Prevalence of Cadmium and Lead Residues in Fried Meat (Suya) Sold in Kaduna Metropolis, Kaduna State, Nigeria

1Saulawa, M.A. and 2Jikamshi, M.A.

1Department of Veterinary Pathobiology, Faculty of Veterinary Medicine, Bayero University Kano, Nigeria
2Nigerian Correctional Service, Kaduna Open Prison Camp, Kaduna State, Nigeria
*Correspondence author: amsaulawa.vpat@buk.edu.ng, +234 803 607 8605

Abstract
Heavy metals are of public health concern worldwide due to their damaging effects on human and animal health. The study was aimed at analyzing the presence of cadmium (Cd) and lead (Pb) residues in suya meats; cattle meat (beef), sheep meat (mutton), goat meat (chevon), fowl meat (chicken) and dog meat sold in the Kaduna metropolis, Kaduna State. A descriptive-quantitative research design was used, with fifty samples collected from four Local Government Areas (Chikun, Igabi, Kaduna North and Kaduna South). Atomic Absorption Spectrophotometery was used to analyze and quantify the presence of these heavy metals. Microsoft Excel (Version 2019) and one-way ANOVA are the statistical tools used for result analysis and Cd and Pb were found to be present in all the suya samples analyzed. The results showed statistical significance (p<0.05) between the overall mean concentration of Cd (0.049 mg/kg) and Pb (0.44 mg/kg) in the samples. Even though the mean concentration of Cd in suya samples varied with regards to which the animal originates viz: cattle (0.033 mg/kg), sheep (0.058 mg/kg), goat (0.048 mg/kg), dog (0.04 mg/kg) and chicken (0.078 mg/kg); likewise that of Pb: cattle (0.47 mg/kg), sheep (0.41 mg/kg), goat (0.41 mg/kg), dog (0.39 mg/kg) and chicken (0.51 mg/kg); the animal species from which the meat used in making the suya had no statistically significant influence on the heavy metal content of the meat (p>0.05). The mean concentration of Cd and Pb obtained within the study areas, in mg/kg were: Chikun (0.046 and 0.43), Igabi (0.044 and 0.43), Kaduna North (0.054 mg/kg) and (0.49 mg/kg), Kaduna South (0.053 mg/kg) and (0.41 mg/kg) respectively. The mean concentration of cadmium and lead in the suya samples was above the permissible limits set by EC and FAO limits of 0.01ug/g lead and 0.003ug/g for cadmium (FAO, 1983), indicating the general contamination of suya meats by heavy metals. The study recommends public measures to minimize environmental pollution and bioaccumulation of Cd and Pb to prevent related ailments and mortality; enforcing regulations governing industrial activities and waste disposal to protect the public from heavy metals pollution.

Keywords: Bioaccumulation, Cadmium (Cd), Lead (Pb), Residues, Processed meat (Suya)

INTRODUCTION

Cows (beef) and other grazing animals freely roam the area and drink water from ponds, streams, rivers, and other potentially polluted water sources. These animals may come into contact with elevated concentrations of heavy metals in their environment, leading to the accumulation of these metals in their organs and tissues over time (Bala *et al.,* 2014). Subsequently, when these animals are consumed by humans and other animals, the heavy metals present in their tissues and organs can pose a health risk (Bala *et al.,* 2014). This ongoing concern within the health sector is primarily due to the potential risks associated with heavy metals such as cadmium, lead, and mercury, as highlighted by Ihedioha *et al.* (2014). Certain

heavy metals, including those resistant to environmental breakdown (Ogabiela *et al.,* 2011; Orisakwe *et al.,* 2012; Pilarczyk *et al.,* 2013), may be ingested by humans through the consumption of contaminated meat from animals that have grazed on polluted pastures (Salem *et al.,* 2000). Raikwar *et al.* (2008) have classified these metals into essential (e.g., Cu, Zn, Co, Cr, Mn, and Fe) and non-essential (e.g., Ba, Al, Li, and Zr) categories, with varying levels of toxicity. The global concern surrounding heavy metals like Pb, Hg, Cd, and As stems from their presence in and around human habitats (Jaishankar *et al.,* 2014; Shalini *et al.,* 2017), often entering the environment through multiple pathways, such as airborne deposition, use of pesticides, and waste disposal (Jaishankar *et al.,*

2014). The European Union has established a comprehensive dataset for monitoring the presence of heavy metals like As, Cd, Cr, Cu, Hg, Pb, Zn, Sb, Co, and Ni (Toth *et al.*, 2016). The utilization of lead (Pb) in various industries has led to environmental contamination, with excessive exposure linked to adverse effects on neurological, reproductive, renal, and hematological systems (Ewers and Shlipkoter, 1991; Juberg, 2000). Notably, studies have shown that children are more vulnerable to lead poisoning than adults, underscoring the importance of addressing lead exposure in childhood (Bala *et al.*, 2014). Cadmium's high toxicity, persistence in the environment, bioaccumulation potential, and ability to increase in concentration up the food chain from continuous low-level exposure are significant concerns (Bala *et al.*, 2014). Cadmium primarily affects kidney function and can lead to bone

demineralization, while industrial workers exposed to airborne cadmium are at a higher risk of developing lung issues and cancer. This study aimed to assess the levels of cadmium and lead in processed meat sold in Kaduna metropolis and compare them against international safety standards.

MATERIALS AND METHODS

Study Area

The research was conducted in Kaduna Metropolis, Kaduna State, Nigeria, a densely populated state with a population of 6 million (NPC, 2006), located between Latitude 10˚20'_N and longitude 7˚45'_E east of the Greenwich Meridian. The state covers an area of 46,053 square kilometers and shares borders with
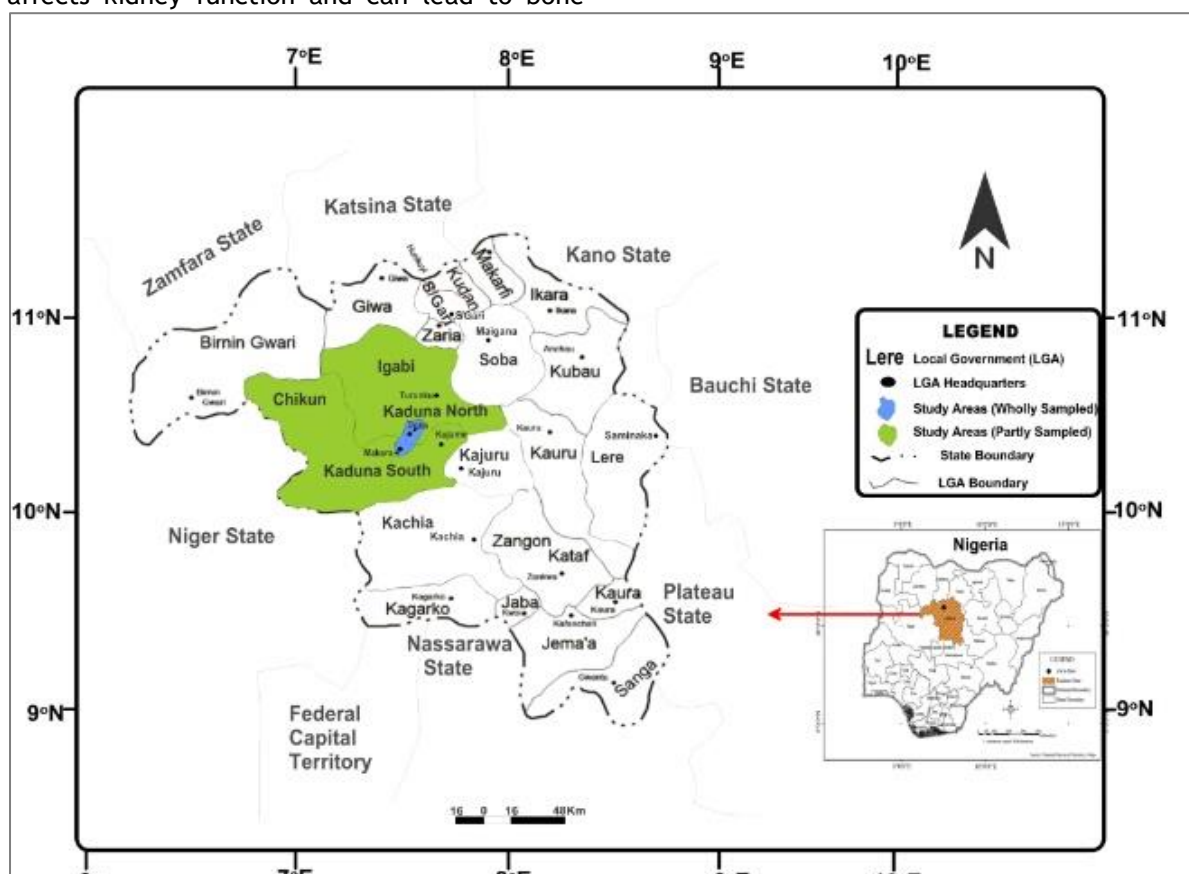

Figure 1: Map of Kaduna state showing the study area.

Source: Public Health Service Solutions, 2024

Niger State to the west, Zamfara, Katsina, Kano States to the north, Bauchi, Plateau States to the east, and FCT Abuja, and Nasarawa State to the south (Figure 1). Kaduna has two distinct seasons: dry and rainy, with the rainy season

typically occurring from April to October. The state comprises 23 Local Government Areas, with four forming the Kaduna metropolis. There are 57 languages spoken as first languages in the state, with Gbagyi and Hausa being

predominant. Agriculture, including animal and poultry farming, serves as the cornerstone of the economy, involving 80% of the population.

Study Design

The research utilized a descriptive-quantitative design, analyzing samples for lead and cadmium via Atomic Absorption Spectroscopy. Suya samples from Kaduna North, Kaduna South, a portion of Igabi, and Chikun were collected for analysis after undergoing processing from meats of different animals such as cattle, sheep, goats, chickens, and dogs using acid digestion.

Sample Collection

Fifty (50) samples of processed meat/suya, including cattle, sheep, goat, chicken, and dog meat from various suya spots in the study area (Ungwan Sarki, Ungwan Rimi, Kakuri, Television Garage, Ungwan Sunday, Ungwan matare, Tudun Wada, Kawo, Sabon Tasha, Malali, Badarawa, Rigasa, Marabar Rido, Narayi, Barnawa), were collected in fresh and sterile polythene bags. They were appropriately labeled for easy identification and then transported to the Veterinary Public Health and Preventive Medicine laboratory of the Faculty of Veterinary Medicine, Ahmadu Bello University Zaria, Kaduna State, Nigeria, where they were frozen and stored in a freezer. Subsequently, the frozen samples were transferred in a cold chain to the Chemical Research Institute Zaria, Kaduna State, Nigeria, for further processing and analysis.

Sample Processing

a. Suya Sample Preparation/Acid Digestion

After drying five (5) grams of processed meat samples at 45°C in an oven, each sample was ground into a fine powder using a mortar and pestle. Subsequently, 1.0 g of the powdered sample was measured into a porcelain crucible. The crucible and fine powdered samples were heated in a muffle furnace at 500°C for six to eight hours. After removal from the furnace, the specimens were cooled in desiccators and reweighed. The ash content percentage was determined by subtracting the weight of the

crucible alone from the weight of the crucible and ash. Following this, $5cm^3$ of a 1M HNO_3 solution was mixed with the remaining ash, dried on a hot plate, and then reheated in a furnace at 400°C for 15-20 minutes until a flawless grayish-white ash was achieved. The samples were cooled in desiccators, and the ash was dissolved by adding $15cm^3$ of hydrochloric acid (HCl). The resulting solution was filtered into a $100cm^3$ volumetric flask and adjusted to a final volume of $100cm^3$ by adding distilled water.

b. Spectrophotometry Techniques for Heavy Metals Detection

The lead and cadmium content of processed meat samples in the Kaduna metropolis were analyzed using an Atomic Absorption Spectrophotometer under specified conditions as per the manufacturer's instructions (AA-6800, Shimadzu Atomic Absorption Spectrophotometer) (Szkoda and Żmudzki, 2005).

Statistical Analysis

The data on cadmium and lead were analyzed using microsoft excel (version 2019) and SPSS version 20, employing one-way ANOVA as a statistical tool, at a significance level of $p < 0.05$. The mean values were tabulated, and the concentrations were assessed using SPSS version 20.

RESULTS

The confirmation of cadmium and lead at varying levels in all suya samples was determined through the analysis performed using Atomic Absorption Spectroscopy (AAS).

Distribution of Samples based on LGA and Suya species in Kaduna Metropolis

The distribution of the 50 suya samples by LGAs and animal species indicated that: Chikun LGA accounted for 28.3%, Igabi LGA for 17.4%, Kaduna North LGA for 23.9%, and Kaduna South LGA for 30.4%. Based on the animals, 24.1% of animals were obtained from cattle, while 17.4% came from chickens, sheep, and dogs respectively, and 21.4% came from goats as indicated in Table1.

Concentration of Cd and Pb in Suya Based on Animal Species

Among the animal species, chickens exhibited the highest cadmium level at 0.078 mg/kg, followed by sheep at 0.058 mg/kg, goats at 0.048 mg/kg, dogs at 0.04 mg/kg, and cattle at 0.033 mg/kg. In terms of lead concentration, chicken meat displayed the highest level at 0.51 mg/kg, while cow, goat, and sheep had similar levels at 0.47 mg/kg, 0.41 mg/kg, and 0.41 mg/kg respectively. Dog meat showed the lowest lead content at 0.39 mg/kg (Table3).

Concentration of Cd and Pb in Suya Based on Location

The levels of Cd and Pb in suya samples from Kaduna Metropolis showed significant variation, with the highest cadmium concentration found in Kaduna North LGA (0.054 mg/kg), followed by Kaduna South (0.053 mg/kg), Chikun (0.046 mg/kg), and Igabi (0.044 mg/kg). Similarly, Kaduna North showed the highest lead concentration (0.4900mg/kg) among the samples, with Chikun (0.43 mg/kg), Igabi (0.42 mg/kg), and Kaduna South (0.41mg/kg) following closely behind according to Table 4.

Table 1: Distribution of Samples Based on LGAs in Kaduna and Suya Species of Animals

LGA	SuyaType					Total (%)
	Cattle	Chicken	Dog	Goat	Sheep	
Chikun	8	2	8	6	2	26 (28.3)
Igabi	6	2	0	4	4	16 (17.4)
Kaduna North	6	6	0	6	4	22 (23.9)
Kaduna South	4	6	8	4	6	28 (30.4)
Total (%)	24 (26.1)	16 (17.4)	16 (17.4)	20 (21.7)	16 (17.4)	92 (100%)

Table 2: Mean (± SEM) Concentration of Cd and Pb in Suya Sold at Kaduna Metropolis

Elements	Number	Min. (ppm)	Max. (ppm)	Mean (± SEM) (ppm)
Cd	46	0.00	0.13	0.049 ± 0.01
Pb	46	0.29	0.78	0.44 ± 0.01

$p < 0.005$

Table 3: Mean (± SEM) Concentration of Cd and Pb in Suya of Different Species of Animals

Suya Type	No. of Samples	Mean (± SEM) (ppm)	
		Cd (ppm)	Pb (ppm)
Cattle	12	0.033 ± 0.01	0.46 ± 0.03
Sheep	8	0.057 ± 0.01	0.40 ± 0.03
Goat	10	0.048 ± 0.01	0.41 ± 0.04
Dog	8	0.04 ± 0.01	0.39 ± 0.02
Chicken	8	0.077 ± 0.01	0.50 ± 0.03

p-values between groups for cadmium (Cd) and lead (Pb) were calculated as 0.06 and 0.09, respectively, at a 95% Confidence Interval (C.I).

Table 4: Mean (± SEM) Concentration of Cd and Pb from Different LGAs of Kaduna Metropolis

Location	No. of samples	Mean (± SEM) (ppm)	
		Cd (ppm)	Pb (ppm)
Chikun	13	0.046 ± 0.01	0.43 ± 0.03
Igabi	8	0.044 ± 0.01	0.42 ± 0.02
Kaduna North	11	0.053 ± 0.01	0.49 ± 0.04
Kaduna South	14	0.052 ± 0.01	0.41 ± 0.01

p-values between groups were calculated as 0.90 for Cd and 0.25 for Pb at a 95% Confidence Interval (C.I).

DISCUSSION

Chemical hazards in meat can come from accidentally added substances like pesticides, cleaners, and heavy metals, as well as naturally occurring hazards like aflatoxins. Additionally, intentional additives such as preservatives and processing aids contribute to chemical hazards in meat products (USDA, 1997). Heavy metals are chemical substances that cannot be broken down or reduced during heat treatment, and can cause various health hazards on humans, which can be either acute or chronic, lethal or sublethal in toxicity (Shaltout *et al.*, 2015). The processing of meat can lead to a possible presence of heavy metals in the final products, and advancements in food production technology are also increasing the risk of contamination with various environmental pollutants, specifically heavy metals. The findings in Table 2 showed that the average lead levels in the meat samples tested is 0.44±0.01 mg/kg in the suya samples from Kaduna metropolis, with a significant difference (p < 0.005) from other heavy metals studied. The values for lead levels (mg/kg) in Table 3 are 0.47 ± 0.03 for cattle, 0.40 ± 0.03 for sheep, 0.41 ± 0.04 for goat, 0.39 ± 0.02 for dog, and 0.50 ± 0.03 for chicken. These values indicate that chicken meat has the highest lead level, followed by beef, chevon, mutton, and dog meat. The results were very similar to those found by Usman *et al.* (2022), who identified 0.72 mg/kg of lead in cattle muscles at Zaria Central abattoir, Kaduna State, Nigeria, but higher than the research conducted by Zahran-Dalia and Hendy-Bassma (2015) (0.18±0.13 ppm) in sausage samples and also surpassing the findings of Adejumo *et al.* (2016) on cured meat products in Nigerian markets, where lead was not detected in any samples, and higher than the results obtained by Meslam-Ebtsam (2018) (0.13±0.01 mg/kg) in locally made minced meat.

Table 4 displayed the lead levels (mg/kg) in the four LGAs of Kaduna metropolis, with Kaduna North LGA having the highest lead content (0.49 ± 0.04 ppm), followed by Chikun (0.42 ± 0.03 ppm), Igabi (0.42 ± 0.02 ppm), and Kaduna South (0.41 ± 0.01 ppm). Pollution in suya meats can be caused by cooking processes, including emissions from vehicles, factory activities, and particles from landfills. Locations such as Kaduna North, Kaduna South, and Chikun are heavily contaminated areas due to the presence of oil and gas industries, companies, refineries, and trailer emissions, which could be potential sources of the heavy metal pollutants found in the samples collected. Lead is one of the few types of elements that are completely toxic in nature. Many elements that are considered harmful in high amounts are necessary nutrients in smaller quantities. Lead does not have a safe exposure level, according to Usman *et al.* (2022). Ingesting lead poses a significant danger to public health, especially for young children who are more prone to lead toxicity due to their efficient absorption of the substance. This can result in delays in both mental and physical growth. Lead is also teratogenic, potentially causing birth defects if consumed during pregnancy. At the same time, adults can experience GI tract damage, dysfunction in procreative capability, nephropathies, as well as damage to both the central and peripheral nervous systems, along with negative blood effects caused by interference with the enzymatic system responsible for synthesizing the HEME group due to lead toxicity (Rubio and colleagues, 2005). The accepted Pb limit set by WHO for these organs is 0.01 µg/g. According to the analysis conducted, all the sampled roasted meats exceeded the standard set by WHO (1991). Therefore, elevated levels of lead in beef can lead to cardiovascular, renal, nervous, and skeletal disorders (WHO,1995).

The findings in Table 2 showed that the average Cd levels in the suya samples were 0.049 ± 0.01 ppm, with a significant variation ($p < 0.01$) between the different samples. The results of this study were similar to the ones reported by Usman *et al.* (2022) at Zaria Central abattoir in Nigeria, where the highest cadmium level (0.05 mg/kg) was found in cattle muscles. Meslam-Ebtsam (2018) also reported higher cadmium levels (0.07 ± 0.01 mg/kg) in minced meat samples. Hoha *et al.* (2018) found levels of 0.16 ± 0.008 mg/kg in luncheon samples, while Zahran-Dalia and Hendy-Bassma (2015) reported levels of 0.11 ± 0.8 ppm in the same type of samples. Meanwhile, Shahat *et al.* (2017) obtained lower results indicating that Cadmium was not found in the minced meat samples they analyzed. It is clear from the data in Table 3 that chicken meat had the highest cadmium level (0.077 mg/kg), with sheep (0.057 mg/kg) coming next, followed by goat (0.048 mg/kg), dog (0.04 mg/kg), and cattle (0.033 mg/kg). This could be due to factors such as feeding, housing/farming practices, environment and types of drugs used in rearing poultry in Kaduna metropolis. The Cd concentrations in samples were determined, revealing varying levels across different LGAs in Kaduna Metropolis. The highest Cd concentration was in Kaduna North LGA (0.0536 mg/kg), followed by Kaduna South (0.052 mg/kg), Chikun (0.046 mg/kg), and Igabi (0.043 mg/kg) (Table 4). Thus, the findings show that all LGAs were discovered to have elevated levels of cadmium, surpassing WHO, (1991) upper limit of 0.003 μg/g. Levels of cadmium in meat rise as the animal grows older and are influenced by the amount of cadmium in their feed, according to Usman *et al.* (2022). According to Binkowski (2012), cadmium has the potential to build up in the human body, leading to potential kidney dysfunction, skeletal damage, and reproductive issues. Cadmium toxicity affects bone demineralization both through direct bone damage and indirectly through renal dysfunction (Solidum *et al.*, 2013). Cd can facilitate the impact of diabetes on the kidneys. If exposure is high and prolonged, kidney damage can continue to advance to End Stage Renal Disease (ESRD) and eventually lead to death. Recent research suggests that Cadmium may also be involved in the progression of additional types of cancer, including testicular, bladder, pancreatic, and gall bladder cancer (Solidum *et al.*, 2013).

CONCLUSION

The study revealed that the consumption of processed meat from cattle, chicken, dog, goat, and sheep in the Kaduna metropolis may not be entirely safe due to elevated levels of lead and cadmium. Despite lower levels of lead in the meat of cattle, goats, and dogs, the safety of consuming these meats is not justified, as prolonged exposure to these heavy metals can result in bioaccumulation, presenting significant public health risks. The study suggests that consuming certain domestic animal meats from the Kaduna metropolis could potentially elevate heavy metal levels in the human body beyond acceptable limits via bioaccumulation.

RECOMMENDATIONS

In light of this, researchers in the area, as well as national health organizations, should engage in continuous monitoring and evaluation of toxic metal levels in foodstuffs. This will help establish national allowable values for the population and strictly control any imported or locally produced products, as levels of toxic metals can fluctuate due to various factors. There is a need for the revision of regulations governing mining and industrial activities, the establishment of grazing reserves, and raising public awareness of the health risks associated with heavy metal consumption. Periodic monitoring of these products is crucial in addressing the chemical hazards that impact human health. Additionally, determining the heavy metal levels in fodder and water fed to animals is also essential.

Overall, the consumption of beef in the Kaduna metropolis could have deleterious effects over a lifetime in humans, especially for children and women of childbearing age. The study suggests that the Kaduna State Government should deploy public health officers to consistently monitor the contamination levels of toxic heavy metals in beef consumption.

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