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Assessment of Heavy Metals Safety in Barbecued Meat Samples Sold in Wudil, Kano State, Nigeria

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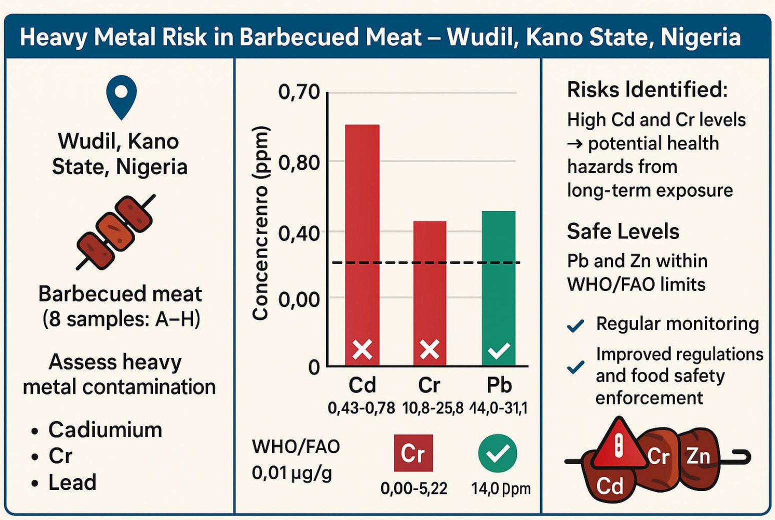
Abstract

This study evaluated the concentrations of Cadmium (Cd), Chromium (Cr), Lead (Pb), and Zinc (Zn) in barbecued meat samples sold in Wudil, comparing the results with World Health Organization (WHO) and Food and Agriculture Organization (FAO) safety standards. Eight samples (A-H) were analyzed using standard laboratory procedures, and the concentrations of these metals were measured in parts per million (ppm). The mean concentrations of Cd ranged from 0.43 to 0.78 ppm, with all samples exceeding the WHO permissible limit of 1.00 µg/g. For Cr, levels varied between 10.84 and 25.84 ppm, surpassing the WHO/FAO guideline of 1.00 µg/g, raising concerns about potential health risks from prolonged exposure. Lead concentrations were notably below the maximum allowable limit of 6.00 µg/g, ranging from 0.00 to 5.22 ppm. Zinc, an essential trace element, was present in all samples at concentrations between 14.09 and 31.21 ppm, within the permissible limits of 50.00 µg/g. Overall, the findings reveal varying levels of heavy metal contamination in barbecued meat samples sold in Wudil, with Chromium and Cadmium levels posing a potential risk to public health. Continuous monitoring and regulatory interventions are recommended to ensure the safety of consumers of these meat products.

Graphical Abstract



Keywords:

Heavy metals;
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Introduction

The increasing consumption of barbecued meat, a popular delicacy in Wudil, Kano State, Nigeria, necessitates an assessment of its safety, particularly regarding heavy metal contamination. In Nigeria, barbecuing is practiced in various styles, and its popularity is growing in both rural and urban areas. Known as "Tsire" in Hausa, "Asuun" in Yoruba, and commonly referred to as Suya, there is an increasing need to continuously monitor the quality and safety of the meat sold to consumers to ensure it is safe for consumption and to enhance food security. Goats, sheep, and beef, including liver and kidney, are major sources of protein for Nigerians, playing a crucial role in promoting growth and health. Meat, which is primarily composed of protein, fat, and essential nutrients, is vital for maintaining good health. However, contamination from heavy metals poses a significant risk, as these metals accumulate in tissues and can have toxic effects (Baykov, 1996). In Southeastern Nigeria, food is often prepared by roasting or smoking over wood, and the ashes from this process have been found to contain high concentrations of heavy metals and polycyclic aromatic hydrocarbons (PAH). People from all social classes widely consume these foods for their nutritional value and accessibility, as they are sold at road junctions and food centers. The global demand for meat has risen, and the consumption of various types of meat can have both health and environmental impacts. Meat provides essential nutrients like protein, iron, zinc, and vitamin B12, though these nutrients can also be obtained from a varied diet that excludes meat (Adam et al., 2024). Meat's nutritional composition is influenced by the type of animal and its diet. The need for minerals depends on factors such as age, health, and living conditions (Baykov, 1996).

Heavy metal contamination poses a serious issue due to its toxicity, bioaccumulation, and magnification in the food chain (Demirezen & Uruc, 2006). Although completely avoiding toxic metal contamination in animal feed is challenging, efforts must be made to minimize it to protect both animal and human health (SCAN, 2003). Even low levels of heavy metal exposure can disrupt trace element metabolism (Goyer, 1997; López-Alonso 2002), and documented contamination cases during meat processing and from polluted environments have been reported (Santhi 2008; Miranda 2005). Heavy metals are metallic chemical elements with high density that become toxic or poisonous when present in large concentrations. These metals occur naturally in the earth's crust and cannot be broken down or destroyed. In trace amounts, some heavy metals, such as copper, selenium, and zinc, are essential for maintaining the body's metabolism. However, at elevated levels, they can lead to poisoning (Ahmad et al., 2024). Airborne heavy metal contamination is a significant environmental issue, posing serious threats to both human health and ecosystems. Industries involved in metal processing, such as mining, smelting, refining, and manufacturing, play a key role in releasing heavy metals into the atmosphere. These metals, including lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As), persist in the environment and accumulate, creating long-term health risks (Oluwasanmi et al., 2024). Once airborne, heavy metals can travel over vast distances depending on their particle size, chemical form, and weather conditions. In terms of human exposure, cadmium is most commonly ingested through food, water, and cigarette smoke. Consuming food or drinking water with high levels of cadmium can irritate the stomach, leading to vomiting and diarrhea. Environmental pollution tends to be more severe in low- and middle-income countries than in developed nations, likely due to poverty, weak legislation, and a lack of awareness about pollution. Unfortunately, people who are unaware of the different types of pollution may unknowingly engage in practices that release harmful byproducts into the environment, exceeding the ecosystem's ability to neutralize them (Abubakar et al., 2024).

Method

Sample Collection

Fresh samples of barbecued meat were collected from eight locations within the Wudil local government area, Kano State, Nigeria, on the same day using filter paper and labeled as samples (A, B, C, D, E, F, G, and H).

Material

Fresh barbecued meat, Sulphuric acid (H_2SO_4), Perchloric acid ($HClO_4$) (Sigma Aldrich), and Distilled water.

Sample Preparation

The samples were dried for two weeks at room temperature and ground using a porcelain pestle and mortar. The grounded samples were then transferred into sampling bottles (coded from A to H) and taken to the laboratory for analysis.

Digestion Method

A 0.2 g portion of each sample was weighed into a micro-Kjeldahl digestion flask, followed by a mixture of concentrated HNO_3, $HClO_4$, and H_2SO_4. The flask was digested on a heating block until a clear solution was obtained. After cooling, the contents were transferred into a volumetric flask and diluted to the volume mark with distilled water (Sahrawat, 2002). The solution was then allowed to cool to room temperature and filtered using Whatman No. 42 filter paper. The filtrate was further diluted with 50 cm^3 of distilled water in a conical flask, and the solutions were stored in polythene bottles until analysis (Adegbola, 2013; Yusuf 2002). The concentrations of four heavy metals—zinc (Zn), cadmium (Cd), chromium (Cr), and lead (Pb)—were subsequently determined using Atomic Absorption Spectrophotometry (AAS).

Preparation of Stock Solutions

Lead stock solution

1 g of Pb is contained in 1000 cm^3 of solution; 207.19 g/mol of Pb is contained in 331.19 g/mol of $Pb(NO_3)_2$; 1 g of Pb will be contained in 331.19 g, which equals 1.59 g of $Pb(NO_3)_2$. The lead stock solution was prepared by dissolving 1.59 g of $Pb(NO_3)_2$ in a beaker with a small amount of distilled water. The solution was then quantitatively transferred into a 1-liter volumetric flask and diluted to the 1-liter mark with distilled water.

Cadmium stock solution

1 g of Cd is contained in 1000 cm^3 of solution; 112.40 g · mol^1 of Cd is contained in 172.40 g · mol^1 of $CdCO_3$; 1 g of Cd will be contained in 172.40 g of $CdCO_3$, which equals 1.53 g of $CdCO_3$. The cadmium stock solution was prepared by dissolving 1.5338 g of $CdCO_3$ in a beaker with a minimal amount of distilled water. The solution was then quantitatively transferred to a 1-liter volumetric flask and diluted to the 1-liter mark with distilled water.

Zinc stock solution

1g of Zn is contained in 1000 cm^3 of solution; 65.38 mol^{-1} of Zn is contained in 65.38 g mol^{-1} of Zn powder; 1g of Zn will be contained in 65.38 = 1.0g of Zn powder. The zinc stock solution was prepared by dissolving 1.0 g of zinc powder in a beaker with a small amount of distilled water. The solution was then quantitatively transferred into a 1-liter volumetric flask and diluted to the 1-liter mark with distilled water.

Results & Discussion

The analysis of heavy metals in barbecued meat samples revealed varying concentrations of cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn), compared to the World Health Organization (WHO) and Food and Agriculture Organization (FAO) standards. Below is a summary of the findings and their potential health implications.

Table 1. Heavy metals concentrations (ppm) in barbecued meat sold in Wudil

S/no	Samples (ppm)	Cadmium (Cd)	Chromium (Cr)	Lead (Pb)	Zinc (Zn)
1.	A	0.54	15.68	3.79	31.21
2.	B	0.43	12.41	5.22	22.15
3.	C	0.56	12.10	4.04	23.75
4.	D	0.52	10.84	1.26	14.09
5.	E	0.65	25.84	0.75	17.05
6.	F	0.66	15.79	0.00	14.62
7.	G	0.66	16.24	1.02	21.38
8.	H	0.78	13.34	1.39	22.56

The analysis of heavy metals in barbecued meat samples revealed varying concentrations of cadmium (Cd), chromium (Cr), lead (Pb), and zinc (Zn), compared to the World Health Organization (WHO) and Food and Agriculture Organization (FAO) standards. Below is a summary of the findings and their potential health implications. Cadmium levels in the samples ranged from 1.10 ± 0.20 µg/g to 2.10 ± 0.30 µg/g, with sample H containing the highest concentration and sample B the lowest. The WHO/FAO limit for cadmium is 1.00 µg/g, and all samples except B exceeded this threshold. Cadmium is a highly toxic metal, and chronic exposure can lead to severe health problems such as kidney damage, skeletal disorders, and cancer. Since cadmium accumulates mainly in the kidneys, prolonged exposure increases the risk of renal dysfunction and osteoporosis. Therefore, the elevated cadmium levels in these samples pose a significant health risk to frequent consumers.

Table 2. Concentration (μg/g) of the barbecued meat compared to the World Health Organization (WHO) standard.

Samples mean ± SD (μg/g)	Cadmium (Cd)	Chromium (Cr)	Lead (Pb)	Zinc (Zn)
A	1.40±0.20	3.10±1.40	1.00±0.30	70.00±0.0000
B	1.10±0.20	2.50±0.70	1.30±0.10	49.70±0.60
C	1.50±0.50	2.40±1.90	1.00±0.40	53.30±0.40
D	1.40±0.20	2.20±1.10	0.30±0.20	31.60±0.30
E	1.70±0.40	5.10±0.90	0.20±0.30	38.20±0.60
F	1.80±0.40	3.10±0.30	-0.10±0.40	26.20±0.60
G	1.80±0.30	3.20±1.70	0.20±0.30	47.90±0.10
H	2.10±0.30	2.60±1.10	0.30±0.30	50.60±0.20
WHO (2005)/ FAO (2001)	1.00	1.00	6.00	50.00

Chromium levels ranged from 2.20 ± 1.10 μg/g to 5.10 ± 0.90 μg/g, with sample E having the highest concentration. The WHO/FAO limit for chromium is 1.00 μg/g, meaning all samples surpassed the recommended limit. Chromium, particularly in its hexavalent form (Cr VI), is highly toxic and a known carcinogen. Prolonged exposure to high levels of chromium can damage the respiratory, gastrointestinal, and immune systems and increase the risk of reproductive and developmental issues. The elevated chromium levels, particularly if in hexavalent form, raise serious concerns about long-term health effects, including cancer.

Lead concentrations ranged from -0.10 ± 0.40 μg/g to 1.30 ± 0.10 μg/g, with sample B showing the highest level. Although the WHO/FAO limit for lead is 6.00 μg/g, and all samples were below this threshold, lead is still highly toxic even at low levels. Chronic exposure to lead can cause neurological, cognitive, and behavioral issues, particularly in children. In adults, it can lead to cardiovascular disease, kidney damage, and reproductive problems. Despite the levels being below the limit, any detectable lead is concerning due to its cumulative toxic effects.

Zinc levels in the samples ranged from 26.20 ± 0.60 μg/g to 70.00 ± 0.00 μg/g, with sample A having the highest concentration. The WHO/FAO limit for zinc is 50.00 μg/g, and samples A, B, C, G, and H exceeded this limit. Zinc is essential for many physiological functions, including the immune response and wound healing. However, excessive zinc intake can lead to gastrointestinal issues and interfere with copper absorption. Long-term overconsumption of high-zinc meat may result in zinc toxicity if dietary intake is unbalanced.

The above analysis shows that cadmium and chromium levels in these barbecued meat samples exceed WHO/FAO standards, posing significant health risks. Cadmium's link to kidney damage and skeletal issues, along with chromium's carcinogenic properties, are particularly alarming. Although lead levels are below the permissible limit, their presence is still concerning, especially for vulnerable groups like children. Zinc, while essential, exceeded safe levels in several samples, and long-term excessive intake could result in zinc toxicity.

Conclusion

The findings highlight that cadmium and chromium levels in the analyzed barbecued meat samples exceed WHO and FAO safety limits, posing substantial health risks to consumers. The elevated cadmium levels are particularly concerning due to their potential to cause kidney damage and bone disorders, while chromium's carcinogenic potential, especially in its hexavalent form, is equally alarming. Although lead levels remain below recommended limits, detecting even trace amounts is worrying because of its toxicity. While beneficial in moderation, zinc was found in excess in multiple samples, raising concerns about the risks of overconsumption.

Recommendations

Continuous Monitoring of Heavy Metals in Food: Regular testing of food products for cadmium, chromium, lead, and other heavy metals must be implemented to ensure that contamination levels stay below safe limits and to prevent long-term health risks. Stricter Enforcement of Food Safety Regulations. Regulatory bodies should enforce stricter guidelines for food safety, particularly to reduce heavy metal contamination from industrial and agricultural sources. Inspections should occur regularly to ensure compliance. Public Education on Heavy Metal Exposure: Consumers should be informed about the risks of heavy metals in food and how to minimize exposure by selecting food from low-risk sources and balancing zinc intake to prevent toxicity.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this paper.

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