Journal of Science and Technology, Vol. 41, No. 2 (2023), pp 50 - 62

https://dx.doi.org/10.4314/just.v41i2.5

RESEARCH PAPER

HEAVY METALS IN STREET-ROASTED FOOD AND HOME-OVEN-ROASTED FOODS.

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ABSTRACT

Economic crises have led to an increase in entrepreneurial activities like street food vending. However, roasting food on the streets can increase food contamination. This study compares the concentrations of heavy metals such as Cd, Cr, Cu, Fe, Mn, Pb, and Zn in home-roasted and street-roasted chicken, maize, meat, fish, and plantain in Nigeria. The food samples were digested with acid, and the concentrations of these elements in the digests were determined using Atomic Absorption Spectrometer. The results showed that the concentrations of the heavy metals in street-roasted food were higher than in home-roasted food. The mean concentration of these metals in street-roasted food decreased in the following order: Fe > Mn > Pb > Cr > Cu > Cd and in home-roasted food in the decreasing order: Fe > Mn > Pb > Cr > Cd > Cu. Moreover, the total heavy metal concentration in street-roasted food followed the decreasing order: Maize > Meat > Chicken > Plantain > Fish, and in home-roasted food, the decreasing order: Fish > Chicken > Maize >Plantain > Meat. The highest risk among the heavy metals studied is posed by Pb, which is likely to pose a risk to both adults and children due to the Target Hazard Quotient of above 1. The findings emphasized the importance of monitoring and regulating the street food industry to reduce the health risks linked with consuming contaminated food.

Keywords: street-roasted food, home-roasted food, heavy metals, contaminants

INTRODUCTION

Some heavy metals, are essential elements but can pose threats to humans when they exceed their threshold values. The metals are mobile in the environment and can be ingested by plants, animals, and humans via the food chain. Of concern are cadmium, lead, manganese, nickel, and zinc, because these metals bioaccumulate and are difficult to eliminate from the human system (Ehis-Eriakha and Akemu, 2022). Heavy metals enter humans via oral, inhalation, and dermal exposure, however, oral exposure is the major route for contaminated food into the body.

Food is vital for human growth and nutrition, providing essential minerals and vitamins. However, food safety is of global concern as it can also be a source of heavy metals that pose health risks to man (Kortei *et al*., 2020). In developing countries including Nigeria, street food vending is a widespread practice (Alimi, 2016) where foods are often boiled, fried, or roasted, however, contamination of food sold in public places is a major concern due to unregulated urbanization and industrialization, and unhygienic practices (ImathIu, 2017).

Roasted foods are ready-to-eat snacks commonly sold on Nigeria streets (Amos-Tautua, Inengite, Abasi, and Amirize, 2013) with roasting achieved using coal fire, tyre or polyethene (Ujowundu, Ogbede, Igwe, and Nwaoguikpe, 2016). The charcoal used in street food preparation can be a potential source of contaminants, including heavy metals, which can enter the food through volatilization (Lee, Coleman, Jones, Jones, and Lohmann, 2005). Unlike boiling, roasting is a tedious process, so some people use microwaves to make it easier and avoid harmful materials. Street vendors selling roasted fish, meat, and chicken are popular, but studies comparing homemade and street-roasted food are limited. Therefore, this study aimed at investigating differences in the concentrations of heavy metals in common street-roasted foods and homemade roasted food.

MATERIALS AND METHODS

Study Area:

Ijebu-Ode, is a city in Ogun State, south west Nigeria which is situated along the highway between Sagamu and Benin City. The city is located 110 km by road North-East of Lagos within 100 km in the Eastern part of Ogun State.

Ijebu-Ode is the second largest city in Ogun State with a population estimate of 222,653 in 2006 (Adedeji, Olayinka, and Tope-Ajayi, 2019). It is the trade centre for farm produce such as cocoa, palm oil, cotton, tobacco and palm kernels meant for export with local trading in yam, cassava, corn, oranges and rubber (Olayiwola, 2013).

Sampling

Freshly roasted meat, chicken, fish, and plantain were purchased from roadside food vendors in Ijebu-Ode town in Ogun State, Nigeria. The roasted corn, plantain and beef were bought from a roadside trader in Lagos garage while the street-roasted chicken and fish were bought at the roadside in Erinlu. This is because roasted chicken and fish are not commonly sold except in some selected places. Fresh (unprocessed or unroasted) meat, chicken, fish, and plantain were also purchased from the city's popular market called New Market. The fresh samples were properly washed and then oven-roasted (model: Haier Thermocool HSB2070E) under hygienic conditions and were regarded as home-roasted foods.

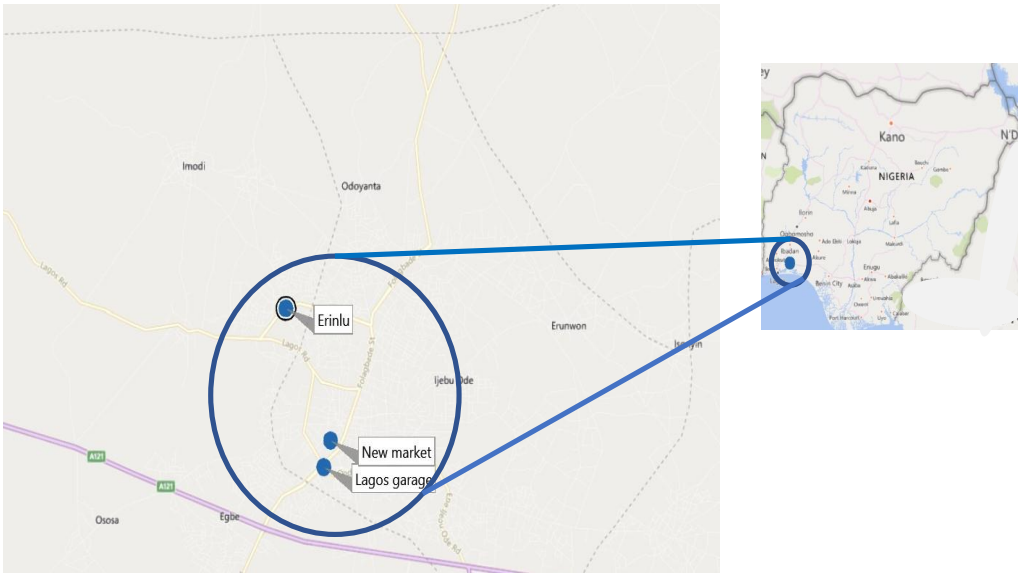

Figure 1: Aerial view of Ijebu-Ode showing the sampling points for the samples.

Figure 1 showed the map of Ijebu Ode detailing the points at which the street-roasted foods and the fresh ones for home-roasted samples were bought.

Sample Preparation

The roasted food samples (home-roasted and street-roasted) were sundried to remove moisture and then pulverised using a stainless-steel blender (Kenwood electric blender: BL330 Series). The pulverised samples (5 g each) were digested with 20 mL nitric acid in a digestion tube at a temperature of 135°C for 90 mins. The digest was then properly filtered into 100 mL volumetric flask and made up to mark with distilled water and stored in the refrigerator at 4°C prior analysis.

Analysis of Samples for Heavy Metals

The digests were allowed to thaw and then analysed for Cd, Cr, Cu, Fe, Mn and Pb using Atomic Absorption Spectrometer (BUCK AAS975.23, 2003).

Human Health Risk Assessment

The multiphase and multicomponent USEPA human health risk models which include carcinogenic and noncarcinogenic risk estimates have been successfully adopted worldwide. The model and the threshold values of the heavy metals were employed in this study to assess the potential human health risks of exposure to heavy metals in roasted foods.

Health risk estimates were done using the chronic daily intake (CDI) values calculated as shown in equation 2.1

$$CDI = \frac{C * InR * EF * ED}{AT * BW} * CF \qquad 2.1$$

Where CDI — chronic daily intake for the ingestion of the food samples; C — concentration of heavy metal in food sample (mg/kg); ED — exposure duration: 70 yrs for adults and 15 yrs for children (USEPA, 2011); EF — exposure frequency: 24 h/d; AT — averaging time for non-carcinogens: 365 × ED d (USEPA, 2011); BW — body weight: 70 kg

for adult and 15kg for children (USEPA, 2011) 1.5kg was used for chicken and 45kg for sheep (Khan *et al*., 2020); CF — units conversion factor (10^{-6} kg mg^{-1}).

The Target Hazard Quotient (THQ) assesses the risk associated with non-carcinogenic health effect by considering the ratio of the determined dose to a reference dose level. If the ratio is less than 1, the exposed population is unlikely to experience obvious adverse effects. The THQ was estimated based on Equation 2.2:

$$THQ = \frac{CDI}{RfD} \qquad 2.2$$

Where RfD is the Oral reference dose which are 0.001, 1.5, 0.04, 0.7, 14 and 0.004 mg/kg/d for Cd, Cr, Cu, Fe, Mn and Pb respectively.

Statistical Analysis

Data were analysed using an independent student's t-test with Minitab 19.0 software and the differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

Quality control

Recovery analysis of the heavy metals in the samples were 98±9 % hence showing good recovery and a reliable result. Also, the Relative standard deviation (RSD) was less than 10% indicating good precision as well.

Concentrations of heavy metals in street and home-roasted roasted food samples.

The concentrations of Cd, Cr, Cu, Fe, Mn and Pb in the street-roasted and home-roasted chicken, fish, maize, meat and plantain are shown in Table 1.

The range of Cd concentration in street-roasted foods was 0.07 to 0.36 mg/kg while it was 0.04 to 0.18 mg/kg in homemade food samples. Onianwa, Lawal, Ogunkeye, and Orejimi (2000) reported that Cd concentration higher than 0.1mg/kg is common in foods from other parts of the world. Their study of heavy metals in raw Nigerian food recorded an average cadmium concentration of 0.16 ± 0.14 mg/kg. The concentration of Cd in homemade beef was comparable to the concentration in beef as studied by Onianwa *et al*. (2000) but the concentration in street food was higher. However, the cadmium concentration was higher than those observed in American food samples with Cd range of <0.001 to 0.110 mg/kg (Voica, Dehelean, and Kovacs, 2012) but lower than the Cd concentrations measured in some commonly consumed foods in Nigeria (Lanre-Iyanda and Adekunle, 2012).

Although humans can be exposed to cadmium through inhalation and dermal exposure, oral ingestion of contaminated foods remained the principal route for non-smoker's exposure to cadmium (Huang *et al*., 2017). Food processing has been found to have significant effect on heavy metals in foods. Roasting increased the Cd concentration in Fish from 0.001 to 0.780 mg/kg (Ujowundu *et al*., 2014). The concentration of Cd in fish in this study was less than those observed by Ujowundu *et al*. (2014). This may be as a result of the substance used in roasting. For instance, charcoal and oven were used for roasting in this study while firewood, tyre and polyethylene were used by Ujowundu *et al*. (2014). Although the maximum limit of Cd in food is 0.05 mg/kg (Bamuwamye, Ogwok, and Tumuhairwe, 2015), both street and homemade food exceeded this level except for homemade roasted maize. The presence of cadmium in low concentrations in most foods which are often consumed in larger quantities makes Cd an element that may be contributing largely to human exposure (Ysart *et al*., 2000).

Table 1: Mean concentrations (mg/kg) of heavy metals in street and home-roasted food samples.

	Cd (mg/kg)		Cr (mg/kg)		Cu (mg/kg)	
	Street	*Home*	*Street*	*Home*	*Street*	*Home*
Chicken	0.29	0.15	0.86	0.90	0.60	0.11
Fish	0.24	0.16	1.76	0.81	ND	ND
Maize	0.09	0.04	1.33	0.50	0.30	0.02
Meat	0.36	0.13	1.23	0.04	1.71	0.20
Plantain	0.07	0.18	1.89	0.82	ND	ND

	Fe (mg/kg)		Mn (mg/kg)		Pb (mg/kg)	
	Street	*Home*	*Street*	*Home*	*Street*	*Home*
Chicken	55.5	27.3	5.70	0.57	5.20	1.70
Fish	28.8	20.4	8.10	21.0	4.80	1.70
Maize	52.6	20.0	78.4	0.40	4.80	2.30
Meat	60.7	0.18	5.80	5.14	5.10	0.16
Plantain	25.1	18.7	13.3	0.50	5.70	1.85

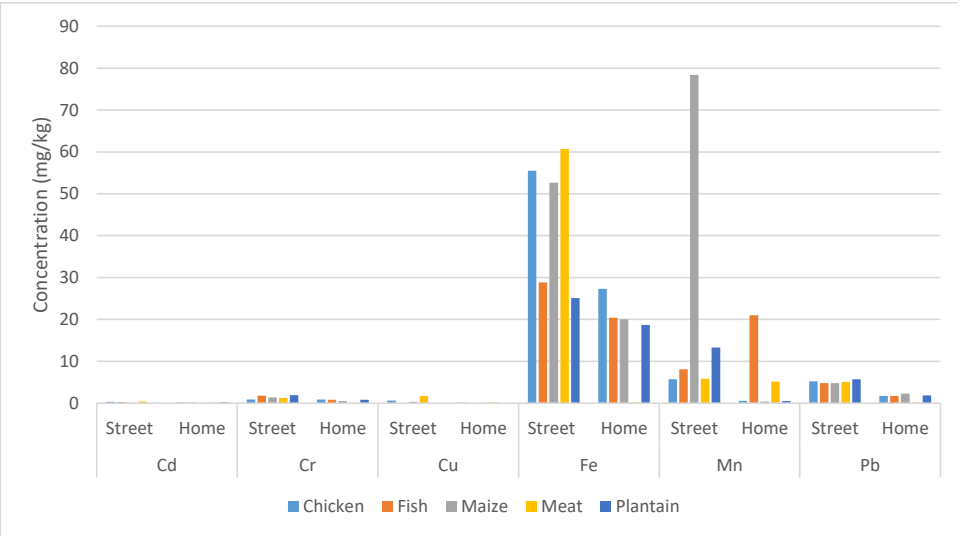

Figure 2: Comparative concentrations of heavy metals in street and homemade foods.

The range of Cr in street food was 0.86 to 1.89 mg/kg while it was 0.04 to 0.90 mg/kg in homemade foods. Chicken had the least Cr concentration in street-roasted food and the highest in homemade food while plantain had the highest Cr concentration in street food, but maize had the least Cr concentration in homemade. The cooking utensils such as wire gauze and oven trays can be a potential source of Cr in food (Dan and Ebong, 2013; Kamerud, Hobbie, and Anderson, 2013). While the maximum limit of Cr is set at 0.05 mg/kg (Massadeh, Al-Massaedh, and research, 2018), the concentrations of Cr in this study mostly exceeded this limit. However, allergic contact dermatitis (ACD) is sometimes as a result of oral exposure to chromium and a single oral dose of 2500 µg of Cr can cause dermatitis in sensitized individuals (Kamerud *et al*., 2013). Human exposure to 0.0021 to 0.0078 mg/kg/day of Cr led to increased excretion of low molecular weight protein. Also, 50% increase in blood or urinary cadmium levels resulted in a significant increase in the risk of stroke and congestive heart failure (Peters, Perlstein, Perry, McNeely, and Weuve, 2010). The dosage at which cadmium causes vomiting for an average body weight of 35 kg is 0.07 mg/kg.

The range of Cu in street food was 0.30 to 1.71 mg/kg while it was 0.02 to 0.20 mg/kg in homemade foods. The concentration of Cu was least in maize and highest in meat for both street and homemade food while Cu was not detected in fish and plantain in both street and homemade foods. Although copper is an essential element because of its principal role in reproduction, utilization of iron, glucose metabolism, and connective tissues (Nardi *et al*., 2009), its excess intake in the body can lead to adverse effects such as dermatitis, liver cirrhosis, and neurological disorders (Brewer *et al*., 2010; Storelli, Barone, Garofalo, and Marcotrigiano, 2007). Copper is widely available in food and can come from both plant and animal sources (Goyer and Clarkson, 2000)

The Fe concentration in the street-roasted food ranged between 25.1 to 60.7 mg/kg. The highest Fe concentration was found in meat and the lowest in plantain. For home-roasted food, the Fe concentration ranged between 0.18 to 27.3 mg/kg with the highest Fe concentration being in chicken and the lowest, in meat. Fe is an essential element required for normal growth in plants and for blood production in humans. For instance, Fe is an integral component of haemoglobin, myoglobin and other enzymes which aid in the transferring of oxygen in the blood of humans from the lungs to the tissues (Garba *et al*., 2021). The main source which Fe gets into humans is via the consumption of iron-rich food including vegetables, plantain, meat, chicken, fish and a small quantity of maize. Meanwhile, Fe accumulation can also be found in soil having close proximity to coal mining ores, or where mining activities are taking place. Vegetables planted on such soil, therefore, absorb this metal which eventually gets into the food chain. The accumulated Fe enters into humans via the consumption of the contaminated vegetables or meats of animals that ingested these contaminated vegetables. Irrespective of how important Fe is, its effects on humans when present in quantities above the threshold value are hazardous to human health. A typical example is the risk of fibrosis, cirrhosis, and hepatocellular carcinoma in humans when excess Fe accumulates in the liver and the risk of cardiomyopathy, heart failure, diabetes, and endocrine dysfunction when excess in tissues (Fisher and Babitt, 2022; Gujja, Rosing, Tripodi, and Shizukuda, 2010). In this study, the Fe concentrations in both street-roasted food and home-roasted food were all below the permissible limit of 425 mg/kg set by WHO (Akhtar *et al*., 2022).

The range of Mn concentration in street-roasted foods was 5.70 mg/kg (chicken) to 78.4 mg/kg (maize) while the range was 0.40 mg/kg (maize) to 21.0 mg/kg (Fisher and Babitt, 2022) in homemade foods.

Similar to Fe, Mn is also an essential element needed in the body for various chemical and biochemical processes including blood sugar regulation, carbohydrate metabolism as well as fat metabolism among others. Its presence in the body is needed for normal bone structure formation, connective tissue formation, blood clotting and functioning of the normal central nervous system (Tegegne, 2015). The main source of Mn to the human body is via the consumption of food (plants and animals) containing Mn. In addition, the consumption of plants and animals cultivated in the soil close to iron ores or mining activities can lead to the accumulation of Mn in the body. More so, the burning of coal adds Mn to the soil (Garba, Dandago, Igwe, and Salami, 2021; Sandeep, Vijayalatha, and Anitha, 2019). When present above the permissible limit by WHO/FAO in food which is 2-9 mg/kg (Nuapia, Chimuka, and Cukrowska, 2018), Mn can be detrimental to the body, leading to poor bone health and Parkinson's disease-related symptoms. In this study, the examined street-food and home-roasted food were both within the permissible limit recommended by WHO except in street-roasted maize (Tegegne, 2015)

The range of Pb concentration in street-roasted foods was 4.80 mg/kg (fish and maize) to 5.70 mg/kg (plantain) while it was 0.16 mg/kg(meat) to 1.85 mg/kg (plantain) in home-roasted foods.

Pb has a damaging effect on renal, hematopoietic, and reproductive functions as well as on the central nervous system (Assi, Hezmee, Sabri, and Rajion, 2016; Collin *et al*., 2022), hence its poisoning is of particular importance, especially in developing countries. Although the recommended permissible limit of Pb in food is 0.01 mg/kg, the Pb concentration in both street and home-roasted foods exceeded this limit. However, the concentration of Pb was lower in homemade foods than in street-roasted food. Hence, constant exposure to street-roasted food may pose health hazards to humans.

Iweala *et al*. (2014) studied the concentrations of Pb, Cd, Ni, Hg, Cu, Mn and Zn in some street foods which included fried yam, fried bean cake, roasted plantain, roasted meat, roasted fish, cassava flour, yam flour, gari, beans and herbal drink. The results showed that Pb was present only in roasted meat (0.02 ± 0.02 mg/kg), gari (0.04 ± 0.06 mg/kg) and roasted plantain 0.004 ± 0.010 mg/kg) while the range of Cu, Cd and Mn were 0.02 ± 0.19mg/kg to 3.55 ± 0.20 mg/kg, 0.02 ± 0.01 mg/kg to 0.59 ± 0.17 mg/kg, and 0.06 ± 0.05 mg/kg to 0.25 ± 0.19 mg/kg respectively (Iweala, Olugbuyiro, Durodola, Fubara-Manuel, and Okoli, 2014).

However, the concentrations in this study were higher than the concentrations reported for fresh or unprocessed foods (Orisakwe, Nduka, Amadi, Dike, and Bede, 2012; Ysart *et al*., 2000) as well as those reported by Iweala *et al*. (2014) in street foods. Although roasting can increase the concentration of heavy metals in foods (Bamuwamye *et al*., 2015), poor food hygiene can also be a means of heavy metal contamination in food. Food handlers in Ijebu-Ode, where this study was carried out, had little or no knowledge of food born infections and food safety practices (Adebukola, Opeyemi, and Ayodeji, 2015). Hence this may contribute to the increase in heavy metal concentrations in street foods. Thus, homemade foods should be encouraged while street food purchases should be discouraged especially because of the poor hygiene (Alimi, 2016; Cortese, Veiros, Feldman, and Cavalli, 2016) in the process of food preparation through which the food may eventually be contaminated.

HEALTH RISK ASSESSMENT OF HEAVY METALS IN ROASTED FOODS TO ADULTS AND CHILDREN

When the THQ value is less than 1, this signifies that the exposed population is unlikely to experience any adverse health hazard. Conversely, if the THQ is equal to or higher than 1, it implies a potential health risk thus requiring related interventions and protective measures. However, none of the heavy metals had THQ equal to or above 1 as obtained from the results and presented in table 2 (Figure 3) and 3 (Figure 4). Among the heavy metals studied, Pb is likely to pose the highest risk to both adults and children. Meanwhile, the risks of heavy metals to children were higher than to adults, this is because children have low body weight. It had been reported that exposure to two or more pollutants may result in additive and/or interactive effects (Ullah, Maksud, Khan, Lutfa, and Quraishi, 2017).

Table 2: Health Risk assessment of heavy metals in the food samples when consumed by Adults

	Cd		Cr		Cu		Fe		Mn		Pb	
	Street-made	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*
Chicken	0.000621	0.000321	1.23E-06	1.29E-06	4.29E-06	7.86E-07	0.00017	8.36E-05	8.72E-07	8.72E-08	0.002786	0.000911
Fish	0.000514	0.000343	2.51E-06	1.16E-06	-	-	8.82E-05	6.24E-05	1.24E-06	3.21E-06	0.002571	0.000911
Maize	0.000193	8.57E-05	1.9E-06	7.14E-07	2.14E-06	1.43E-07	0.000161	6.12E-05	0.000012	6.12E-08	0.002571	0.001232
Meat	0.000771	0.000279	1.76E-06	5.71E-08	1.22E-05	1.43E-06	0.000186	5.51E-07	8.88E-07	7.87E-07	0.002732	8.57E-05
Plantain	0.00015	0.000386	2.7E-06	1.17E-06	-	-	7.68E-05	5.72E-05	2.04E-06	7.65E-08	0.003054	0.000991

Table 3: Health Risk assessment of heavy metals in the food samples when consumed by Children

	Cd		Cr		Cu		Fe		Mn		Pb	
	Street-made	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*	*Street-made*	*Home-made*
Chicken	0.001933	0.001	3.82E-06	0.000004	1.33E-05	2.44E-06	0.000529	2.71E-06	2.71E-07	0.008667	0.008667	0.002833
Fish	0.0016	0.001067	7.82E-06	3.6E-06	-	-	0.000274	00.000194	3.86E-06	0.00001	0.008	0.002833
Maize	0.0006	0.000267	5.91E-06	2.22E-06	6.67E-06	4.44E-07	0.000501	0.00019	3.73E-05	1.9E-07	0.008	0.003833
Meat	0.0024	0.000867	5.47E-06	1.78E-07	0.000038	4.44E-06	0.000578	1.71E-06	2.76E-06	2.45E-06	0.0085	0.000267
Plantain	0.000467	0.0012	8.4E-06	3.64E-06	-	-	0.000239	0.000178	6.33E-06	2.38E-07	0.0095	0.003083

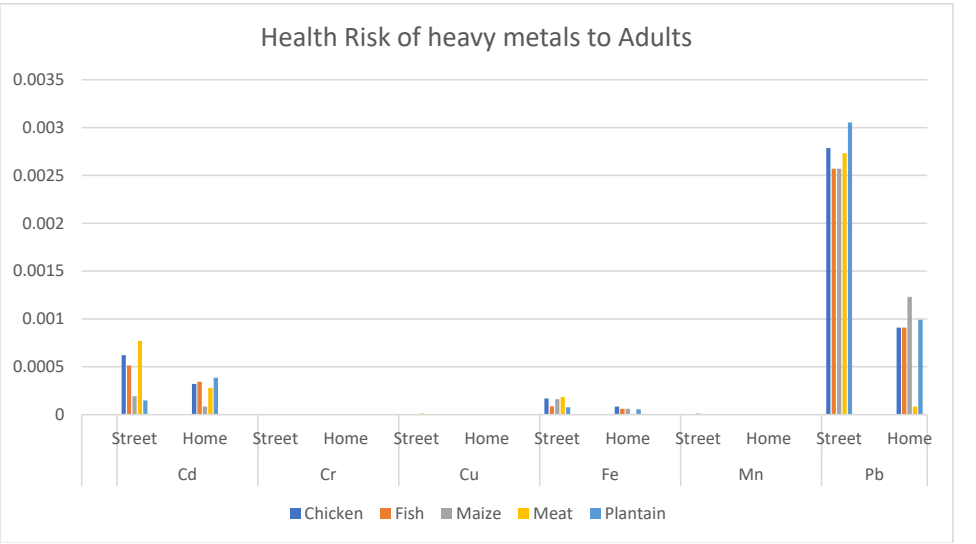

Figure 3: Health risk assessment of heavy metals in the street and homemade foods to Adults.

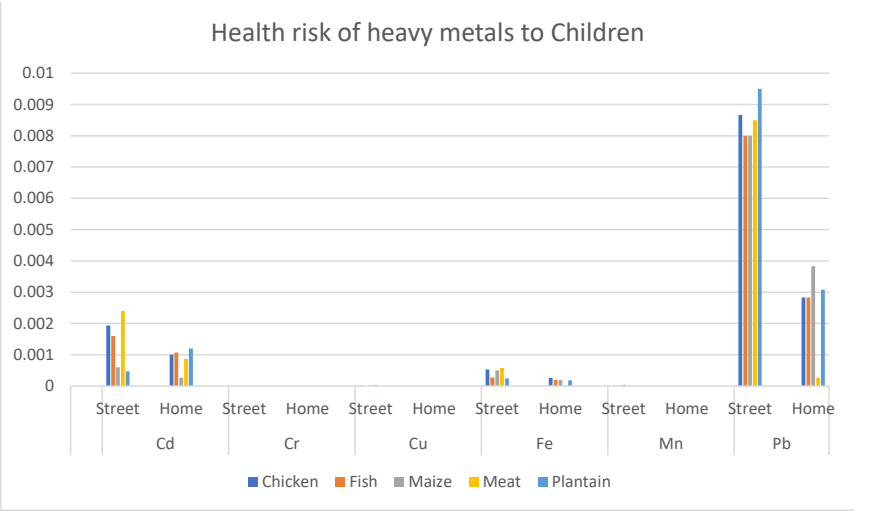

Figure 4: Health risk assessment of heavy metals in the street and homemade foods to children.

CONCLUSION

Street food buying should be discouraged as a result of several findings which indicated that street food could pose a severe threat to human health (Alimi, 2016; Ekhator *et al*., 2017). Generally, the concentrations of heavy metals in all the food sampled were higher in street-roasted food than in homemade. Also, the reason for the consumption of street food to pose a higher risk to children than adults may be because of the low body weight of children relative to that of adults. However, the concentrations of heavy metals in the street foods in this study may not pose hazards to human health because the threshold hazard quotients were below one.

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