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EVALUATION AND HEALTH RISK ASSESSMENT OF SOME HEAVY METALS IN PORK AND BEEF SOLD IN OKPUNO, AWKA SOUTH, ANAMBRA STATE, NIGERIA

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ABSTRACT: *The study was undertaken to evaluate some heavy metals in beef and pork sold at Okpuno and assess their health risks. Six samples of pork and beef were bought and analysed for three months for heavy metals viz. cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn), and iron (Fe) with the use of atomic absorption spectrophotometer (AAS). The results generated from the analysed heavy metals were utilised in computing the potential human health risk associated with consuming both types of meat by consumers. The result showed that in pork, Fe, Zn and Pb were highest within the three months with the following mean concentrations 0.22 ± 0.22, 0.16 ± 0.15, and 0.09 ± 0.07mg/kg respectively. Also, Fe (0.30 ± 0.25 mg/kg) and Zn (0.21 ± 0.20 mg/kg) recorded higher concentrations in beef. The estimated daily intakes of all five heavy metals were found to be low when compared to the recommended daily dietary intake. Concerning health risk, the target hazard quotient of the analysed heavy metals ranged from 0.003566 to 0.00000179 and followed the increasing order of Cd > Pb > Cu > Fe > Zn. The target hazard quotient of the five metals poses little threat to human health (THQ<1). The computed carcinogenic risk for Cd (0.0000112) and Pb (0.0000000152) were within the tolerable limit ($1 \times 10^{-6} < CR < 1 \times 10^{-4}$). However, the carcinogenic risk value for Cd in this study indicates that serious health concerns associated with cadmium toxicity may occur over time from the consumption of these meats. Findings from this study revealed that some of the heavy metals were within safety limits for human consumption, hence, intake of these meats (pork and beef) poses no threat to consumers.*

KEYWORDS: Heavy metals, Pork, Beef, Health risk assessment, Okpuno.

INTRODUCTION

In recent years, much attention has been focused on the concentrations of heavy metals in meat and other foods to check for those hazardous to human health (Iyegbu *et al.*, 2022). Meat which is a source of protein and very important human food may potentially accumulate toxic minerals and represent one of the sources of heavy metals for humans. It is a very rich and convenient source of nutrients, including microelements (Badis *et al.*, 2014). Despite these advantages, meat can be a source of toxic substances by bioaccumulation of heavy metals (HMs) and trace elements at a toxic level which can increase the risk of specific diseases (Emami *et al.*, 2023). The contamination of heavy metals in meat (beef and pork) is caused by animal feeds, especially in some areas with intense manufacturing activities, industrial emissions, coal combustion, and ore mining (Han *et al.*, 2022). Beef contamination is particularly a serious problem in the sub-Saharan region of Africa because of the loosely regulated manners in which donor animals are raised and how their carcasses are handled. In Nigeria and Ghana, beef, mutton, caprine, pork and chicken have been found to contain cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), zinc (Zn) or manganese (Mn) at times above the recommended levels by international standards (Ekou *et al.*, 2021).

Heavy metal pollution even at low levels and their cumulative health effects are among the leading health concerns all over the world. Heavy metal residues in pork and beef slaughtered for daily human consumption are implicated in serious health challenges such as nephrotoxicity, hepatotoxicity, neurotoxicity, gastrointestinal disorders and so on. Therefore, it is important to ensure that these meats are safe for human consumption. Information about heavy metal concentrations in beef and pork intake is very important for assessing their risk to human health (Bamuwamye *et al.,* 2015). This research is crucial because Awka is a developed city and also well-populated. Here, there is a higher demand for pork and beef due to its lower cost price, it is very much affordable when compared to other animals, but the masses are unaware of the dangers of heavy metal contamination in these meats. This study was aimed at evaluating some heavy metals in raw pork and beef sold at Okpuno market, Awka, Anambra State, their potential health implications in consumers and also establish the need to educate the consumers of meat (pork and beef) on the adverse health issues heavy metals in meat and animals slaughtered for daily human consumption could predispose them when ingested in great quantity.

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MATERIALS AND METHODS

Description of Study Area

The area of study was Okpuno town, one of the five towns that make up Awka municipal urban in Awka South Local Government Area in Anambra State. It is located between latitudes 6° 13'N and 6° 23'E, longitudes 6° 49'N and 7° 04'E, with a population of 13,761, both male and female. Okpuno is situated in the Anambra – Imo River Basin Authority underlaid in the basic sedimentary rocks (Otti and Akabuike, 2013).

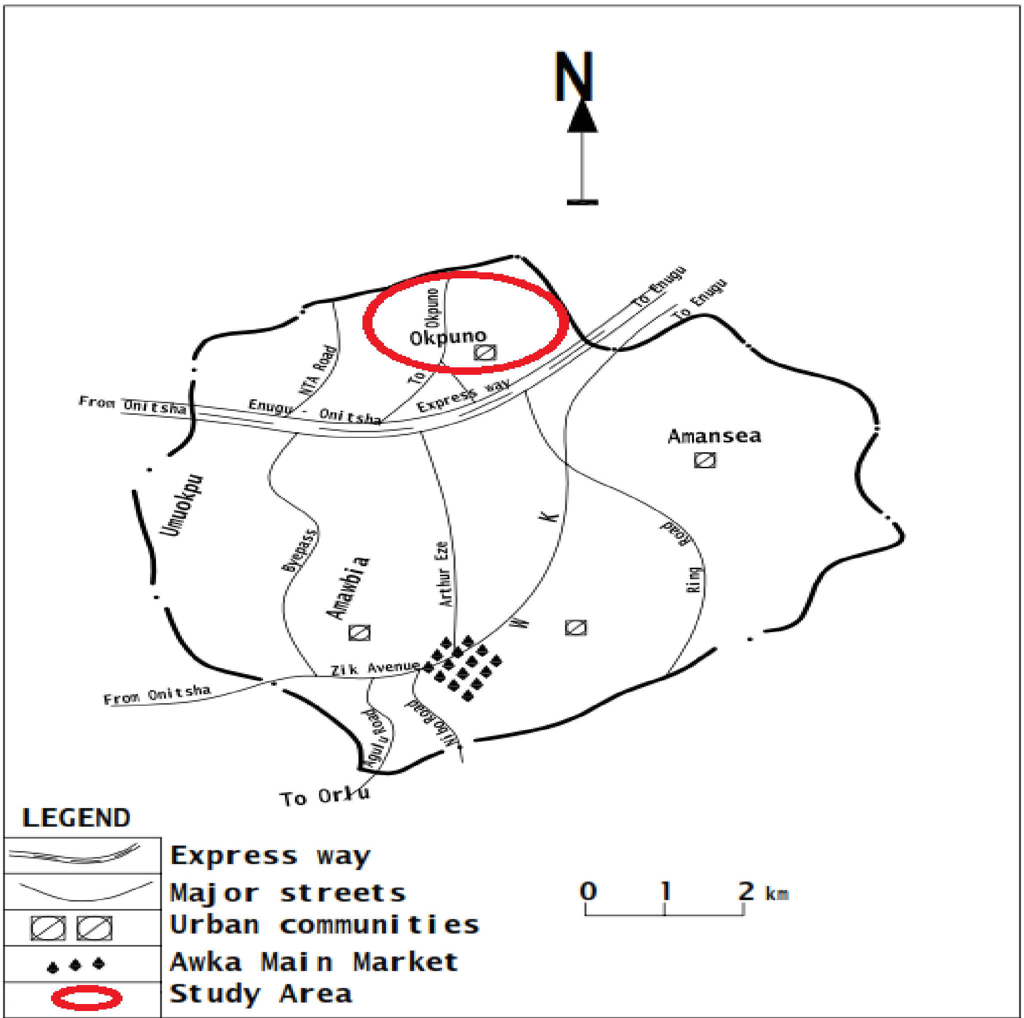

Fig. 1 MAP OF AWKA URBAN AREA

Sample Collection

Pork and beef samples were bought from a market in Okpuno in order to assess the presence and levels of heavy metals concentration. The samples were bought monthly for three months and were replicated twice. The fresh meat samples were taken to the laboratory where it was washed with water to reduce the moisture content.

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Sample Digestion (Wet Digestion) and Heavy Metal Analysis

The heavy metal analysis was conducted in the laboratory of the Department of Biochemistry, Nnamdi Azikiwe University, Awka, Anambra State. Samples were placed on a flat stainless plate and left to dry in the oven at 105 ^{o}C for about four hours. After drying, they were blended and samples weighing approximately 1 g were transferred into a 100 ml digestion flask, then 10 ml of 70 % HNO_3 was added followed by heating for about 30 − 45 minutes until any vigorous reaction subsided. After cooling, 8 ml of 70 % perchloric acid was added to each flask and the contents were gently heated on a hot plate until the solution became colourless or nearly so, and white fumes of $HCLO_4$ were evolved making sure that the contents did not dry. After cooling, approximately 30 ml of distilled water was added to each flask and boiled for another 10 minutes, cooled and then filtered at room temperature.

Metal analysis was conducted using Varian AA240 Atomic Absorption Spectrophotometer according to the method of APHA (1995).

Health Risk Assessment

The potential health risks of heavy metal consumption through meats were assessed based on the estimated daily intake, health risk index (HRI) and the target hazard quotient (THQ). The estimated daily intake of each metal was calculated to averagely estimate the daily loading into the body system of a specified body weight of a consumer. Human health is determined under non-carcinogenic risk and carcinogenic risk.

Estimated Daily Intake (EDI):

Estimated daily intake (EDI) was calculated based on the formula below:

$$EDI = \frac{C \times FIR}{BW}$$

Where C is the average heavy metal concentration in wet weight

FIR – Food ingestion rate (g/day)

BW – Average body weight in adults (70kg) (USEPA, 2005).

Non-Carcinogenic Risk:

Non-carcinogenic risk was calculated using the target hazard quotient (THQ) with the formula below:

$$THQ = \frac{EF \times ED \times FIR \times CO \times 10-3}{BW \times AT \times RFD}$$

Where EF is the Exposure frequency (365 days/year)

ED – Exposure duration (55 years), whereby the life expectancy in Nigeria for males is 54 years and for females is 56 years

FIR – Food ingestion rate (g/day)

CO – Concentration of heavy metals

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10^{-3} – Conversion factor 0.001

BW – Body weight (70 kg in adults)

AT – Average time for non-carcinogenic (365 x 55 years)

RFD – Oral reference dose (mg/kg/day)

The oral reference dose for Cd, Cu, Pb, Zn, and Fe are 0.0005, 0.04, 0.0035, 0.3 and 0.7 mg/kg/day respectively (USEPA, 2005). If the values are greater than 1, then it could lead to or induce non-carcinogenic health risk (the risk is high) but, if the values are equal to or less than 1, there could be a possibility or potential or a sign of non-carcinogenic health risk.

Hazard Index or sum of Target Hazard Quotient (HI or ∑THQ): This is the summation of all the heavy metals.

$$HI = \sum HQ$$

Carcinogenic Risk

Carcinogenic risk is calculated using the formula below:

$$\frac{EF \times ED \times FIR \times CO \times CSF \times 10-3}{BW \times AT}$$

Where EF is the Exposure frequency (365 days/year)

ED – Exposure duration (55 years), whereby the life expectancy in Nigeria for males is 54 years and for females is 56 years

FIR – Food ingestion rate (g/day)

CO – Concentration of heavy metals

CSF – Cancer slope factor

10-3 – Conversion factor 0.001

BW – Body weight (70kg in adults)

AT – Average time for carcinogenic (365 x 55 years)

If the carcinogenic risk is between 1.8×10^{-6} to 1.0×10^{-4}, then it is within the tolerable limit, if it is close to 1×10^{-4}, then there could be potential carcinogenic health risk over time but, if it is above 1×10^{-4}, there is a high possibility of causing cancer.

Statistical Analysis

Data generated were subjected to T-test analysis at a 0.05 % level of significance to determine if there was a significant difference in the mean concentrations of heavy metals between the pork and beef collected in three months. One-way analysis of variance (ANOVA) (SPSS for Windows 21.0) was used to analyse the results and Duncan's test was used to compare the means.

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RESULTS

Tables 1 and 2 show the concentration of the five metals in pork and beef for January, February and March respectively. In pork, Fe, Zn and Pb were highest within the three months with the following mean concentrations: 0.22 ± 0.22, 0.16 ± 0.15, and 0.09 ± 0.07 mg/kg respectively. There was no significant difference in the mean concentration of each metal (P > 0.05). In beef, the mean concentration of Fe and Zn were the highest with the following figures 0.30 ± 0.25 and 0.21 ± 0.20 mg/kg respectively within the three months. However, there was no significant difference in the mean concentration of each metal (P > 0.05)

Table 1. Concentration of heavy metals in pork for three months

Month	Cadmium (Cd) (mg/kg)	Copper (Cu) (mg/kg)	Lead (Pb) (mg/kg)	Zinc (Zn) (mg/kg)	Iron (Fe) (mg/kg)
January	0.0235^{b}	0.0535^{a}	0.1475^{a}	0.2085^{a}	0.2105^{a}
February	0.0425^{b}	0.0385^{b}	0.061^{a}	0.1705^{a}	0.2135^{a}
March	0.0545^{a}	0.03^{b}	0.058^{a}	0.115^{a}	0.23^{a}
	Mean ± SD 0.04 ± 0.05	Mean ± SD 0.04 ± 0.04	Mean ± SD 0.09 ± 0.07	Mean ± SD 0.16 ± 0.15	Mean ± SD 0.22 ± 0.22

Rows sharing similar superscripts are not significantly different (P>0.05)

Table 2. Concentration of heavy metals in beef for three months

Month	Cadmium (Cd) (mg/kg)	Copper (Cu) (mg/kg)	Lead (Pb) (mg/kg)	Zinc (Zn) (mg/kg)	Iron (Fe) (mg/kg)
January	0.028^{b}	0.029^{a}	0.088^{a}	0.235^{a}	0.4265^{a}
February	0.0325^{b}	0.023^{a}	0.107^{a}	0.2545^{a}	0.305^{a}
March	0.0565^{a}	0.0365^{a}	0.044^{b}	0.141^{a}	0.1675^{a}
	Mean ± SD 0.04 ± 0.04	Mean ± SD 0.03 ± 0.03	Mean ± SD 0.08 ± 0.08	Mean ± SD 0..21 ± 0.20	Mean ± SD 0.30 ± 0.25

Rows sharing similar superscripts are not significantly different (P>0.05)

Table 3 shows the mean concentration of both pork and beef. It reveals the mean concentration of Cd was higher in beef in March (0.06 ± 0.01mg/kg) and the least in pork in January (0.02 ± 0.00mg/kg). There was no significant difference between the mean concentration of cadmium in pork and beef (P > 0.05). In Cu, the mean concentration in pork was higher in January (0.05 ± 0.00mg/kg) and the least in beef in February (0.02 ± 0.00mg/kg). There was no significant difference in the mean concentration of copper in both pork and beef (P > 0.05). Pb was the least in beef in March (0.04 ± 0.03mg/kg) and the highest in pork in January (0.15 ± 0.03mg/kg), but there was no significant difference between pork and beef in all months (P ≥ 0.05).

The mean concentration in Zn was higher in beef in February (0.25 ± 0.01) and recorded least in pork in March (0.12 ± 0.00mg/kg). There, was no significant difference between the mean concentration of iron in both pork and beef (P > 0.05). In addition, Fe had the highest mean concentration in beef in January (0.43 ± 0.13mg/kg) and also the least in March (0.16 ± 0.00mg/kg). However, there was no significant difference between the mean concentration of iron in both pork and beef (P > 0.05).

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Table 3. The mean concentration comparison between pork and beef

Month	Cadmium (Cd) (mg/kg)	Copper (Cu) (mg/kg)	Lead (Pb) (mg/kg)	Zinc (Zn) (mg/kg)	Iron (Fe) (mg/kg)
Heavy metal concentration in pork					
January	0.02 ± 0.00^{b}	0.05 ± 0.00^{a}	0.15 ± 0.03^{a}	0.21 ± 0.01^{a}	0.21 ± 0.01^{a}
February	$0.04 \pm 0.00_{b}$	0.04 ± 0.00^{b}	0.06 ± 0.01^{a}	0.17 ± 0.01^{a}	0.21 ± 0.04^{a}
March	0.05 ± 0.00^{b}	0.03 ± 0.00^{b}	0.06 ± 0.01^{a}	0.12 ± 0.00^{a}	0.23 ± 0.01^{a}
Heavy metal concentration in beef					
January	0.03 ± 0.01^{b}	0.03 ± 0.01^{b}	0.09 ± 0.01^{a}	0.24 ± 0.03^{a}	0.43 ± 0.13^{a}
February	0.03 ± 0.00^{b}	0.02 ± 0.00^{b}	0.11 ± 0.06^{a}	0.25 ± 0.01^{a}	0.31 ± 0.12^{a}
March	0.06 ± 0.01^{a}	0.04 ± 0.00^{b}	0.04 ± 0.03^{b}	0.14 ± 0.01^{a}	0.16 ± 0.00^{a}

Rows sharing similar superscripts are not significantly different ($P>0.05$)

Table 4 reveals the estimated daily intake (EDI) of each heavy metal of which Zn and Fe had the highest figures, but they all had low estimated daily intake when compared to the recommended daily dietary intake. Furthermore, cadmium (Cd) and lead (Pb) had the least EDI and this was followed by copper (Cu). They all had low estimated daily intake when compared to the recommended daily dietary intake.

Table 4. The estimated daily intake of heavy metals

Heavy metals	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Iron (Fe)
Estimated daily intake	0.0018	0.0036	0.0018	0.0054	0.0054
Recommended daily dietary intake (mg/day/person)	0.06[a]	3 – 30[b]	0.21[a]	18 – 60[b]	10 – 15[c]

[a] PTDI: provisional tolerable daily intake (70kg body weight) (JECFA, 1982)

[b] PMTDI: provisional maximum tolerable daily intake (JECFA, 1982)

[c] ESADDI: estimated safe and adequate daily intake (NRC, 1989)

Table 5 reveals the health hazard quotient value of each metal. The target hazard quotients of the analysed heavy metals ranged from 0.003566 to 0.0.00000179. The highest target hazard quotient was recorded in cadmium (Cd) while the least was observed in zinc (Zn). Overall, the target hazard quotient for all the analysed heavy metals follows the increasing order of Cd > Pb > Cu > Fe > Zn.

Table 5. The target hazard quotient of heavy metals

Heavy metals	Cadmium (Cd)	Copper (Cu)	Lead (Pb)	Zinc (Zn)	Iron (Fe)
Total Hazard Quotient	0.003566	0.000089	0.000509	0.00000179	0.00000765

However, the health hazard index of the five metals shows no threat to human health because they were within tolerable limits ($HI<1$).

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Table 6 reveals the carcinogenic risk of Cd and Pb. The highest cancer risk was recorded in cadmium and it was observed to be far higher than the cancer risk observed in lead (Pb).

Table 6. The carcinogenic health risk of cadmium and lead

Heavy metals	Cadmium (Cd)	Lead (Pb)
	0.0000112	0.0000000152

This shows that there is a high possibility of them causing cancer because they are above the tolerable limit (CR>1×10^{-4}).

DISCUSSION

The values of the analysed heavy metals; Cd, Cu, Pb, Zn and Fe were detected in both pork and beef but the lowest values were observed in beef. This is in accordance with the study by Islam (2018). Cu which is an indispensable trace metal element in the human body, leads to certain ailments when in excess. The level of copper concentration in the beef and pork samples was not higher but within the allowable limit. The copper concentrations obtained from this study were lower than those recorded by Badis *et al.* (2014). The result shows that the level of lead concentration in the beef samples was higher than the allowable limits (> 0.1 ppm).

Zn recorded the highest concentration level in pork and beef but this was not in concordance with Garba *et al*. (2018). The differences in concentration may be attributed to the seasonal variation in the periods of sample collection as well as activities taking place and/or traffic density. Fe was one of the heavy metals with the highest concentration in both pork and beef. This agrees with the study carried out by Adzitey *et al.* (2018) which could be a result of the meats being exposed to feed containing iron.

The estimated daily intake of all the five heavy metals did not exceed the recommended daily dietary intake by JECFA (1982) and NRC (1989). This agrees with the study undertaken by Islam (2018). The overall target hazard quotient for all the analysed heavy metals showed that the five metals posed no threat to human health because they were within tolerable limits (HI<1) which is in agreement with the findings of Ya *et al*. (2017). In addition, the cancer risk for Cd and Pb was within tolerable limits, indicating that the consumption of these meats poses no threat to consumers. However, health concerns may likely arise from cadmium due to its value which shows the possibility of causing cancer over time from constant bioaccumulation of this metal in the human system. However, the values from this finding are higher than those reported by Bamuwamye *et al.* (2015).

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CONCLUSION AND RECOMMENDATION

The masses should be enlightened on the dangers of excess intake of some of these heavy metals to avoid a lot of serious implications. Steps should be taken to improve and proper handling of animals and maintenance of good hygienic protocols in abattoirs to reduce contamination of meats by toxicants like heavy metals.

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