Scientific African 7 (2020) e00289

Contents lists available at ScienceDirect

Scientific African

journal homepage: www.elsevier.com/locate/sciaf

Health risks of toxic metals (Al, Fe and Pb) in two common street vended foods, *fufu* and fried-rice, in Kumasi, Ghana

Gloria Mathanda Ankar-Brewoo[a,b,*], Godfred Darko[c], Robert Clement Abaidoo[d], Anders Dalsgaard[b,e], Paa-Nii Johnson[f], William Otoo Ellis[a], Leon Brimer[b]

[a] *Department of Food Science and Technology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[b] *Department of Veterinary and Animal Sciences, Faculty of Health and Medical Sciences, University of Copenhagen, Denmark*
[c] *Department of Chemistry, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[d] *Department of Theoretical and Applied Biology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana*
[e] *School of Chemical and Biomedical Engineering, Nanyang Technological University, Singapore*
[f] *Department of Agro-processing Technology and Food Biosciences, CSIR-College of Science and Technology, Accra, Ghana*

A R T I C L E I N F O

Article history:
Received 31 October 2019
Revised 29 November 2019
Accepted 22 January 2020

Editor: Dr. B. Gyampoh

Keywords:
Food contamination
Metal toxicity
Toxicology
Human health risk

A B S T R A C T

The preparation practices, handling and raw materials for street food vending could be sources of toxic metals in street food vending business which is yet to be explored in-depth as microbial contamination. The concentrations and dietary risk of the toxic metals Al, Fe, and Pb were assessed in *fufu* and fried-rice, two commonly consumed street-vended foods in Ghana. The mean concentrations for Pb found to be between 3.30 and 11.25 mg kg^{-1} in the cooked foods, far exceeded the maximum tolerable daily intake of 0.3 mg kg^{-1} body weight per day for consumers. Al and Fe concentrations were between 3.04 and 18.49 mg kg^{-1} and 1.44 and 7.82 mg kg^{-1}, respectively. Hazard index was less than 1 at the 5th percentile level of consumption, but greater than 1 at the 50th and 95th percentile level of consumption; indicating risk of metal toxicity with increasing probability as the level of consumption and HI increase. The patronage of street vended foods is unlikely to reduce. Hence vendors must be educated on safe preparation and handling processes such as the use of stainless steel utensils will likely reduce the levels of the toxic metals to acceptable levels.

Introduction

Street-vended foods are very popular in Ghana, as in most developing countries. The dishes on a typical street-food vendor's menu vary widely from breakfast to supper meals and are usually cheaper than those on the same menu items of a standard restaurant. Consumption of street-vended foods is increasing and are patronized by most people including

* Corresponding author at: Department of Food Science and Technology, College of Science, Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.
E-mail addresses: gankar-brewoo.sci@knust.edu.gh (G.M. Ankar-Brewoo), gdarko.sci@knust.edu.gh (G. Darko), abaidoorc@yahoo.com (R.C. Abaidoo), adal@sund.ku.dk (A. Dalsgaard), paanii.johnson@gmail.com (P.-N. Johnson), elliswo@yahoo.com (W.O. Ellis), lbr@sund.ku.dk (L. Brimer).

https://doi.org/10.1016/j.sciaf.2020.e00289

babies [2,27], school going children [11] to the elderly and tourists in the urban cities of Ghana. Apart from providing cheap sources of foods, street-vended food businesses are sources of employment and livelihood for many people. Therefore, the street-vended food businesses may also contribute significantly to the economy of the country.

While street-vended foods are important for food security and livelihoods, they present higher health risks to consumers compared to foods prepared in households [37,37], mainly as a result of poor hygiene practices used during the food preparations, Unhygienic practices undertaken during the preparation and storage of the street food [28,32,37,37] coupled with higher environmental temperature encourage microbial growth in them [10,17,21,24,28]. It has been suggested that the use of improper cookware, utensils and food containers may release undesirable chemicals such as metals into the food. Other food handling practices likely to introduce chemical hazards include source of raw food ingredients, exposure to environmental pollutants such as exhaust fumes from cars, dust particles from the environment and equipment used in food preparation. In spite of all, limited information is available about hazardous chemical contaminants such as levels of toxic metals in the vended meals. Thus, the possibility of these heavy metals getting into the food chain is high [12]. The processing and cleaning activities used by vendors at food contact areas together with the poor storage and transport conditions could all contribute to the overall burden of contamination in street foods.

Metals in foods are of dual importance as they are essential nutritional elements but they can also be toxic when present at elevated concentrations (National Research Council [29, Committee, 1990]. A variety of the metals such as copper, iron, manganese, zinc, calcium, magnesium, potassium, and sodium are essential elements. For instance, K and Fe are essential for the synthesis of metalloproteins. However, excess intake of these trace elements are implicated in pathological events such as the deposition of iron oxides in Parkinson's disease [30]. In addition to aiding the neurological depositions, these redox-active metals enhance premature aging [30] and cause oxidative damage, a key component of chronic inflammatory disease and an initiator of cancer [30,43]. Heavy metals such as lead cause renal failure, liver damage, impaired hearing, mental retardation, and shortened gestation in humans [22]. Knowledge about the concentration of metals in foods is essential for calculating the dietary intake and evaluate human exposure to toxic metal concentrations [22].

The objective of this study was to assess the concentrations and associated health risks of the toxic metals (Al, Fe and Pb) in *fufu* and fried-rice, the two most commonly consumed street-vended foods in Ghana. Sources of the identified toxic metals are discussed and measures for their prevention and control are proposed.

Materials and methods

Study area description

The study was carried out in Kumasi, the second largest city in Ghana. Kumasi has a fast growing population of more than two million inhabitants [18]. Geographically, Kumasi is sited between latitude 6.35°–6.40° and longitude 1.30°–1.37°. A purposive study design was used in selecting study area and vendors [33]. The study was conducted in three of 10 sub-metropolitan areas, i.e. Oforikrom, Asawase and Subin, within the Kumasi metropolis, where street food vending activities are very popular. In each of the three areas, two locations with high numbers of street food vendors selling so-called "*fufu*" and fried rice dishes were selected. A total of 18 *fufu* and 18 fried rice vendors who had been in operation for at least three years and had orally consented to the study were recruited into the study.

Fufu, fried rice and sample collection

Fried rice and *fufu* meals are two commonly consumed street-vended foods in Ghana and were therefore selected for this study. *Fufu* is a major staple food, prepared usually from cooked cassava (*Manihot esculenta*) and plantain (*Musa paradisiaca*) pounded together into a thick dough-like consistency and served with different, but often tomato-based soups with meat or fish. Fried rice is prepared from cooked rice stir-fried with vegetables, which is served with chicken or fish and salad. Control food samples which were the uncooked food samples used to prepare the two dishes, were also collected from the vendors and analyzed.

Sampling of the foods was done from May to August 2014. Meals were bought from the vendors and separated into the various components at the point of sale by the vendors. A total of 156 components of the two meals bought from 18 *fufu* and 18 fried rice vendors. The food samples were immediately transported to the laboratory and stored at −20 °C freezer (HTF-519GB, Lagos, Nigeria) (prior to analysis).

Consumption studies

A guided interview questionnaire was administered to 188 regular consumers of the vended meals. The questionnaire covered topics on consumption information such as ingestion rates, exposure duration and exposure frequency to the street-vended foods. Exposure frequency and duration (Table 4) describes how long and how often exposure occurs and it varies among individuals and must often be estimated [16]. This information was needed to assess health risks associated with consumption of the street-vended foods. The regular consumers were used because the most severe possible outcome that can reasonably be projected to occur in the given situation (worst-case scenario) was desired.

Metal analysis

A 10 mL portion of freshly prepared aqua regia (HNO_3: HCl, 1:3) was added to 1 g of the food sample in appropriately labeled digestion tubes and digested on a heating mantle (Tecator, ITAL 7821, Sweden) at 110 °C for approximately 2 h. The digested samples were filtered upon cooling and made to the mark (50 mL) using deionized water [25,41].

Iron and lead measurements

Iron and lead concentrations were determined using flame atomic absorption spectrophotometric methods [1,14]. The basic setup (air pressure = 50–60 psi, acetylene pressure = 10–15 psi) of the atomic absorption spectrophotometer (Buck Scientific, USA, model: 210 VGP) was ensured. The file for the type of analysis and hollow cathode lamps were selected with appropriate wavelengths as follows: Fe at 248.3 nm, and Pb at 283.3 nm, slit for both elements was set at 0.7 nm. A calibration curve was plotted using the concentration and absorbance data for a set of standards for each of the elements to be analyzed from the stock standards (Buck Scientific, USA). The limits of detection, based on 3 signal-to-noise ratio, for Fe and Pb were 0.03 mg/kg and 0.10 mg/kg, respectively.

Aluminum determination

Calibration standards were made in concentrations of 50, 100 and 150 µg/L by auto-calibration from a stock solution of 200 µg/L under the following graphite furnace atomic absorption spectrophotometry (GFAAS) conditions: 15 µL loads of standards and samples injected at 309.3 nm wavelengths, D2 background correction, peak height, argon purge (~50 mL/min), auto-zero off, in the grooved furnace tube. The analysing conditions were as follows: drying: 25 °C to 120 °C in 10 s ramp, 5 s hold; ashing: 120 °C to 1000 °C in 45 s ramp, 20 s hold and atomizing: 1000 °C to 2500 °C in fast ramp or step, 2 s hold [7].

Data handling and analysis

Two-way analysis of variance using Graphpad Prism version 6, (USA), was performed at 95% confidence interval to determine if there were significant differences between the contaminants in the food samples from the different areas and among the vendors. Mean concentrations of Fe, Pb and Al in each of the components of the food together with their standard error of mean were determined. The concentrations of the metals and data from the interviews were made to fit a distribution using the @risk software version 6 (Palisade Inc, USA), with the best akaike information criterion (used as a guide in model selection) [36,42] and iterated over 10,000 simulations using the first Monte Carlo order. These were used as input data for the health risk assessment. Results were presented in the 5th, 50th and 95th percentile ranges, this statistic is so useful because they are benchmark points giving an accurate picture of the reported risk assessment. The 50th percentile for a normal distribution represents the median, and mean [19].

Health risk assessment

The chronic daily intake (CDI) of the metals over the period consumed was first determined using Eq. (1) as;

$$\mathrm{CDI} = \frac{Cs \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

Where, CDI is the chronic daily intake, the intake amount per kilogram of body weight per day, mg kg^{-1} day^{-1}. Cs represents the concentration of the metal (mg kg^{-1}, wet weight basis); IR (kg day^{-1}) is the ingestion rate of the metals; EF is the stochastic distribution of the exposure frequency (days yr^{-1}); ED is the exposure duration (yr) representing the stochastic distribution of the total number of years the consumers have been exposed to the hazard; BW represents the body weight of the consumer, where an assumed average body weight of 70 kg for adult consumers was used; and AT is the specific period (days) of exposure, for non-carcinogenic effects (30 yr) [38].

The non-cancer health risk assessment was expressed in terms of hazard quotient (HQ) for a single substance (Eq. (2)), or as hazard index (HI) for multiple substances (Eq. (3)), [38]. The HI was calculated for the individual metals in each of the meals, where an HI above 1 means that there was a chance of adverse non-cancer effects of the hazards, with an increasing probability as the value increases [1].

$$HQ = \frac{CDI}{\mathrm{RfD}} \quad (2)$$

$$\mathrm{HI} = \mathrm{HQ}\,(n = 1) + \mathrm{HQ}\,(n = 2) + \cdots + \mathrm{HQ}\,(\mathrm{n}) \quad (3)$$

The oral reference doses (R_fD) for iron and lead are 0.7 and 0.14 mg kg^{-1} day^{-1}, respectively [1]. Aluminum has no R_fD value, therefore the provisional tolerable weekly intake of 1 mg kg^{-1} day^{-1} established by the World Health Organization [45] was used.

Table 1
Mean concentrations (±SEM) of Fe, Pb and Al in different food ingredients used to prepare *fufu* and fried rice.

Food sample	Metro area	Fe (mg kg^{-1})	Pb (mg kg^{-1})	Al (mg kg^{-1})
Rice	Oforikrom	2.33 ± 0.19^{a}	3.30 ± 0.42^{a}	11.34 ± 7.53^{a}
	Subin	4.53 ± 0.55^{b}	4.40 ± 0.54^{ac}	7.87 ± 3.52^{a}
	Asawase	2.62 ± 0.44^{a}	9.32 ± 1.56^{bc}	6.04 ± 0.85^{a}
Vegetables	Oforikrom	2.25 ± 0.34^{a}	4.23 ± 0.36^{a}	3.04 ± 1.25^{a}
	Subin	2.47 ± 0.21^{a}	6.23 ± 0.81^{a}	6.12 ± 3.34^{a}
	Asawase	1.83 ± 0.25^{a}	5.89 ± 0.79^{a}	4.33 ± 1.53^{a}
Chicken	Oforikrom	3.08 ± 0.24^{a}	4.91 ± 0.58^{a}	3.35 ± 0.61^{a}
	Subin	2.94 ± 0.18^{a}	4.20 ± 0.44^{a}	3.31 ± 0.67^{a}
	Asawase	3.22 ± 0.49^{a}	9.22 ± 1.08^{b}	5.05 ± 2.22^{a}
Hot pepper sauce	Oforikrom	6.74 ± 1.27^{a}	11.25 ± 1.81^{a}	5.27 ± 0.91^{a}
	Subin	7.82 ± 0.47^{a}	7.43 ± 1.44^{a}	18.49 ± 9.63^{a}
	Asawase	7.73 ± 0.55^{a}	8.99 ± 1.10^{a}	12.21 ± 6.66^{a}
Ketchup	Oforikrom	1.44 ± 0.10^{a}	7.15 ± 1.52^{a}	10.96 ± 0.51^{a}
	Subin	2.57 ± 0.55^{a}	6.14 ± 0.79^{a}	13.47 ± 0.95^{a}
	Asawase	2.33 ± 0.49^{a}	4.14 ± 0.35^{a}	13.29 ± 3.23^{a}
Mayonnaise	Oforikrom	2.42 ± 0.24^{a}	8.46 ± 1.68^{a}	8.59 ± 1.27^{a}
	Subin	1.82 ± 0.50^{a}	6.47 ± 0.92^{a}	9.23 ± 1.42^{a}
	Asawase	1.82 ± 0.15^{a}	6.31 ± 1.10^{a}	8.54 ± 1.34^{ab}
Macaroni	Oforikrom	2.06 ± 0.46^{a}	4.30 ± 0.44^{a}	9.15 ± 6.68^{a}
	Subin	3.95 ± 0.10^{a}	6.58 ± 1.39^{a}	6.15 ± 0.87^{a}
	Asawase	3.57 ± 0.56^{a}	8.23 ± 2.20^{a}	3.24 ± 1.33^{a}
Fufu	Oforikrom	2.23 ± 0.33^{a}	6.02 ± 0.87^{a}	35.05 ± 28.65^{a}
	Subin	2.27 ± 0.37^{a}	3.35 ± 0.59^{ab}	24.69 ± 6.55^{a}
	Asawase	3.05 ± 0.43^{a}	7.53 ± 0.78^{ac}	21.90 ± 18.10^{a}
Soup	Oforikrom	4.27 ± 0.25^{a}	7.80 ± 1.11^{a}	13.72 ± 8.49^{a}
	Subin	3.60 ± 0.30^{a}	4.63 ± 0.60^{a}	4.58 ± 1.43^{a}
	Asawase	2.24 ± 0.32^{b}	6.61 ± 1.09^{a}	17.62 ± 12.77^{a}
Control	Rice	0.65	6.80	–
	Vegetable	1.20	5.65	5.12
	Chicken	1.50	5.45	3.2
	Fish	9.65	6.50	–
	Ketchup	0.40	5.90	32.83
	Mayonnaise	0.80	6.45	20.05
	Macaroni	1.70	7.95	3.59
	Fufu	0.80	7.10	3.90
	Soup	1.15	7.65	4.68
	Fish	9.65	6.50	11.53
	Salt	2.00	9.70	4.79

(Means followed by the letters within a column are not significantly different at the confidence level 95%) Same letters in the superscript in a column indicate non-significance at 95% Confidence Interval.

Sensitivity analysis

Sensitivity analysis was performed on the hazard index value of the metals by ranking the correlation coefficients of the output mean between each input variable and the output (risk). The sensitivity of each variable relative to one another was assessed by calculating rank correlation coefficients between each input and output during simulations and then estimating each input's contribution to the output variance by squaring the output variance and normalizing to 100% [38].

Results and discussion

Relatively high concentrations of the metals were recorded in all the food samples (Table 1). Al was found at higher concentrations in the food samples than Fe and Pb. Significant differences ($p < 0.05$) were seen in the concentrations of Fe and Pb in rice samples from the three metropolitan areas. Rice, chicken, hot pepper sauce and macaroni were cooked in locally manufactured cooking pots and had higher concentrations of metals than their corresponding control samples. Pb concentrations in all food samples were higher than 0.3 mg kg^{-1} food safety limit specified by FAO/WHO Joint Expert Committee on Food Additives (JECFA) [45].

Fried rice and chicken

Concentrations of Al in the fried rice and chicken ranged from 3.04 to 11.34 mg kg^{-1} (Table 1). The concentration of Al in the fried rice (6.04–11.34 mg kg^{-1}) was lower compared with a mean value of 18 mg kg^{-1} reported in a similar study from Cote D'Ivoire [13]. Meanwhile Ekhator et al. reported Al concentrations of 0.004 mg kg^{-1}, 0.007 mg kg^{-1} and 0.012 mg kg^{-1} for street vended plain rice, jollof rice and fried chicken, respectively [15]. The preparation procedure for these foods in Nigeria is not known. These reported values are way lower than those observed for the fried rice samples in this study. The chicken samples had Al concentrations ranging from 3.31 mg kg^{-1} to 5.05 mg kg^{-1} which were higher than the concentration (3 mg/kg) found in the uncooked control chicken sample. This implies that Al in the locally manufactured cooking pots may have leached into the food [44]. However, the varying Al concentrations observed in the rice and chicken samples could also be as a result of the varying cooking and frying times of the rice and chicken, as well as varying sources food samples [20,35,44]. The cooking times ranged from one to two hours depending on the variety and quantity of the rice, whilst the frying times were between 30 min and 1 h 30 min, again depending on the frying technique used and quantity of chicken, and intensity of heat being delivered. The time of exposure can influence the rate of leaching of metals from the cookware into the food materials [35]. The source of water used for all cooking purposes by the street food vendors was the municipal water which is treated with Al salts and thus could contribute to the observed concentrations. Generally, there were no statistical differences ($p > 0.05$) among the different Al concentrations in rice and chicken samples from the three metropolitan areas used for this study.

Concentrations of Pb in the fried rice and chicken samples ranged from 0.9 mg kg^{-1} to 18 mg kg^{-1}. Lower values of Pb being 0.31 and 1.033 mg kg^{-1} for jollof and plain rice, then 0.26 mg kg^{-1} for fried chicken, was also reported in a close study [15]. The raw, uncooked chicken samples had a mean Pb concentration of 5 mg kg^{-1} which was not significantly different ($p > 0.05$) from those of the cooked and fried chicken samples. In Uganda very low values of 0.006 and 1.271 mg kg^{-1} for Pb was reported for fresh and roasted chicken, respectively [6]. Similar results of 0.015 mg kg^{-1} and 0.016 mg kg^{-1} were recorded for fried chicken and boiled rice in Catalonia, Spain [35]. The rice grain used had a Pb concentration of 6.8 mg kg^{-1} and that of the cooked rice ranged between 3.30 and 9.32 mg kg^{-1} (Table 1). This finding was similar to a study by Dabonne et al. [13], where cooked rice samples had higher concentrations of Pb than their corresponding uncooked ones, indicating that the utensils used could have contributed to the in difference in concentrations. A related study, [5], reported 0.0027–0.1106 mg/kg of Pb in commercially available rice in Ghana. These concentrations are far lower than the concentrations observed in our study. Surprisingly although Asawase rice had higher Pb concentration than control, the rice from Subin and Oforikrom had lower Pb concentration than the control (Table 1). The differences could lie in the geographic origins (Vietnam, Taiwan, Thailand etc.) of cultivation for the commercially available rice varieties or cultivars (Thai, jasmine, basmati etc.) [4,20]. All the fried rice and chicken samples had mean Pb concentrations higher than the 0.3 mg kg^{-1} food safety limit set by FAO/WHO, [45].

Concentrations of Fe in the fried rice and chicken samples ranged from 1 to 7 mg kg^{-1} and 75% of the sample had concentrations below the tolerable daily take of 5 mg kg^{-1} [45]. Statistically, significant differences ($p < 0.05$) existed between rice samples from the three sub- metropolitan areas. The chicken stock and spices used could contribute to the iron concentration in the meal [8]. Most street food vendors in Ghana use commercial attrition mills for milling the spices and the other ingredients used in the meal. The surfaces of the working plates of the attrition mills easily wear away over long usage, releasing the metals into the ingredients [39].

The Fe concentrations in the control rice (0.65 mg kg^{-1}) and chicken (1.5 mg kg^{-1}) samples were relatively lower than in the cooked rice and chicken samples which ranged from 1 to 7 mg kg^{-1}. This indicates the possibility of leaching of the Fe from the locally made utensils, or from the water used for cooking [13]. Statistically, no significant differences ($p > 0.05$) existed among the different fried chicken samples.

Salads

The salad component of the fried rice is not cooked, and had mean concentrations of 5.12 mg kg^{-1} Al, 5.65 mg kg^{-1} Pb and 1.20 mg kg^{-1} Fe (Table 1). Several studies have established the use of low quality water during the cultivation of vegetables in the peri–urban areas of Ghana [23,26]. Sanda and Dibal, observed high level of chemical contaminants in some low quality water for irrigation [40]. Different concentrations of metals in the salad samples could be attributed to the different locations where the vegetables were grown [31]. According to the research, cultivating vegetables in the different locations, in Kumasi, had effect on concentration of metals. Pb concentration was higher in value in the range of 2.42–3.50 mg kg^{-1} (Table 1) than the WHO/FAO recommended guideline value of 0.30 mg kg^{-1}.

Ketchup and mayonnaise

Concentrations of Al in the ketchup and mayonnaise samples ranged between 8.54 mg kg^{-1} and 13.47 mg kg^{-1}. These values were lower compared to the concentrations of Al in the control mayonnaise (20 mg kg^{-1}) and ketchup (32 mg kg^{-1}) samples. Mayonnaise and ketchup are commercial products which are not prepared by the vendors however, some vendors mix the products with water to enable them dispense the product easily and also to increase the volume of the product to maximize the number of persons to be served [32]. It is not clear whether the dilution of these products with water may increase the concentrations of the metals.

Hot pepper sauce and macaroni

The concentrations of the metals in the hot pepper sauce and macaroni samples differed among all vendors. The mean concentrations in the metals ranged from 1.82 to 2.84 mg kg^{-1} for Fe, 4.30 – 11.25 mg kg^{-1} for Pb and 5.27 – 18.49 mg kg^{-1} for Al. Lower values for Pb (0.24 mg kg^{-1}) and 0.013 mg kg^{-1} for Al were reported for Spaghetti (macaroni) samples in

Table 2
Hazard index due to metal in Fried rice and *Fufu* meals.

Fried rice	Min	Max	Mean	Percentiles		
				5th	50th	95th
Fe	−0.01	13.59	0.56	0.01	0.27	2.08
Pb	−0.11	241.64	5.11	0.10	2.30	19.07
Al	−0.03	625.81	1.06	0.02	0.36	3.46
Fufu	Min	Max	Mean	5th	50th	95th
Fe	−0.79	61.06	1.27	0.01	0.39	5.06
Pb	−30.46	797.22	12.65	0.09	3.82	50.20
Al	−22.19	144335.11	100.33	0.02	0.90	42.05

Nigeria [15]. The concentrations of Pb far exceeded the WHO/FAO limit of 0.03 mg kg^{-1}, rendering the products unsafe for consumption. The concentrations of Fe in the hot pepper sauce samples (9.65 mg kg^{-1}), could be due to the use of the dried fish powder whilst the concentration of Fe in dried spices (anise, rosemary, curry, ginger and dried pepper powder) ranged between 83.36 and 480.82 mg kg^{-1} [14]. The cooking pot used to prepare the hot pepper sauce had evidence of pitting indicating possible leaching of the utensils into the hot pepper sauce [44]. The concentrations of Fe in the dried fish powder could be due to the milling of the smoked dry fish, in a commercial mill (disk attrition) [34]. In the commercial mills, metal flaking and continuous wear and tear of machine parts could have contributed to the high metal concentrations in the fish powder used to prepare the hot pepper sauce [39]. No statistically significant difference ($p > 0.05$) existed between all the 'hot pepper sauce' samples from the different metropolitan areas.

Fufu

Mean concentration of Al in the *fufu* and soup samples (>10 mg kg^{-1}) were relatively higher than the mean concentration of Fe and Pb (<10 mg.kg^{-1}) in these same samples (Table 1). These values were correspondingly higher than those of the control samples in each case. This phenomenon could also be attributed to possible leaching of metals from the locally manufactured cooking ware. Also, some vendors milled the *fufu* initially using an aluminum milling machine before pounding to obtain the right consistency, [13,44]. In addition, the use of metal scouring sponge in cleaning the pots could enhance the leaching of the metals into the food samples during cooking. There were no significant differences ($p > 0.05$) in the mean concentration of the metals in *fufu* and soup samples from the different metropolitan areas (Table 1).

Risk analysis

From the questionnaire survey, distributions of the input variables, ingestion rate, exposure duration and consumption frequency, needed to complete the risk estimate of the consumption of these toxic metals were determined (Table 4). Ingestion rate represents the quantities (kg day^{-1}) of the components of the meals consumed by an individual in a day. Of the two meal types, the carbohydrate components of the meals which are the rice component for the fried rice meal and *fufu* component for the *fufu* meal, showed the highest ingestion rate. In regards to the modal quantities ingested, macaroni, mayonnaise and hot pepper sauce had the lowest ingestion rate of 0.01 kg day^{-1}. These components are used as toppings on the meal hence the very low modal ingestion rates.

Stochastic distributions of the exposure duration (years), exposure frequency (days/year) and consumption frequency (per day) of the meal types are all displayed (Table 4). The 5th percentile value represents a section (5%) of the population whose consumption are up to the stated weights at the 5th percentile column. The 5th percentile limit of consumption for the fried rice consumers used for the study is 0.28 kg day^{-1} whilst that for the 95th percentile is 0.57 kg day^{-1}.

Hazard index

The hazard index represents non-cancer risks for single substance (metal), or multiple of metals in the same exposure pathway. The hazard index due to the different metals in the street vended meals at the 5th, 50th and 95th percentile levels of consumption in the population used in the study are shown in Table 2.

At the 5th percentile level of consumption, consumers in this study had very low hazard index ($\leq$0.1) for all the meals as previously reported [38]. This figure indicates that consumers at this level of consumption of the meals may not suffer from the adverse non-cancer effects of the metals in the street vended meals. At the 50th percentile level of consumption, the corresponding population could be suffering the non-cancer effects due to Pb in the meals, since their hazard index was greater than 1. The consumers would not suffer the non-cancer effects of Fe and Al, since the hazard index is less than 1. This finding was similar to studies conducted on street vended food in Nigeria and Ghana, where the HQ of the foods was <1 for all the toxic metals analysed for [9,15]. This indicates low concern for such consumers (5th and 50th percentile consumers) However, at the 95th percentile level of consumption, the corresponding consumers would likely suffer the non-cancer effects of all the metals in the street vended meals as the HI becomes greater than 1, with an increasing probability as the number increases.

Table 3
Sensitivity analysis on the impact of input factors on the hazard index.

Fufu meal			Rice meal		
IF	Metal	CC	I F	Metal	CC
ED	–	0.76	ED	–	0.78
EF	–	0.45	EF	–	0.52
Fufu	Al	0.19	Rice	Pb	0.17
Soup	Pb	011	Rice(IR)	–	0.09
Fufu	Pb	011	Rice	Al	0.04
IR(Soup)	–	0.07	Chicken	Pb	0.04
IR (Fufu)	–	0.06	Chicken(IR)	–	0.03
Soup	Al	0.05			

IF – input factor; CC – Spearman's rank correlation coefficient; ED – exposure Duration; EF – exposure frequency; IR – ingestion rate.

Table 4
Probabilistic distribution for ingestion and exposure duration (input factors) of the commonly eaten foods.

Food samples	Parameters	Distribution model	Data ranges				Percentile values		
			Min	Max	Mean	Mode	5th	50th	95th
Fufu	Ingestion rate (kg/day)	Loglogistic(−0,039534;0,45583;5,3792)	0.01	28.23	0.44	0.39	0.27	0.43	0.58
Soup	Ingestion rate (kg/day)	Logistic(0,372538;0,050994)	0.00	0.95	0.37	0.37	0.17	0.37	0.52
Fried Rice	Ingestion rate (kg/day)	Weibull(1,7367;0,17127;Shift(0,25874)	0.26	0.99	0.41	0.36	0.28	0.41	0.57
Salad	Ingestion rate (kg/day)	Uniform(−0,00097183;0,069972)	0.00	0.07	0.03	0.05	0.03	0.05	0.07
Chicken	Ingestion rate (kg/day)	Weibull(1,2182;0,039238;Shift(0,047147)	0.05	0.30	0.08	0.06	0.05	0.08	0.13
Hot pepper sauce	Ingestion rate (kg/day)	ExtvalueMin(0,027724;0,004255)	0.00	0.04	0.03	0.03	0.02	0.03	0.04
Ketchup	Ingestion rate (kg/day)	Triang(0,007;0,007;0,044151)	0.01	0.04	0.02	0.01	0.01	0.2	0.04
Mayonnaise	Ingestion rate (kg/day)	Triang(0,01;0,01;0,048084)	0.01	0.05	0.02	0.01	0.01	0.03	0.04
Macaroni	Ingestion rate/ (kg/day)	Expon(0,014389;Shift(−0,00019985)	0.00	0.15	0.01	0.01	0.02	0.04	0.05
Fufu meal	Exposure duration/years	Lognorm(4036;8,7655;Shift(−0,055694)	0.00	629.33	4.01	0.22			
	Exposure frequency/ (days/year)	Weibull(1,8115;265,86;Shift(−26,107)	0.00	941.19	210.25	132.66			
	Consumption Frequency (per day)	Expon(0,59791;Shift(0,03056)	0.03	63,811.00	0.63	0.03			
Fried rice	Exposure duration/years	Expon(2,5048;Shift(−0,018385)	0.00	23.37	2.49	0.00			
	Consumption Frequency (per day)	Expon(2,5048;Shift(−0,018385)	0.00	23.37	2.49	0.00			
	Exposure frequency/ (days/year)	Uniform(−5,1408;370,14)	−5.11	370.13	182.50	285.70			

Sensitivity analysis

Table 3 shows the Spearman's ranking correlation coefficients of the input factors on the overall mean risk estimate as hazard index due to the presence of the metals in both meal types. The correlation coefficients values for the input factors indicated that the exposure duration and exposure frequency had the highest impact on the overall mean estimate of the hazard index. Continuous consumption of huge quantities of street vended meals is likely to cause and individual to experience the adverse health effects of a hazard present in the meal. The exposure frequency as an input factor was followed by the concentration of Al in the *fufu* samples (0.18) and levels of Pb in both the *fufu* and soup samples. In a similar but unrelated study on risk assessment due to acrylamide in some street vended foods, the sensitivity analysis revealed that cancer risk was sensitive to weight of consumers and followed by consumption frequency as input factors [3].

The correlation coefficients of the input factors on the overall hazard index of fried rice meal featured the exposure frequency and duration as having the strongest impact on the overall risk estimate. The effects of Pb concentration in the rice and chicken components on the overall risk estimate were 0.17 and 0.04, respectively.

Conclusion

Consumption of high quantities of the street-vended foods especially at the 95th percentile exposed individuals to high risk of the adverse effects of the toxic metals studied, especially Pb. At the 5th percentile level of consumption, of both meals, high concentrations of aluminum were recorded, rendering the meals unsafe for consumption.

Declaration of Competing Interest

Authors declare no conflicts of interest.

References

[1] O. Akoto, F. B. Eshun, G. Darko, E. Adei, Concentrations and health risk assessments of heavy metals in fish from the Fosu lagoon, Int. J. Environ. Res. 8 (2) (2014) 403–410.
[2] M. Al Mamun, S.M.M. Rahman, T.C. Turin, Knowledge and awareness of children's food safety among school-based street food vendors in Dhaka, Bangladesh, Foodborne Pathog. Dis. 10 (4) (2013) 323–330, doi:10.1089/fpd.2012.1283.
[3] E. Anyimah-Ackah, A stochastic dietary risk estimate modeling of acrylamide exposure in commonly eaten foods among consumers in the tropics, Thesis, Kwame Nkrumah University of Science and Technology, Ghana, 2017, pp. 1–83.
[4] K.K.I.U. Arunakumara, B.C. Walpola, M.H. Yoon, Current status of heavy metal contamination in Asia's rice lands, Rev. Environ. Sci. Biotechnol. (2013), doi:10.1007/s11157-013-9323-1.
[5] A.A. Asamoah, Arsenic, cadmium and leadcontent of rice sold in the Greater Accra region, Thesis, Kwamne Nkrumah University of Science and Technology. Ghana, 2016.
[6] M. Bamuwamye, P. Ogwok, V. Tumuhairwe, Cancer and non-cancer risks associated with heavy metal exposures from street foods: evaluation of roasted meats in an urban setting, J. Environ. Pollut. Hum. Health 3 (2) (2015) 24–30, doi:10.12691/jephh-3-2-1.
[7] A.I. Barros, D. Victor de Babos, E.C. Ferreira, J.A. Gomes Neto, Effect of different precursors on generation of reference spectra for structural molecular background correction by solid sampling high-resolution continuum source graphite furnace atomic absorption spectrometry: determination of antimony in cosmetics, Talanta 161 (2016) 547–553, doi:10.1016/j.talanta.2016.09.017.
[8] L.S. Borquaye, G. Darko, M.K. Laryea, E.N. Gasu, N.A.A. Amponsah, E.N. Appiah, Nutritional and anti-nutrient profiles of some ghanaian spices, Cogent Food Agricult. 3 (1) (2017) 1–12, doi:10.1080/23311932.2017.1348185.
[9] N. Bortey-Sam, S.M.M. Nakayama, Y. Ikenaka, O. Akoto, E. Baidoo, Y.B. Yohannes, M. Ishizuka, Human health risks from metals and metalloid via consumption of food animals near gold mines in Tarkwa, Ghana: estimation of the daily intakes and target hazard quotients (THQs), Ecotoxicol. Environ. Saf. 111 (2015) 160–167, doi:10.1016/j.ecoenv.2014.09.008.
[10] C.O. Chukuezi, Food safety and hyienic practices of street food vendors in Owerri, Nigeria, Stud. Sociol. Sci. 1 (1) (2010) 50–57, doi:10.3968/j.sss.1923018420100101.005.
[11] G. Codjia, FAO, FAO/WHO Regional Conference on food safety for Africa, in: Jt. Secr. Reg. Conf. Food Saf. Africa, 2005, p. 41. http://www.fao.org/3/a0215e/A0215E26.htm (accessed February 6, 2020).
[12] A. Berhanu, The food security role of agriculture in Ethiopia, electron, J. Agric. Dev. Econ. 1 (2004) 138–153 http://www.www.fao.org/es/esa/eJADEVol. (accessed February 6, 2020).
[13] S. Dabonne, B.P.K. Koffi, E.J.P. Kouadio, A.G. Koffi, E.A. Due, L.P. Kouame, Traditional utensils: potential sources of poisoning by heavy metals, Br. J. Pharmacol. Toxicol. 1 (2) (2010) 90–92.
[14] B. Darko, I. Ayim, R.B. Voegborlo, Heavy metal content in mixed and unmixed seasonings on the Ghanaian market, Afr. J. Food Sci. 8 (1) (2014) 14–19, doi:10.5897/AJFS2013.1107.
[15] O.C. Ekhator, N.A. Udowelle, S. Igbiri, R.N. Asomugha, Z.N. Igweze, O.E. Orisakwe, Safety evaluation of potential toxic metals exposure from street foods consumed in mid-west Nigeria, J. Environ. Publ. Health 2017 (2017) 1–8, doi:10.1155/2017/8458057.
[16] C. Gerba, Risk assessment, in: Risk Manag., 2008, pp. 1–17.
[17] M. Ghosh, S. Wahi, M. Kumar, A. Ganguli, Prevalence of enterotoxigenic staphylococcus aureus and Shigella spp. in some raw street vended Indian foods, Int. J. Environ. Health Res. 17 (2) (2007) 151–156, doi:10.1080/09603120701219204.
[18] GSS. (2014). 2010 population and housing census, district analytical report, Sekondi-Takoradi metropolitan.
[19] D.J. Hand, Elementary statistics, in: Res. Methods Postgraduates, third ed., 2012, pp. 289–298, doi:10.1002/9781118763025.ch28.
[20] B. Hu, X. Jia, J. Hu, D. Xu, F. Xia, Y. Li, Assessment of heavy metal pollution and health risks in the soil-plant-human system in the Yangtze River Delta, China, Int. J. Environ. Res. Pub. Health 14 (9) (2017), doi:10.3390/ijerph14091042.
[21] O.A. Idowu, S.A. Rowland, Oral fecal parasites and personal hygiene of food handlers in Abeokuta, Nigeria, Afr. Health Sci. 6 (3) (2006) 160–164, doi:10.5555/afhs.2006.6.3.160.
[22] C.M.A. Iwegbue, Composition and daily intakes of some trace metals from canned beers in Nigeria, J. Inst. Brew. 116 (3) (2010) 312–315, doi:10.1002/j.2050-0416.2010.tb00436.x.
[23] B. Keraita, P. Drechsel, F. Huibers, L. Raschid-Sally, Wastewater use in informal irrigation in urban and Periurban areas of Kumai, Ghana, Urban Agr. Mag. 6 (December) (2002) 11–13.
[24] L.K. King, B. Awumbila, E.A. Canacoo, S. Ofosu-Amaah, An assessment of the safety of street foods in the Ga district, of Ghana; implications for the spread of Zoonoses, Acta Trop. 76 (1) (2000) 39–43, doi:10.1016/S0001-706X(00)00087-5.
[25] K. Kińska, K. Bierla, S. Godin, H. Preud'homme, J. Kowalska, B. Krasnodębska-Ostręga, J. Szpunar, A chemical speciation insight into the palladium(ii) uptake and metabolism by: Sinapis Alba. Exposure to PD induces the synthesis of a pd-histidine complex, Metallomics 11 (9) (2019) 1498–1505, doi:10.1039/c9mt00126c.
[26] V. Levasseur, C. Kouamé, M.W. Pasquini, L. Temple, A review of urban and peri-urban vegetable production in West Africa, Acta Horticult. 762 (2007) 245–252, doi:10.17660/ActaHortic.2007.762.23.
[27] P. Mensah, D. Yeboah-Manu, K. Owusu-Darko, A. Ablordey, Street foods in Accra, Ghana: how safe are they? Bull. World Health Organ. 80 (7) (2011) 546–554, doi:10.1590/S0042-96862002000700006.
[28] O.K. Muinde, E. Kuria, Hygienic and sanitary practices of vendors of street foods in Nairobi Kenya, Afr. J. Food Agricult. Nutr. Dev. 5 (7) (2005) 1–14 Retrieved fromwww.ajfand.net.
[29] National Research Council (US) Committee, Diet and health: implications for reducing chronic disease risk, Choice Rev. Online 27 (06) (1990) 27–3332, doi:10.5860/choice.27-3332.
[30] D.P. Naughton, A. Petróczi, Heavy metal ions in wines: meta-analysis of target hazard quotients reveal health risks, Chem. Cent. J. 2 (1) (2008) 1–7, doi:10.1186/1752-153X-2-22.
[31] S.N. Odai, E. Mensah, D. Sipitey, S. Ryo, E. Awuah, Heavy metals uptake by vegetables cultivated on urban waste dumpsites: case study of Kumasi, Ghana, Res. J. Environ. Toxicol. 2 (2) (2008) 92–99, doi:10.3923/rjet.2008.92.99.
[32] A.M. Omemu, S.T. Aderoju, Food safety knowledge and practices of street food vendors in the city of Abeokuta, Nigeria, Food Control 19 (4) (2008) 396–402, doi:10.1016/j.foodcont.2007.04.021.
[33] L.A. Palinkas, S.M. Horwitz, C.A. Green, J.P. Wisdom, N. Duan, K. Hoagwood, Purposeful sampling for qualitative data collection and analysis in mixed method implementation research, Admin. Policy Mental Health Mental Health Serv. Res. 42 (5) (2015) 533–544, doi:10.1007/s10488-013-0528-y.
[34] J.P. Panduwawala, C.D.K. Illeperuma, U. Samarajeewa, Iron contamination during commercial grinding of spices, J. Natl. Sci. Found. 16 (1) (1988) 105, doi:10.4038/jnsfsr.v16i1.8281.
[35] G. Perelló, R. Martí-Cid, J.M. Llobet, J.L. Domingo, Effects of various cooking processes on the concentrations of arsenic, cadmium, mercury, and lead in foods, J. Agric. Food Chem. 56 (23) (2008) 11262–11269, doi:10.1021/jf802411q.
[36] D. Posada, T.R. Buckley, Model selection and model averaging in phylogenetics: advantages of akaike information criterion and bayesian approaches over likelihood ratio tests, Syst. Biol. (2004), doi:10.1080/10635150490522304.
[37] S. Rane, Street vended food in developing world: hazard analyses, Indian J. Microbiol. (2011, January 26), doi:10.1007/s12088-011-0154-x.
[38] M. Rausand, Risk assessment risk assessment risk assessment, Encycl. Inf. Assur. (2008) 1–7, doi:10.1081/E-EIA-120046557.
[39] A.S. Sampare, Investigations into the Quality of Mill Plate Wear Using Attrition Mills in Ghana, Kwame Nkrumah University of Science and Technology, 2016 Retrieved fromhttp://hdl.handle.net/123456789/9960.

[40] A. Sanda, J. Dibal, Analysis of irrigation water quality at kadawa irrigation project for improved productivity, Int. J. Environ. 3 (3) (2014) 235–240, doi:10.3126/ije.v3i3.11082.
[41] A.-.R. Shareef, Z. Lin, K. Emanuele, S. Healey, P. Regan, B. Baker, Rapid detection of enriched uranium in food, Appl. Radiat. Isot. 126 (2017) 76–78, doi:10.1016/j.apradiso.2017.03.007.
[42] R. Shibata, Selection of the order of an autoregressive model by Akaike's information criterion, Biometrika 63 (1) (1976) 117–126, doi:10.1093/biomet/63.1.117.
[43] M. Valko, C.J. Rhodes, J. Moncol, M. Izakovic, M. Mazur, Free radicals, metals and antioxidants in oxidative stress-induced cancer, Chemico-Biological Interactions, Elsevier, 2006, March, doi:10.1016/j.cbi.2005.12.009.
[44] J.D. Weidenhamer, P.A. Kobunski, G. Kuepouo, R.W. Corbin, P. Gottesfeld, Lead exposure from aluminum cookware in Cameroon, Sci. Total Environ. 496 (2014) 339–347, doi:10.1016/j.scitotenv.2014.07.016.
[45] World Health Organization, Evaluation of Certain Food Additives and Contaminants, WHO Food Additives Series, 2011.