34	5.64	0.06	27.97	0.30
	Liver	3275	36	4.95	0.05	105.93	1.15
	Kidney	1260	14	4.63	0.05	33.18	0.36
	Intestine	3730	41	13.51	0.15	140.01	1.52
	Tripe	2097	28	6.14	0.07	86.64	0.94
	Total	13 459	153	34.87	0.38	393.73	4.22
Undergraduate students	Muscle	3186	49	6.57	0.10	32.57	0.50
	Liver	2913	45	4.40	0.07	94.20	1.45
	Kidney	819	13	3.01	0.05	21.57	0.33
	Intestine	2359	36	8.54	0.13	88.54	1.36
	Tripe	2463	39	7.21	0.11	101.77	1.57
	Total	11 740	182	29.73	0.46	338.65	5.21
School children	Muscle	2320	66	4.78	0.14	23.72	0.68
	Liver	2932	84	4.46	0.13	95.49	2.73
	Kidney	1085	31	3.99	0.11	28.12	0.80
	Intestine	1974	56	7.15	0.20	74.11	2.12
	Tripe	2165	62	6.34	0.18	89.46	2.56
	Total	10 496	299	26.72	0.76	310.90	8.89

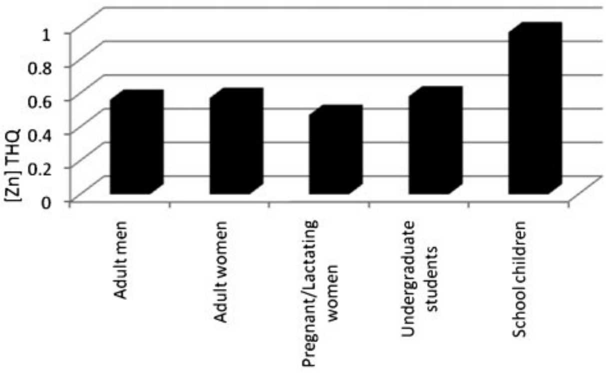

Figure 2 Target hazard quotient (THQ) for zinc.

more food per kilogram of bodyweight than adults. They are more exposed to chemical hazards in food than adults.[51] Infants consume twice the amount of food per unit of body weight as adults, thus their developing organs and tissues are more susceptible to the toxic effects of certain chemicals.

In conclusion, the levels of zinc and chromium in the different parts of cow tissues were moderately high compared to values in the literature. The EDI of chromium from cow meat was high compared to established standards, while those of zinc and nickel were low. High percent intakes were recorded in children in all cases. Cow meat contamination is due mainly to environmental pollution as the animals are free ranging. Waste management policies are non-existent or not enforced in Nigeria, resulting in the proliferation of dumpsites and the indiscriminate open dumping of waste. Several studies have shown elevated levels of heavy metals in leachate, water bodies, and soil around solid waste dumpsites in Nigeria.[52,53] Diffuse dispersion and exposure to these metal contaminants by free ranging animals may occur during grazing on contaminated agricultural land, runoff from waste dumps, and contaminated water, increasing the metal burden transferred into the food chain. Therefore, there is need for a drastic reduction in these environmental contaminants in order to safeguard the food chain. We recommend that the Nigerian government create, implement, and enforce policies to address the problem of waste management in the country. Waste should be properly disposed in waste dumps protected from rainfall and relevant agencies in the country should monitor the discharge of tanning waste, especially in regions where animals are raised. This study is the first of its kind to investigate the dietary intake and risks involved in the consumption of cow meat and will serve as baseline data in Nigeria and for future studies. We suggest a future research to investigate the dietary intake of heavy metals and risks involved in the consumption of poultry, as more Nigerians are consuming leaner meats in an effort to avoid the dangers of high cholesterol.

Disclaimer Statements

Contributors C. O. B. Okoye designed the study on metal analysis in meat with regard to environmental pollution and contributed to the write up while J. N. Ihedioha designed the dietary intake and risk assessment and wrote the article. U.A. Onyechi constructed the food frequency questionnaire and the picture models used in estimating portion sizes. She also contributed in the write up.

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