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Original Research Article

Heavy metal contamination of cooked foods hawked at Chuka town in Tharaka Nithi County, Kenya

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ABSTRACT

Background: Contamination of cooked foods with heavy metals is an emerging global concern, particularly due to the associated health outcomes and economic considerations. These chemicals are introduced into cooked foods mainly through poor food handling practices and sometimes from their natural milieu such as soil, water, or air.
Methods: This was a descriptive cross-sectional study. The study analysed 151 food samples collected from 151 hawkers of cooked foods in Chuka town. The samples were analysed for lead, cadmium, and copper using an atomic absorption spectrophotometer (AAS) assisted by closed microwave digestion.
Results: The concentration of lead in the food samples ranged from <0.001 to 0.7 mg/kg with a mean of 0.207±0.16, cadmium ranged from <0.001 to 0.933 with a mean of 0.105±0.195, while copper ranged from <0.001 to 2 mg/kg with a mean of 0.461±0.456. The recorded levels of copper were below the maximum allowable limits in all the food samples. However, 57 (37.7%) and 44 (29.1%) food samples were contaminated with lead and cadmium, respectively. Overall, more than half 86 (57%) of the hawked-cooked foods were contaminated with either lead, cadmium, or both lead and cadmium.
Conclusions: Cooked foods hawked at Chuka town are contaminated with either lead, cadmium, or both lead and cadmium. The County government of Tharaka Nithi to champion interventions on preventing the sale of contaminated cooked foods.

Keywords: Cadmium, Cooked foods, Copper, Food contamination, Hawked foods, Heavy metals, Lead, Street foods, Street-vended foods

INTRODUCTION

Heavy metals are tiny chemical substances that naturally exist in the environment in trace amounts. These substances may sometimes enter the food chain in concentrations that are harmful to the consumers and thus considered chemical contaminants. The other priority chemical contaminants in food include persistent organic pollutants (POPs), polycyclic aromatic hydrocarbons (PAHs), perflourinated compounds, pharmaceutical and personal care products, radioactive elements, electronic waste, plastics, and nanoparticles.[1] Chemical contaminants usually exist in food in very low concentrations usually measurable in parts per million and sometimes in parts per trillion.[2] Heavy metals and other chemical contaminants are usually inadvertently introduced into the food chain through human activities such as the use of agrochemicals; cross-contamination from food processing equipment, utensils, food packaging materials, or unauthorised food additives, or simply from natural sources such as soil, water, or air.[3,4]

However, there are documented cases where chemical contaminants have been deliberately introduced into the food chain.[5] This is well indicated by the widespread use of sodium metabisulphite, a proscribed food additive, as a preservative for fresh food such as meat and vegetables sold in Kenya, particularly in Nairobi and its environs.[6]

Human exposure to chemical contaminants can result to devastating health problems such as gastroenteritis, endocrine malfunction, hepatic disorders, renal disorders, neurological disorders, reproductive dysfunction, developmental retardation, mutation of cells, harm to unborn children, and different types of cancer.[5,7]

Heavy metal contaminants contribute to a disproportionately high burden of these health problems, especially when ingested at levels beyond safe human remediation. There are four general classes of heavy metals based on their potential to cause harm to human beings: essential heavy metals which include elements such as chromium, manganese, zinc, copper, iron, and cobalt; non-essential heavy metals including aluminium, lithium, and barium, among others; less toxic heavy metals such as tin; and highly toxic heavy metals which include mercury, lead, and cadmium, among others. Essential heavy metals are a basic requirement in various body functions and become toxic only when ingested in amounts more than the maximum allowable levels.[8,9] The common heavy metals implicated in food contamination include lead (Pb), mercury (Hg), arsenic (As), cadmium (Cd), tin (Sn), and copper (Cu).[3,5] This study investigated the levels of lead, cadmium, and copper in hawked-cooked foods.

Lead is known to accumulate in several body organs including the brain, liver, teeth, and bones where in addition to causing damage to the affected organ, it can also be released into the blood and toxify other organs. Exposure to lead is particularly associated with retarded brain, irreversible behavioural disorders, reduced intelligence quotient, increased antisocial behaviours, and developmental disorders of the nervous system which trigger life-threatening conditions such as coma and episodes of convulsions in young children. In adults, ingestion of lead results in renal disorders, hypertension, immunotoxicity, anaemia, and reproductive disorders. Lead is also associated with miscarriage, low birth weight, and preterm birth in pregnant women.[10] There are usually no safe levels of lead concentrations in the blood, and even very small levels of exposure can result to fatal health outcomes. The adverse effects of lead are more pronounced in children.[11]

Cadmium, just like lead is a highly toxic heavy metal that possesses no single health benefit to humans and animals. It is usually introduced into the environment – soil, water, and air – from anthropogenic sources, particularly industrial processes and contemporary technologies.[12] Human exposure to cadmium is mostly through water, cigarette smoking, air contamination, and food.[12,13] Food is ordinarily the single most important source of cadmium among the general populace.[14] This is especially due to the continuing production and handling of foods in polluted environments. Intake of cadmium from contaminated foods and other sources results in various devastating health effects and has been responsible for a significantly high number of fatalities across the world.[13] Cadmium can trigger profound damaging processes in the kidney, liver, lungs, and skeletal framework. Moreover, Cadmium is associated with several forms of cancer including breast, prostate, pancreas, and nasopharynx cancers, among others.[12] People exposed to cadmium are also more likely to develop diabetes and cardiovascular diseases.[14] However, cadmium is considered less harmful than lead due to its low absorption rate.[15]

Copper is an essential heavy metal, required in various physiological processes of the human body, and becomes toxic only when ingested in excess amounts. It occurs naturally in the soil, water and some foods.[16] When taken in controlled amounts, copper is useful in iron metabolism, energy production, synthesis of neuropeptides, synthesis of neurotransmitters, transmission of nerve impulses, development of immunity, and pigmentation, among others.[17] However, consumption of large quantities of copper is responsible for a myriad of injurious health outcomes including oxidative cell damage and cell death, liver damage, diarrhoea, abdominal aches and cramps, vomiting, and nausea. The effects are more common in persons with underlying health conditions such as those with hereditary copper homeostasis defect and Wilson’s disease.[17,18]

To protect consumers from exposure to harmful concentrations of heavy metals, the United Nations through the World Health Organization (WHO) and Food and Agriculture Organization (FAO) developed a guide – Codex Alimentarius – on the allowable maximum levels of most of the highly toxic food contaminants, including heavy metals.

Though not a substitute for national legislation, the standards essentially form part of the food standards in all WHO and FAO member states. Besides protecting the health of consumers, the guidelines are also aimed at promoting fair trade practices. According to the Codex Alimentarius Commission (CAC), the threshold of lead for regulated food products ranges from 0.01 mg/kg in infant formula to 2 mg/kg in food-grade salts while the allowable limits for cadmium range from 0.003 mg/kg in natural waters to 0.5 mg/kg in food-grade salts.[19] CAC considers copper more for its physiologic and quality importance than as a food contaminant and thus it doesn’t expressly provide for its maximum allowable limits in food. However, existing literature sets the maximum allowable limits for copper at 10 mg/kg.[20]

Objective of the study

The objective of this study was to determine the heavy metal contamination of cooked foods hawked at Chuka town in Tharaka Nithi County.

METHODS

Study area

The study was carried out at Chuka town in Tharaka Nithi County (TNC). TNC is among the 47 county governments in Kenya. There are four major urban centres in TNC including Chuka, Marimanti, Chogoria and Kathwana town. Chuka town is home to almost half of the urban population in TNC and hosts the majority of modern social amenities, and enterprises.

Study design

This was a descriptive cross-sectional study where a single cooked food item was analysed from every participating food hawker. The food samples were collected from January to April 2021.

Study population

The study analysed cooked foods hawked at Chuka town. The samples comprised food items prepared by the hawkers or their associates by applying heat (such as boiling, roasting, baking, or frying) and kept hot or required to be reheated before consumption. Since the legal age in Kenya is 18 years, the study collected food samples only from hawkers aged 18 years and above. Those who were not available during the time of sample collection were excluded from the study.

Sample size determination

There were approximately 164 food hawkers in Chuka town based on estimates from the service-level data availed at the Chuka sub-county public health office. The study targeted to collect a total of 164 cooked food samples, one each from every single food hawker, because it was technically and logistically feasible to enlist all the 164 cooked food hawkers at Chuka town.

Sampling techniques

Tharaka Nithi County was purposively selected essentially due to its relatively higher burden of foodborne diseases compared to other Counties in the upper Eastern region of Kenya. The study deployed simple random sampling technique aided by a random number generator application installed in a mobile smartphone to identify a single food item from every participating hawker of cooked foods.

Identification and collection of food samples

The study collected a single cooked food sample from each participating food hawker. All the cooked foods from every participant were assigned consecutive numerical values. A random number generator from a smartphone was deployed to identify a single food item based on the numerical value of the respective food items. The study bought a representative amount of about 250 grams of the selected cooked food. The sample was labelled and transported to the laboratory in a sterile cool box for further processing and analysis. The study endeavoured for as much as practically possible to maintain the original status of the collected food samples. The food samples were delivered to the laboratory within two hours after collection.

Laboratory procedure for analysis of heavy metals

Analysis for lead (Pb), cadmium (Cd), and copper (Cu) was carried out at Chuka University chemistry laboratory using atomic absorption spectrophotometer (AAS) assisted by closed microwave digestion. The samples were prepared and processed in a clean environment. All glassware and plasticware were thoroughly cleaned using running water and detergent, then rinsed in 10% nitric acid followed by double distilled water.

Test principle

Analytical samples were prepared and analysed in triplicates. The samples were first dried and uniformly blended by grinding into fine particles. The finely ground sample was weighed into triplicates of 0.5 g each and separately mixed with nitric acid and hydrogen peroxide before digesting in a closed microwave. The digested samples were cooled and filtered into a 50 ml volumetric flask. The 50 ml volumetric flask was filled to the mark using double distilled water and the resulting analyte was processed using a flame atomic absorption spectrophotometer.[21]

Procedure for sample preparation

One-half (0.5) grams of dried and properly homogenized food samples were weighed into a teflon material (TFM) vessel using analytical balance. The TFM vessel was introduced into a fume hood within which 7ml of concentrated analytical nitric acid and 1ml of 30% hydrogen peroxide were added into the sample. The particles of the food sample that remained on the inner walls of the TFM vessel were washed into the mixture by adding drops of nitric acid before mixing the solution by swirling. The vessel was then closed and introduced into the rotor segment.

The rotor segment was inserted into the microwave cavity after which the microwave digestion programme was run to completion. The rotor was allowed to cool before filtering the contents into a 50 ml volumetric flask. The 50 ml volumetric flask containing the filtrate was filled to volume using double-distilled water. The sample blank was prepared using the same procedure used for sample preparation, similar amounts of reagents, and subjected to the same treatments. Sample standards ranging from 0.01 ppm to 4 ppm separate for lead, cadmium, and copper were prepared using known concentrations of the respective laboratory metals.

Procedure for determining heavy metal content in a food analyte using atomic absorption spectrophotometer (AAS)

Atomic absorption spectrophotometer (AAS) instrument was set according to the manufacturer's instructions. Standards curves separate for every element were prepared by reading the absorbance of at least five different concentrations of the respective standard metal solutions. Absorbances of the blank solution and food analytes were then read and recorded accordingly. The concentration of heavy metal in the food analytes was calculated by factoring the absorbance of the food analyte, the absorbance of the blank solution, weight of the food sample, and the dilution factor (50 ml) of the analyte. The sensitivity of the AAS instrument was assured by reading an analyte of known concentration of the respective heavy metal after every ten samples.

Data management and analysis

Quantitative data was analysed using statistical product and service solutions (IBM SPSS Statistics 24). The results were reported in form of mean, range, and proportions.

RESULTS

The study analysed 151 samples of hawked-cooked foods, each for lead, cadmium, and copper. The concentration of lead ranged from <0.001 to 0.7 mg/kg with a mean of 0.207±0.16, cadmium ranged from <0.001 to 0.933 with a mean of 0.105±0.195, while copper ranged from <0.001 to 2 mg/kg with a mean of 0.461±0.456.

Table 1: Heavy metal contamination of cooked foods hawked at Chuka town in Kenya.

Variables (n=151)	Frequency (N)	Proportion (%)
Status of food samples (n=151)		
Contaminated	86	57
Not contaminated	65	43
Status of contamination based on the predominant nutrient (n=86)		
Carbohydrate-rich foods	49	57
Protein-rich foods	37	43
Status of contamination with lead (n=151)		
Contaminated	57	37.7
Not contaminated	94	62.3
Status of contamination with cadmium (n=151)		
Contaminated	44	29.1
Not contaminated	107	70.9
Status of contamination with copper (n=151)		
Contaminated	0	0
Not contaminated	151	100

The observed concentrations of heavy metals in individual food samples were compared with the recommended maximum allowable levels for the respective heavy metals, following which a food sample was categorized as either "contaminated" or "not contaminated". The maximum allowable level for lead was taken as 0.2 mg/kg, cadmium 0.1 mg/kg, while that of copper was taken as 2 mg/kg.[19,22] The levels of copper in all food samples were below the set maximum allowable limits. However, 57 (37.7%) and 44 (29.1%) of the samples surpassed the recommended allowable levels for lead and cadmium respectively. In sum, more than half 86 (57%) of the samples were contaminated with either lead, cadmium, or both lead and cadmium. Carbohydrate-rich foods 49 (57%) were more likely to be contaminated with these heavy metals compared to protein-rich foods 37 (43%). The difference in contamination between these two food categories was, however, not statistically significant (χ^2=0.575, df=1, p=0.448) (Table 1).

DISCUSSION

The Codex Alimentarius Commission (CAC) set the maximum allowable level for lead (Pb) in foods at 0.2 mg/kg.[19] In the current study, the concentration of Pb ranged from <0.001 to 0.7 mg/kg with a mean of 0.207±0.16 mg/kg. Ekhator et al documented somewhat comparable results where foods hawked in Mid-West Nigeria were found to contain Pb in the range of 0.014 to 1.37.[23] The findings of the current study indicated that 37.7% of the hawked-cooked foods exceeded the maximum allowable levels of Pb as set out by CAC. The proportion of foods exceeding the maximum allowable levels for Pb was however relatively small compared to a study carried out in selected locations of Lagos State in Nigeria where all (100%) the samples were found to exceed the safe levels of lead.[24] Lead is a highly toxic heavy metal that when ingested in excess amounts is known to accumulate in several body organs where in addition to damaging the organ, it is also released into the systemic circulation and toxify other organs.[10,11] The concentration of Cd in this study ranged from <0.001 to 0.933 mg/kg with a mean of 0.105±0.195 mg/kg. Besides, 29.1% of the food samples exceeded the maximum allowable limits for Cd in food (0.1 mg/kg) as set out by the CAC.[19] These findings compare closely with a study carried out in Western Nigeria where the mean concentration of Cd in foods hawked at Ilorin city was found to range from <0.001 to 0.193 mg/kg.[25] Just like Pb, cadmium is a non-essential heavy metal that when ingested in excess amounts is known to damage the kidney, liver, lungs, and bones. Cd is also associated with various types of cancer including breast cancer, prostate cancer, pancreas cancer, and nasopharynx cancer, among others.[12] The levels of Cu in the hawked cooked foods ranged from <0.001 to 2 mg/kg with a mean concentration of 0.461±0.456. The recorded concentration of copper in the food samples did not exceed the recommended maximum allowable limit which ranges from more than 2 mg/kg to 10 mg/kg in different types of foods.[22,26] These findings are consistent with studies by Damastuti et al and Mohammed et al where the concentrations of copper in foods hawked at Bandung city in Indonesia and Ilorin city in Nigeria were found to be within the maximum allowable limits.[22,25]

Unlike Pb and Cd, copper is an essential heavy metal necessary in iron metabolism, energy production, boosting immunity, and impulse transmission, among other elemental functions in the human body.[17] However, when ingested in excessively large amounts, copper is known to damage the liver and some cells of the body. Excess intake of copper is also associated with diarrhoea, abdominal discomfort, and vomiting, among other debilitating health effects.[8,9,17,18]

Limitations

This study analysed lead, cadmium and copper to estimate the heavy metal contamination of cooked foods hawked in Chuka town. Though the selected heavy metals were the most likely to be found in cooked foods, a focus on a wide range of heavy metals would have provided a better perspective on the magnitude of the problem. The study was also carried out during the COVID-19 pandemic. This somewhat affected the quantities and types of cooked foods hawked in Chuka town particularly because of restrictions on social interactions that was imposed by the government of Kenya to mitigate the spread of COVID-19.

CONCLUSION

This study has shown that cooked foods hawked at Chuka town are generally contaminated with lead and cadmium. These heavy metals are more likely introduced into hawked-cooked foods from substandard cooking utensils and contaminated environments. The findings are crucial in advancing the literature on heavy metals in cooked foods. Further, the study has provided a scientific basis for interventions to promote the safety of hawked-cooked foods.

Recommendations

The County government of Tharaka Nithi to target interventions on preventing the contamination of hawked-cooked foods with heavy metals. Some viable programmes include sensitising hawkers of cooked foods on food safety practices, and heightened surveillance of the quality of hawked cooked foods. In the long term, the County should develop a policy on hawking of cooked foods, and possibly designate hawking areas for cooked foods in Chuka town, and other major towns in Tharaka Nithi County.

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