Nigerian Research Journal of Chemical Sciences (ISSN: 2682-6054)
Volume 13, Issue 2, 2025

Concentration and Health Risk Assessment of Metals in Cow Meat Processed by Singeing with Scrap Tyres in Abattoirs of Warri, Nigeria

[1]Iwekumo E. Agbozu, [1]Kelechi J. Ugwu, [2]Enenwan P. Udoinyang, and *[3]Godswill O. Tesi
[1]Department of Environmental Management and Toxicology,
Federal University of Petroleum Resources, Effurun, Nigeria
[2]Department of Animal and Environmental Biology, University of Uyo, Uyo, Nigeria
[3]Department of Chemistry, Federal University of Petroleum Resources, Effurun, Nigeria
*Corresponding Author: godswillinfodesk@yahoo.com

Accepted: September 29, 2025. Published Online: October 7, 2025

ABSTRACT

This study assessed the concentrations and health risks of selected metals in cow meat singed with tyres from abattoirs in Warri and environs, Delta State, Nigeria. Samples of cow muscle, liver and skin were collected from five abattoirs, digested using a mixture of nitric and perchloric acid (6:1 v/v), and analysed using an atomic absorption spectrophotometer. The concentrations of metals (mg kg^{-1}) were as follows: Fe: 0.05–6.79; Zn: 0.05-2.11; Cu: 0.02-0.56; Cd: 0.01-0.25; Pb: 0.01-0.04 and Mn: <0.01-0.33. The metal concentrations in the cow meat were as follows: Fe > Zn > Cu > Mn > Cd > Pb. On average, the metals concentrations in the meat were in the order of liver > muscle > skin. The estimated daily intakes of metals in the meat samples were generally low and below their respective tolerable daily limit. The cow meat were generally healthy for consumption as the hazard index and total cancer risk values showed no adverse non-cancer or cancer risks associated with metals. Although there is no health risks associated with the metals in the cow meat dehaired with tyre, there is need for regulatory control of unsafe processing methods to safeguard public health in Nigeria.

Keywords: Cow, singed, liver, muscle, skin; hazard index, cancer risk

INTRODUCTION

In many Nigerian abattoirs, singeing of slaughtered cattle is still performed with readily available fuels, such as scrap tyres, because they are fast, cheap, and produce an aesthetically appealing "smoked" surface. However, tyres contain numerous additives and metal salts (e.g., Zn, Pb, Cd, Ni, Cr) that can volatilize or transfer to edible tissues during combustion, alongside carcinogenic products of incomplete combustion such as polycyclic aromatic hydrocarbons (PAHs) and dioxins [1-4].

Recent studies across West and Central Africa show that meat or hides singed with tyres consistently carry higher burdens of toxic contaminants than those processed with firewood or liquefied petroleum gas (LPG), thereby, raising concerns about dietary exposure for consumers. For instance, tyre-singed meats have been reported to exhibit significantly higher total PAHs, with benzo[a]pyrene often dominant, and levels that remain elevated even after washing compared with non-tyre fuels [5, 6].

Beyond PAHs, heavy metals are central to food-safety concerns in singed bovine products. Investigations in Nigeria on cattle and small ruminants indicate that tyre-assisted singeing can increase concentrations of Pb, Cd, Cr, Ni, Cu and Zn in hides and sometimes in underlying muscle/offal, with several reports linking measured levels to potential non-carcinogenic and carcinogenic health risks when standard exposure models are applied [7, 8]. These toxic metals can impose a serious health issue, including neurological disorders, developmental delays and increased cancer risks [9, 10].

Recent studies have also expanded the hazard profile to include dioxins, which are potent, bioaccumulative toxicants, showing significantly elevated concentrations in hides processed with tyres beyond FAO/WHO acceptable levels [1].

Warri metropolitan area and its environs in Delta State, Nigeria, within the oil-rich Niger Delta, present a particularly relevant context for such assessments. Local abattoirs operate amid documented environmental pressures [11]. A recent work reported physicochemical, microbial, and heavy-metal concerns in waters receiving abattoir wastes, thereby, underscoring plausible pathways for cross-contamination of meat during slaughter and processing [12].

Research shows that in Nigeria, metals in muscle often exceed the permissible limits set by the World Health Organization (WHO) [13]. Regionally, broader Niger Delta studies have quantified metals in commonly consumed animal products and evaluated associated health risks, further motivating location-specific measurement and risk characterization for consumers in Delta State [14].

Health risk assessment (HRA) for dietary metals typically integrates measured concentrations in edible tissues with consumption rates and toxicological benchmarks using established metrics such as Estimated Daily Intake (EDI), Target Hazard Quotient (THQ) for non-cancer effects, and lifetime Excess Cancer Risk (ECR) for carcinogens. The THQ approach, which is anchored on United States Environmental Protection Agency (USEPA) reference doses, provides a dimensionless index of potential non-carcinogenic risk (THQ > 1, which suggests concern), while summed THQs across metals yield a Hazard Index (HI) [15, 16]. Regulatory guardrails continue to evolve. For example, the Codex Alimentarius Commission recently revised and adopted new maximum limits for lead and other contaminants in foods, emphasizing global efforts to minimize exposure from dietary sources [17, 18].

These developments highlight an urgent need to quantify potentially toxic metals in cow meat dehaired with tyres at abattoirs in Warri and surrounding communities, and to translate those measurements into consumer-relevant health risk metrics. Therefore, this study assessed the concentrations and potential risks of selected metals in different parts of tyre-singed cow meat from Warri and environs.

MATERIALS AND METHODS

Sample collection and preparation

A total of 15 tissues of tyre- singed cows comprising of five samples each of muscle, liver and skin were collected from five abattoirs in Warri and its environs, Delta State, Nigeria. The samples were wrapped in aluminum foil, kept in a cooler containing ice block and taken to the laboratory.

Sample digestion and analysis

The samples were digested with minor modifications, as defined by Tesi *et al*. [19]. Approximately 2 g of the sample was put in a Pyrex beaker and a mixture of nitric and perchloric acid (6:1 v/v) of 35 mL was applied to the beaker which was placed on a hotplate. The samples were digested until a colourless solution was created. The solution was steadily evaporated to near dryness, cooled and dissolved in 5 mL of 20% nitric acid, and diluted with deionized water to 25 mL. The sample solution was analyzed for metals using an atomic absorption spectrophotometer (Perkin Elmer Analyst 200).

Quality control

Quality control procedures were conducted to ensure the results were reliable. All used glassware were washed and sterilized and then rinsed several times with distilled water. A procedural blank was used for monitoring interferences. All results were blank-corrected. In addition, a recovery analysis of the overall analytical technique for metals in selected samples was carried out by spiking samples already analyzed with aliquots of metal standards and then reanalyzed. The samples were spiked at three concentration levels (5, 10 and 20 mg kg^{-1}). The percentage recovered ranged from 97.4 to 102% for all metals.

Estimation of daily intake and risk

The daily intake (DI) of metals through the consumption of the cow meat samples was estimated as:

$$DI\ (mg\ kg^{-1}\ bw\ day^{-1}) = (C \times IngR) / BW \qquad (1)$$

Where C is the concentration of metals in the meat, IngR is the ingestion rate (9 g/day), and BW is the average body weight (60 kg for adults and 15 kg for children) [20].

Assessment of non-carcinogenic risk

The non-cancer risk associated with metals via consumption of the cow meat samples was assessed as hazard index (HI). This was evaluated using equations (2) and (3) [21]. The HI was obtained by adding up the hazard quotients (HQs) based on dose additivity [22] as expressed in equations 2. The HQs for the metals were computed with equation 3.

$$HI = HQ1 + HQ2 + HQ3 + \ldots + HQn \qquad (2)$$

$$HQ = \left[\frac{C \times IngR \times EF \times ED}{BW \times AT_{nc}} \times 10^{-6} \right] / RfD \qquad (3)$$

Where, RfD = oral reference dose [21], EF = exposure frequency (day/yr) = 350; ED = exposure duration = 6 and 30 years for children and adults respectively [23]; ATnc = averaging time for non-carcinogenic risk = ED x 365. An HI value greater than 1 indicates the presence of non-carcinogenic risk while HI value less than 1 indicates the absence of non-carcinogenic risk [21].

Assessment of carcinogenic risk

The carcinogenic risk associated with metals via consumption of the cow meat samples was assessed as total cancer risk (TCR). This was evaluated using equations (4) and (5) [21]. The TCR was obtained by adding up the incremental lifetime cancer risks (ILCRs) based on dose additivity [22] as expressed in equation 4.

$$TCR = ILCR1 + ILCR2 + ILCR3 + \ldots + ILCRn \qquad (4)$$

The ILCRs for the metals were computed with equation 5.

$$ILCR = \frac{C \times IR \times EF \times ED \times CF \times CSF}{BW \times ATca} \qquad (5)$$

Where, CSF = cancer slope factor [17]; ATca is the averaging time for carcinogens = LT x 365 [20]; LT = Life expectancy of an average Nigerian = 55 years [24]. TCR value greater than 1 × 10^{-6} indicates the presence of carcinogenic risk while TCR less than 1 × 10^{-6} indicates the absence of carcinogenic risk [21].

Statistical analysis

All the statistical analyses were performed using statistical software SPSS version 27.0. One way analysis of variance (ANOVA) was used to determine significant variations in metal concentrations among the different samples. The relationship among the metals was determined using Pearson's correlation analysis.

RESULTS AND DISCUSSION

Metals concentrations in the cow meat

The concentrations of metals in the cow meat dehaired with burning tyres are shown in Table 1. The metal concentrations in the cow meat were as follows: Fe > Zn > Cu > Mn > Cd > Pb. The liver had the highest levels of Fe, Zn, Cu and Pb. Muscle had the highest concentration of Mn while the skin had the highest concentrations of Cd. However, on average, the metals concentrations in the cow meat parts were in the order of liver > muscle > skin. A similar trend was also observed for dioxins and furans in cow meat dehaired with tyre [11]. The higher concentrations of metals in the liver reflect the role of the liver as a detoxification and storage organ for toxic contaminants while the lowest concentration observed in the skin might be due to the washing of the skin after the dehairing process.

Table 1: Metals concentrations (mg kg^{-1}) in the cow meat dehaired with burning tyre

Parts	Samples	Fe	Zn	Cu	Cd	Pb	Mn
Muscle	BS1	1.23	0.05	0.06	0.01	0.02	0.06
	BS2	1.71	0.05	0.09	0.01	0.02	0.06
	BS3	1.65	0.14	0.08	0.01	0.02	0.19
	BS4	0.26	0.06	0.07	0.01	0.01	<0.01
	BS5	0.88	0.05	0.13	0.01	0.02	<0.01
Liver	LS1	3.10	1.05	0.23	0.01	0.02	0.04
	LS2	6.79	0.58	0.56	0.02	0.04	0.02
	LS3	2.44	0.54	0.19	0.01	0.02	0.06
	LS4	2.70	2.11	0.16	0.01	0.02	0.01
	LS5	3.23	1.91	0.36	0.01	0.03	0.33
Skin	SS1	0.08	0.35	0.02	0.15	0.01	0.01
	SS2	0.10	0.17	0.03	0.25	0.01	0.01
	SS3	0.05	0.49	0.02	0.01	0.01	0.09
	SS4	0.08	0.60	0.01	0.05	0.01	0.00
	SS5	0.09	0.20	0.03	0.09	0.01	0.01

Table 2 showed a comparison of metals obtained in this study with others previously reported. ANOVA found that there was significant difference ($p < 0.05$) in metal concentrations in the different parts of the cow meat dehaired with burning tyre which might be due to likely influenced by both environmental factors and the heterogeneous nature of tyre combustion residues.

Table 2: Comparison of metals concentrations in the cow meat dehaired with tyre with others in literature

Location	Animal	Parts	Fe	Zn	Cu	Cd	Pb	Mn	Reference
Warri	Cow	Muscle	1.14	0.07	0.09	0.01	0.02	0.10	This Study
Warri	Cow	Liver	3.65	1.24	0.30	0.01	0.03	0.09	This Study
Warri	Cow	Skin	0.08	0.36	0.02	0.11	0.01	0.02	This Study
Calabar	Goat	Muscles	-	-	-	4.31	0.20	-	Edet *et al.* [6]
Abuja	Cattle	Skin	-	196	24.8	2.18	2.45	1.21	Useh & Linus [25]
Minna	Cow	Skin	-	-	-	3.65	0.87	-	Egwuonu *et al.* [26]
Minna	Cow	Meat	-	-	-	3.64	0.88	-	Egwuonu *et al.* [26]
Minna	Cow	Bone	-	-	-	3.68	0.77	-	Egwuonu *et al.* [26]
Kaduna	Goat	Skin	2.47	1.25	-	0.07	0.23	-	Aliyu *et al.* [7]
Kaduna	Cow	Skin	2.10	1.40	-	0.12	0.22	-	Aliyu *et al.* [7]
Lokoja	Cattle	Skin	33.6	63.2	20.8	-	0.52	-	Ebaloma & Shaibu [27]
Lagos	Cow	Skin	-	7.11	-	-	0.91	-	Okiei *et al.* [28]

The concentrations of Fe in the cow meat dehaired with burning tyre ranged from 0.05 to 6.79 mg kg^{-1}. On the average, the liver had the highest concentrations of Fe, followed by the muscle and the skin had the lowest. The concentrations of Fe obtained in the skin of the cow meat in our study were lower than those reported by Aliyu *et al.* [7] and Ebiloma and Shaibu [27].

The concentrations of Zn in the the cow meat dehaired with burning tyre ranged from 0.05 to 2.11 mg kg^{-1}. On the average, the Zn concentrations in the cow meat was in the order of liver > skin > muscle. The concentrations of Zn obtained in the skin of the cow meat in our study was similar to the concentration reported by Aliyu *et al.* [7] but were lower than those reported by Ebiloma and Shaibu [24[, Useh and Linus [25] and Okiei *et al.* [28].

The concentrations of Cu in the cow meat dehaired with burning tyre ranged from 0.02 to 0.56 mg kg^{-1}. Like Fe and Zn, the average Cu concentrations in the cow meat was in the order of liver > skin > muscle. The concentrations of Cu obtained in the skin of the cow meat in our study were lower than those previously reported [25, 27].

The concentrations of Cd in the cow meat dehaired with burning tyre ranged from 0.01 to 0.25 mg kg^{-1}. The skin had the highest concentrations of Cd. The concentrations of Cd obtained in the skin of the cow meat in our study were lower than those reported by Edet *et al*. [6], Aliyu *et al*. [7], Ebiloma and Shaibu [27], Useh and Linus [25], Egwuonu *et al*., [26] and Okiei *et al*. [28].

The concentrations of Pb in the cow meat dehaired with burning tyre ranged from 0.01 to 0.04 mg kg^{-1}. On average, the Pb concentrations in the meat was in the order of liver > muscle > skin. The Pb concentration obtained in this study were below the widely used regulatory benchmark of Pb in edible meat which is 0.1 mg kg^{-1} [29]. The concentrations of Pb obtained in the skin of the cow meat in our study were lower than those reported by Edet *et al*. [5], Aliyu *et al*. [7], Ebiloma and Shaibu [27], Useh and Linus [25], Egwuonu *et al*. [27] and Okiei *et al*. [28].

The concentrations of Mn in the cow meat singed with tyre ranged from <0.01 to 0.33 mg kg^{-1}. On the average, the muscle had the highest concentrations of Mn, followed by the liver and the skin had the lowest. The concentrations of Mn obtained in the skin of the cow meat in our study were lower than those reported by Useh and Linus [25].

Estimated daily intake of metals

The estimated daily intakes of metals in the cow meat dehaired with tyre are shown in Table 3. The estimated daily intakes of metals in the meat samples were generally low and below their respective provisional tolerable daily intake set by the FAO/WHO [30], European Food Safety Authority [31] and WHO [32]. However, the daily intake values of children were higher than those of adults suggesting that children are more vulnerable to metals toxicity.

Table 3: Daily Intake (mg kg^{-1} bw day^{-1}) of metals in cow meat dehaired with burning tyre

		Child						Adult					
	Code	Fe	Zn	Cu	Cd	Pb	Mn	Fe	Zn	Cu	Cd	Pb	Mn
Beef	BS1	0.515	0.022	0.026	0.003	0.006	0.027	0.129	0.005	0.006	0.001	0.002	0.007
	BS2	0.719	0.019	0.039	0.005	0.008	0.024	0.180	0.005	0.010	0.001	0.002	0.006
	BS3	0.693	0.060	0.034	0.004	0.007	0.079	0.173	0.015	0.008	0.001	0.002	0.020
	BS4	0.109	0.024	0.029	0.002	0.005	0.000	0.027	0.006	0.007	0.001	0.001	0.000
	BS5	0.368	0.020	0.055	0.003	0.008	0.000	0.092	0.005	0.014	0.001	0.002	0.000
Liver	LS1	1.301	0.441	0.095	0.005	0.008	0.018	0.325	0.110	0.024	0.001	0.002	0.005
	LS2	2.851	0.242	0.234	0.006	0.015	0.008	0.713	0.060	0.058	0.002	0.004	0.002
	LS3	1.026	0.228	0.081	0.005	0.008	0.025	0.256	0.057	0.020	0.001	0.002	0.006
	LS4	1.134	0.884	0.067	0.003	0.010	0.004	0.284	0.221	0.017	0.001	0.002	0.001
	LS5	1.358	0.803	0.151	0.005	0.013	0.139	0.340	0.201	0.038	0.001	0.003	0.035
Skin	SS1	0.035	0.147	0.007	0.061	0.004	0.003	0.009	0.037	0.002	0.015	0.001	0.001
	SS2	0.042	0.070	0.011	0.103	0.003	0.005	0.010	0.018	0.003	0.026	0.001	0.001
	SS3	0.019	0.206	0.008	0.002	0.005	0.036	0.005	0.051	0.002	0.001	0.001	0.009
	SS4	0.032	0.252	0.005	0.019	0.004	0.002	0.008	0.063	0.001	0.005	0.001	0.000
	SS5	0.038	0.084	0.011	0.037	0.005	0.004	0.010	0.021	0.003	0.009	0.001	0.001

Risk assessment

The computed hazard index and total cancer risk values associated with exposure of children and adults to metals in the cow dehaired with tyre in this study are shown in Tables 4 and 5, respectively. The HI ranged from 3.06×10^{-6} to 3.44×10^{-5} for children exposure, while adult exposure ranged from 7.64×10^{-7} to 8.60×10^{-6}. In these cow meat, the HI values of metals were < 1. This suggests that the ingestion of these cow meat dehaired with tyre may not have any adverse non-carcinogenic health effects.

Table 4: Hazard index of metals in cow meat dehaired with tyre

Category	Parts	Samples	Fe	Zn	Cu	Cd	Pb	Mn	TOTAL
Child	Muscle	BS1	7.05E-07	6.98E-08	6.14E-07	1.07E-06	1.73E-06	1.84E-07	4.37E-06
		BS2	9.85E-07	6.04E-08	9.46E-07	1.61E-06	2.19E-06	1.64E-07	5.95E-06
		BS3	9.50E-07	1.91E-07	8.05E-07	1.21E-06	1.96E-06	5.41E-07	5.65E-06
		BS4	1.49E-07	7.52E-08	7.05E-07	6.71E-07	1.50E-06	0.00E+00	3.10E-06
		BS5	5.03E-07	6.31E-08	1.31E-06	9.40E-07	2.19E-06	0.00E+00	5.00E-06
	Liver	LS1	1.78E-06	1.41E-06	2.27E-06	1.75E-06	2.07E-06	1.27E-07	9.40E-06
		LS2	3.90E-06	7.73E-07	5.61E-06	2.01E-06	4.03E-06	5.75E-08	1.64E-05
		LS3	1.40E-06	7.30E-07	1.95E-06	1.48E-06	2.19E-06	1.70E-07	7.92E-06
		LS4	1.55E-06	2.83E-06	1.60E-06	1.07E-06	2.65E-06	2.88E-08	9.73E-06
		LS5	1.86E-06	2.57E-06	3.61E-06	1.61E-06	3.45E-06	9.49E-07	1.41E-05
	Skin	SS1	4.83E-08	4.70E-07	1.61E-07	1.96E-05	1.04E-06	1.73E-08	2.13E-05
		SS2	5.70E-08	2.24E-07	2.62E-07	3.30E-05	8.05E-07	3.16E-08	3.44E-05
		SS3	2.65E-08	6.58E-07	1.91E-07	6.71E-07	1.27E-06	2.45E-07	3.06E-06
		SS4	4.37E-08	8.04E-07	1.31E-07	6.04E-06	1.15E-06	1.15E-08	8.18E-06
		SS5	5.24E-08	2.67E-07	2.72E-07	1.17E-05	1.27E-06	2.59E-08	1.36E-05
Adult	Muscle	BS1	1.76E-07	1.75E-08	1.54E-07	2.68E-07	4.32E-07	4.60E-08	1.09E-06
		BS2	2.46E-07	1.51E-08	2.37E-07	4.03E-07	5.47E-07	4.10E-08	1.49E-06
		BS3	2.37E-07	4.77E-08	2.01E-07	3.02E-07	4.89E-07	1.35E-07	1.41E-06
		BS4	3.73E-08	1.88E-08	1.76E-07	1.68E-07	3.74E-07	0.00E+00	7.74E-07
		BS5	1.26E-07	1.58E-08	3.27E-07	2.35E-07	5.47E-07	0.00E+00	1.25E-06
	Liver	LS1	4.45E-07	3.52E-07	5.66E-07	4.36E-07	5.18E-07	3.16E-08	2.35E-06
		LS2	9.76E-07	1.93E-07	1.40E-06	5.03E-07	1.01E-06	1.44E-08	4.10E-06
		LS3	3.51E-07	1.83E-07	4.88E-07	3.69E-07	5.47E-07	4.24E-08	1.98E-06
		LS4	3.89E-07	7.06E-07	4.00E-07	2.68E-07	6.62E-07	7.19E-09	2.43E-06
		LS5	4.65E-07	6.42E-07	9.04E-07	4.03E-07	8.63E-07	2.37E-07	3.51E-06
	Skin	SS1	1.21E-08	1.17E-07	4.03E-08	4.90E-06	2.59E-07	4.32E-09	5.33E-06
		SS2	1.42E-08	5.60E-08	6.54E-08	8.26E-06	2.01E-07	7.91E-09	8.60E-06
		SS3	6.62E-09	1.64E-07	4.78E-08	1.68E-07	3.16E-07	6.11E-08	7.64E-07
		SS4	1.09E-08	2.01E-07	3.27E-08	1.51E-06	2.88E-07	2.88E-09	2.05E-06
		SS5	1.31E-08	6.68E-08	6.80E-08	2.92E-06	3.16E-07	6.47E-09	3.39E-06

Table 5: Total cancer risk of metals in cow meat dehaired with burning tyre

		Child			Adult		
	Samples	Cd	Pb	TCR	Cd	Pb	TCR
Muscle	BS1	1.22E-08	5.13E-10	1.28E-08	1.67E-10	7.00E-12	1.74E-10
	BS2	1.84E-08	6.50E-10	1.90E-08	2.50E-10	8.87E-12	2.59E-10
	BS3	1.38E-08	5.82E-10	1.44E-08	1.88E-10	7.94E-12	1.96E-10
	BS4	7.65E-09	4.45E-10	8.10E-09	1.04E-10	6.07E-12	1.10E-10
	BS5	1.07E-08	6.50E-10	1.14E-08	1.46E-10	8.87E-12	1.55E-10
Liver	LS1	1.99E-08	6.16E-10	2.05E-08	2.71E-10	8.40E-12	2.80E-10

	LS2	2.30E-08	1.20E-09	2.42E-08	3.13E-10	1.63E-11	3.29E-10
	LS3	1.68E-08	6.50E-10	1.75E-08	2.30E-10	8.87E-12	2.38E-10
	LS4	1.22E-08	7.87E-10	1.30E-08	1.67E-10	1.07E-11	1.78E-10
	LS5	1.84E-08	1.03E-09	1.94E-08	2.50E-10	1.40E-11	2.64E-10
Skin	SS1	2.23E-07	3.08E-10	2.24E-07	3.05E-09	4.20E-12	3.05E-09
	SS2	3.76E-07	2.40E-10	3.77E-07	5.13E-09	3.27E-12	5.14E-09
	SS3	7.65E-09	3.77E-10	8.03E-09	1.04E-10	5.13E-12	1.09E-10
	SS4	6.89E-08	3.42E-10	6.92E-08	9.39E-10	4.67E-12	9.44E-10
	SS5	1.33E-07	3.77E-10	1.34E-07	1.82E-09	5.13E-12	1.82E-09

The TCR values, however, ranged from 8.03×10^{-9} to 3.77×10^{-7} and 1.09×10^{-10} to 5.14×10^{-9} respectively for children and adults' exposure. The TCR values obtained in this study were less than 1×10^{-6} which suggests that there is no potential carcinogenic risk for both children and adults who consume these cow meat dehaired with burning tyre. However, the HI values of children were four times that of adults while the TCR for children were twice those of adults. This implies that children will be more at risk from metal exposure via consumption of these cow meat dehaired with tyre.

Pearson's correlation coefficient

The Pearson's correlation coefficient of metals in the cow meat dehaired with burning tyre is shown in Table 6. From Table 6, Fe correlated with Zn, Cu, Pb and Mn while Zn correlated with Cu, Pb and Mn. Copper correlated with Pb and Mn while Pb correlated with Mn. The positive correlation observed among these metals suggest that they likely originated from the same contamination source (e.g., tyre combustion residue). There was no correlation between Cd and the other metals which imply that Cd is from a different source.

Table 6: Pearson's correlation coefficients of metals in the cow meat singed with tyre

	Fe	Zn	Cu	Cd	Pb	Mn
Fe	1.00					
Zn	0.44*	1.00				
Cu	0.96**	0.44*	1.00			
Cd	-0.39	-0.22	-0.35	1.00		
Pb	0.92**	0.51*	0.94**	-0.54	1.00	
Mn	0.42*	0.40*	0.41*	-0.28	0.41*	1.00

*Pearson's correlation significant at 0.05 level of significance
**Pearson's correlation significant at 0.01 level of significance

CONCLUSION

The concentrations of metals in the cow meat dehaired with tyre were generally low compared to others previously reported in literature. The metal concentrations were as follows: Fe > Zn > Cu > Mn > Cd > Pb while the capacity of the different cow parts to concentrate the metals examined was in the order of liver > muscle > skin. The estimated daily intakes of metals in the meat samples were generally low and below their respective provisional tolerable daily intake. The cow meat were generally healthy for consumption as the hazard index and total cancer risk values show that there are no adverse non-cancer or cancer risks associated with the metals in the meat. Although there is no health risks associated with the metals in the cow meat dehaired with tyre, there is need for regulatory control of unsafe processing methods, continuous monitoring of metals in food, and strengthened food safety interventions are urgently recommended to safeguard public health in Nigeria.

REFERENCES

[1] Zakariyau, U., Amadu, L., Kabir, J., Bolugun, S., Edukugho, A., Yahaya, L. B., (2025). Dioxin levels in cattle hide processed using different fuel sources for singeing in Zaria, Nigeria. *Journal of Interventional Epidemiology and Public Health,* 8(1), 4. https://doi.org/10.37432/jieph.supp.2025.8.1.12. 4

[2] Obioha, F.C., Ogugua, J.A., Nwanta, J.A., & Anaga, A.O. (2024). Determination of polycyclic aromatic hydrocarbons in edible cattle hides in Enugu State, Nigeria. *Public Health Toxicol*. 4(2), 8 https://doi.org/10.18332/pht/189941.

[3] Ujowundu, C.O., Ogbede, J.U., Igwe, K.O., Okwu, G.N., Agha, N.C., & Okechukwu, R.I. (2014) Quantitative assessment of polycyclic aromatic hydrocarbons and heavy metals in fish roasted with firewood, waste tyres and polyethylene materials. *Biochem Anal Biochem* 4, 162. http://dx.doi.org/10.4172/2161-1009.1000162

[4] Wang, Z., Li, K., Lambert, P., & Yuang, C. (2007). Identification, characterization and quantitation of pyrogenic polycylic aromatic hydrocarbons and other organic compounds in tire fire products. *Journal of Chromatography A,* 1139 (2007) 14–26. https://doi.org/10.1016/j.chroma.2006.10.085

[5] Abdulai, P. M., Ossai, C., Ezejiofor, A. N., Frazzoli, C., Rovira, J., Ekhator, O. C, Firempong, C. K. & Orisakwe, O. E. (2025). Polycyclic Aromatic Hydrocarbons Burden of Meats Singed

with Different Fuel Sources from Abattoirs in Ghana and Associated Cancer Risk Assessment. *Environmental Health Insights,* 19. https://doi.org/10.1177/11786302241310842.

[6] Edet, U., Joseph, A., Bebia, G.P. & Mbim, E., (2024). Health risk of heavy metals and PAHs contaminants in goat meat de-haired with waste tyres and plastic in Calabar, Nigeria. *Journal of Food Composition and Analysis,* 131(2-3), 106216.

[7] Aliyu, S., Amina, M. & Adamu, A. (2023). Analysis of Heavy Metals in Goat and Cow Hides Singed with Scrap Tyre in Tudun Wada Zango Abattoir, Kaduna State, Nigeria. *Eurasian Journal of Science and Engineering,* 9(2), 1–9.

[8] Adam, I., Teye, M. & Daniel O. (2024). Assessment of Heavy Metal Residues in Hides of Goats Singed with Tyres, and the Effect of Boiling on the Heavy Metal Concentrations in the Hides . *J. Vet. Adv.,* 3(5), 165. https://doi.org/10.5455/jva.20130531104440.

[9] Wang, T., Feng, W., Kuang, D., Deng, Q., Zhang, W., Wang, S., He, M., Zhang, X., Wu, T., & Guo, H. (2015). The effects of heavy metals and their interactions with polycyclic aromatic hydrocarbons on the oxidative stress among coke-oven workers. *Environmental Research*, 140, 405–413. https://doi.org/10.1016/j.envres.2015.04.013.

[10] Webb, E., Moon, J., Dyrszka, L., Rodriguez, B., Cox, C., Patisaul, H., Bushkin, S. & London, E. (2018). Neurodevelopmental and neurological effects of chemicals associated with unconventional natural gas operations and their potential effects on infants and children. *Reviews on Environmental Health*, 33(1), 3-29. https://doi.org/10.1515/reveh-2017-0008.

[11] Agbozu, I.E., Ogundimu, I., Udoinyang, E.P. & Tesi, G.O. (2025). Concentrations and associated human health risk assessment of dioxins and furans in the consumption of muscle, liver and skin cow meat de-haired with waste tyres and plastics in Warri and its environs, Delta State, Nigeria. *Journal of Applied Science & Environmental Management*, In press

[12] Oghenevwogaga, J., & Onojake, M. (2024). Environmental and Health Impacts of Abattoir Activities on Selected Water Bodies in Warri, Nigeria. *International Journal of Multidisciplinary Research and Publications*, 6(9), 60–69.

[13] Onakpa M. M., Njan. A.A. & Kalu, O. C (2018). A review of heavy metal contamination of food crops in Nigeria. *Annals of Global Health,* 84(3), 488-494. *https://doi.org/10.29024/aogh.2314*.

[14] Okoye, E. A., Orisakwe, O. E., Bocca, B. & Ruggieri, F. (2022). Arsenic and toxic metals in meat and fish consumed in the Niger Delta, Nigeria: Health risk assessment across life-stages. *Environmental Research*, 212, 113255.

[15] EPA (U.S. Environmental Protection Agency). (1993). *Reference Dose (RfD): Description and Use in Health Risk Assessments.* Washington, DC.

[16] Antoine, J. M. R., Fung, L. A. H., & Grant C.N. (2017). Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. *Toxicol Rep*. 29(4), 181-187. doi: 10.1016/j.toxrep.2017.03.006. PMID: 28959639; PMCID: PMC5615120.

[17] Codex Alimentarius Commission (CAC). (2025). General Standard for Contaminants and Toxins in Food and Feed (CXS 193-1995, latest revision). Rome: FAO/WHO. (Updated PDF accessed 2025).

[18] Codex Alimentarius/FAO-WHO. (2024). Outcomes of CCCF17: New maximum limits for lead and other contaminants in foods. The National Law Review (report).

[19] Tesi, G.O., Iniaghe, P. O., Ogwu, I. F., Okunoja, H. B., Iwegbue, C.M.A., & Egobueze, F. E. (2024). Safety evaluation of human exposure to potentially toxic metals in the organs of sheep from southern Nigeria. *Journal of Trace Elements and Minerals,* 9(2024), 1-9. https://doi.org/10.1016/j.jtemin.2024.100184.

[20] USDOE (United States Department of Energy) (2011). The risk assessment information system (RAIS). US Department of Energy, Oak Ridge Operations (ORO) Office: Oak Ridge, TN, USA.

[21] USEPA. (2022). Regional screening levels (RSL) summary tables. http://www.epa.gov/risk/risk-based-screening-table-generic-tables (Accessed on 21 December, 2022).

[22] Tesi, G.O., Lari B., Felagha I., Ogbuta, A.A., Ogbomade, W.E., Obodoka, G.C., Dolor, A.O., Tesi, J.N., Iniaghe, P.O., Kpomah, E.D. & El-Mansi, M. (2025). Contamination levels, risks and sources of polycyclic aromatic hydrocarbons in current herbal formulations in Nigeria. *International Journal of Environmental Health Research*, 1-12, https://doi.org/10.1080/09603123.2025.2547847

[23] USEPA (United States Environmental Protection Agency). (2011). Regional Screening Level Table (RSL) for Chemical Contaminants at Superfund Sites. U.S. Environmental Protection Agency: Washington, DC, USA.

[24] World Health Organization (WHO) (2018). Nigeria: Life Expectancy. Retrieved on November 5th, 2019 from https://www.worldlifeexpectancy.com/nigeria-life-expectancy.

[25] Useh, M.U. & Linus, E. (2023). Comparative analysis of cattle hides singed with scrap tyre and cattle hide singed with firewood in Abuja, Nigeria. *Nigerian Research Journal of Chemical Sciences,* 10(2), 73-86

[26] Egwuonwu, F., Abdulkadir, A., & and Hamzah, R. U. (2019). Effect of different dehairing methods on the concentrations of some heavy metals in cow tail sold in Minna Abattoir. *GSC Biological and Pharmaceutical Sciences,* 8(03), 079–084.

[27] Ebiloma, I.P and Shaibu, N. V. (2023). Assessment of Heavy Metal Residues in Hides of animals Singed with Tyres, and Public Health Implications Associated with such Practice in Lokoja Metropolis. *International Journal of latest Technology in Engineering, Management & Applied Science (IJLTEMAS),* 7(4), 18-29. *https://doi.org/10.51583/IJLTEMAS.2023.12403.*

[28] Okiei, W., Ogunlesi, M., Alabi, F., Osiughwu, B. & Sojinrin, A. (2009). Determination of toxic metal concentrations in flame treated meat products, *ponmo*. African Journal of Biochemistry Research, 3(10), 332-339

[29] Thomas, V.G., Pain, D.J., Kanstrup, N. & Green, R. E., (2020). Setting maximum levels for lead in game meat in EC regulations: An adjunct to replacement of lead ammunition. *Ambio,* 49, 2026–2037.

[30] FAO/WHO, Joint FAO/WHO (2011). Food Standards Programme. Codex Committee on Contaminants in foods, 5th Session. The Hague, the Netherlands.

[31] European Food Safety Authority (EFSA), Scientific Opinion statement ion tolerable weekly intake for cadmium, EFSA J. 9 (2011) 1975

[32] World Health Organization (WHO) (2013). Summary and conclusion of the 61st meeting of the Joint FOA/WHO Expert Committee on Food Additives (JECFA) JECFA/Sc Rome, Italy 10–19.