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Evaluation of Heavy Metals in Singed Edible Cattle Hides (Ponmo) from Yobe North, Nigeria

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ABSTRACT
Edible singed cattle hide (ponmo), a beef delicacy highly valued in Nigeria and across West Africa, is traditionally prepared through singeing with discarded tyres, synthetic polymers, petroleum-derived fuels, and fuelwood, a process that facilitates the deposition of hazardous toxicants into the meat. This study assessed lead (Pb), cadmium (Cd), chromium (Cr), arsenic (As), and mercury (Hg) concentrations in cattle hides from six Yobe North markets. Atomic absorption spectrophotometry revealed hazardous levels: Pb (up to 3.40 mg/kg) exceeded WHO (0.1 mg/kg) and NAFDAC (2.0 mg/kg) limits; Cd (0.57–1.10 mg/kg) was above WHO (0.05 mg/kg) and NAFDAC (0.2 mg/kg) limits; Cr (up to 5.10 mg/kg) surpassed the 2.0 mg/kg limit; and As (up to 0.73 mg/kg) exceeded both WHO (0.1 mg/kg) and NAFDAC (0.5 mg/kg) standards. Hg levels (7.9–16.0 µg/kg) remained within permissible thresholds. The findings highlight potential public health risks and call for regulatory enforcement, safer dehairing methods, market surveillance, and consumer awareness to reduce exposure.

Keywords:
Food safety,
Heavy metals,
Cattle hides, Beef,
Public health.

INTRODUCTION

Heavy metals remain a significant source of health concern for humans and other living organisms. These metals are largely non-biodegradable, as they persist in the environment, bioaccumulate, biomagnify, and sustain their presence in the food chain for considerable periods of time (Renuka & Patyal, 2025). Many of these substances have been characterized as carcinogenic, teratogenic, and generally toxic to living systems (Bwala *et al.*, 2023; Parida & Patel, 2023; Kankara *et al.*, 2021).

The accumulation of heavy metals may occur in plants through residual pesticides, herbicides, and other agrochemicals, or in animals through contaminated water and food, originating from both anthropogenic and natural sources (Suleiman & Ibrahim, 2025; Angon *et al.*, 2024; Ibrahim *et al.*, 2024). Meat, in particular, has been reported to serve as a favourable matrix for heavy metal, Polycyclic aromatic hydrocarbon and other toxic chemicals accumulation due to the presence of fat, which stores these chemicals in adipose tissues (Benjamin *et al.*, 2023; Sani *et al.*, 2023; Zungum & Imam, 2021). This facilitates their buildup over time, ultimately posing toxicological risks to consumers.

Singeing of edible hide meat, a common practice in sub-Saharan Africa and among African enclaves in European countries, involves dehairing animal carcasses such as cattle with the intent of enhancing flavour and preserving longstanding cultural traditions The delicacies are prepared from the head, legs, tails, and body hide of cattle, camel goat, sheep, and bushmeat. (Ahmad *et al.*, 2021; Zungum *et al.*, 2020). However, this process often involves the use of fuels such as rubber, petroleum, and petroleum-derived substances, which introduce harmful contaminants, including polycyclic aromatic hydrocarbons (PAHs) and heavy metals, into the meat (H. A. Ibrahim *et al.*, 2023; Sani *et al.*, 2023). This raises additional food safety concerns.

Heavy metals such as Arsenic (As), Lead (Pd), Mercury (Hg), Cadmium (Cd), Chromium (Cr) even in small quantities could interrupt several biochemical processes in human, pose health risk, and rises to chronic diseases and like cancer,

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deformity, damage to central nervous systems and neurological disorder (Emurotu *et al.,* 2024). According to the international agency for research on cancer (IARC), Arsenic, Cadmium, and Chromium are classified in group1 carcinogens, indicting sufficient evidence of human carcinogenicity. Lead on another hand is classified as possible human carcinogen group 2B, whereas, Mercury although highly toxic, is not categories as carcinogen (group 3) (IARC, 2025).

In addition, other previous research has established the extensive toxicity profile of these heavy metals in miniature and large quantity such that Lead and Cadmium were observed to cause cardiovascular diseases, kidney dysfunction, anaemia, mutation, neurological disorders, hypertension, prostate diseases, immunosuppression, skeletal damage and bone disorder in human (Balali-Mood *et al.,* 2021; Haidar *et al.,* 2023; Rasin *et al.,* 2025). Additionally, Lead exerts teratogenic consequence on foetus whose pregnant mothers ingest it. Also, infant that excessively consumes Lead faces extensive challenge with biosynthesis of hormonal vitamin D process leading to calcium metabolism as it relates to the healthy bone (Emurotu *et al.,* 2024). These effects equally, culminate to chronic and permanent disorders in both adult and specially children whose developmental process could be altered due to the teratogenic effect of resultant mother's ingestion of heavy metals.

Lately, research has been reporting substantial astronomical disease rise in Yobe with unexplainable cause, most notably, Yobe North where kidney and liver related illness has resulted in mortality rise (Babagana Kyari *et al.,* 2022; Goni *et al.,* 2024; Sulaiman *et al.,* 2024). Yobe North, as an agricultural hub, for fish, farm produce and animal husbandry such as cattle, goat, sheep and camel that is sustained by the Kamodugu river catchment linked to wetland that is a resting sink for heavy metals and other toxins (Zungum *et al.,* 2019). Therefore, requires intervention research to unravel the various causative factors leading to the incessant health challenge and mortality risks.

MATERIALS AND METHODS

Study Area

Yobe North (Zone C) comprises six local government areas: Bade (219,800), Nguru (236,900), Jakusko (365,500), Karasuwa (165,000), Machina (95,900), and Yusufari (174,100), totaling 1,258,100. Collectively, they constitute one of the 3 geopolitical zones of Yobe State. Most of which are located along the Kumodugu-Yobe River catchment and, by extension, the Hadejia-Nguru wetland (Zungum *et al.,* 2019). The area is within the Sahel belt on longitude 12.875" N, with a mostly dry and hot season, and borders Niger Republic's Diifa and Zinder to the North and Jigawa, and Bauchi to the West (Ali *et al.,* 2016).

Table 1: Sampling Station

Sampling	Location	Coordinate of GPS	Samples
A	Machina Main Market	13° 08' 11.00" N, 10° 02' 57.26"E	Singed edible hides (beef)
B	Yusufari Main Market	13° 04' 3.60" N, 11° 10' 19.80"E	Singed edible hides (beef)
C	Jakusko Main Market	12° 22' 5.39"N, 10° 46' 13.79"E	Singed edible hides (beef)
D	Jajimaji Main Market	12° 53' 56.42"N, 10° 48' 12.08"E	Singed edible hides (beef)
E	Gashua Main Market	12° 52' 26.33"N, 11° 02' 26.05"E	Singed edible hides (beef) and non-singed hides
F	Nguru Main Market	12° 52' 37.02" N, 10° 27' 19.30" E	Singed edible hides (beef)

Sample Collection

The singed and non-singed (control) edible cattle hide samples were randomly procured in triplicate from January to April. Taking from each of the following locations: Machina Main Market, Yusufari Main Market, Jakusko Main Market, Jajimaji Main Market, Gashua Main Market, and Nguru Main Market. The samples were collected from freshly singed cattle heads, and the control from freshly slaughtered cattle. Taking slices from the neck region after it was put on display on the sales desk.

The samples were stored in an ice-cooled cooler after being carefully placed in labelled plastic containers and wrapped in foil paper. The samples were handled with great care to avoid contamination using hand gloves and face masks throughout the exercise. The samples were conveyed to the chemistry laboratory at Yobe State University, Damaturu, on the same day and were stored prior to analysis. Subsequently, the samples were extracted and analysed.

Sample Preparation

The singed and non-singed (control) edible hides were oven-dried at 105°C for 144 hours, for about 6 days, to remove moisture (Bwala *et al.,* 2023). The dried samples were blended into powder using a stainless-steel blender (Series 330 Kenwood electric blender) (Kingsley *et al.,* 2023). The powdered samples were stored in well-labelled airtight containers for the subsequent digestion process.

Digestion Process

The powdered samples (2 each) were subjected to extraction with concentrated nitric acid and hydrogen peroxide (2:1) v/v. The samples were inserted into the tube of the digester, and HNO3 (65%) and H2O2 (30%) (2:1) were added for the reaction to proceed prior to

mounting on the digestion chamber (Bwala *et al.*, 2023). Afterward, mounted onto the digestion chamber for 2 – 3 hours and reduced to about 4 – 5mL. The digested sample was then allowed to cool, filtered, and topped up with deionized water, and marked for the heavy metal analysis (Bwala *et al.*, 2023).

Analysis For Heavy Metals

The digested beef samples of both singed and non-singed (control) were subjected to analysis for heavy metals: Lead, Cadmium, Chromium, Arsenic, and Mercury in application of Atomic Absorption Spectrometer (AAS) with the model details of Buck Scientific Model 210 VGP in the laboratory of chemistry department of Yobe State University Damaturu, Nigeria.

Statistical Analysis

The data obtained from the analysis were recorded in triplicate and expressed as mean and standard deviation. The data was subjected to statistical analysis using R software (version 4.2.1). All results were tabulated using Microsoft Excel 2019, and simple descriptive statistics were used for data display.

Quality Control

The recovery analysis of the metal samples was 97±7%, which indicates a desirable recovery and reliable results. In addition, the relative standard deviation was less than 10% showing good precision as well.

RESULTS AND DISCUSSION

Heavy Metal Concentrations Across Sampling Stations

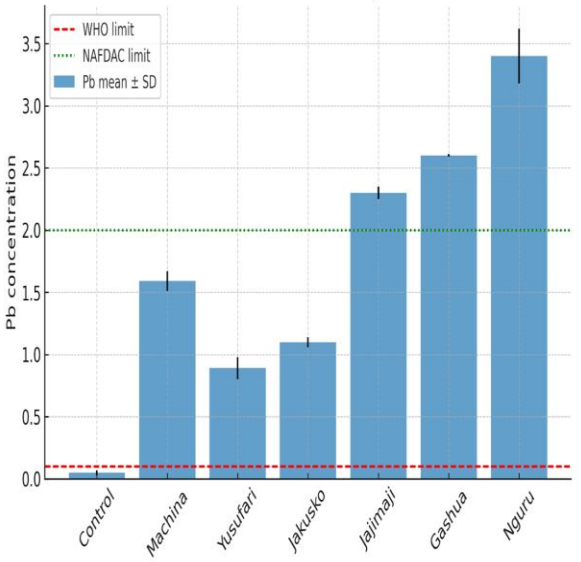
All the heavy metals were measured in mg/kg, with the exception of Hg, which was quantified in µg/kg due to its low detection levels.

The mean concentrations (±SD) of Pb, Cd, Cr, As, and Hg in singed cattle hides from different markets in Yobe North of Yobe State are presented in Figures 1 to 5. Overall, market samples showed substantially higher concentrations of all measured heavy metals compared to the control, except in the case of mercury, which is significantly lower in all cases.

ANOVA and Post-hoc Analysis

One-way ANOVA revealed highly significant differences ($p < 0.001$) among sampling stations for most of the analyzed metals (Pb, Cd, Cr, and As). Tukey's post-hoc comparisons further indicated that all market samples differed significantly from the control ($p < 0.05$), except for arsenic in Yusufari, which was statistically comparable to the control. In contrast, mercury (Hg) concentrations remained consistently low across all sampling stations and did not differ significantly from the control ($p > 0.05$).

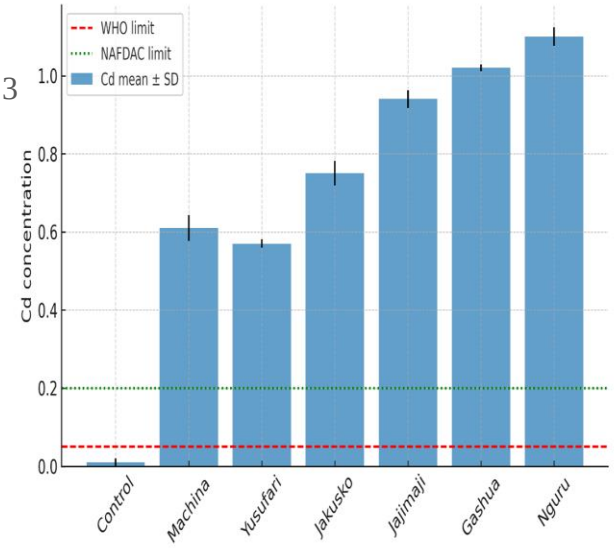
Figure 1: Lead (Pb) Across Sampling Station



Lead (Pb)

Pb concentrations ranged from 0.89 ± 0.09 mg/kg (Yusufari) to 3.40 ± 0.22 mg/kg (Nguru) compared to 0.05 ± 0.02 mg/kg (control). All market samples significantly exceeded the WHO permissible limit of 0.1 mg/kg, while Jajimaji (2.3 mg/kg), Gashua (2.6 mg/kg), and Nguru (3.4 mg/kg) also surpassed the NAFDAC standard of 2.0 mg/kg.

Figure 2: Cadmium (Cd) Across Sampling Station

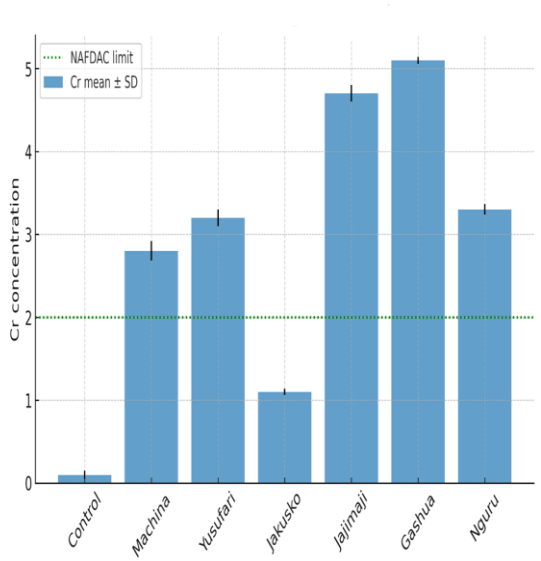


Cadmium (Cd)

Cd levels varied from 0.57 ± 0.01 mg/kg (Yusufari) to 1.10 ± 0.02 mg/kg (Nguru), all significantly higher than the control (0.01 ± 0.01 mg/kg). These concentrations were far above both the WHO (0.05 mg/kg) and NAFDAC (0.2 mg/kg) permissible limits. The highest

levels were observed in Gashua (1.02 mg/kg) and Nguru (1.10 mg/kg).

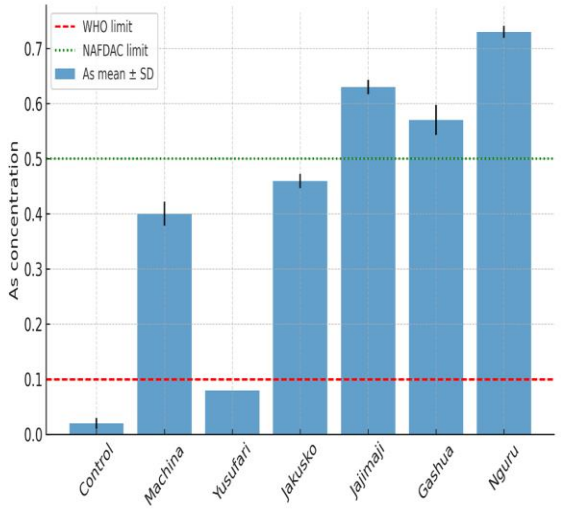
Figure 3: Chromium (Cr) Across Sampling Station



Chromium (Cr)

Cr concentrations ranged between 1.10 ± 0.04 mg/kg (Jakusko) and 5.10 ± 0.04 mg/kg (Gashua). With the exception of Jakusko, all market samples exceeded the NAFDAC guideline of 2.0 mg/kg. No WHO standard is available for comparison.

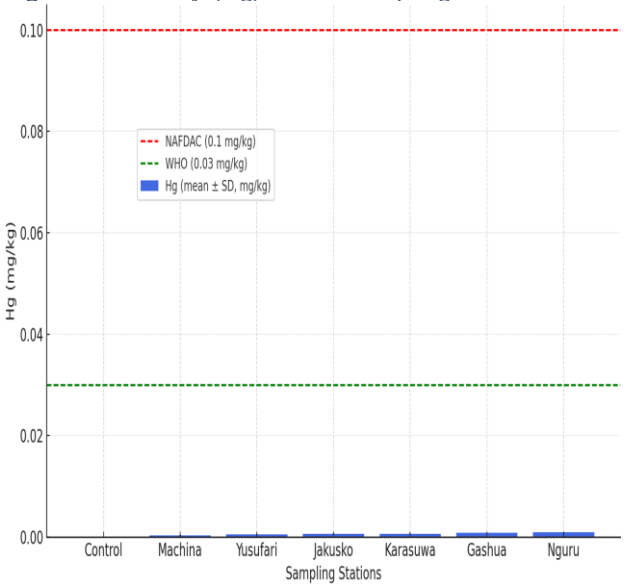
Figure 4: Arsenic (AS) Across Sampling Station



Arsenic (As)

As concentrations varied from 0.08 ± 0.00 mg/kg (Yusufari) to 0.73 ± 0.01 mg/kg (Nguru) compared to 0.02 ± 0.01 mg/kg in the control. All markets except Yusufari exceeded the WHO guideline of 0.1 mg/kg, while Jajimaji (0.63 mg/kg), Gashua (0.57 mg/kg), and Nguru (0.73 mg/kg) also surpassed the NAFDAC limit of 0.5 mg/kg.

Figure 5: Mercury (Hg) Across Sampling Station



Mercury (Hg)

Mercury (Hg) concentrations in the market samples were comparatively low, ranging from 7.9 ± 0.20 µg/kg in Yusufari to 16.0 ± 0.22 µg/kg in Nguru, with the control recording 0.50 ± 0.30 µg/kg. When benchmarked against international and national safety thresholds, all values fell within permissible limits. The WHO guideline limit (0.03 mg/kg ≈ 30 µg/kg) and the NAFDAC standard (0.1 mg/kg ≈ 100 µg/kg) were not exceeded by any of the tested samples. Thus, despite detectable levels of mercury, concentrations across all markets remained well below the maximum allowable levels, suggesting minimal public health risk from Hg exposure through these samples.

This study provides clear evidence that singed cattle hides sold in major markets of Yobe North of Yobe State are contaminated with heavy metals at levels exceeding international and national food safety standards. The presence of Pb, Cd, Cr, and As at concentrations above WHO and NAFDAC permissible limits accentuates the significant public health risks associated with the consumption of such products. Except Hg, whose limits were below both NAFDAC and WHO's thresholds.

Lead concentrations observed in this study (up to 3.40 mg/kg in Nguru) greatly exceeded the WHO permissible limit (0.1 mg/kg) and, in some markets, even surpassed the NAFDAC limit (2.0 mg/kg). Lead exposure is associated with neurotoxicity, nephrotoxicity, and teratogenic effects, especially in children and pregnant

women (Emurotu *et al.,* 2025). The detection of elevated cadmium in all markets, at levels 5–20 times higher than the WHO guideline, is also concerning, given cadmium's Group 1 carcinogenic status (IARC) and its established role in osteoporosis, and endocrine disruption and Kidney dysfunction (Gonzalez-Villalva *et al.,* 2025). Chronic kidney disease has been reported as a major public health concern and leading cause of mortality, with its etiology yet to be fully elucidated(Babagana-Kyari *et al.,* 2022; Goni *et al.,* 2025).

Chromium concentrations exceeded NAFDAC standards in nearly all markets, with the highest values found in Gashua (5.1 mg/kg). Although chromium exists in multiple oxidation states, exposure to its hexavalent form [Cr(VI)] is particularly hazardous, being a recognized human carcinogen (IARC, 2025). Arsenic contamination was similarly notable, with levels surpassing WHO limits in most markets; chronic arsenic exposure has long been linked to skin lesions, cardiovascular disease, and carcinogenesis (Rahaman *et al.,* 2021).

Mercury contamination was the most below the safety standards, with concentrations ranging from 7.9 to 16.0 µg/kg, which is several times lover than the WHO and NAFDAC standards. Mercury bioaccumulates in tissues and is strongly associated with neurodevelopmental disorders, immunotoxicity, and endocrine disruption (Charkiewicz *et al.,* 2025). Though, didn't exceed the standard threshold, still its presence strongly suggest that the singeing process, particularly when rubber or petroleum-derived products are used, is a major contributor to Hg contamination.

The singeing of hides is a traditional practice in sub-Saharan Africa, often carried out using readily available fuels such as scrap tyres, plastics, and petroleum derivatives. These materials are known to release toxic heavy metals and polycyclic aromatic hydrocarbons (PAHs) during combustion, which can permeate animal tissues and bioaccumulate over (Egwuonwu *et al.,* 2023; Sani *et al.,* 2023). The elevated levels observed in Nguru and Gashua markets may reflect greater intensity of such practices or proximity to contaminated water sources, as these areas rely heavily on the Komadugu River floodplain, which has previously been identified as a sink for agricultural and industrial pollutants (Dagari *et al.,* 2024; Zungum *et al.,* 2019).

Our findings are consistent with prior reports from Nigeria and other parts of Africa. Similar studies in Kano and Lagos observed Pb and Cd concentrations several-fold higher than international food safety limits in singed hides. However, lower than the highest obtained by the findings Pb (1.54 mg.kg -1)(Okiei *et al.,* 2009). Also, in Lokoja, 0.61 ± 0.04 was obtained, which is higher than the permissible limit yet lower than that of the finding (Ebiloma & Shaibu, 2023). Additionally, a study reported that Pb and Cd were found to exceed the maximum permissible limit (MPL) of European Commission Regulation (ECR) (Aliyu *et al.,* 2023).

Our findings are consistent with previous reports from Nigeria and other parts of Africa. Similar studies in Kano and Lagos observed Pb and Cd concentrations several times higher than international food safety limits in singed hides, although still lower than the highest levels obtained in the present study for Pb (1.54 mg/kg) (Okiei *et al.,* 2009). In Lokoja, concentrations of 0.61 ± 0.04 mg/kg were reported, which, although exceeding the permissible limit, remained lower than those found in the current study (Ebiloma & Shaibu, 2023). Furthermore, Aliyu et al. (2023) reported that Pb and Cd concentrations exceeded the maximum permissible limits (MPL) of the European Commission Regulation (ECR). In Ghana, higher concentrations than those reported here for Cd and slightly lower concentrations for Pb were recorded, with Pb at 3.17 ± 2.39 mg/kg and Cd at 3.47 ± 3.19 mg/kg (Aliyu *et al.,* 2023; Okiei *et al.,* 2009.). Other Ghanaian studies have also linked tyre-based singeing practices to elevated heavy metal residues in both meat and (Obiri-Danso *et al.,* 2008). Collectively, these results demonstrate that the problem is widespread and not restricted to Yobe State. Similar observations were reported in Lagos, where Cr (0.79 mg/kg) and As (2.85 mg/kg) were detected (Okiei *et al.,* 2009). In Ghana, studies have also linked tyre-based singeing practices to elevated heavy metal residues in both meat and hide samples.

Regular surveillance of food products sold in local markets, coupled with public health campaigns discouraging unsafe singeing practices, is critical. Safer alternatives, such as mechanical dehairing or singeing with clean fuel sources such as liquefied petroleum gas, should be promoted. In addition, intervention research is required to quantify exposure pathways, assess cumulative risk, and propose mitigation strategies for communities reliant on singed hides as a delicacy.

Limitations and Future Directions

This study focused on heavy metal residues, but the potential presence of polycyclic aromatic hydrocarbons (PAHs) and other organic contaminants was not assessed. Future studies incorporating a wider range of chemical hazards, as well as biomonitoring of exposed populations, would provide a more comprehensive risk assessment.

CONCLUSION

This study demonstrated that singed cattle hides sold across major markets in Yobe North of Yobe State are heavily contaminated with toxic metals, notably Pb, Cd, Cr, As, and Hg, at concentrations far exceeding WHO and NAFDAC permissible limits. The contamination levels observed, particularly for mercury and lead, present a

significant public health risk, especially to vulnerable groups such as children, pregnant women, and individuals with pre-existing health conditions such as kidney burden. The findings strongly implicate traditional singeing practices, especially the use of tyres, plastics, and petroleum-derived products as fuel, and contaminated water used for soaking the hides as the major contributors to heavy metal contamination.

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