Toxic Metals Contamination of Cattle Hide Singed With Scrap Tyres

Tijjani Rufa'i Buhari*[1], Isa Baba Koki[2], Kamalu Garba Sulaiman[2], Abdurrahman Saed Baba[2] and Kabiru Garba Sule[3]
[1]Department of Biological Sciences Yusuf Maitama Sule University, Kano, Nigeria.
[2]Department of Chemistry Yusuf Maitama Sule University, Kano, Nigeria.
[3]Biochemistry Division, National Veterinary Research Institute, Vom, Plateau, Nigeria.
*Corresponding author email: trbuhari@yahoo.com
kamalugarba93@gmail.com

D.O.I: 10.56201/ijccp.v9.no2.2023.pg12.22

ABSTRACT

Processed cattle hide popularly known as "Ganda" in Nigeria is widely eaten as a substitute for meat but the commercial method of processing this food delicacy through singeing with scrap tyres has become a source of concern due to possible heavy metals contamination. This study evaluates the presence and levels of Cd, Cu, Fe, Pb, and Zn in the cattle hide samples obtained by using Atomic Absorption Spectrophotometry (AAS). The hide samples analyzed were obtained from seven states across the three geopolitical zones in northern Nigeria. Cd was not detected in most of the samples, notably from Niger, Zamfara, Adamawa and Plateau states, while concentrations of 0.0001±5.77E-5, 0.0005±4.71E-5, and 0.009±0.001 mg/kg detected from Kano, Kaduna, and Taraba, respectively, were lower than the maximum permissible level of 0.05 mg/kg set by the reference limits. Pb concentrations in all the samples analyzed were 1.080±0.072 to 1.760±0.160 mg/kg which surpassed the maximum permissible level of 0.1 mg/kg set by the reference limits, while other heavy metals were below the safe limits. The high levels of Pb introduced to the singed hide beyond the reference limits could be linked to the use of scrap tyres in the burning hairs of the hide, and it could be of great concern after consumption. In view of the above possible health implications that might arise, a detailed and proper health risk assessment technique needs to be employed in future research.

Keywords: *AAS, Assessment, Consumption, Lead, Singed hide, Scrap tyres*

INTRODUCTION

It has been estimated worldwide that cattle hide is considered a source of food for many (Dada *et al.*, 2017). Although the method of its processing differs from culture to culture and country to country, but they all involve dehairing of the hide and the end products content after being processed is reported to be relatively the same (Okiei *et al.*, 2009). Processed cattle hide is popularly known as "*Ganda*" in northern Nigeria. The "*Ganda"* also known as "*Kponmo*" in South-Western Nigeria and "*Welle*" in southern Ghana is served as a food delicacy in several parts of Africa (Obiri-Danso *et al.*, 2008; Okiei *et al.*, 2009). Removal of the hair from the hide in some parts of Nigeria is traditionally done by singeing with firewood. But recently with scrap tyres to get

rid of the fur, the burnt hide is scraped to remove ash (black soothe) followed by washing with water to give the finished product "*Ganda*". According to Okiei *et al.* (2009), removal of the hair from the hides is traditionally done by tenderizing the hides in hot water followed by shaving with razor blade to give the finished product "*Kponmo*". This practice of tenderizing with hot water and shaving is mostly used in southwestern part of Nigeria. Singeing is largely favored in many respects in African countries because it maintains the carcass hide for consumption and evokes flavors in meat that are highly acceptable by the local populace (Adam *et al.*, 2013). Singeing of hide in the open fire using firewood was traditionally used, but the relative scarcity of firewood in the recent time has resulted in local butchers using scrap tyres as an alternative source of fuel to singe slaughtered livestock because of their high heating value. The practice, though unconventional and potentially dangerous, is increasingly favored by local butchers; reason being that fire from the scrap tyres is able to selectively burn off the animal's fur without cracking the hide (Sunu, 2013). Most of the butchers in Nigeria have been using scrap tyres as substitute for firewood to singe slaughtered ruminants. This practice is also reported in other African countries like Ghana (Obiri-Danso *et al.*, 2008).

In recent time, many people in some parts of Nigeria tend to use scraped tyres as shown in figure 1 as a source of fire instead of using firewood. This could be due to factors, such as relative scarcity of firewood, increasing number of cattle hide for singeing, and increasing ponmo market (Okie *et al.*, 2009; Ekenma *et al.*, 2015). Tyres are reported to contain harmful substances which have the tendency to pollute the environment (Asthana and Patil, 2006; Hassanien, 2007; Nova Scotia Environment, 2008). **US** Agency for Toxic Substances and Diseases Registry exposed that "tyre-derived fuel" (TDF) are proven to be carcinogenic to users, and this is directly related to the presence of several heavy metals including lead (Pb), zinc (Zn), copper (Cu) etc, especially when exposed at a longer period. Moreover, a considerable amount of heavy metals residues in goat and cattle hide was reported by Warner *et al.* (2002), which made them endangered human health. Contamination of meat (singed cattle hide) by heavy metals is a severe threat because of their toxicity due to bioaccumulation in the food chain (Demirezen & Uruc, 2006). Although polluting animal feed with toxic metals cannot be perfectly escaped, there is a need to minimize such contamination, with the aim of reducing direct and indirect effects on both animal and human health respectively (Odoh, *et al.*, 2016). Accumulating evidence has revealed that, the threat of heavy metal contamination is to both food safety and human health because of the harmful nature of these metals even at relatively small concentrations (Mahaffe, 1977; Brito *et al.*, 2005; Santhi *et al.*, 2008).

The use of scrap tyres for roasting meat is quite worrisome since it has gained ground and could introduce different contaminants into the meat, thereby rendering it unsafe for human consumption (Richard *et al.*, 2014). Scrap tyres have been used in Nigeria for burning in order to obtain iron & steel frames, also as fuels for different purposes such as singeing of animal skin (Kirk, 2000; Air Resources Board, 2005; Luch, 2005; Asthana and Patil, 2006; Hassanien, 2007; Haines *et al.*, 2010; Ziadat and Sood 2014). In October, 1997, USEPA ''Air emissions from scrap tyres Combustion'' revealed that, about 250 million automobile tyres are abolished, predisposing the United States to a disastrous condition every year. Moreover, over the last decades, the trend has been maintained in the U.S and other parts of the world, including Nigeria. Furthermore, heavy metals poisoning has negative effect on body organs and is implicated in many diseases like cough, dryness, irritation of

the nose and throat, headache, dizziness, weakness, fever, chills, chest pain, respiratory tract and kidney problem amongst others, which upon exposure to such toxic metals may result (Beetsch and Onum, 2013).

Considering the chemical composition of tyres which may vary and include heavy metals compounds especially Cu, Pb, and Cd on trace levels as an attendant substance of zinc oxide (Anne and Russ, 2006), there is the possibility of the emission of toxic metals and suspended particulate matter into the environment, especially the atmosphere, and the absorbance of such substances by the hide during combustion. Moreover, the ash and dust left after the singeing of hide is completed are indiscriminately discarded into water drainages, which may introduce toxic substances to the environment (Collins et al., 2002; Shakya et al., 2006; Mensah et al., 2019). The singed hide that was washed several times may still retain significant levels of heavy metals (Okiei *et al.*, 2009).

The objectives of this study are therefore to determine the presence and levels of selected heavy metals (Cd, Cu, Fe, Zn, and Pb) in the hide singed with scrap tyre from the selected states in northern Nigeria, and to compare the metal levels with United States Department of Agriculture (USDA) and European Union Regulation (OJEC) reference standards.

MATERIALS AND METHODS

Sample collection

All the laboratory analysis for this study was conducted in the department of chemistry laboratory, faculty of science Yusuf Maitama Sule University Kano. Chemicals of analytical grade were used in the preparation of the reagent solutions. Three tyre singed hide samples were collected each from Adamawa, Kaduna, Kano, Niger, Plateau, Taraba, and Zamfara states across the northern regions of Nigeria. Control samples were also obtained in addition. The samples were placed in air polyethylene bags and transported to the laboratory for further room drying and chemical analysis (Egwuonwu *et al.*, 2019).

Sample preparation

Singed cattle hide samples (figure 2) were dried in an oven at 105 °C to constant weight. The dried samples were grinded using mortar and pestle and homogenized, the grinding was repeated until fine particles are obtained. Control sample (unsinged hide) was also treated under the same condition (Egwuonwu *et al.*, 2019).

Sample Digestion

The samples were decomposed by wet digestion method for the determination of various metals. The method used in this study was adopted from *Obiri-Danso et al.* 2008 were 1g of powdered sample (singed skin) was carefully weighed into 50 cm^3 volumetric flask, 3 cm^3 of conc. HNO_3 and 2 cm^3 of conc. HCl were added to the powdered sample and shaken gently for proper mixing. The mixture was heated on a hot plate at 200 °C for 30 min until a clear solution was observed. The mixture was allowed to cool, and de ionized water was added to the 100 mL mark. The resulting solution was filtered and analyzed for the presence of Cd, Cu, Fe, Zn, and Pb using Atomic Absorption Spectrophotometry. The method is then repeated to digest the unsinged skin (control). The same mixture of acid was used in the preparation of the blank solution in triplicates.

Metal analysis

Atomic absorption spectrophotometer (Buck scientific world 210VGP) was used for the determination of heavy metal concentrations in singed cattle hide samples, blank solutions, and certified reference materials.

Quality control

Quality control was practiced to ensure reliable results. All the plastic containers and glasswares were soaked in 10% HNO_3 (v/v), washed with detergent, and later rinsed twice with deionized water before drying in an oven. All the reagents used were of high analytical grade (Analar®), and deionized water was used in the analysis. CertiPUR® reference materials (Merck, Germany) were analyzed in triplicates for the validation of analytical results. The percentage recovery was calculated and compared with the certified values. Analyses of the results were carried out in triplicate.

Data analysis

The descriptive statistics (mean, standard deviation, minimum and maximum values) for the dataset obtained in this study was carried out using MS Excel 2010. Furthermore, one way ANOVA was applied to identify the elemental variations among the singed hide samples analyzed, and the results were reported at $p<0.05$ levels.

Figure 1. Singeing of cattle hide using scrap tyre

Figure 2. Singed cattle hide with scrap tyre

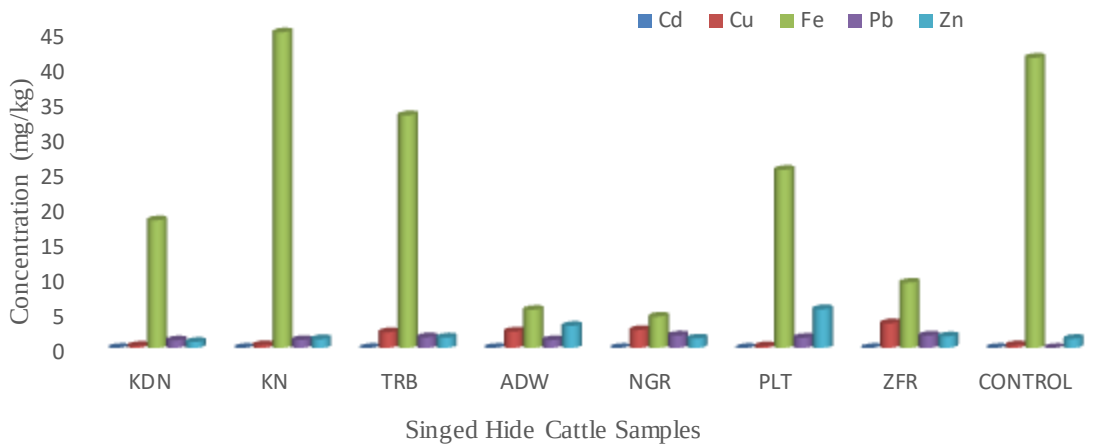

Figure 3. Heavy metals concentrations in singed hide samples

RESULTS AND DISCUSSION

Table 1. Concentration of metals in singed cattle hide (mg/kg)

Samples	Cd	Cu	Fe	Pb	Zn
KDN	0.0005±4.71E-5	0.301±0.584	18.161±0.584	1.080±0.072	0.856±0.085
KAN	0.0001±5.77E-5	0.408±0.001	44.930±0.490	1.124±0.012	1.247±0.148
TRB	0.009±0.001	2.236±0.165	33.094±1.305	1.523±0.223	1.486±0.059
ADW	ND	2.331±0.101	5.422±0.474	1.115±0.079	3.132±0.256
NGR	ND	2.535±0.461	4.452±0.408	1.773±0.123	1.335±0.077
PLT	ND	0.254±0.010	25.328±0.957	1.440±0.163	5.503±0.328
ZFR	ND	3.510±0.380	9.282±0.572	1.760±0.160	1.644±0.053
Control	ND	0.387±0.009	41.278±4.936	ND	1.285±0.290
MPL+	0.05	20.00	50.00	0.10	50.00

ND=Not detected. KDN=Kaduna, KAN=Kano, TRB=Taraba, ADW=Adamawa, NGR=Niger, PLT=Plateau ZFR= Zamfara. MPL= Maximum Permissible Limit.
+ USDA, 2006; OJEC, 2001; European Commission Regulation, 2006

The analysis for the presence and levels of selected heavy metals in seven different samples of singed hide revealed a significant variation ($p<0.05$) in the presence of Cu, Fe, Pb, and Zn, as shown in Table 1.

Scrap tyres are not regarded as hazardous waste, however during combustion such as tyre fire toxic substances including heavy metals, oils, and gasses are discharged into the environment (USEPA, 2016). The chemical reaction and degradation product of the content releases various toxic chemicals and heavy metals which could be of challenge to human health (Nadal, 2016).

Cadmium

The mean Cd concentrations in singed hide samples analyzed were found to be 0.0001, 0.0005 and 0.009 mg/kg for Kano, Kaduna and Taraba states respectively which are far below the maximum permissible limit of 0.05 mg/kg set by USDA (2006), and OJEC (2001). On the other hand Cd was not detected in the samples obtained from Niger, Adamawa, Zamfara, and Plateau states. This result is similar to the findings of Friday and Nwite (2016), who have not detected Cd in the cattle hide singed with scrap tyre.

Cd was found to have implications on human health. Too much exposure of Cd over a long period of time can lead to kidney disease, cancer, and bone damage. High concentration of cadmium can damage the kidney, liver and heart, and in severe cases may cause death (Koki and Jimoh, 2013). Based on the findings of the present study, Cd is not of concern and may not pose a health threat to the consumers of singed cattle hide from the states under consideration.

Copper

The highest mean Cu concentration of 3.510 mg/kg was obtained from Zamfara and the lowest concentration of 0.254 mg/kg from Plateau states. Samples collected from Taraba, Adamawa, and Niger were found to be in close range of Cu concentrations of 2.236, 2.331, and 2.535 mg/kg respectively, which are much higher than the control as shown in Table 1. This is similar to the findings of Obiri-Danso et al., (2008) detected low Cu concentration of 5.67±1.24 mg/kg. Cu concentrations in all the samples analyzed were within the maximum permissible limit of 20.0 mg/kg set by USDA (2006).

Considering the toxicological implication of Cu, excess copper intake may lead to toxic manifestations. Cu can oxidize proteins and lipids; it can enhance the production of free radicals. Chronic toxicity is manifested as diarrhea and blue green discoloration of saliva. Cu poisoning may result in hemolysis, hemoglobinuria, and renal failure.

Iron

Fe concentrations vary significantly among the singed hide samples analyzed with the highest mean concentration of 44.93 mg/kg for Kano, followed by Taraba with mean concentration of 33.094 mg/kg. The sample from Niger state has the lowest Fe concentration of 4.45 mg/kg. The results from Kano, Taraba, and Plateau indicate moderate concentrations of Fe in the singed hide below the permissible limit of 50.00 mg/kg. Considering the Fe concentration of 41.278 mg/kg in the control

(unsinged hide) of this study, and 28.91±0.04 mg/kg as reported by Ijeoma et al., (2015), it could be inferred that Fe derive its source from the natural abundance in animal skin and blood (Pantapoulous et al., 2012).

Lead

Pb was detected in all the singed hide samples analyzed, but not present in the control sample. The concentrations were found to be in the range of 1.080 to 1.773 mg/kg with sample from Niger having the highest concentration. This finding is contrary to the results obtained by Beetseh and Onum, (2013) with an average Pb concentration of 0.0267 mg/kg. All the results obtained in the present study revealed Pb concentrations above the maximum permissible limit 0.10 mg/kg (USDA, 2006, and OJEC, 2001). This is also in agreement with the findings of Essumang et al., (2007) which attributed heavy metals in cattle hides in Ghana to tyre-singed treatments. Furthermore, Kalu et al., (2015) reported Pb concentration of 4.36±0.79 mg/kg in singed hide using scrap tyres. It can be inferred that scrap tyre used to burn the hairs introduced elevated concentrations of Pb which may be toxic to humans.

Pb was found to have high toxicological implications on human health. The accumulation of Pb in children may result in cognitive deficits; while in adults it may cause progressive renal disease. Symptoms of Pb poisoning include abdominal pain and diarrhea followed by constipation, nausea, vomiting, dizziness, headache, and general weakness (Beetseh and Onum, 2013). According to blood lead level testing, Pb interferes with a variety of body processes and is toxic to many organs and tissues, including the heart, bones, intestines, kidneys, and reproductive and nervous systems. It interferes with the development of the nervous system and is therefore particularly toxic to children, causing potentially permanent learning and behavior disorders. Symptoms include abdominal pain, confusion, headache, anemia, irritability, and in severe cases, seizures, coma and death (Martins and Griswold, 2009).

Zinc

There was a clear variation of Zn concentrations in singed hides analyzed with the highest concentration of 5.503 mg/kg for sample from Plateau state while the least was 0.856 mg/kg for samples from Kaduna state. Furthermore, hide samples collected from Taraba, Niger, Zamfara and Kano revealed lower Zn concentrations of 1.486, 1.335, 1.644 and 1.247 mg/kg respectively. Similarly, the control sample was observed to Zn concentration of 1.285 mg/kg. Low concentrations of Zn obtained in this study is in agreement with the findings of Beetseh and Onum, 2013; Odoh *et al.*, 2016; Aya and Nwite, 2016 who also reported low Zn concentration from singed cattle hide samples. This study indicates that all the Zn concentration in the samples analyzed is within the maximum permissible limit of 50.0 mg/kg set by (European Commission Regulation, 2006). According to Adam et al 2013, Zn is an important micro-nutrient in the body, but higher doses could result in a type of dermatitis known as "Zinc Pox", and also in irritation of the digestive tract causing nausea and vomiting (WHO, 1996).

CONCLUSION

It is evident from the findings of this study that singeing of hide with scrap tyres introduces heavy metals which may not be removed or washed out completely due to ignorance of the metals' presence, levels, and possible toxicity. The source of the heavy metals is associated with the chemical composition of the tyre which was not in any way expected to be mixed with food meant for humans. Zn, Fe, and Cu may not be of health concern, but the elevated concentrations of Pb

beyond the permissible limit in all the singed hide samples indicate contamination and may reach a toxic level even after several washings. The prolonged exposure to the low concentrations of Cd in some of the samples could also be of health threat. The regulatory agencies responsible for food regulations need to monitor and discourage the public from the use of scrap tyres, and highlight the danger associated with the practice of burning animal skin with scrap tyres for human consumption, especially during festive periods.

REFERENCES

Adam, I., Okyere, D., and Teye, M. 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. *Journal of Veterinary Advanced* 3(5) (2013), 165-169.

Anne, E., and Russ, E. The composition of a tyre: Typical components. *The Waste & Resources Action Programme, Oxen*, 2006.

Air Resources Board. Report on air emissions from waste tyre burning in California. California Environmental Protection Agency, 2005.
http://www.arb.ca.gov/ei/tyre/2005_tyre_burning_report.pdf.

Asthana, S. R., and Patil, R. K. Use of Alternative Fuels in Indian Cement Industry. *Advanced Energy Research* 1 (2006), 347-350

Anya, F.C. and Nwite, J.N. Implication of Roasting Goats with Tyre on Human Health and the Environment in Abakaliki, Ebonyi State, Nigeria, *Journal of Pollution effect and control* 4 (2016), 1-4.

Beetseh, C. I., and Onum, D. E. Chemical Implications of Metal Toxicity of Meat Processed Through Tyre Fire. *Journal of Chemistry and Materials Research* 3(10) (2013), 79-89

Brito, G., Díaz, C., Galindo, L., Hardisson, A., Santiago, D., and García, M.F. Levels of Metals in Canned Meat Products: Intermetallic Correlations. *Bulletin of Environmental Contamination and Toxicology* 44(2) (1990), 309-316.

Collins, K. J., Jensen, A. C., Mallinson, J. J., Roenelle, V., and Smith, I. P. Environmental impact assessment of a scrap tyre artificial reef. *ICES Journal of Marine Science* 59 (2002), 243-249.

Dada, EO., Soares MT, Okunribido FG, and Akinola MO. Ground water quality in the neighborhood of a medium-sized abattoir in Lagos, Nigeria. *FUNAI Journal of Science and Technology* 3(2) (2017), 91-102

Demirezen, D. and Uruç, K. Comparative Study of Trace Elements in Certain Fish, Meat and Meat Products. *Meat Science* 74 (2006), 255-260

Egwuonwu, F.C., Abubakar, A., and Hamzah, R.U. 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(3) (2019), 079–084

Ekenma, K. and Anaga, A.O. Determination of the presence and concentration of heavy metals in cattle hides singed in Nsukka abattoir. *Journal of Veterinary Medicine and Animal Health* 7(1) (2015), 9-17

Essumang, D. K., Dodoo, D. K., Adokoh, K. C., Koka, V., Nkrumah, B. N., and Nuer, A. C. D. Heavy metal levels in singed cattle hide (wele) and its human health implications. In *Proceedings–The First International Conference on Environmental Research, Technology and Policy*, ERTEP (2007), 19.

European Commission Regulation. No 1881/2006, Setting maximum levels for certain contaminants in foodstuff. *Official Journal of the European Union* 364 (2006), 5-24.

Aya F. C., and Nwite, J. N. Implication of roasting goats with tyre on human health and the environment in Abakaliki, Ebonyi State, Nigeria. *Journal of Pollution Effects & Control* 4(1) (2016), 1-4.

Haines, G., McCulloch M., and Wong, R. End-of-life tyre management LCA: A comparative analysis for Alberta recycling management authority. The Pembina Institute, 2010.

Hassanien M.A. Risk assessment of atmospheric toxic pollutants over Cairo, Egypt. *International Journal of Environmental Impact* 123 (2009), 353 - 363.

Ijeoma, L., Ogbonna, P., and Effiong, I. D. Effects of various methods of singeing on the heavy metal, proximate and sensory properties of singed cow hide (Ponmo). Scholars Research Library. *Archives of Applied Science Research* 7(4) (2015), 44-50.

Kalu, E., Nwanta, J. A., and Anaga, A. O. Determination of the presence and concentration of heavy metal in cattle hides singed in Nsukka abattoir. *Journal of Veterinary Medicine and Animal Health* 7(1) (2015), 9-17.

Kirk, B. L. Potential dioxin release associated with tyre derived fuel use in a cement Kiln Gallatin county, Montana. University of Idaho, Principles of Environmental Toxicology, 2000.

http://www.webpages.uidaho.edu/etox/resources/case_studies/dioxtir3.pdf.

Koki, I., and Jimoh, W. L. O. Determination of heavy metals in soils from dump site of tanneries and farmlands in Challawa Industrial Estate Kano, Nigeria. *Bayero Journal of Pure and Applied Sciences* 6(2) (2013), 57-64.

Luch, A. T*he Carcinogenic Effects of Polycyclic Aromatic Hydrocarbons.* Imperial College Press, London, IN, England, 2005.

Mahaffe, K. R. Mineral concentrations in animal tissues: Certain aspects of FDA's regulatory role. *Journal of Animal Science* 44(3) (1977), 509-515.

Martin, S., and Griswold, W. Human health effects of heavy metals. *Environmental Science and Technology briefs for citizens* 15 (2009), 1-6.

Mensah, N. J., Antwi-Akomeah, S., Akanlu, S., Sixtus, B. M. B., and Godfred, S. E. Residual levels of heavy metal contaminants in cattle hides singed with scrap tyre and firewood fuel sources: A comparative study in the Wa Municipality of Ghana. *American Journal of Environmental Science and Technology* 3(1) (2019), 11-21.

Nadal, M., Rovira, J., Díaz-Ferrero, J., Schuhmacher, M., and Domingo, J. L. Human exposure to environmental pollutants after a tyre landfill fire in Spain: Health risks. *Environment international* 97 (2016), 37-44.

Nova Scotia Environment. Interdepartmental committee on used-tyre management in Nova Scotia. Report to the Minister of Environment, 2008.

Obiri-Danso, K., Hogarh, J. N., and Antwi-Agyei, P. Assessment of the contamination of singed hides from cattle and goats by heavy metals in Ghana. *African Journal for Environmental Science and Technology* 2(8) (2008), 217-221

European Commission Regulation (ECR) No 466/2001. Setting Maximum Levels for Certain Contaminants in Foodstuffs. *Official Journal of the European Communities* 77(1) (2001), 1-13

Okiel, W., Ogunlesi, M., Alabi, F., Osiughwu, B., and Sojinrin, A. Determination of toxic metal concentrations in flame treated meat products, Ponmo. *African Journal of Biochemistry Research* 3(10) (2009), 332 – 339.

Pantopoulos, K., Porwal, S. K., Tartakoff, A., and Devireddy, L. Mechanisms of mammalian iron homeostasis. *Biochemistry* 51(29) (2012), 5705-5724.

Odoh, R., Ogah, E., and Ushie, A.O., Determination of some heavy metal profiles in meat of domesticated animals in the vicinity of kaduna south industrial area, Nigeria. *FUW Trends in Science & Technology Journal* (1)2 (2016), 337–343.

Richard, A. O., Joseph, B. A., and Samuel, A. Meat contamination through singeing with scrap tyres in Akropong-Akuapem abattoir, Ghana. *Applied Research Journal* 1(1) (2014), 12–19.

Santhi, D., Balakrishnan, V., Kalaikannan, A., and Radhakrishnan, K. T. Presence of heavy metals in pork products in Chennai (India). *American Journal of Food Technology* 3(3) (2008), 192-199.

Shakya, P. R., Shrestha, P., Tamrakar, C. S., and Bhattarai, P. K. Studies and determination of heavy metals in waste tyres and their impacts on the environment. *Pakistan Journal of Analytical & Environmental Chemistry* 7(2) (2006), 70-76

Sunu, N. E. Comparative assessment of heavy metal levels in animal hide singed with motor vehicle scrap tyres and liquefied petroleum gas (lpg) as source of fuel. Kwame Nkrumah University of Science and Technology, Kumasi, Ghana, Ph.D. Thesis, 2013.

United States Environmental Protection Agency, Air Emissions from Scrap Tyre Combustion, EPA/600/SR-97/115, 1997.

United States Department of Agriculture. Foreign Agricultural Service GAIN Report Global Agriculture Information Network Voluntary Report-public distribution GAIN Report Number CH 6064, China Peoples Republic of FAIRS Product. Specific maximum levels of contaminants in Foods, Jim Butterworth and Wu Bugang, 2006.

United States Environmental Protection Agency. Wastes – Resources Conservation – Common Wastes & Materials – Scrap Tyres, 2016. https://archive.epa.gov/epawaste/conserve/materials/tyres/web/html/fires.html

Warner, L.R., Sokhi R.S., Luhana, L., Boulter, P. G., McCrae, I., Wright, J., Reeves, N. and Osbon, D. Non-exhaust particle measurements, 2002. http://vergina.eng.auth.gr/particles/

World Health Organization, International Standards of Drinking Water, Geneva, 1996.

Ziadat, A., and Sood, E. An Environmental Impact Assessment of the Open Bunting of Scrap Tyres. *Journal of Applied Sciences* 14(21) (2014), 2695-2703.