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Assessment Of Concentration Of Heavy Metals In Raw And Roasted-meat (*suya*) On The University Of Abuja Campuses And Its Environs

Isa Adams Olamide[1], Okunlola Oyebanji Basit[1], Mobolaji Abdulateef Ayoola[1], Usende Ifukibot Levi[1]

[1] *Department of Veterinary Anatomy, Faculty of Veterinary Medicine, University of Abuja.*

[*]**Mentor & Corresponding Author:** Usende Ifukibot Levi, Email: ifukibot.usende@uniabuja.edu.ng

ABSTRACT

Heavy metals toxicity is a major health burden worldwide. This study was undertaken to assess heavy metals concentrations of raw and commercial roasted meat (*suya*) in the campuses of University of Abuja, Nigeria and its environ. A total of 32 samples comprising of 16 *suya* samples and 16 raw meat samples were collected in Ziploc bags and used for this study. All samples were collected for a period of two weeks and stored in desiccators at ambient temperature before analysis using atomic absorption spectrophotometer. Arsenic, cadmium, chromium, iron, mercury, lead, vanadium and zinc were analyzed. The results revealed that the concentrations (mg/kg) of arsenic, cadmium, chromium and mercury in raw meat samples were below the detectable limit. It was also found that the concentrations of iron, zinc and lead although detected in raw meat samples, were below maximum permissible limit for heavy metals in meat as approved by World health Organization (WHO). A similar pattern was observed in the concentrations of iron and zinc for *suya* meat. Notably, it was found that the concentrations (mg/kg) of arsenic, cadmium, chromium, mercury, lead and vanadium in *suya* samples were above maximum permissible limit approved for roasted meat by WHO, posing a potential health risk to individual consuming these products in these areas. These findings highlight the importance of scrutinizing not only raw materials but also the entire food preparation chain. Continuous monitoring, awareness campaigns, and regulatory measures are indispensable in safeguarding public health and ensuring safety of the population.

Key words: Heavy metals, Raw and *Suya* meat, Maximum permissible limit, World Health Organization, Atomic Absorption Spectrophotometric.

1. Introduction

Recently, studies have revealed that heavy metals serve as primary pollutants, thereby leading to severe cytotoxicity, mutagenicity, and carcinogenesis in both humans and animals (Ojebah and Ewhre, 2015; Usende *et al.,* 2020, 2022a). Heavy metal toxicants, such as lead, vanadium, cadmium, and others, could potentially exist in roasted meat (known as *suya*) that is consumed by the general public. The continuous consumption of *suya* contaminated with these heavy metals beyond the permissible limits poses a considerable public health risk due to its gradual accumulation within the human body. *Suya,* a piquant meat preparation consisting of skewered beef, ram, or chicken, has gained considerable popularity as a culinary delicacy in West Africa, notably Nigeria (Eke *et al.,* 2014). Its widespread appeal can be attributed to its affordability and wide availability. In the recent past, *suya* was hailed as a unifying element within Nigerian society (Gambrell, 2012). However, the recurring issue of *suya* contamination with heavy metals exceeding the permissible safety thresholds poses a significant public health concern. Consequently, this research endeavor seeks to assess the concentrations of heavy metals in both raw meat and roasted meat (*suya*) across the campuses of the University of Abuja and its surrounding areas, namely Iddo, Giri, and Gwagwalada. By shedding light on the risks associated with *suya* consumption, this study aims to furnish crucial data in the emerging field of food toxicity, which holds paramount importance for the well-being of the University of Abuja's faculty and students.

2. Materials and Methods

2.1 Sample collection

Commercial *suya* (500 g) and raw meat (500 g) samples were purchased from major vendors in the University of Abuja campuses (Mini campus and Permanent sites) and its environs (Iddo and Giri) and used for this study. A total of 32 samples consisting of 16 *suya* samples and 16 raw meat samples were collected in Ziploc bags and immediately transported to the Department of Veterinary Anatomy, University of Abuja storage facility. First, the raw meat samples were collected and then followed same batch to processing to roasted meat which we collected as *suya* meat. All samples were collected for a period of two weeks and stored in desiccators at ambient temperature before immediate analysis using atomic absorption spectrophotometer.

2.2 Heavy metals analysis

The concentrations of heavy metals were assessed using atomic absorption spectrophotometer, following the protocol described by Usende *et al.* (2017). In brief, samples were collected in petri dishes and were subjected to oven drying. All samples were initially digested with 20 mL perchloric-nitric acid solution. The samples were subsequently brought to a total volume of 50 mL by adding the same perchloric-nitric acid. Subsequently, the samples were dispensed into glass vials and analyzed for the presence of iron, lead, cadmium, mercury, vanadium, zinc, selenium, and copper. This was achieved by configuring the lamps to correspond to each metal of interest, using the AnalytikJenaVRContr AA30 Atomic Absorption Spectrophotometer (Analytik JenaAG, Germany). The spectrophotometer was operated with a C_2H_2 flame in water, and the acetylene pressure output set at 80-100 kPa for maintenance. Air pressure was critically maintained at 300-600 kPa. Determination of metals concentration of interest in *suya* and raw meat in dry matter basis was then calculated and expressed in milligram per kilogram (mg/kg). For internal quality control measures, we performed all samples in triplicate repetition for each sample, and we quantify by taken the mean of the triplicate repetitions to ensure reliability. All chemicals utilized for this experiment were of analytical grade.

2.3 Statistical analysis

Statistical analysis was performed using GraphPad Prism version 9. All data generated are presented as mean and standard error of mean and tabulated.

3. **Result**

3.1 Concentrations of heavy metals in raw meat

The results of the concentrations of eight (8) selected heavy metals of interest (arsenic, cadmium, chromium, iron, mercury, lead, vanadium and zinc) in raw meats samples from the major *suya* spots in the University of Abuja main campus, mini campus, Iddo and Giri are represented in table 1. Similarly, table 2 shows the heavy metal level in *suya* from the same location. Of the metals, Fe is the most abundant in the raw meat from the four (4) sampling spots. The Fe concentration in the raw meat was highest in Giri sampling spot with value of 30.71 ± 3.72 compared to Iddo, Mini campus and Main campus sampling spots with values of 27.24 ± 4.08, 26.98 ± 4.38 and 23.94 ± 1.54 respectively (Table 1). However, these values obtained from raw meat from the four sampling spots were below the maximum permissible limit for heavy metals in meat approved by World Health Organization.

Zinc was the next in terms of abundance followed by vanadium and lead (Table 1). For zinc, the highest concentration in raw meat was seen in Iddo (1.15 ± 0.07) followed by Mini campus (0.85 ± 0.17), Giri (0.84 ± 0.07) and Main campus (0.74 ± 0.05) respectively. For vanadium, the highest concentration in raw meat was seen in Main campus (0.07 ± 0.00) followed by Iddo (0.02 ± 0.01) and Giri (0.01 ± 0.0) respectively. However, vanadium was undetectable in raw meat sampled from Mini campus. Moreso, these values of vanadium concentration obtained from raw meat from Main campus, Iddo and Giri sampling spots were high above the maximum permissible limit for heavy metals in meat approved by approved by United State Environmental Protection Agency (USEPA). Concerning the lead concentration, Iddo and Giri had equal concentration in raw meat (0.02 ± 0.01) and a lower concentration (0.01 ± 0.00) was seen in sample collected from Main campus. Also, lead was undetectable in raw meat sampled from Mini campus. Like in iron and zinc, these values of lead concentration obtained from raw meat from Main campus, Iddo and Giri sampling spots were below the maximum permissible limit for heavy metals in meat approved by World Health Organization. The concentrations of arsenic, cadmium, chromium and mercury in raw meat samples were below detectable limit (not detected) in all the areas of study.

Table 1. Heavy metals concentrations (mg/kg) in raw meat samples from major *suya* spot in University of Abuja main campus, mini campus, Iddo and Giri.

Heavy metals	**Main campus**	**Mini campus**	**m Iddo**	**Giri**	**Maximum Permissible limit (WHO)**
Arsenic (Ar)	ND	ND	ND	ND	0.01
Cadmium (Cd)	ND	ND	ND	ND	0.005
Chromium (Cr)	ND	ND	ND	ND	0.5
Iron (Fe)	23.94 ± 1.54	26.98 ± 4.38	27.24 ± 4.08	30.71 ± 3.72	48
Mercury (Hg)	ND	ND	ND	ND	0.001
Lead (Pb)	0.01 ± 0.00	ND	0.02 ± 0.01	0.02 ± 0.01	0.20
Vanadium (V)	0.07 ± 0.00	ND	0.02 ± 0.01	0.01 ± 0.00	0.001 (USEPA)
Zinc (Z)	0.74 ± 0.05	0.85 ± 0.17	1.15 ± 0.07	0.84 ± 0.09	60.0

ND: Not detected

3.2 Concentrations of heavy metals in suya meat

The results of the concentrations of eight (8) selected heavy metals of interest in *suya* meat from the four sample spots are presented in Table 2. Of the metals, Fe is the most abundant in the *suya* meat from the four (4) sampling spots. The Fe concentration in the *suya* meat was highest in Giri sampling spot with value of 41.14 ± 1.57 compared to Iddo, Main campus and Mini campus sampling spots with values of 40.31 ± 0.21, 36.48 ± 0.92 and 33.83 ± 3.15 respectively (Table 2). However, these values obtained from *suya* meat from the four sampling spots although higher than what was obtained in raw meat were below the maximum permissible limit for heavy metals in meat approved by World Health Organization.

Zinc was the next in terms of abundance followed by chromium and lead (Table 2). For zinc, the highest concentration in *suya* meat was seen in Giri (6.88 ± 0.17) followed by Iddo (5.91 ± 0.15), Mini campus (5.82 ± 0.80) and Main campus (5.27 ± 0.15) respectively. For chromium, the highest concentration in *suya* meat was seen in Main campus (1.24 ± 0.20) followed by Iddo (1.13 ± 0.07), Giri (0.61 ± 0.27) and Mini campus (0.05 ± 0.00) respectively. For lead concentration in *suya* meat, Iddo had the highest concentration (1.04 ± 0.03) followed by Mini campus (0.89 ± 0.16), Giri (0.42 ± 0.21) and Main campus (0.09 ± 0.01) respectively. Whereas the value obtained for zinc in these four sampling spots were below the maximum permissible limit, the values obtained for chromium and lead were above the maximum permissible limit for these heavy metals in meat as approved by World Health Organization (Table 2).

Also, values obtained for cadmium, arsenic, vanadium and mercury were above the maximum permissible limit for these heavy metals in meat as approved by World Health Organization (cadmium, arsenic and mercury) and United State Environmental Protection Agency (vanadium) for the four sampling spots (excepting mercury in Mini campus and Iddo sample spots) (Table 2). Speaking in terms of concentrations seen in samples spots, for cadmium, Main campus had the highest concentration (0.19 ± 0.01) followed by Mini campus (0.18 ± 0.01), Iddo (0.17 ± 0.11) and Giri (0.14 ± 0.02) respectively. For arsenic, Main campus and Giri had the highest and equal concentration (0.07 ± 0.0) followed by Iddo (0.06 ± 0.01) and Mini campus (0.04 ± 0.01). For vanadium, approximately equal and highest concentration were seen in Iddo and Giri (0.05 ± 0.01 and 0.05 ± 0.00 respectively) and lower and equal concentrations were reported for Main campus and Mini campus ((0.03 ± 0.00). Lastly, mercury had its highest concentration (0.04 ± 0.00) in Main campus *suya* meat sample spot and a lower concentration (0.01 ± 0.00) in Giri *suya* meat sample spot. The concentration of mercury in *suya* meat samples were below detectable limit (not detected) in Mini campus and Iddo sample spots.

Table 2. Heavy metals concentrations (mg/kg) in *suya* samples from major*suya* spot in Universityof Abujamaincampus, mini campus, Iddo and Giri.

Heavy metals	Main campus	Mini campus	Iddo	Giri	Maximum Permissible limit (WHO)
Arsenic (Ar)	0.07 ± 0.00	0.04 ± 0.01	0.06 ± 0.01	0.07 ± 0.00	0.01
Cadmium (Cd)	0.19 ± 0.01	0.18 ± 0.01	0.17 ± 0.01	0.14 ± 0.02	0.005
Chromium (Cr)	1.24 ± 0.20	0.05 ± 0.00	1.13 ± 0.07	0.61 ± 0.27	0.5
Iron (Fe)	36.48 ± 0.92	33.83 ± 3.15	40.31± 0.21	41.14± 1.57	48
Mercury (Hg)	0.04 ± 0.00	ND	ND	0.01 ± 0.00	0.001
Lead (Pb)	0.09 ± 0.01	0.89 ± 0.16	1.04 ± 0.03	0.42 ± 0.21	0.20
Vanadium (V)	0.03 ± 0.00	0.03 ± 0.00	0.05 ± 0.01	0.05 ± 0.00	0.001 (USEPA)
Zinc (Z)	5.27 ± 0.15	5.82 ± 0.80	5.91 ± 0.15	6.88 ± 0.17	60.0

ND: not detected

4. Discussion

This study investigates the level of heavy metals in raw and *suya* meat, as food safety implications in the University of Abuja campuses and its environs. Of-note, the risks for human health derived from heavy metals exposure is of great concern (Usende *et al.,* 2017). Consequently, interest have recently increased in accessing the heavy metal concentration in Ready- to- eat street foods including *suya* meat in Nigeria (Adeyeye and Ashaolu, 2022; Oyet and Samuel, 2020). However, this is the first study to focus on the campuses of the University of Abuja and its immediate environs, Iddo and Giri, known communities populated by the University's staff and students.

Interestingly, the study showed that raw meat sampled from the four sampling spots (Main campus, Mini campus, Iddo and Giri) do not pose a health risk due to exposure to heavy metals to the human populations living in these places as the level of these heavy metals (except vanadium) detected were not detectable or very low below the maximum permissible limits approved by World Health Organization (WHO, 2006). Specifically, this present study has shown that arsenic, cadmium, chromium and mercury concentrations were not detectable in the raw meat sampled from the four study spots and that the concentrations of lead, iron and zinc were low below the maximum permissible limits. This findings of undetectable levels of arsenic and cadmium in sampled raw meat corroborate well with the findings of Korish and Attia (2020) in raw meat and and meat products sampled from Jeddah City, Saudi Arabia, but differs from recent report of Adjei *et al.* (2023). In their report (Adjei et al., 2023), high level of these heavy metals were seen in raw meat, liver and kidney of cattle sampled from three regions of Ghana (Ashaiman, Madina and Makola). Also, Korish and Attia (2020) showed undetectable levels of lead and a low level of chromium and zinc, below maximum limit in raw meat and meat products sampled from Jeddah City, Saudi Arabia, similar to our present report. The similarity of the finding of this present results to that of Korish and Attia (2020), as well as the difference as reported by Adjei *et al.* (2023) can be attributed to the type of animal husbandry and the nutritional content of feed fed to these animals (Khan et al., 2016). It can be concluded that the absence of significant heavy metal contamination in raw meat sampled from all spots in this study provides reassurance for consumers, underscoring the importance of procuring meat from reliable and regulated suppliers (Johnson-Hall, 2017).

In contrast to the raw meat and surprisingly, this findings reported that except for iron and zinc, the concentrations of heavy metals (arsenic, cadmium, chromium, mercury, lead and vanadium) in *suya* meat sampled from the four sample spots showed higher values above the maximum permissible limits, that may raise concerns about potential health hazards to both students and staff of the University of Abuja and its environs (Giri and Iddo). With this findings, it is predicted that the processes that transform these raw meats to *suya* is highly implicated causing the accumulation of these contaminants. These processes include; washing of meat with water, addition of spices and roasting on iron rods with direct open flame. Heavy metals are naturally occurring in the atmosphere and soil which gets washed to water bodies thus contaminate the water (Usende *et al.,* 2024). Spices may harbor various heavy metals contingent upon the soil in which they were cultivated and the consequent interactions with meat might also augment the accumulation of these metals within the *suya* meat.

While the maximum permissible limit for arsenic is 0.01 mg/kg we reported a seven folds increase (0.07 mg/kg) of this metal (arsenic) in *suya* meat sampled from from Main campus and Giri, a six folds (0.06 mg/kg) increase in *suya* meat sampled from Iddo and a four folds (0.04 mg/kg) increase in *suya* meat sampled from Mini campus. Our data corroborate well with the report of Adeyeye and Ashaolu, (2022) who showed the concentration of arsenic in *suya* meat sampled from Abeokuta, Akure and Osogbo to be about 0.07mg/kg while those sampled from Ado-Ekiti and Ibadan had this metal concentration of 0.08 mg/kg, slightly higher than our current report. Similarly increased arsenic concentration have been reported in *suya* meat sampled from different locations in Ghana (Adjei *et al.,* 2023). Arsenic toxicity has become a global health problem affecting many millions of people (Ratnaike, 2003) due to its contamination of drinking water (a possible source for this present study) and food chain from natural geological sources and from smelting, mining, or agricultural sources such as pesticides and fertilisers (Matschullat, 2000).

Cadmium is known to be ubiquitous but is non-essential metal (Asagba and Eriyamremu 2007; Usende *et al.,* 2017). Exposure to cadmium as shown in this present study from *suya* meat sampled from the four study areas having values higher that the maximum permissible limit is known to induce toxicity symptoms of varying degrees in exposed population (Asagba and Eriyamremu 2007). Similar pattern of increased cadmium concentration has been reported in *suya* meat sampled from other parts of Nigeria and in Ghana (Adeyeye and Ashaolu, 2022; Oyet and Samuel, 2020; Adjei *et al.,* 2023). The increase of this metal in the *suya* meat will lead to increase bioaccumation in the biological system and it has been reported to accumulate more in the liver and kidney causing their damage in exposed individual (Asagba and Eriyamremu 2007; Usende *et al.,* 2017).
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We have also shown herein that the concentration of chromium in *suya* meat sampled from Main campus and Iddo is above two folds increase when compared to the maximum permissible limit, indicating a potential health risk associated with the consumption of *suya* products from these areas. Similar findings have been reported by Adeyeye and Ashaolu, (2022), Oyet and Samuel, (2020), and Adjei *et al.* (2023). The major route for chromium exposure is via contaminated water (Shekhawat *et al.,* 2015). We therefore linked the high concentration of chromium in these studied area to the source of water used in the preparation of the *suya* meat. Of note, in human studies, oral exposure to chromium has been linked to indigestion, ulcers, acute necrosis, abdominal pains, vomiting, kidney failure and eventually death (Beaumount et al., 2008; Shekhawat *et al.,* 2015). Furthermore, the present findings showed that mercury concentration was increased more than one hundred folds in Main campus (0.04 mg/kg) and Giri (0.01 mg/kg) sampled areas compared to the 0.001 mg/kg maximum permissible limits approved by World Health Organization (WHO, 2006). Mercury is a known neurotoxicant and can affect renal, immune, endocrine and muscular functions (Bernhoft, 2012). Continuous exposure to this heavy metal by people living in the Main campus and Giri study areas to this metal via consumption of contaminated *suya* meat therefore pose a great health risk.

Lead is a known heavy metal pollutant in the ecosystem and is sequestrated predominately in the blood, bones, and other soft tissues (Dabrowska-Bouta *et al.* 2008; Usende *et al.,* 2017). Once ingested (as will eventually happened as the *suya* meat will be consumed), lead has a half-life of nearly 25 years and is gradually released based on physiological or pathological conditions of the body into the blood stream (Silbergeld 1991; Juberg e*t al.,* 1997), making the problem of lead toxicity of major concern. Lead exposure has been linked with many clinical conditions, with neurological deficits inclusive (Dabrowska-Bouta *et al.,* 2008; Usende *et al.,* 2017) which may be a risk concerns for those living in this present study areas and consumed these *suya* meat with high level of lead. *Suya* meat collected from all areas of this study like the raw meat has more than 100 fold increase in vanadium concentration compared to the maximum permissible limit by USEPA. This could be consequent upon the increase in industrial activities leading to environmental contamination with this heavy metal (Usende *et al.* 2016, 2017; Olopade and Connor 2011). Several studies have shown that exposure to vanadium causes upper respiratory tract inflammation and gastrointestinal disturbances (Barceloux 1999; Shrivastava *et al.,* 2007), neurotoxicity (Usende *et al.*, 2017, 2022a), as well as cardiovascular diseases (Haider *et al.,* 1998) and reproductive toxicity (Usende *et al.,* 2022b). Also, necrosis of hepatocytes of the liver and seminiferrous tubules of the testis, as well as the kidney proximal convoluted tubules have also been associated with vanadium toxicity (Usende *et al.,* 2020). These could be health challenges faced by humans living in this area and constantly consumed meat (including *suya* meat) processed in these areas, therefore calling for quick environmental cleanup and remediation.

In conclusion, the present findings have revealed that *suya* meat sold in the Main campus and Mini campus of the University of Abuja and its environ (Iddo and Giri) are potential health risk for people leaving and consuming these products in these area. Specifically, although the raw meat appeared relatively safe, the *suya* meat from these areas has considerably high level of heavy metals above the maximum permissible safety limit and are considered potential public health hazards. These findings therefore show it is important to scrutinize not only raw materials but also the entire food preparation chain. Continuous monitoring, awareness campaigns, and regulatory measures are indispensable in safeguarding public health and ensuring the safety of popular foods like *suya* meat.

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Competing Interests

The authors have no financial or non-financial interests to disclose.

Author Contributions

All authors contributed to study design and conception. Material preparation, data collection and analysis were performed by Isa Adam Olamide, Okunlola Basit Oyebanji, Mobolaji Abdulateef Ayoola and Usende Ifukibot Levi. The first draft of the manuscript was written by Isa Adam Olamide, Okunlola Basit Oyebanji and Usende Ifukibot Levi and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript. Funding was acquired by Isa Adam Olamide and and Okunlola Basit Oyebanji.

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