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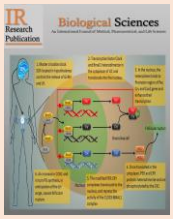

Potential Human Health Risk Assessment of Heavy Metals in Various Brands of Sausages and Salami Sold in Different Eateries in Lafia Township-Nigeria

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ABSTRACT

Accumulation of heavy metal concentrations in food and products due to industrialization is posing a serious threat to humans due to their toxicity and ability to accumulate in the human body parts and eventually lead to death. Specifically, in Nigeria and Lafia in particular there is a lack of data related to the heavy metal contamination in sausages and salami for human consumption. The current study was conducted to determine the concentration of heavy metals in meat products and associated human health risk assessments. All the samples were analyzed using an atomic absorption spectrophotometer. Samples were taken from different eateries in the city of Lafia, Nigeria. Recorded values of Cd, Ni, and Cu in both sausage and salami in all eateries were within the permissible limits by the WHO and FAO. Pb was not detected in any of the analyzed samples in all the eateries. The EDI for all analyzed heavy metals was below the recommended values. Similarly, THQ calculated for Pb, Cd, Cr, Cu, and Ni were below 1 while the HI for all analyzed heavy metals was less than unity, indicating no non-carcinogenic adverse effects. Equally the calculated cancer risk values in all the sausage and salamis in all the eateries were within the acceptable range of 10^{-6}-10^{-4}. Therefore, it is recommended that proper monitoring of sausage and salami be carried out to avoid health challenges that accompany contamination of meat products as well as the formation of a national policy that will strictly be for monitoring and prevention of human health risk.

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Introduction

The basic necessity for the survival and maintenance of good human health is food. Unsafe food is related to many diseases and can even cause death. Contamination of food is the biggest problem facing us today. It occurs due to contaminants such as heavy metals, pesticides, antibiotics, and toxins. But in all of them, heavy metals pose a serious threat to the safety of food [1]. The frozen food market is growing rapidly around the globe because of the high demand from consumers [2]. Despite the fact,

that people are not aware of the presence of different heavy metals in such products. The use of cadmium, arsenic, mercury, and lead as ingredients is prohibited in frozen food products as per the regulations of the European Commission [3].

Heavy metals include metals and metalloids, which have high density and toxicity even at low concentrations. For proper development of the human body, small concentrations of metals such as zinc (Zn), copper (Cu), and iron (Fe) are important for human development and are considered essential elements, but even if the intake of these metals increases rapidly and continuously, it will result in the toxicity deteriorating the human health. On the other hand; elements such as lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) are non-essential and toxic elements as they can cause neurological and biochemical changes in the body even at low concentrations [4].

Heavy metal contamination is a serious threat worldwide due to its toxicity and its ability to bioaccumulate and biomagnify in the food chain. These toxic metals can enter into living organisms from both dietary and non-dietary exposures, and once they enter the human body, they remain there for many years[5]. Exposure to these heavy metals affects intelligence, memory, and cognitive abilities. These heavy metals can also cause cardiovascular disorders, leukemia, gastrointestinal colitis, and respiratory, renal, and nervous system problems. It has been seen that most of the intake of these heavy metals occurs due to the consumption of heavy metal-contaminated foods, but this exposure varies from place to place as well currently, the maintenance of food safety has become a major concern in many areas, including food production and food management. It has now become a major economic, political, and livelihood concern globally for people and governments as well. As for Sustainable Development Goals, SDG-3, also known as "Good Health and Well-Being," focuses on ensuring healthy lives and promoting well-being for all people of all ages. A lot of progress has been made in reducing the main causes of death and disease in the context of SDG-3, but with the increase in anthropogenic activities, human health is greatly affected. The main reason behind this is the advancement in technology along with the changing lifestyles of people, as people are shifting towards processed foods and a major portion of this food is meat, especially chicken and beef [7].

Throughout the world, meat products (processed and fresh) are commonly consumed because they are not only a rich source of protein, iron, zinc, amino acids, vitamin B6, and vitamin B12, as well as fats, but they also play an essential role in the healthy development of the human body. Although meat provides essential nutrients to the human body, at the same time, it can also act as a source of toxic metals for humans. Literature reveals that heavy metals can accumulate in cattle in Nigeria due to their grazing ability and obtaining water from all available sources, which may be highly contaminated with toxic metals like nickel, lead, chromium, mercury, zinc, copper, manganese, cobalt, and cadmium [8]. In the case of processed meat, the source of these toxic metals may be due to contact of meat products with tools, installations, as well as machinery, or maybe other processes like drying, salting, and smoking, or it may be possible that during the addition of preservatives or the packaging process, toxic metals can contaminate these meat products [9]. Furthermore, different studies also show that due to the absence of standardization in the various processes, sensory as well as physiochemical parameters like color, moisture, acidity, and pH of these meat products are also greatly affected and that these changes may occur during the preparation of these processed meat products in industries [10].

Although good health and well-being are fundamental human rights and are central to the SDGs. In contrast to developed countries, in developing countries like Nigeria, people are less conscious about healthy food intake, because of lack of awareness. Due to their benefits, such as high nutritional quality and ease of use, sausages and salamis are found to have a large consumption of chicken and beef due to their benefits, such as high nutritional quality and ease of use. According to the literature, an average person consumes salami and sausages three to four times a week so; to assess the risk of consuming meat and meat products, it is necessary to determine daily exposure to the elements by estimating daily intake and then comparing these with toxicological values [11]. Attention should be given to the health and safety of meat products that may contain high concentrations of different heavy metals like Cd, Ni, Cu, Cr, As, Pb, Fe, and Mn [12]. However, the data about the presence of heavy metals in chicken, meat, and meat products like sausages and salami produced and consumed in Nigeria is limited.

Materials and Methods

Sample collection

The study was carried out in 2024. The aim was to determine the concentrations of heavy metals (Lead, Cadmium, Copper, Nickel, and Chromium) and calculate the non-carcinogenic and carcinogenic human health risk in two types of meat products Sausages and Salami. All Samples were fresh and purchased on the same day and were bought from different Eateries in Lafia township (Figure 1)

(Lavista, Lace, Lafia City Mall, Dexter's, and Chicken Republic). A total of 20 samples ten for sausages and ten for salami samples were collected in the five eateries. Two sausages and salami each in every eatery were used for the study and examined for the presence of heavy metals. All these samples were properly sealed to avoid drying out and spoilage and were kept frozen at (-18°C) in a refrigerator.

Chemicals and reagents

All reagents were of analytical grade. For sample preparation, nitric acid (HNO3) and perchloric acid (HClO4) were used. Standard calibration solutions were also used. All the samples were prepared in deionized water collected from the Department of Chemistry Laboratory, Joseph Sarwuan Tarka University, Makurdi formally, Federal University of Agriculture, Makurdi, Benue state-Nigeria.

Sample preparation

All the plastic and glassware were cleaned by soaking in dilute HNO3 and were rinsed with deionized water before use to avoid any contamination. Then 5 grams of each sample were taken in separate crucibles and placed in an oven at a temperature of about 105 °C for 24 hours. After this, 1 gram of oven-dried sample was taken, and then it was crushed with the help of a pestle and mortar. Then the crushed samples were taken in labeled crucibles and placed in the muffle furnace at a temperature of about 550 °C for the time duration of about 4 hours until they converted into ash [14]. After that, to form one normal solution of HNO3, 6.6 ml of nitric acid in 1000 ml of deionized water was added. Then 20 beakers were taken, and 100 ml of this normal solution was added to each beaker. They left the beakers for almost 30 minutes, and after that, all the samples were filtered with the help of Whatman filter paper. Then these filter papers, along with the filtered ash, were placed in the oven at a temperature of about 105 °C for about 3 hours. With the help of a weighing balance, the exact weight of dried samples was determined. After that, 1 g of ash of dried samples was added to each beaker containing 100 ml of solution covered all the beakers with aluminium foil to avoid contamination and left the beakers for 24 hours for acid digestion. Then neutralize the samples by adding a 1M solution of sodium hydroxide (NaOH). Triplets of each sample were prepared for testing [15].

Sample analysis

All the samples were run through an Atomic Absorption Spectrophotometer (Thermo Fisher Scientific ICE 3000 Series, Germany) to find out the concentration of different heavy metals. All the readings were noted down. The Atomic Absorption Spectrophotometer determines the concentration of heavy metals in any liquid sample based on energy absorbed by the sample at a certain wavelength range from 190 to 900nm. AAS includes a monochromatic, a flame burner, and a photon detector. All the elements present in the sample absorb light at a specific wavelength in the UV or visible spectrum. The wavelength of the sample depends on the absorption done by the sample. After all that, the transmitted value is detected with the help of a detector present in the atomic absorption spectrophotometer after passing through a monochromatic.

Health Risk Assessment

The consumption of sausages and salami has become a common practice among people of all ages in eateries in Lafia and Nigeria in general. However, the entry of heavy metals into the body through the intake of sausages and salami can cause health risks. A health risk assessment was performed that involves the measurement of the Evaluation of Dietary Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and non-carcinogenic and carcinogenic effects. These calculations were carried out to estimate the health risks associated with the consumption of heavy metal-contaminated sausages and salami in Lafia township, Nigeria to ascertain whether people taking it will result in non-carcinogenic or carcinogenic effects.

Evaluation of dietary intake of heavy metals

The dietary intake was calculated by using the value of EDI (estimated dietary intake) in mg/day by considering the consumption of a product (100 g) per day [16].

$$\text{EDI (mg/Kg/ day)} = \frac{C \times IR}{BW} \times 10^{-3}$$

Evaluation of human health risk (non-carcinogenic risk)

After calculating the average daily dose, the total hazard quotient for oral toxic metal exposure and the risk of non-cancer can be calculated using Eq. (2).

$$\text{THQ} = [\frac{EDI}{RfD}]$$

Carcinogenic risk assessment

$$\text{Cancer risk} = \text{CDI} \times \text{CSF} \quad (3)$$

where: THQ is the Target Hazard Quotient, *EF* is Exposure Frequency = 365 days/year, *ED* is Exposure Duration = 70 years, *FIR* is Food Ingestion Rate = 4 g/person/day, *MC* is the Mean Concentration of Heavy Metal, *WAB* is Average Body Weight = 60 kg for adults, *RfD* is Reference Dose = mg/kg/day, *AT* is Average Exposure Time = 70 years.

Table 1. reference dose (RfD) for heavy metals.

Heavy metal	Reference dose (RfD) (mg/kg)
Pb	0.004
Cr	0.003
Cd	0.001
Ni	0.02
Cu	0.04

If the value of THQ is higher than 1, it means that the exposure level is smaller than the reference dose and the exposure is not likely to cause any hazardous effects on human health. The effects are negligible if the value of THQ is less than 1. However, if the value of THQ increases, there will be an increase in non-carcinogenic effects affecting human health [17].

Hazard Index

Meat and meat products can be contaminated with several heavy metals and the consumption of such contaminated food products can pose serious health hazards, making it necessary the determine the Hazard Index [18]. The following formula can be used to calculate it:

$$\text{Hazard index, HI} = \sum THQ$$

Carcinogenic Risk

Carcinogenic risk is the probability for an adult or child to have cancer over time. It can be evaluated by the linear equation.

$$\text{Cancer Risk} = CDI \times CSF \times 10^{-3}$$

CDI is the chronic daily intake ($mg \cdot kg^{-1} \cdot d^{-1}$) of a single toxic metal; CSF is the slope factor for the toxic metal ($Kgd^{-1}mg^{-1}$).

The acceptable or tolerable maximum limit for TCR, for regulatory purposes, is within the range of 10^{-6}-10^{-4}

Results and Discussion

Distribution of heavy metals in Sausage and Salami samples

Chromium

The mean Cr concentration was recorded and presented in Table 3 for both sausage and salami in all the eateries in Lafia Township. Chromium is another toxic heavy metal that, if present in a higher concentration, causes neurotoxicity, osteoporosis, immunosuppression, and hepatotoxicity. The concentration of chromium in all sausage was within

Table 2. Limit of detection (LOD) and limit of quantitation (LOQ) of all assed metals.

Heavy Metal	LOD	LOQ
Cr	0.002	0.001
Cu	0.002	0.001
Cd	0.002	0.001
Ni	0.002	0.001
Pb	0.002	0.001

the permissible limit of 1.0 mg/kg set by FAO/WHO except for sausage samples in Lafia city mall (9 and 10) having concentrations of 1.893±0.002 and 1.784±0.002 ppm, exceeding the permissible limit of 1.0 ppm [19, 20]. Whereas the permissible limit of chromium in salami by WHO and FAO is 0.05 mg/kg. The chromium concentration exceeds the permissible limits in all the samples of salami recorded in Lavista, Lace, Lafia City Mall, Dexter's, and Chicken Republic respectively. The highest and lowest Cr mean concentrations in salami were recorded in Lafia City Mall sample 11 and Lavista sample 4 with values of 0.969±0.016 and 0.328±0.006 ppm respectively (Table 3).

Copper

Copper is considered an essential element as it helps in the absorption of iron in the body, maintaining nerves, bones, and blood vessels, as well as immune functions of the human body. According to the standards of WHO/FAO, the permissible limit for copper in meats is 0.10 mg/kg. In many cases, the highest concentration of copper in meat can be due to a faulty milling machine through which heavy metals can leach out during the production process. The limit for daily intake given by WHO and FAO for salami is 3 mg/kg [19, 20]. The highest and lowest mean concentrations of Cu in sausage samples were recorded in Lavista sample 1 and Lace sample 6 with values of 0.206±0.02 and 0.013±0.02 ppm while Salami's highest and lowest mean Cu concentrations were recorded in Lafia Mall sample 11 and Lavista sample 4 with values of 0.188±0.03 and 0.016±0.02 ppm respectively. The mean concentrations of Cu in

sausage and salami in all the eateries were below the permissible limit by the WHO and FAO.

Nickel

The consumption of nickel is due to the intake animals and plants that contain it. We are concerned with its concentration because it can become a cause of some chronic diseases like sinusitis, asthma, and rhinitis [21]. The mean Ni concentrations in sausage and salami are presented in Table 3. The highest and lowest concentrations of Ni were recorded in sausage from Lace sample 5 and Lace sample 6 with values of 0.179±0.002 and 0.000±0.000 ppm respectively while the highest and lowest mean Ni concentration in salami were recorded in Lace sample 8 and Lavista sample 4 with values of 0.208±0.004 and 0.094±0.01 ppm respectively. The Ni concentrations in Lafia City Mall, Dexter's, and Chicken Republic for both sausage and salami were below the detectable limit. The concentration of nickel observed in all the sausage and salami in the detectable eateries were all within the permissible limit of FAO/WHO of 0.2 ppm except in Lace salami sample 8 which was slightly above the limit with a value of 0.208±0.004 ppm.

Lead

The concentrations of Pb in both sausage and salami were below the detectable limits. The line of detection and line of quantification for all metals are presented in Table 3. The permissible limit set by FAO/WHO for lead in meat products is 0.4 mg/kg.

Cadmium

Cadmium is considered the group 1 agent responsible for causing cancer. It has been seen that chronic exposure to at the lowest level is responsible for cancer.

Cd was detected in all the samples of sausage and salami. The highest and lowest mean concentrations of Cd in the sausage were in Lafia city mall sample 9 and Lafia city mall sample 10 with values of 0.15±0.022 and0.048±0.02 ppm respectively while in salami the highest and lowest values were recorded in Chicken Republic sample 20 and Lafia city mall sample 11 with values of 0.161±0.06 and 0.068±0.03 ppm respectively. The reason for the presence of Cd in sausage and salami can be justified by the fact that these products are highly spiced so, they were found contaminated with cadmium [22]. The concentration of cadmium in one sample of sausage exceeded the recommended value. Although most of the analyzed samples contaminated with cadmium were below the permissible limit the consumption of food at higher levels of cadmium causes cancer.

Estimated daily intake (EDI)

Table 3. Mean concentration and standard deviation of the analyzed heavy metals in Sausage and Salami.

No	Sample ID	Cr Mean ± SD	Cu Mean ± SD	Cd Mean ± SD	Ni Mean ± SD	Pb Mean ± SD
1	SauLavista 1	0.462±0.003	0.206±0.02	0.097±0.07	0.048±0.003	BDL
2	SauLavista 2	0.146±0.002	0.202±0.03	0.098±0.02	0.038±0.003	BDL
3	SalLavista 3	0.434±0.004	0.017±0.02	0.096±0.02	0.187±0.002	BDL
4	SalLavista 4	0.328±0.006	0.016±0.02	0.096±0.03	0.094±0.01	BDL
5	SauLace 5	0.464±0.005	0.019±0.07	0.098±0.02	0.179±0.002	BDL
6	SauLace 6	0.696±0.008	0.013±0.02	0.096±0.02	0.000±0.000	BDL
7	SalLace 7	0.342±0.006	0.028±0.08	0.099±0.02	0.172±0.03	BDL
8	SalLace 8	0.532±0.002	0.030±0.03	0.098±0.02	0.208±0.004	BDL
9	SauLafia Mall 9	1.893±0.002	0.069±0.06	0.15±0.022	BDL	BDL
10	SauLafia Mall 10	1.784±0.002	0.067±0.06	0.048±0.02	BDL	BDL
11	SalLafia mall 11	0.969±0.016	0.188±0.03	0.068±0.03	BDL	BDL
12	SalLafia mall 12	0.939±0.016	0.067±0.04	0.089±0.03	BDL	BDL
13	SauDexter's 13	0.849±0.012	0.108±0.05	0.093±0.03	BDL	BDL
14	SauDexter's 14	0.794±0.012	0.097±0.05	0.099±0.03	BDL	BDL
15	SalDexter's 15	0.442±0.006	0.031±0.07	0.099±0.02	BDL	BDL
16	SalDexter's 16	0.415±0.006	0.019±0.07	0.095±0.02	BDL	BDL
17	Sauchicken republic17	0.464±0.005	0.017±0.05	0.098±0.08	BDL	BDL
18	Sauchicken republic18	0.442±0.005	0.033±0.02	0.097±0.08	BDL	BDL
19	Sauchicken republic19	0.723±0.008	0.082±0.02	0.134±0.06	BDL	BDL
20	Salchicken republic 20	0.688±0.008	0.164±0.01	0.161±0.06	BDL	BDL

BDL= below detectable limits; Sau = sausage; Sal = salami, All concentrations are average of 3 values ± S.D.

The estimated daily intake values of heavy metals through the consumption of all samples of sausage and salami are presented in Table 4.

The impacts of heavy metals on human health are necessary to collect information about daily intake. EDI is an estimated everyday exposure of humans to heavy metals without having any adverse health impacts during their lives [22]. The EDI values for Cu and Ni for both sausage and Salami were all below the reference dose of 0.04 and 0.02 mg/kg respectively while the values of Pb for sausage and Salami were below the detectable limit of 0.004 mg/kg. The values of Cr in Sausage from Lavista sample 1, Lace samples 5 and 6, Lafia City Mall samples 9 and 10, Dexter's samples 13 and 14, and as well as the Chicken Republic samples 17 and 18 were slightly above the reference dose value while Salami values from Lavista samples 3 and 4, Lace samples 7 and 8, Lafia city mall samples 11and 12, Dexter's samples 15 and 16 and Chicken republic samples 19 and 20 were slightly above the reference dose of 0.003 mg/kg. The Cd values for both sausage and salami were all above the reference dose value of 0.001 milk.

Non-Carcinogenic Risk Assessment

The non-carcinogenic human risk assessment was calculated and presented in Table 5. The target Hazard Quotient for potential toxic heavy metals was also calculated in this study which showed no public health concern. In all the analyzed samples the THQ was less than 1. The calculated THQ value for Chromium, copper, Cadmium, and Nickel was less than 1 as well and lead was not detected, presenting no public health concerns in all samples of sausages and Salami consumed in all the eateries in the Lafia metropolis were safe for consumption daily due to their reduced toxic effects and low non-carcinogenic.

The Hazard Index is another parameter to express health risk assessment that was also computed in the current study that represents the combined risks of toxicity of heavy metals. The calculated HI results in all the eateries for both sausage and Salami showed values less than 1 which indicates no adverse health effects on humans due to the consumption of such salami and sausage samples.

Carcinogenic health effects

Carcinogenic health Effects through the Consumption of sausages and Salami in Eateries in Lafia are presented in Table 6. Carcinogenic risk is the probability for human beings to have cancer over time. Long-term exposure to even low amounts eatery could result in many types of cancer if of toxic contaminated. It is shown from the study that the value of the cancer risk for heavy metals (Cr, Cd, and Ni) for both the sausage and salami in all the eateries was below the range of 10^{-6} - 10^{-4} and Pb was not detected in all sausage and salami in all the eateries. These showed clearly that the possibility of those eating sausage or salami in all the eateries in the

Table 4. Estimated daily intake (EDI, mg/kg/day) of heavy metals through the consumption of all samples of sausages and salami in Eateries in Lafia

No	Sample ID	Cr	Cu	Cd	Ni	Pb
1	SauLavista 1	0.03080	0.01370	0.00647	0.00320	BDL
2	SauLavista 2	0.00973	0.01347	0.00653	0.00253	BDL
3	SalLavista 3	0.02893	0.00113	0.00640	0.01247	BDL
4	SalLavista 4	0.02187	0.00107	0.00640	0.00627	BDL
5	SauLace 5	0.03093	0.00127	0.00653	0.01193	BDL
6	SauLace 6	0.04640	0.00087	0.00640	0.00000	BDL
7	SalLace 7	0.02280	0.00187	0.00660	0.01147	BDL
8	SalLace 8	0.03547	0.00200	0.00653	0.01387	BDL
9	SauLafia Mall 9	0.12620	0.00460	0.01000	BDL	BDL
10	SauLafia Mall 10	0.11893	0.00447	0.00320	BDL	BDL
11	SalLafia mall 11	0.06460	0.01253	0.00453	BDL	BDL
12	SalLafia mall 12	0.06260	0.00447	0.00593	BDL	BDL
13	SauDexter's 13	0.05660	0.00720	0.00620	BDL	BDL
14	SauDexter's 14	0.05293	0.00647	0.00660	BDL	BDL
15	SalDexter's 15	0.02947	0.00207	0.00660	BDL	BDL
16	SalDexter's 16	0.02767	0.00127	0.00633	BDL	BDL
17	Sauchicken republic17	0.03093	0.00113	0.00653	BDL	BDL
18	Sauchicken republic 18	0.02947	0.00220	0.00647	BDL	BDL
19	Salchicken republic 19	0.04820	0.00547	0.00893	BDL	BDL
20	Salchicken republic 20	0.04587	0.01093	0.01073	BDL	BDL

metals for eating sausage or salami in any Lafia metropolis cannot develop cancerous cells with time.

Conclusion

Heavy metals (Cr, Cu, Ni, Cd, and Pb) mean concentrations for consumption of sausage and salami in five eateries (Lavista, Lace, Lafia City Mall, Dexter's, and the Chicken Republic) in Lafia, Nasarawa state, Nigeria metropolis recorded values of Cd, Ni, and Cu in both sausage and salami in all eateries below the permissible limit by the WHO

Table 5. Target Hazard Quotient THQ and Hazard Index HI of heavy metals through the consumption of sausages and salami in Eateries in Lafia

No	Sample ID	Cr	Cu	Cd	Ni	Pb	HI
1	SauLavista 1	1.03E-2	3.43E-4	4.70E-3	1.60E-4	BDL	1.55E-2
2	SauLavista 2	3.24E-3	3.37E-4	6.53E-3	1.27E-4	BDL	1.02E-2
3	SalLavista 3	9.64E-3	2.83E-5	6.40E-3	6.24E-4	BDL	1.67E-2
4	SalLavista 4	7.29E-3	2.68E-5	6.40E-3	3.14E-4	BDL	1.40E-2
5	SauLace 5	1.03E-2	3.18E-5	6.53E-3	5.97E-4	BDL	1.75E-2
6	SauLace 6	1.55E-2	2.18E-5	6.40E-3	0.00000	BDL	2.19E-2
7	SalLace 7	7.60E-3	4.68E-5	6.60E-3	5.74E-4	BDL	1.48E-2
8	SalLace 8	1.18E-2	5.00E-5	6.53E-3	6.94E-4	BDL	1.91E-2
9	SauLafia Mall 9	4.21E-2	1.15E-4	1.00E-2	BDL	BDL	5.22E-2
10	SauLafia Mall 10	3.96E-2	1.12E-4	3.20E-3	BDL	BDL	4.29E-2
11	SalLafia mall 11	2.15E-2	3.13E-4	4.53E-3	BDL	BDL	2.63E-2
12	SalLafia mall 12	2.09E-2	1.12E-4	5.93E-3	BDL	BDL	2.69E-2
13	SauDexter's 13	1.89E-2	1.80E-4	6.20E-3	BDL	BDL	4.44E-2
14	SauDexter's 14	1.76E-2	1.62E-4	6.60E-3	BDL	BDL	2.44E-2
15	SalDexter's 15	9.82E-3	5.18E-5	6.60E-3	BDL	BDL	1.65E-2
16	SalDexter's 16	9.22E-3	3.18E-5	6.33E-3	BDL	BDL	1.56E-2
17	Sauchickenrepublic 17	1.03E-2	2.83E-5	6.53E-3	BDL	BDL	1.69E-2
18	Sauchicken republic18	9.82E-3	5.50E-5	6.47E-3	BDL	BDL	1.63E-2
19	Salchicken republic 19	1.61E-2	1.37E-3	8.93E-3	BDL	BDL	2.64E-2
20	Salchicken republic 20	1.53E-2	2.73E-4	1.07E-2	BDL	BDL	2.63E-2

Table 6. Carcinogenic Health Risk of heavy metals through the consumption of sausages and salami in Eateries in Lafia.

No	Sample ID	Cr	Cd	Ni	Pb
1	SauLavista 1	1.54E-5	9.71E-5	2.69E-6	BDL
2	SauLavista 2	4.87E-6	9.79E-5	2.13E-6	BDL
3	SalLavista 3	1.45E-5	9.60E-5	1.05E-5	BDL
4	SalLavista 4	1.09E-5	9.60E-5	5.27E-6	BDL
5	SauLace 5	1.55E-5	9.79E-5	1.00E-5	BDL
6	SauLace 6	2.32E-5	9.60E-5	0.00000	BDL
7	SalLace 7	1.14E-5	9.90E-5	9.63E-6	BDL
8	SalLace 8	1.78E-5	9.79E-5	1.17E-5	BDL
9	SauLafia Mall 9	6.31E-5	1.50E-4	BDL	BDL
10	SauLafia Mall 10	5.95E-5	4.80E-5	BDL	BDL
11	SalLafia mall 11	3.23E-5	6.79E-5	BDL	BDL
12	SalLafia mall 12	3.13E-5	8.89E-5	BDL	BDL
13	SauDexter's 13	2.83E-5	9.30E-5	BDL	BDL
14	SauDexter's 14	2.65E-5	9.90E-5	BDL	BDL
15	SalDexter's 15	1.47E-5	9.90E-5	BDL	BDL
16	SalDexter's 16	1.38E-5	9.49E-5	BDL	BDL
17	Sauchicken republic17	1.55E-5	9.79E-5	BDL	BDL
18	Sauchicken republic 18	1.47E-5	9.71E-5	BDL	BDL
19	Salchicken republic 19	1.41E-5	1.34E-4	BDL	BDL
20	Salchicken republic 20	2.29E-5	1.61E-4	BDL	BDL

and FAO while Pb was below the detectable limits in all eateries for both sausage and salami. Chromium in Lafia City Mall (9 and 10) from sausage has exceeded the permissible limits by the WHO and FAO. The value of chromium in all the eateries exceeded the permissible limits by the FAO and WHO respectively. For Health risk assessment, the calculated THQ value for Chromium, copper, Cadmium, and Nickel was less than 1 as well and lead was not detected, presenting no public health concerns in all samples of sausages and Salami consumed in all the eateries in Lafia metropolis were safe for consumption daily due to their reduced toxic effects and low or no non-carcinogenic effects. The calculated HI results in all the eateries for both sausage and Salami showed values less than 1which indicates no adverse health effects on humans due to the consumption of such salami and sausage samples. The calculated carcinogenic effect showed values within the acceptable range of 10-6 to 10-4. These showed clearly that the probability of those eating sausage or salami in all the eateries in the Lafia metropolis developing cancerous cells with time is zero. Sausage and salami are now the most useful and favorable foods in most eateries hence there is a need to monitor them closely and frequently to avoid mental pollution that can result in health challenges and even death as well as the formation of national policy that will strictly be for monitoring and prevention of human health risk.

Contribution of authors

I.S.I.: project conceptualization, design, resources, and supervision. I.S.I., T.T.U and E.O.E: writing, result extraction, analysis, and article first draft. I.S.I, E.O.E., T.T.U, and R.O.A: result extractions and final article draft and review. All authors have read and agreed to the published version of the manuscript.

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Conflict of Interest

The authors declare that they have no conflicts of interest.

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Data Availability Statements

The original data presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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