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AN INVESTIGATION OF THE LEVEL OF HEAVY METALS CONTAMINATION OF GOAT MEAT ROASTED WITH SCRAP TYRES IN WUKARI, NIGERIA

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Abstract

The present study was undertaken to investigate the potential for heavy metals (Fe, Cr, Cd, Pb, and Cu) contamination of goat meat roasted with scrap tyres in Wukari using atomic absorption spectrophotometer (AAS). Goat meat samples were obtained from two slaughter points (new market and Mammara). The results revealed the mean concentrations of Fe, Cr, and Cu in the unroasted goat meat samples (UMN and UMM) in both new market and Mammara slaughtering points as 1.7600 ± 1.4000, 0.0012 ±0.0000, 0.8700, 3.2500 ± 0.0000, 0.0025 ± 0.0000, and 0.7850 ± 0.0071 mg/kg respectively. Cd and Pb were not detected in any of the samples. The mean concentrations of Fe, Cr, Cd, and Cu in the goat meat roasted with scrap tyres (RMN1 and RMM1) in both slaughtering houses (new market and Mammara) were 4.1300 ± 0.0141, 0.0025 ± 0.0001, 0.0011 ± 0s.0000, 1.1250 ± 0.0071, 5.1500 ± 0.0000, 0.0035 ± 0.0001, 0.0012 ± 0.0000, and 1.0500 ± 0.0000 mg/kg respectively. Pb was not detected in all the samples. Also, the mean concentrations of Fe, Cr, and Cu in the goat meat roasted with firewood (RMN2 and RMM2) in slaughtering houses (new market and Mammara) were 3.7750 ± 0.0000 mg/kg, 0.0013 ± 0.0000, 0.9850 ± 0.0000, 4.9150 ± 0.0071, 0.0026 ± 0.0000, and 0.8650 ± 0.021 mg/kg respectively. Cd was detected in the samples obtained from Mammara (0.0012 ± 0.0000) but was not detected

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in the samples collected from new market. Pb was not detected in any of the samples obtained from both slaughtering houses. The mean concentrations of Fe and Cu in (UMN, UMM), (RMN1, RMM1), and (RMN2, RMM2) in both slaughtering points were above the maximum permissible level set by (FAO) and (WHO).The result of this present study show that the practice of roasting goat meat with scrap tyres is dangerous because the meat could accumulate high and unacceptable levels of heavy metals that could pose a threat to human lives, and hence, should be outlawed.

Keywords: Goat meat, Heavy metals, Scrap tyre, Wukari, Firewood

INTRODUCTION

Meat makes up an essential part of the food we eat and is mainly composed of protein, fat and some important essential elements (Akan *et al*., 2010). It is also a good source of niacin, vitamins B6 and B12, phosphorous, zinc, and iron ,animal proteins also have high biological value (Ziegler, 1968; Nkansah and Ansah, 2014), and the presence of essential amino acids in them make complete proteins (Bastin, 2007). Apart from meat and meat products forming an important part of the human diet as well as an important source of a wide range of nutrients, they may also carry certain toxic substances (Bastin, 2007; Bando *et al.* 2023a). Toxic substances in meat tissues can be from different sources including animal drugs, pesticides, feed and other agricultural or industrial chemical substances (Fathy *et al*., 2011). Instances of heavy metal contamination in meat products during processing have also been reported (Akan *et al*., 2010; Harlia and Balia, 2010). Methods such as singeing off the hairs of the animals in flame fuelled by various substances such as wood mixed with spent engine oil, plastics mixed with refuse or tyres can contaminate the meat during processing because some of these materials contain toxic substances such as heavy metals which can contaminate the meat and render them unfit for human consumption (Okiei *et al*., 2009; Bando *et al.* 2019; Bando *et al.* 2023b). In other cases, contaminated animal feed and rearing of livestock in proximity to polluted environment were reportedly responsible for heavy metal contamination in meat (Fathy *et al*., 2011). Heavy metals in their standard state have a specific gravity (density) of more than about 5 g/cm^3. Heavy metals such as copper, nickel, chromium and iron, are essential in very low concentrations for the survival and functioning of all forms of living organisms. According to Fathy *et al.* (2011) contamination of environment with heavy metals is a severe threat because of their toxicity,

bioaccumulation and bio-magnification in the food chain. These pollutants often have direct physiological toxic effects because they are stored or incorporated in tissues, sometimes permanently (Fathy *et al.*, 2011). According to Binkowski, (2012) heavy metals such as mercury, plutonium, and lead are toxic metals that have no known vital or beneficial effect on organisms and their accumulation over a period of time in the bodies of animals and humans can cause serious damages. Among all heavy metals, however, cadmium and lead are known as highly toxic (Binkowski, 2012). Lead is also associated with severe damages of vital body organs such as kidney and brain (Imran *et al.*, 2015; Inobeme *et al.*, 2018). There are different methods available for processing meat, and these methods tend to expose them to heavy metals in different extent as well as varying levels of contamination (Inobeme *et al.*, 2018).

METHODS

Study Area description

This study was conducted in Wukari situated on longitude 9° 47'E and latitude 7° 51'N in Taraba State, Northeastern Nigeria. The vegetation of the area is predominantly characteristics of savannah zone and with major climatic seasons of wet or rainy seasons, which starts in March or April, and ends in October and the dry season, which starts in November and ends in March or April. Wukari covers an area of 4,308 km2 and with a population of about 241,546 at the 2006 census, traditional state rich with various cultures, norms and value. Fishing, farming and trading are the major occupation of the people.

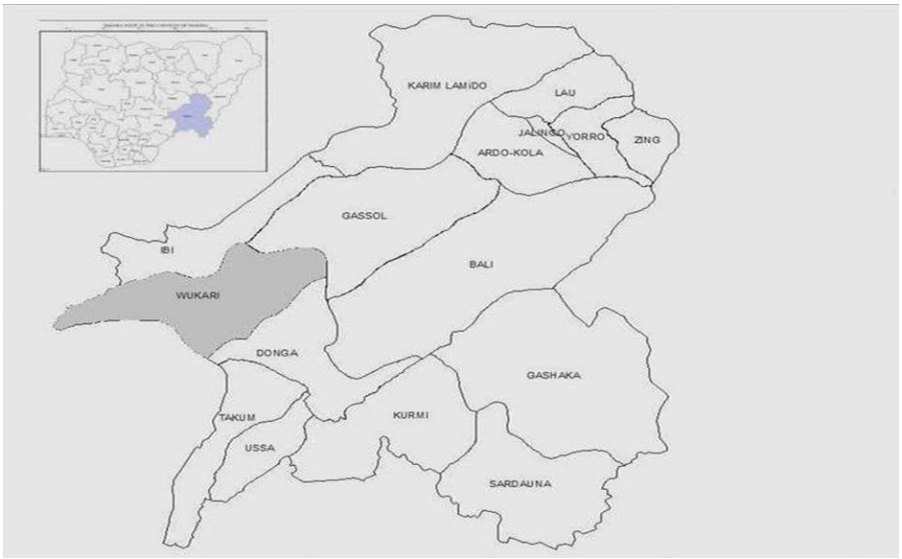


Figure 1: Map of Nigeria and Taraba showing the location of Wukari, study area.

Samples collection and preparation

Goat meat samples (scrap tyres roasted meat, firewood- roasted meat, and unroasted meat which serve as a control) were collected from two different slaughter houses (new market and Marmara) in Wukari Taraba State, Nigeria. The meat samples were placed into six different sterile plastic bags, properly labelled and transported to the laboratory, Federal Universty Wukari, where the meat samples were washed with distilled water. The samples were reduced into smaller sizes using knife and oven dried at 100 ºC until properly dried. After drying, the samples were pulverised into powdered form using mortar and pestle.

Samples digestion

The powdered meat samples were subjected to dry ashing, followed by acid digestion. The digestion of the samples was done using concentrated HNO_3 in line with the method reported by AOAC (2010). For each of the samples, 5 g was weighed using weighing balance and transferred into porcelain crucible and labelled properly. The porcelain crucibles containing the samples were then placed into muffle furnace at 550 ºC. The samples were ashed until white or grey ash was observed in the crucibles. The ashes were dissolved by adding 2 ml of conc. HNO_3 to each crucible containing the samples, after which the dissolved ashes were transferred into six (6) different 100 mL standard volumetric flasks and made up to the 100 mL marks with distilled water, then shaken and filtered using No.1 Whatman filter paper.

Heavy metals determination

The standard and the meat samples (filtrate) were ran through the atomic absorption spectrophotometer (AAS) in order to determine the presence as well as the concentrations of the selected heavy metals in the meat samples. The heavy metals analysis in each digested samples were determined in duplicates.

RESULTS

Table 1: ***Mean concentrations (mg/kg) of heavy metals in unroasted goat meat (UMN), goat meat roasted with scrap tyres (RMN1), and goat meat roasted with firewood (RMN2) in new market slaughtered house, Wukari.***

Sample	Fe	Cr	Cd	Pb	Cu
UMN	1.7600 ± 1.4000	0.0012 ± 0.0000	ND	ND	0.8700 ± 0.0141
RMN1	4.1300 ± 0.0141	0.0025 ± 0.0001	0.0011 ± 0.000	ND	1.1250 ± 0.0071
RMN2	3.7750 ± 0.000	0.0013 ± 0.0000	ND	ND	0.9850 ± 0.0000

ND: Not Detected.

UMM: Unroasted goat meat in new market slaughtered house.

RMN1: Goat meat roasted with scrap tyres in new market slaughtered house.

RMN2: Goat meat roasted with firewood in new market slaughtered house.

Table 1 show the mean concentrations of heavy metals in UMN, RMN1, and RMN2 in new market slaughtering house. The concentrations of Fe, Cr, and Cu in UMN were 1.7600 ± 1.4000, 0.0012 ± 0.0000, and 0.8700 ± 0.0141 mg/kg respectively except for Cd and Pb which were not detected. Higher Fe, Cr, Cd, and Cu concentrations were also recorded as 4.1300 ± 0.0141, 0.0025 ± 0.0001, 0.0011 ± 0.0000 and 1.1250 ± 0.0071 mg/kg respectively for the RMN1. The levels of Fe, Cr, and Cu in RMN2 3.7750 ± 0.0000, 0.0013 ± 0.0000, and 0.9850 ± 0.0050 mg/kg respectively were also recorded except for Cd and Pb which were not detected. Cd was not detected in UMN and RMN2 but a trace concentration of Cd, 0.0011±0.0000 mg/kg was detected in RMN1. Lead (Pb) was not detected in all the three samples. Variation in heavy metals concentrations between the control samples(UMN) and RMN1 and RMN2 were statistically significant ($p < 0.05$) for all metals except for the concentration of Cr in RMN2 which was not statistically significant when compared with the control samples (UMN) ($p < 0.05$) as shown in Table 1. Iron (Fe) concentration 1.7600 ± 1.4000, 4.1300 ± 0.0141 and 3.7750 ± 0.0000 mg/kg was observed to be higher in UMN, RMN1, and RMN2 respectively, when compared with the concentrations of other metals in all the three samples.

Table 2: ***Mean concentrations (mg/kg) of heavy metals in unroasted goat meat (UMM), goat meat roasted with scrap tyres (RMM1), and goat meat roasted with firewood (RMM2), in Mammara slaughtered house, Wukari.***

Sample	Fe	Cr	Cd	Pb	Cu
UMM	3.2500 ± 0.0000	0.0025 ± 0.0000	ND	ND	0.7850 ± 0.0071
RMM1	5.1500 ± 0.0000	0.0035 ± 0.0001	0.0012 ± 0.0000	ND	1.0500 ± 0.0000
RMM2	4.9150 ± 0.0071	0.0026 ± 0.0001	0.0012 ± 0.0000	ND	0.8650 ± 0.0212

ND: Not Detected.

UMM: Unroasted goat meat in Mammara slaughtered house.

RMM1: Goat meat roasted with scrap tyres in Mammara slaughtered house.

RMM2: Goat meat roasted with firewood in Mammara slaughtered house.

Table 2 showed the mean concentrations of heavy metals in UMM, RMM1, and RMM2 in Mammara slaughtering house, Wukari. The concentrations of Fe, Cr, and Cu in UMM were 3.2500 ± 0.0000, 0.0025 ± 0.0000, and 0.7850 ± 0.0071 mg/kg respectively except Cd and Pb which were not detected in the samples. Higher levels of Fe, Cr, Cd, and Cu were noted as 5.1500 ± 0.0000, 0.0035 ± 0.0001, 0.0012 ± 0.0000, and 1.0500 ± 0.0000 mg/kg respectively in RMM1, but Lead (Pb) was not detected. The concentrations of Fe, Cr, Cd, and Cu in RMM2 were 4.9150 ± 0.0071, 0.0026 ± 0.0001, 0.0012 ± 0.0000, and 0.8650 ± 0.0212 mg/kg respectively except for Pb which was not detected in the samples. Cadmium (Cd) was not detected in UMM, but minor concentration of Cadmium (Cd) was detected in RMM1 and RMM2 as 0.0012 ± 0.0000 and 0.0012 ± 0.0000 mg/kg respectively. In all the three samples UMM, RMM1, and RMM2, it was observed that Lead (Pb) was not detected in any of the samples. Variations in heavy metals concentrations between the control samples (UMM) and the samples of RMM1 and RMM2 were statistically significant ($p < 0.05$) for all metals except for the concentration of Cr in RMM2 that was not statistically significant when compared with the control samples (UMM) ($p < 0.05$) as shown in table 3. Iron (Fe) concentration (3.2500 ± 0.0000, 5.1500 ± 0.0000, and 4.9150 ± 0.0071) in UMM, RMM1, and RMM2 respectively was noted to be higher when compared with the levels of other heavy metals in all the three samples.

Table 3: **ANOVA of the mean concentrations of heavy metals in goat meat roasted with scrap tyres and firewood in new market slaughtered house and Mammara slaughtered house, Wukari.**

Sample	Fe	Cr	Cd	Pb	Cu
RMN1	4.1300[a]	0.0025[a]	0.0011[a]	ND	1.1250[a]
RMN2	3.7750[a]	0.0013[b]	ND	ND	0.9850[a]
RMM1	5.1500[a]	0.0035[a]	0.0012[a]	ND	1.0500[a]
RMM2	4.9150[a]	0.0026[b]	0.0012[a]	ND	0.8650[a]

From the ANOVA table, the mean values with superscript "a" shows that there are statistically significant differences when comparing with the control (unroasted goat meat) ($p< 0.05$), while the mean values with superscript "b" shows statistically insignificant when comparing with the control (unroasted goat meat) ($p< 0.05$).

ND: Not Detected.

RMN1: Goat meat roasted with scrap tyres in new market slaughtered house.

RMN2: Goat meat roasted with firewood in new market slaughtered house.

RMM1: Goat meat roasted with scrap tyres in Mammara slaughtered house.

RMM2: Goat meat roasted with firewood in Mammara slaughtered house.

DISCUSSION

The results from this present study showed that (UMN, UMM), RMN1, RMM1), and RMN2, RMM2) in both new market slaughtering house and Mammara slaughtering house, Wukari accumulated varying levels of heavy metals (Fe, Cr, Cd, Pb, and Cu).

Iron (**Fe**)**:** Fe was detected in all the goat meat samples obtained from the two different slaughtering houses (new market and Mammara). The mean concentration of Fe in the unroasted goat meat (UMN), goat meat roasted with scrap tyres (RMN1), and goat meat roasted with firewood (RMN2) were 1.7600 ± 1.4000, 4.1300 ± 0.0141, and 3.7750 ± 0.000 mg/kg respectively in new market slaughtering house. The concentration of Fe in the unroasted goat meat (UMM), goat meat roasted with scrap tyres (RMM1) and goat meat roasted with firewood (RMM2) were also recorded as 3.2500 ± 0.0000 mg/kg, 5.1500 ± 0.0000 mg/kg, and 4.9150 ± 0.0071 mg/kg respectively in Mammara slaughtering house.

The concentration of Fe in all the three samples obtained from Mammara slaughtering house were observed to be higher than in all the three samples collected from new market as shown in Tables 1 and 2.

Variations in Fe concentrations between the control samples (UMN and UMM) and the individual samples of (RMN1, RMN2, RMM1 and RMM2) were statistically significant ($p < 0.05$) in both slaughtering houses as shown in Table 6. It was observed that RMN1 and RMM1 accumulated higher levels of Fe than UMN and UMM as well as in RMN2 and RMM2 in both slaughtering houses. The observed increase may be due to the Fe content present in scrap tyres used during processing, and this agreed with report of Essumang *et al.* (2007); Elikem, (2013) which reported the elevated level of Fe (206.40 mg/kg) in hides processed with scrap tyres as a source of fuel. Amfo-out *et al.* (2014) also recorded higher level of Fe in goat meat roasted with scrap tyres as 19.0 mg/kg (in unwashed meat), 13.6 mg/kg (in washed meat, and 9.4 mg/kg (boiled meat) which were all far above the recommended intake level (0.01 mg/kg) reported by FAO (1982) shown in Table 1. Therefore, higher level of Fe observed in RMN1 (4.1300 ± 0.0141 mg/kg) and RMM1 (5.1500 ± 0.000 mg/kg) might be as result of Fe content in scrap tyres used during processing.

The higher concentration of Fe in UMN and UMM (1.7600 ± 1.4000 and 3.2500 ± 0.0000 mg/kg) in both new market and Mammara slaughtering houses respectively might be attributable to the presence of heavy metals in the local environment which the animals could easily have come in contact with through scavenging in open waste or refuse dumps, free range grazing, drinking water from polluted streams and drains and exposure to atmospheric depositions especially from automobile fumes and open burning of solid waste as reported by Obiri-Danso *et al.* (2008). The observed increase in the concentration of Fe in RMN2 and RMM2 (3.7750 ± 0.000 and 4.9150 ± 0.0071 mg/kg) in both new market and Mammara slaughtering houses respectively may be due to the iron grid material on which the slaughtered goats were placed on during processing. This observation was also made by Inobeme *et al.* (2018).

The Fe content in all the goat meat samples collected from the two different slaughtering houses were far above the WHO permissible level (0.01 mg/kg) (FAO/WHO, 2000). This is thus toxic and unfit for human consumption.

Chromium (**Cr**): Cr was detected in all the goat meat samples collected from the two different slaughtering houses. UMN and UMM were observed to accumulate trace amount of Cr (0.0012 ± 0.0000 and 0.0025 ± 0.0000 mg/kg) in new market and Mammara slaughtering houses respectively as shown in Tables and 4 and 5. This could be due to the feeding habits of the goats as earlier observed by Obiri-Danso *et al.* (2008). Tables 1 and 2 also show the mean concentration of Cr (0.0013 ± 0.0000 and 0.0026 ± 0.0001 mg/kg) in RMN2 and RMM2 in both new market and Mammara slaughtering houses respectively. The observed increase in the concentration of Cr in RMN2 and RMM2 might be due the material (metal grid) on which the slaughtered goats were placed on during processing as earlier recorded by Inobeme *et al.* (2018). The concentration of Cr in RMN1 and RMM1 in both new market and Mammara slaughtering houses was also recorded as (0.0025 ± 0.0001 and 0.0035 ± 0.0001 mg/kg) respectively. The observed increase may as a result of Cr content in the scrap tyres used during processing, and this agreed with the finding of Essumang *et al.* (2007); Elikem, (2013) which recorded the higher level of Cr as (14.40 mg/kg) in hides processed with used scrap tyres. Variations in Cr concentrations between the control samples (UMN and UMM) and RMN1 and RMM1 were statistically significant ($p < 0.05$) in both new market and Mammara slaughtering houses but not statistically significant ($p < 0.05$) when compared the control samples (UMN and UMM) with RMN2 and RMM2 in both slaughtering houses as shown in Table 3. However, the concentration of Cr in the control samples (UMN, UMM), samples roasted with scrap tyres (RMN1, RMM1) and samples roasted with firewood (RMN2, RMM2) in both new market and Mammara slaughtering houses respectively were observed to be far below the permissible limit (0.05 mg/kg) recorded by Codex Alimentarius Commission (1994) .

Cadmium (**Cd**): Cadmium was not detected in most of the goat meat samples analysed. The trace concentration of Cd (0.0012 ± 0.0000 and 0.0012 ± 0.0000 mg/kg) was observed to be found in (RMM1 and RMM2) respectively in Mammara slaughtering house, but Cd was not detected in (UMM). The concentration of Cd (0.0011 ± 0.0000 mg/kg) was also detected in (RMN1) in new market slaughtering house, but was not detected in the control samples (UMN and UMN2). Inobeme *et al.* (2018) reported that Cd was not detected from fresh chicken meat samples analysed. Okiei (2009) also reported the non-detectable level of Cd in meat products (ponmo) processed with firewood. From Table 5, the mean concentration of Cd (0.0012 ± 0.0000 and 0.0012 ± 0.0000, mg/kg) in (RMM1 and RMM2) respectively in Mammara slaughtering was observed to be the same, this might be

that the scrap tyres as well the metal grid used during processing did not contain Cd, and this was in line with the report of Eremong (2011) and Elikem (2013) who observed that in analyzing tyre- singed samples before and also after boiling, Cd was not detected. Okiei (2009) also reported the absence of Cd in meat (ponmo) processed with firewood and meat products (ponmo) processed with scrap tyres. Therefore, the concentration of Cd (0.0012 ± 0.0000 and 0.0012 ± 0.0000 mg/kg) in (RMM1 and RMM2) respectively may be due to vehicular traffic deposition especially on the firewood which are mostly dried by the road side in Wukari.

The observed concentration of Cd (0.0011 ± 0.0000 mg/kg) in (RMN1) may also be as result of the feeding habits of the goats and not from the scrap tyres used during processing as earlier observed by Amfo-otu *et al.* (2014). The Cd concentration could also be from atmospheric deposition on the meat during processing as well as contamination from feeds (Aljaff *et al.*, 2014).

The concentration of Cd detected in the meat samples obtained from both new market and Mammara slaughtering houses were far below the permissible level (0.5 mg/kg) advised by FAO (1983). Variations of Cd levels between the samples were statistically significant ($p< 0.05$) in new market and Mammara slaughtering houses. Cd have been reported to have no known bio-importance in human biochemistry and physiology and that its consumption even at very low concentrations can be toxic (Ekenma *et al.*, 2015).

Lead (**Pb**): Lead is a very toxic metal and has the ability of binding with enzymes and other essential cellular components thereby causing damage to vital body organs such as kidney and brain (Cunningham and Saigo, 1997). Pb was not detected in all the goat meat samples obtained from the two different slaughtering houses (new market and Mammara slaughtering). This could be that the scrap tyres as well as material (metal grid) used during processing in both slaughtering houses did not contain Pb. It could also be that the goats were not exposed to Pb in their environment or during feeding as earlier reported by Eremong, (2011) and Elikem (2013). Elikem (2013) also reported that the non-detected level of Pb could be that animals were reared far away from towns or cities where industrial wastes, refuse dumps and incinerators serves as main sources of this metal.

Copper (**Cu**): Copper was detected in all the goat meat samples analysed in both new market and Mammara slaughtering houses. It was observed that the heavy metals content in all the three samples obtained from new market slaughtering house were higher than the

goat meat samples collected from the Mammara slaughtering house as shown in Tables 3 and 4. The content of Cu in UMN, RMN1, and RMN2 were 0.8700 ± 0.0141, 1.1250 ± 0.0000, and 0.9850 mg/kg respectively in new market slaughtering house as shown in Table 4. The concentration of Cu in UMM, RMM1, and RMM2 were 0.7850 ± 0.0071, 1.0500 ± 0.0000, and 0.8650 ± 0.0212 mg/kg respectively in Mammara slaughtering as shown in Table 2.

The higher level of Cu was observed in RMN1 and RMM1 (in both new market and Mammara slaughtering houses). This increase may be as result of the Cu in the scrap tyres used during processing. Amfo-out *et al.* (2014) recorded higher level of Cu in goat meat roasted with scrap tyres as 1.2 mg/kg (in unwashed meat), 1.5 mg/kg (in washed meat, and 0.5 mg/kg (boiled meat). Therefore, higher level of Cu observed in RMN1 (1.1250 ± 0.0000 mg/kg) and RMM1 (1.0500 ± 0.0000 mg/kg) is as result of Cu in scrap tyres used during processing. Variations in Cu concentrations between the control samples (UMN and UMM) and samples roasted with scrap tyres (RMN1 and RMM1) as well as samples roated with firewood (RMN2 and RMM2) in both new market and Mammara slaughtering houses were statistically significant ($p < 0.05$) as shown in Table 3. The high concentration of Cu recorded in (UMN and UMM) in both new market and Mammara slaughtering houses may be attributable to the presence of heavy metals in the local environment which the animals could easily have come in contact with through scavenging in open waste or refuse dumps, free range grazing, drinking water from polluted streams and drains and exposure to atmospheric depositions especially from automobile fumes and open burning of solid waste (Obiri-Danso *et al.*, 2008). This metal could also have come from various sources such as vehicle emissions, agricultural chemicals, urban and industrial wastes (Okoye and Ugwu, 2010). Also the observed level of Cu in RMN2 and RMM2 in both slaughtering houses may be due to the fact that the slaughtered goats were placed directly on metal grids during processing as observed by Ekenma *et al.* (2015). The concentrations of Cu in all the samples in both new market and Mammara slaughtering houses were observed to be far above the permissible limit (0.05- 0.5 mg/kg) as recorded by FAO (1982). Consequently, the goat meat from these slaughtering houses were considered unfit for human consumption because copper toxicity is associated with many health problem such as anorexia, fatique, premenstrual syndrome, depression, anxiety, liver and kidney damage, migraine headaches, allergies, childhood hyperactivity and learning disorders (Ekenma *et al.*, 2015).

CONCLUSION

From the findings of the present study, it was obvious that the goat meat samples obtained from the two different slaughtering houses (new market and Mammara) Wukari bio-accumulated different levels of heavy metals Fe, Cr, Cd, Pb and Cu. The levels of Fe and Cu far exceeded the maximum permissible levels and therefore can pose a threat to humans consuming goat meat in Wukari. It could also be concluded that the high level of heavy metal concentrations in goat meat samples obtained from the two different slaughtering houses in the present study may be as a result of both the method of processing, rearing and environmental factors.

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