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Effect of Singeing Materials on Distribution of Some Metals in Liver and Kidney Samples of *Capra aegagrus hircus* Slaughtered in Uyo Village Road Abattoir in Niger Delta Region of Nigeria and Health Risk Assessment

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Authors' contributions

This work was carried out in collaboration among all authors. Author GAE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors EUD and UEU managed the analyses of the study. Author UEU managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A number of local butchers in Uyo metropolis usually make use of used scrap car tyres (USCT) and condemned plastics (CPS) as close substitutes for firewood to singe slaughtered ruminants. This study evaluated the effect of singeing materials on the distribution of some metals (Cd, Cr, Ni, Pb, Cu, Zn and Fe) in liver and kidney samples of *Capra aegagrus hircus* (goat) slaughtered in Uyo Village Road Abattoir in the Niger Delta Region of Nigeria using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES). Carcinogenic and non-carcinogenic health risks for children and adults were also estimated using Estimated Chronic Daily Intake (ECDI), Hazard Quotient (HQ) and Hazard Indices (HI) of metals in liver and kidney. Relative to unsinged samples, singed treatments generally demonstrated elevated heavy metal levels in both goat liver and the kidney. Apart from

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nickel, iron and zinc, the range of values obtained for all the metals in singed samples studied were above the threshold stipulated by the Food and Agricultural Organization and World Health Organization. The health risk assessment revealed Cd, Pb, Ni and Cr as potential carcinogens in the signed samples evaluated. The continuous use of these dangerous materials for singeing of goat meat for human consumption poses great risk to human health and should be discontinued.

Keywords: Capra aegagrus hircus; health risk; meat; singeing; metals.

1. INTRODUCTION

Meat is an integral part of the human diet. It is one of the chief sources of dietary protein and fat for the human populace. World over, the consumption of goat meat has increased largely due to its distinct nutritional attributes when compared to other forms of red meat. Additionally, goat meat comparatively has a lower total fat, saturated fatty acid and cholesterol content, which makes it a healthful product [1]. Singeing is a traditional method of processing cows, goat and other animals for meat. This usually proceeds in open fire using firewood as fuel. The relative scarcity of firewood in recent times has resulted in the use of scrap tyres by local butchers as an alternative source of fuel to singe slaughtered livestock. The practice, though unconventional and potentially dangerous, is increasingly favored by local butchers; reasons being that fire from the scrap tyres is able to selectively burn off the animal fur without cracking the hide.

The use of scrap tyres for singeing meat is worrisome since it can introduce different contaminants into the meat, thereby rendering it unsafe for human consumption. In view of the fact that tyres contain many potentially harmful substances [2], singed treatment with scrap tyres imposes enormous risk of deposition of toxic materials. The risk of toxic metal contamination in meat remains a great concern for both food safety and human health because of the toxic nature of these metals even at relatively minute concentrations [3]. It has also been reported that the use of scrap tyres for singeing meat is said to pose a serious public health risk to people working in and living around slaughter houses in Ghana because the open burning practices can release volatile organic compound (VOCs) and polycyclic aromatic hydrocarbons (PAHs) into the environment [4].

Although a few reports exist on the use of scrap tyres and condemned plastics for the processing of meat for food [5-7], information is quite scanty on this subject in this study area. The present study therefore, assesses the effect of singeing materials on the distribution of some metals in liver and kidney samples of *Capra aegagrus hircus* procured from a popular abattoir in Uyo metropolis in Niger Delta Region of Nigeria and health risk assessment.

2. MATERIALS AND METHODS

2.1 Sampling and Sample Pre-treatment

Three grams (3.00 g) portion each of liver and kidney from goat singed with used scrap car tyres (USCT), condemned plastic (CPS) and wood (WOS) were carefully procured from Uyo village abattoir in Uyo Metropolis, Akwa Ibom State, Southern Nigeria in August, 2019. Similar weight of liver and kidney in the same abattoir were also obtained from goat not singed and used as Control (USS) for this study. The samples were collected using plastic bags in an ice box, transported to the laboratory before oven drying at 105 ℃ to constant weight. The resulting samples were pulverized in a porcelain mortar and then stored in a desiccator for total toxic metal determination.

2.2 Determination of Some Metals in Liver and Kidney

Prior to atomization, 2.00 g each of the powdered liver and kidney samples for both singed and unsinged meat were placed in a crucible before adding a solution comprising of 10 ml Nitric (HNO_3) and Perchloric acid ($HClO_4$) in the ratio of 3:2. Resulting solutions were left to digest under reflux for 24 h and then heated at 70℃ in a water bath for 3 h. When cooled, the resultant digest were decanted into 20 ml standard flask rinsed with de-ionized water before making up to the graduated mark with de-ionized water. Metal analyses of the samples were carried out using Agilent 710 inductively coupled plasma optical emission spectrometer (ICP-OES) in triplicates.

2.3 Health Risk Assessment of Some Metals in Liver and Kidney

For this study, both cancer and non-cancer health risk assessments were carried out for

Table 1. Risk assessment of parameters and values applied

Parameters	Values
Body weight (kg)	15 kg – child [a,d] 70 kg – adult [d]
Estimated quantity of liver and kidney (g/person/day)	22.31 – child (liver)[e] 17.11 – adult (liver)[e] 11.07 – child (kidney)[e] 11.42 – adult (kidney)[e]
Exposure frequency (E_f)	350 days / year [c]
Exposure duration	6 yrs – child [b] 30 years – adult [b]
Oral reference dose	Pb – 0.004, Cd – 0.001, Cr – 0.001, Ni - 0.02, Cu – 0.04, Fe – 0.07, Zn – 0.04
Average time for non-carcinogens (day /yr)	365 days/yr [d]
Cancer slope factor (CSF)(ingestion)	Cd – 15, Pb – 0.0085, Ni – 0.91, Cr – 0.5

Source: [a] [9]; [b] [10]; [c] [11]; [d] [12]; [e] [8]

children and adult populations. For non-cancer assessment, estimated chronic daily intake (ECDI), hazard quotient (HQ) and hazard indexes (HI) were evaluated. Estimated daily intake for metals in liver and kidney was calculated using equation (1):

$$ECDI = \frac{MI \times MC}{BW} \quad (1)$$

Where

MI = estimated quantity of liver and kidney consumed (g/person/day),

Values used in this study for both children and adult populations are those reported elsewhere [8], obtained through food frequency questionnaire method (FFQ),

MC = mean concentration of metals in the meat part as analyzed in $mgkg^{-1}$,

BW = average body weight of each group (children and adult) of subject under study in Kg.

Hazard quotient (HQ) was determined using equation (2):

$$HQ = \frac{Ef \times EDtotal \times EDI}{RfDo \times BW \times AT} \times 10\,E-3 \quad (2)$$

Hazard indexes of toxic metals were estimated as the summation of individual hazard quotients of each metal as indicated in equation (3):

$$THI = HQP_b + HQ\,Z_n + HQ\,C_r + HQ\,Cd + HQ\,Cu + HQ\,Fe + HQ\,Ni \quad (3)$$

The health risk parameters and values used in this study are listed in Table 1.

Cancer health risk of toxic metals through ingestion or consumption of the studied parts of goat meat was determined using the incremental lifetime cancer risk model and calculated according to equation (4) below

$$ILCR = EDI \times CSF \quad (4)$$

Where, EDI = estimated daily intake of each metal measured in $mgkg^{-1}BWday^{-1}$; CSF = cancer slope factors.

3. RESULTS AND DISCUSSION

3.1 Results

3.1.1 Metal concentration in liver and kidney

The results of metal concentration ($mgkg^{-1}$) in liver and kidney samples of goat meat (*Capra aegagrus hircus*) obtained from abattoir in Uyo metropolis, Akwa Ibom State, Niger Delta Region, Nigeria are presented in Tables 2 and 3 respectively. The results indicated variations in the concentration of studied metals by parts of the studied goat meat and among different singeing materials.

3.2 Discussion

3.2.1 Metal concentration in liver and kidney

A total of seven metals namely cadmium (Cd), chromium (Cr), nickel (Ni), lead (Pb), copper

(Cu), zinc (Zn) and Iron (Fe) were analyzed in the samples of the liver and kidney of goat singed with three different materials (used scrap car tyres, condemned plastic and wood). These results are presented in Tables 2 and 3. The result for Cd indicated that the concentration of the element was higher (0.12 $mgkg^{-1}$) in liver singed with used scrap car tyres and least in liver and kidney of unsinged samples. In specific terms, the concentration of Cd was higher in singed samples than in unsinged ones, whether liver or kidney.

The range for Cd concentration in liver and kidney were 0.001 – 0.120 $mgkg^{-1}$ and 0.001 – 0.08 $mgkg^{-1}$ respectively. The obtained result for Cd in both liver and kidney agrees with 0.03 - 0.9 $mgkg^{-1}$ earlier reported [7], but smaller than a mean of 5.51 $mgkg^{-1}$ reported by Oladipo and co-workers [13]. The variation observed between reported concentrations of Cd and that obtained in this work may be due to differences in the excretory ability of goat prior to use in this study. Higher amounts of Cd in liver and kidney singed with used scrap car tyres obtained in this study may also be explained by the fact that Cd is one of the major trace metals present in a used scrap car tyres. Shakya and co-workers [14] reported the following: Zn > Cd > Cr > Pb, as the order of abundance of trace metals in used scrap car tyres.

Again, the result showed that unsinged liver and kidney recorded least (almost negligible) amount of Cd when compared to others. These findings agree with the reports of Aya and Nwite [15] and Inobeme and co-workers Inobeme et al. [16], who also reported a non-detectable concentration of Cd in some parts of goat sourced from different parts of Nigeria. Cd is very toxic and not needed in the human body at any concentration. It is almost absent in the human body at birth although the body begins to accumulate it through ingestion of Cd containing food over time [17]. Several adverse effects caused by Cd in the human body have been reported including kidney dysfunction, hypertension and hepatic injury and can even damage the lungs [18]. However, result of Cd reported in this study for liver and kidney for all cases were all lower than 0.50 mgkg-1 permissible limit stipulated by Food and Agricultural Organization and the World Health Organization [19] except for liver singed with used scrap car tyres.

The order of accumulation of Cr in the liver was in the order: CPS (1.24) > USCT (1.16) > WOS (0.93) > USS (0.20), while that of the kidney was in the order: CPS (1.11) > USCT (1.07) > WOS (1.01) > USS (0.20). The result indicated that unsinged liver and kidney recorded least Cr concentration than the singed sample. The difference in Cr concentration among singed and unsinged samples may be attributed to the effect of singeing materials used. Essumang and co-workers [20], opined that materials used for singeing of animals can contribute to the concentration of toxic metals in animals. The highest amount of Cr obtained in liver and kidney singed with condemned plastics in this study may be attributed to the impact of burnt plastic used. The result of Cr obtained in this study for both liver and kidney singed with different materials is in agreement with 0.84 $mgkg^{-1}$ reported elsewhere [21] 0.74 $mgkg^{-1}$ by Akoto and co-workers [22] but lower than 1.28 $mgkg^{-1}$ and 1.42 $mgkg^{-1}$ reported by Akan and co-workers [23] and Nkansah and others [24] respectively in their previous reports. The presence of Cr in liver and kidney of goat is a pointer to the intake of Cr containing food substance including vegetables. Although Cr is one of the essential elements needed in the human body to compliment sugar, protein and fat usage in the body, over-accumulation in the body can lead to detrimental effect including cancer [25]. Interestingly, concentrations of Cr obtained in this study in both liver and kidney were higher than the 0.05 $mgkg^{-1}$ permissible limit allowed for meat by Food and Agricultural Organization [19].

The concentration of Ni in liver and kidney of goat singed with used scrap car tyre, condemned plastic and wood were in the range 0.01 – 0.18 mg/kg and 0.02 – 0.06 mg/kg respectively. For unsinged liver, the concentration of Ni was 0.18 mg/kg while liver singed with condemned plastic recorded the highest concentration (0.18 mg/kg) of Ni. Similarly unsinged kidney recorded least (0.01 mg/kg) amount of Ni, while kidney singed with used scrap car tyres recorded highest nickel concentration (0.06 mg/kg), among the singed samples. The result indicated that liver and kidney singed with all the three different materials have higher amounts of Ni than unsinged liver and kidney.

The singeing materials (used scrap car tyres, condemned plastic and wood) have been reported to contain significant amounts of trace metals including Ni as previously reported by different authors [7,14]. However, it is noteworthy to observe that the concentrations of Ni reported in this study are indeed lower than 0.5 mg/kg Ni

Table 2. Concentration ($mgkg^{-1}$) of some metals in liver of *Capra aegagrus hircus* meat

Samples/metals	Cd	Cr	Ni	Pb	Cu	Zn	Fe
USCT	0.120±0.00	1.16±0.01	0.13±0.00	1.09±0.02	8.32±0.21	3.86±0.06	22.63±1.00
CPS	0.070 ±0.00	1.24±0.03	0.18±0.01	0.41±0.01	11.61±0.08	1.94±0.01	11.42±0.18
WOS	0.030±0.00	0.93±0.01	0.08±0.00	0.62±0.00	14.81±1.20	0.83±0.05	16.53±1.04
USS	0.001±0.00	0.20±0.00	0.01±0.00	0.15±0.01	2.43±0.03	0.54±0.00	8.62±0.34

Each value represents mean ± SEM of three determinations; USCT – Used scrap car tyres singed sample; CPS – Condemned plastic singed sample; WOS – Wood singed sample; USS – Unsinged sample

Table 3. Concentration ($mgkg^{-1}$) of some metals in kidney of *Capra aegagrus hircus* meat

Samples/metals	Cd	Cr	Ni	Pb	Cu	Zn	Fe
USCT	0.08 ±0.00	1.07±0.04	0.06±0.00	1.24±0.01	6.43±0.20	4.60±0.06	14.75±1.02
CPS	0.05 ±0.00	1.11±0.02	0.04±0.00	1.13±0.01	7.52±0.07	2.07±0.03	8.54±0.08
WOS	0.05 ±0.01	1.01±0.00	0.03±0.00	0.84±0.04	5.84±0.02	2.23±0.00	10.31±0.34
USS	0.01 ±0.00	0.03±0.00	0.02±0.00	0.36±0.02	1.27±0.01	0.85±0.00	6.46±0.02

Each value represent mean ± SEM of three determinations; USCT – Used scrap car tyres singed sample; CPS – Condemned plastic singed sample; WOS – Wood singed sample; USS – Unsinged sample stipulated for consumable meat products [19]. Nickel is a micronutrient essential for proper functioning of the human body. It increases hormonal activity and is involved in lipid metabolism. Large doses of nickel or prolonged contact with it could cause a variety of side effects. The harmful effects of Nickel are genotoxicity, haematotoxicity, teratogenicity, immunotoxicity and carcinogenicity [26].

The concentrations of Pb in liver and kidney of singed and unsinged goat liver and kidney sample are also shown in Tables 1 and 2. The result indicated that the highest Pb concentration (1.09 mg/kg) was recorded in liver sample singed with used scrap car tyre and least (0.41 mg/kg) in liver singed with condemned plastic. In the singed kidney samples, the highest Pb concentration (1.24 mg/kg) was recorded in sample singed with used scrap car tyre and least (0.84 mg/kg) in liver sample singed with wood.

The disparities in the concentrations of Pb in liver and kidney samples with respect to different singed materials can be attributed to the impact of the materials on the overall Pb load in the singed and unsinged. In both liver and kidney, liver and kidney singed with used scrap car tyre recorded highest abundances of Pb followed by those singed with condemned plastics and wood. One of the most predominant metals associated with car tyre is Pb and during the singeing process, significant amount may leached into the sample leading to relative increase in total Pb concentration in the tested samples.

The result also revealed that unsinged liver and kidney recorded least concentration of Pb with kidney having a higher value than liver. The ranges of 0.15 – 1.09 mg/kg Pb and 0.36 – 1.24 mg/kg Pb obtained for liver and kidney respectively for all samples agree with the mean of 0.68 mg/kg, 0.39 mg/kg, and 1.04 mg/kg previously reported [16,27,28]. However, the reported ranges are indeed lower than mean value of 1.80 mg/kg also reported earlier [29]. According to the US Centre for Disease Control and Prevention and the World Health Organization, a blood lead level of 10 μg/dL or above is a cause for concern. However there is no threshold value below which lead exposure can be considered safe. It has been found to impair development and have harmful effects even at lower levels [30-31].The result obtained for Pb in this study is higher than 0.1 mg/kg stipulated by the Food and Agricultural Organization and the World Bank for meat products [19].

The concentration of Cu in liver and kidney of goat singed with used scrap car tyre, condemned plastic and wood are presented in Tables 2 and 3. The results indicate that the concentration of Cu in singed liver ranged from 8.32 – 14.18 mg/kg with wood singed liver recording the highest (14.18 mg/kg) Cu while the least (8.32 mg/kg) was recorded for liver singed with used scrap car tyre. Also, for the kidney, the range was 5.84 – 7.52 mg/kg. Kidney signed with condemned plastic recorded the highest concentration (7.52 mg/kg) and least concentration (5.84 mg/kg) was for kidney singed with wood. In both liver and kidney, singed samples recorded higher Cu concentration than unsinged samples. Higher Cu in singed samples when compared to unsinged ones further reveals the effect of singed materials. The range of Cu (2.43 – 14.18 mg/kg) in liver and 1.27 -7.52 mg/kg in kidney obtained in this study for singed and unsinged samples are consistent with range 1.04 – 8.82 mg/kg; 1.67 – 14.14.40 mg/kg; and 0.48 – 11.09 mg/kg previously reported respectively by other researchers [22,27,29]. Results obtained for Cu for both singed and unsinged liver and kidney samples obtained in this study are higher than 0.05 – 0.5 mg/kg stipulated Cu limit allowed for consumable meat products [19].

The results for Fe Concentration in liver and kidney of singed and unsinged goat indicated significant variation in concentration of Fe with respect to goat parts and singeing materials. In singed liver samples, sample singed with used scrap car tyre recorded the highest amount (22.63 mg/kg) of Fe, while least amount (11.42 mg/kg) was recorded in sample singed with condemned plastic. A similar trend was also obtained for singed kidney though the concentration of Fe was lower in the case of kidney than liver. On comparing the concentration of Fe in singed and unsinged liver and kidney samples, unsinged samples recorded lower abundances of Fe than the singed samples. The concentration of Fe in the liver and kidney samples of goat obtained in this study are below 30 – 150 mg/kg stipulated for meat products [19].

The ranges for Zn concentration in goat singed with used scrap car tyre, condemned plastic and wood including unsinged samples (Tables 2 and 3) were 0.54 – 3.86 mg/kg and 0.85 – 4.60 mg/kg for the liver and kidney respectively. In both liver and kidney, the concentration of Zn was higher in samples singed with used scrap car tyre and least in unsinged samples. Zn in the form of ZnO is reported to be a major constituent of most car tyres [32]. The ranges for Zn concentration for liver and kidney obtained in this study are slightly in good agreement with mean (mg/kg) of 4.61, 3.86 and 3.43 previously reported [21,29,33]. However, obtained ranges are lower than the mean (mg/kg) of 96.10, 86.21, and 43.11 reported by earlier workers [15,22,34] in their respective studies. Zn is important in the human body as it helps in the healing of wounds, regulates hormones and glands in the endocrine system and in blood coagulation. Adequate amount of Zn in the human body can help in the prevention of age – related muscular degeneration and neurological disorders [8]. In this study, mean ranges for Zn in liver and kidney of goat singed with different materials are well below 50 mg/kg permissible limit recommended [19].

3.2.2 Health risk assessment

In this study, both carcinogenic and non-carcinogenic health risks were evaluated. The aim of this activity was to evaluate the potential health effects to human (children and adult) through consumption of either liver and kidney of the goat samples. For non-carcinogenic health risk, the assessment was done by determining the estimated chronic daily intake (ECDI), hazard quotient (HQ) and hazard indices of toxic metals.

3.2.2.1 Estimated Chronic Daily Intake (ECDI), Hazard quotient (HQ) and Hazard Indices (HI) of toxic metals in liver and kidney

The results for the estimated chronic daily intake of toxic metals through consumption of liver and kidney of studied goat samples are presented in Tables 4 and 5. The results indicated varied daily intake values for each toxic metal studied between liver and kidney with respect to adult and children population.

For liver, the following ranges of ECDI for adult and children were recorded: Cd (0.0003 – 0.0300) (0.0020 – 0.1800); Cr (0.0500 – 0.3100) (0.2900 – 1.85); Ni (0.0030 – 0.0500) (0.0200 – 0.2600); Pb (0.0400 – 0.2700) (0.2300 – 1.6200); Cu (0.6100 – 3.5100) (3.6200 – 21.1300); Zn (0.1400 – 0.9700) (0.8100 – 5.7500) and Fe (2.1600 – 5.6600) (12.8400 – 33.7200).

Also for kidney, ranges for adult and children populations as indicated in Tables 4 and 5 were Cd (0.0020 – 0.0100)(0.0007 – 0.0600); Cr (0.0050 – 0.1800)(0.0200 – 0.8200); Ni (0.0032 - 0.0096)(0.0100 – 0.0400); Pb (0.0600 – 0.1000) (0.2700 – 0.9200); Cu (0.2000 – 1.2000)(0.9400 – 5.5600); Zn (0.1400 – 0.7400)(0.6300 – 3.3900) and Fe (1.0400 – 2.3600)(4.7700 – 10.8900).

For the individual metals and in both liver and kidney, ECDI values were seen to be lowest in unsinged samples than in singed ones. Among all the toxic metals studied, values for ECDI were higher in Cu, Zn and Fe for both liver and kidney, while lower ECDI's were recorded by Cd and Ni for both population. On comparing the obtained ECDI's with tolerable daily intake (TDI) as listed in Tables 4 and 5, all the toxic metals studied for both liver and kidney were well below the stipulated values.

Table 4. Chronic daily intake indices (mg/kg) for toxic metals via consumption of liver and kidney

Toxic metals	Samples	Liver		Kidney		TDI
		Adult	Children	Adult	Children	
Cd	USCT	0.0300	0.1800	0.0100	0.0600	
	CPS	0.0200	0.1000	0.0080	0.0400	1.0000
	WOS	0.0080	0.0500	0.0080	0.0400	
	USS	0.0003	0.0020	0.0002	0.0007	
Cr	USCT	0.2900	1.7300	0.1700	0.7900	
	CPS	0.3100	1.8500	0.1800	0.8200	7.0000
	WOS	0.2300	1.3900	0.1600	0.7500	
	USS	0.0500	0.2900	0.0050	0.0200	
Ni	USCT	0.0300	0.1900	0.0096	0.0400	
	CPS	0.0500	0.2600	0.0064	0.0300	10.0000
	WOS	0.0200	0.1200	0.0048	0.0200	
	USS	0.0030	0.0150	0.0032	0.0100	

USCT – used scrap car tyres singed sample; CPS – condemned plastic singed sample; WOS – wood singed sample; USS –unsinged sample; TDI – tolerable daily intake

Table 5. Chronic daily intake indices (mg/kg) for toxic metals via consumption of liver and kidney

Toxic metals	Samples	Liver		Kidney		TDI
		Adult	Children	Adult	Children	
Pb	USCT	0.2700	1.6200	0.2000	0.9200	
	CPS	0.1000	0.6100	0.1810	0.8300	3.6000
	WOS	0.1600	0.9200	0.1300	0.6200	
	USS	0.0400	0.2300	0.0600	0.2700	
Cu	USCT	2.0800	12.3900	1.0300	4.7500	
	CPS	2.9000	17.2900	1.2000	5.5600	500.000
	WOS	3.5100	21.1300	0.9300	4.2900	
	USS	0.6100	3.6200	0.2000	0.9400	
Zn	USCT	0.9700	5.7500	0.7400	3.3900	
	CPS	0.4900	2.8900	0.3300	1.5300	300 - 1000
	WOS	0.2100	1.2400	0.3500	1.6400	
	USS	0.1400	0.8100	0.1400	0.6300	
Fe	USCT	5.6600	33.7200	2.3600	10.8900	
	CPS	2.8600	17.0100	1.3700	6.3000	1000
	WOS	4.1300	24.6300	1.6500	7.6100	
	USS	2.1600	12.8400	1.0400	4.7700	

USCT – Used scrap car tyres singed sample; CPS – Condemned plastic singed sample; WOS – Wood singed sample; USS –Unsinged sample; TDI – Tolerable daily intake

Table 6a. Hazard quotient indices for toxic metals via consumption of liver and kidney

Toxic metals	Samples	Liver		Kidney	
		Adult	Children	Adult	Children
Cd	USCT	4.2 E – 04	1.2 E – 02	1.4 E – 04	3.8 E – 03
	CPS	2.8 E – 04	6.4 E – 03	1.2 E – 04	2.6 E – 03
	WOS	1.1 E – 04	3.2 E – 03	1.2 E – 04	2.6 E – 03
	USS	4.2 E – 06	1.3 E – 04	2.0 E – 06	4.5 E – 05
Cr	USCT	4.1 E – 03	1.1 E – 01	2.4 E – 03	5.1 E – 02
	CPS	4.3 E – 03	1.2 E – 01	2.5 E – 03	5.2 E – 02
	WOS	3.0 E – 03	8.9 E – 02	2.2 E – 03	4.8 E – 02
	USS	7.0 E – 04	1.8 E – 02	7.0 E – 05	1.3 E – 03
Ni	USCT	1.4 E – 04	1.8 E – 03	2.1 E – 03	1.5 E – 02
	CPS	2.0 E – 04	1.2 E – 03	1.6 E – 03	1.3 E – 02
	WOS	5.3 E – 04	6.4 E – 03	4.2 E – 03	3.4 E – 02
	USS	1.8 E – 05	2.0 E – 05	2.8 E – 05	1.0 E – 03
Pb	USCT	9.2 E – 04	4.0 E – 04	6.7 E – 04	2.3 E – 04
	CPS	3.4 E – 04	1.5 E – 04	6.2 E – 04	2.1 E – 04
	WOS	5.4 E – 04	2.3 E – 04	4.4 E – 04	1.6 E – 04
	USS	1.4 E – 04	5.8 E – 05	2.0 E – 04	6.8 E – 05

USCT – Used scrap car tyres singed sample; CPS – Condemned plastic singed sample; WOS – Wood singed sample; USS – Unsinged sample

Hazard quotient (HQ) of Cd, Cr, Ni, Pb, Cu, Zn and Fe for liver and kidney (adult and children) are presented in Tables 6a and 6b. Individual toxic metals recorded variable hazard quotient values that were far smaller and differ insignificantly based on singeing materials. For liver and kidney in the case of adult and children population, HQ's for unsinged samples were smaller than the singed samples for all toxic metals studied. This may be as a result of higher ECDI values recorded for the samples as ECDI and HQ are directly related according to equation (2).

Hazard index also called total chronic hazard index (THI) obtained during equation (3) indicated values lower than 1.0 suggesting that people would not experience significant negative health risk from the intake of individual metals through consumption of liver and kidney singed with any of the materials used in this study. Huang and co-workers opined that when hazard index exceeds the threshold value of 1.00, it raises concern as there would be potential health negative effect from the consumption of the subject under consideration [35].

Table 6b. Hazard quotient indices for toxic metals via consumption of liver and kidney

Toxic metals	Samples	Liver		Kidney	
		Adult	Children	Adult	Children
Cu	USCT	7.1 E – 04	3.1 E – 04	3.5 E – 04	1.2 E – 04
	CPS	9.9 E – 04	4.0 E – 04	4.1 E – 04	1.4 E – 04
	WOS	1.2 E – 03	5.0 E – 04	3.2 E – 04	1.1 E – 04
	USS	2.1 E – 04	9.1 E – 05	7.0 E – 05	2.4 E – 05
Zn	USCT	3.3 E – 04	1.4 E – 04	2.5 E – 04	8.5 E – 05
	CPS	1.7 E – 04	7.2 E – 05	1.0 E – 04	3.8 E – 05
	WOS	7.1 E – 05	3.0 E – 05	1.2 E – 04	4.1 E – 05
	USS	4.8 E – 05	2.0 E – 05	4.8 E – 05	1.6 E – 05
Fe	USCT	1.1 E – 03	1.5 E – 04	4.5 E – 04	4.7 E – 04
	CPS	5.0 E – 04	8.8 E – 05	3.0 E – 04	2.4 E – 04
	WOS	7.0 E – 04	1.1 E – 04	3.0 E – 04	3.5 E – 04
	USS	4.0 E – 04	6.7 E – 05	2.0 E – 04	1.8 E – 05

USCT – used scrap car tyres singed sample; CPS – condemned plastic singed sample; WOS – wood singed sample; USS –unsinged sample

Table 7. Hazard indices for toxic metals via consumption of liver and kidney

Population/sample stations	Liver		Kidney	
	Adult	Child	Adult	Child
USCT	4.6 E – 03	5.6 E – 02	7.6 E – 03	1.2 E – 01
CPS	3.8 E – 03	5.5 E - 02	7.6 E - 03	1.2 E - 01
WOS	3.5 E – 03	5.1 E - 02	5.6 E - 03	9.3 E - 02
USS	5.9 E – 03	1.6 E - 03	1.5 E - 03	1.8 E - 02

USCT – used scrap car tyres singed sample; CPS – condemned plastic singed sample; WOS – wood singed sample; USS –unsinged sample

Table 8. Hazard quotients for cancer health risk of toxic metals via consumption of liver and kidney

Toxic metals	Samples	Liver		Kidney	
		Adult	Children	Adult	Children
Cd	USCT	6.3 E – 03	1.8 E – 01	2.1 E – 03	5.7 E – 02
	CPS	4.2 E – 03	9.6 E – 02	1.8 E – 03	3.9 E – 02
	WOS	1.5 E – 03	4.8 E – 02	1.8 E – 03	3.9 E – 02
	USS	6.3 E – 05	2.0 E – 03	3.0 E – 05	7.0 E – 04
Pb	USCT	2.3 E – 03	1.4 E – 02	1.7 E – 03	7.8 E – 03
	CPS	8.5 E – 04	5.2 E – 03	1.6 E – 03	7.1 E – 03
	WOS	1.4 E – 03	7.8 E – 03	1.2 E – 03	5.3 E – 03
	USS	3.4 E – 04	2.0 E – 03	5.1 E – 04	2.3 E – 03
Ni	USCT	2.7 E – 02	1.7 E – 01	8.7 E – 03	3.6 E – 02
	CPS	4.6 E – 02	2.4 E – 01	5.8 E – 03	2.7 E – 02
	WOS	1.8 E – 02	1.1 E – 01	4.4 E – 03	1.8 E – 02
	USS	3.0 E – 03	1.4 E – 02	2.9 E – 05	9.0 E – 03
Cr	USCT	1.4 E – 01	8.8 E – 01	8.5 E – 02	3.9 E – 01
	CPS	1.6 E – 01	9.2 E – 01	9.2 E – 02	4.1 E – 01
	WOS	1.2 E – 01	6.9 E – 01	8.0 E – 02	3.8 E – 01
	USS	2.5 E – 02	1.5 E – 01	2.5 E – 03	1.0 E – 01

USCT – Used scrap car tyres singed sample; CPS – Condemned plastic singed sample; WOS – Wood singed sample; USS – Unsinged sample

In both liver and kidney in the case of adult and children, HI recorded same trend of USCT > CPS > WOS > USS although $HI_{CPS} > HI_{USCT}$ as indicated in Table 7. However, HI for children is greater than for adult for both parts of the goat meat samples. The carcinogenic risk of 4.6 E – 03 obtained for liver singed with used scrap car tyre for adult indicates that 1 person in every 220 adults may be affected, while 1 child may be affected (5.6 E - 02) for every 18 individuals in that order.

3.2.2.2 Cancer health risk

Of the seven (7) metals analyzed for in liver and kidney of goat meat singed with different materials carried out in this study, Cd, Pb, Ni and Cr were considered potential carcinogens with oral cancer slope factors (CSF) indicated in Table 1. Results for cancer health risks obtained in this study are presented in Table 8.

The results indicated that ILCR values were higher in samples singed than the unsinged. For adult and children populations, sample singed with used scrap car tyres recorded highest ILCR value for Cd and Pb, while samples singed with condemn plastic recorded higher values of Ni and Cr. For kidney, sample singed with used scrap car tyres recorded highest ILCR value for the toxic metals except for Cr with highest ILCR value for samples singed with condemned plastics. Lower ILCR values for unsinged samples (liver and kidney) obtained in this study than singed samples are as a result of lower EDI recorded in these samples as presented in Tables 4 and 5. From the results presented in Table 8, toxic metals studied recorded ILCR values higher than United State Environmental Protection Agency permissible range of 1.00 E – 06 to 1.00 E – 04 in food products. Cancer risk (in terms of ILCR value) of 6.3 E – 03 for Cd (adult) as presented in Table 8 for instance implies that one adult in every 160 persons may be affected through consumption of liver samples singed with used scrap car tyres and continues in that order.

4. CONCLUSION

Singeing is a traditional method of processing ruminants for meat. The relative scarcity of firewood in recent times has resulted in the use of scrap tyres by local butchers as an alternative source of fuel to singe slaughtered livestock. The use of scrap tyres for singeing meat is worrying since it can introduce different contaminants into the meat, thereby rendering it unsafe for human consumption. This study evaluated the effect of singeing materials on the distribution of metals (Cd, Cr, Ni, Pb, Cu, Zn, Fe) in liver and kidney samples of *Capra aegagrus hircus* (goat) slaughtered in Uyo Village abattoir in the Niger Delta Region of Nigeria using Inductively Coupled Plasma Optical Emission Spectrometer (ICP-OES) and its health risk assessment. Relative to unsinged samples, singed treatments generally demonstrated elevated metal levels in both goat liver and the kidney. The use of these dangerous materials remains a big threat to the health of people who patronize them and should be strongly discouraged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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