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QUALITY ASSESSMENT AND SAFETY OF COMMERCIALLY SOLD STEAK MEAT "SUYA" IN IBADAN METROPOLIS: A MENACE TO PUBLIC HEALTH

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ABSTRACT
The study evaluated the quality and safety of suya—a popular ready-to-eat meat—produce in Ibadan, Nigeria. Suya samples were analyzed from four local government areas: Ibadan North-West (SB), Ibadan North (BD), Oluyole (NG), and Egbeda (EG). The microbial analysis showed significant contamination, with total bacterial counts exceeding recommended limits. Although coliform bacteria were absent, but the presence of *Staphylococcus aureus*in samples from BD and SB highlighted evidence of poor hygiene. Additionally, *Salmonella typhi and Pseudomonas aeruginosa* were detected in BD samples, posing foodborne illness risks. Heavy metals were analyzed, with Zinc within safe limit, but chromium significantly exceeded the 1.0 mg/kg limit in all samples. Cadmium was slightly above the threshold in samples from NG and EG. While lead was within acceptable limits. Arsenic was alarmingly high across all the samples. Estimated daily intake (EDI) values for arsenic and chromium indicated significant exposure risks, with arsenic EDI surpassing the provisional tolerable daily intake (PTDI) in all samples. Target hazard quotient (THQ) values for chromium and arsenic were above 1 in most samples, indicating potential health hazards, and Hazard Index (HI) values exceeded the safe threshold in all the samples for non-carcinogenic assessment, indicating a high possibility of adverse health effects. Exposure to arsenic and cadmium has been linked to high cancer risks, according to carcinogenic risk assessment utilizing incremental lifetime cancer risk (ILCR) values; all samples had ILCR values over the acceptable risk range. This study emphasizes the necessity of strict food safety laws, improved hygiene among suya vendors and public health education.

Keywords: Suya meat, Heavy metals, Microbial quality, Health risk assessment, Carcinogenic, Health index

INTRODUCTION

Suya is a roasted boneless meat from a sheep, goat, or cow that is grilled over a bright charcoal fire while the meat pieces are arranged on wooden sticks. It can be flavored with various ingredients like peanut cake powder, spices, vegetable oil, or salt. Suya has become a very popular street food in many countries, particularly in West Africa (Iwar, 2017; Garba *et al*., 2017). Suya can be served with slices of onion, cabbage, tomato and cucumber in order to enhance its nutritional value, organoleptic qualities and antioxidant properties. Hausa/Fulani people of Northern Nigeria and other neighboring countries, such as Cameroon, Niger and Sudan account for 80% of cattle rearing population in the region. Cattle rearing is a major source of income for the Hausa/Fulani people, who are believed to be the originators of Nigerian suya meat (Egbebi and Muhammad, 2016; Falegan *et al*., 2017; Garba *et al*., 2017).

Suya merchants are active from mid-day until dusk and can be found in both big and small cities. Suya is becoming a well-liked party delicacy in affluent circles. Customers find it to be a quick and easy lunch, but because it is made locally with basic tools and there is a chance of contamination. It is frequently made and sold under unsanitary conditions in the streets (Oguntoyinbo, 2014). In addition, while spices enhance the nutritional content of suya, they can also be potential sources of contamination during preparation and packaging (Obadina *et al.*, 2014; Kelvin and Lawrence, 2015; Odu *et al.*, 2020).

Across the world, ensuring food safety is a challenge, particularly in underdeveloped countries where food safety regulations are lacking. Obstacles are created by things like inadequate public health institutions and infrastructure, out-of-date laws and policies, and a shortage of experienced regulators (Ades *et al.*, 2014). Poor environmental sanitation, lack of food laws, and lack of awareness of basic hygiene procedures are some of the reasons that restrict access to healthy street food in underdeveloped nations (Egbebi and Seidu, 2011; Hassan and Dimassi, 2014). Even in situations where food safety and sanitation guidelines are set, a lack of resources and infrastructure may make it difficult to enforce these laws. (Egbebi and Seidu, 2011; Ndife *et al*., 2022). Contaminated foods are estimated by the World Health Organization (WHO, 2017) to be the cause of 1.5 billion instances of diarrhoea and 1.5 million newborn deaths annually. According to estimates, foodborne infections claim the lives of over 420,000 people globally and cost US$ 3.6 billion annually. Approximately, 600 million (i.e., 1 in 10) people are at risk of contracting a foodborne illness (Kirk *et al.*, 2015). The World Health Organization (WHO) estimated that over 200,000 people die from diarrhoea each year as a result of food poisoning (Afolabi and Odubanjo, 2012; Torgerson *et al*., 2015).

According to earlier studies, harmful microbes, heavy metals, and polycyclic aromatic hydrocarbons (PAHs) are present in suya that is sold and consumed in Nigeria (Falegan *et al.*, 2017; Akpoghelie, 2018). Heavy metals may be introduced through contaminated utensils and water during processing. Accumulation of heavy metals in the body due to consumption of contaminated food may have dangerous consequences and require medical intervention (Ahmad *et al.*, 2023). Over exposure to heavy metals can cause structural changes and damage to deoxyribonucleic acid (DNA), which may have an effect on the control of cell division, the onset of cancer, or programmed cell death. This happens because of the way that metal ions interact with biological elements like DNA and nuclear proteins (Beyersmann and Hartwig, 2008). Given the high approval rate and broad distribution of suya in Ibadan, it is critical to examine its microbiological quality, heavy metal level, and potential health effects.

MATERIALS AND METHODS

Study area

The study area was metropolitan city of Ibadan in Oyo state, Nigeria. Figure 1 shows the map of Ibadan metropolis and the relative position of the study areas on the map (Coloured 1, 2, 3 and 4). The city lies between latitude 3°49`E and 3°57`E and longitude 7°20`N and 7°27`N (Obasi *et al*., 2020). There are a total number of eleven (11) local government areas (LGAs) in the city with a total pollution of 2.55 million people according to 2006 population census and a projected population for the year 2022 estimated at 3.65 million people. The study area (4 local government areas) has a total land area of about 923.04 km^2, a population of 949,252 people in the year 2006 census and a projected population estimated at 1,356,700 people in year 2022 (Adewole *et al*., 2023).

Figure 1: Map of Ibadan showing strategic points of study area (Ogundiwin, 2023)
(1 = Ibadan North-West (SB), 2 = Ibadan North LGA (BD), 3 = Oluyole LGA (NG), 4= Egbeda LGA (EG))

Collection of samples

Suya samples were bought from street vendors in selected locations within Ibadan metropolis as shown in Figure 1. At each sale point, ready-to-eat suya samples were purchased and aseptically taken into sterile polythene bags and quickly transported to the laboratory for analysis.

Microbiological analysis

The isolation and enumeration of total bacterial count was determined using the methods as described by (Ayeloja *et al*., 2018). Serial dilution (10-fold) and aliquots of appropriate dilutions (10^{-3} and 10^{-6}) were plated on Nutrient agar, MacConkey agar, Manitol salt agar and Eosine methylene blue agar, using pour plate method. Incubation was done at 37^0C for 24 – 48 hours for total bacterial and coliform counts. All enumerations were expressed as colony forming units per milliliter (CFU/g) of plated samples. Bacterial isolates were identified and characterized based on their morphological, cultural and biochemical tests using standard methods as described by (Walker *et al*., 2006; Yakubu and Ngueku, 2015; Obasi *et al*., 2017). The isolated organisms were then confirmed as described by (Obasi and Danladi, 2023).

Determination of heavy metals

Sample treatment and preparation

The collected samples were washed with distilled water to remove any contaminant particles, cut into small pieces and dried in an oven at 100^{o}C for 3 hours. After drying, 2g of each suya sample was weighed into 100 ml conical flask and aqua regia (HNO_3: HCl) was added and heated for a few minutes. After cooling to room temperature, the volume was made to mark with distilled water, shaken and filtered into polyethylene (PET) bottles respectively for atomic absorption spectrophotometer analysis (Mukhi *et al*., 2024).

Procedure for Atomic Absorption Spectrophotometry (AAS)

A standard solution was made for detection of each of the metals of interest: arsenic (As), lead (Pb), chromium (Cr), cadmium (Cd) and zinc (Zn). Serial dilutions were made from the stock solution, and standard peaks were created using the AAS. The heavy metals were determined by identifying peaks that lined up with the standard peaks. In this study, the Perkin Elmer Analyst 200 model atomic absorption spectrophotometer was employed (Mohammad *et al*., 2023).

Health Risk Assessment

Determining the risk level and classifying health hazards as either carcinogenic or non-carcinogenic has allowed for the assessment of the health risk associated with heavy metals (Wongsasuluk *et al*., 2014; Mohammadi *et al*., 2019). Thus, the hazard quotients (HQ), hazard index (HI), and incremental lifetime cancer risk (ILCR) were employed to quantify the carcinogenic and non-carcinogenic health risks of heavy metals in suya meat due to oral ingestion.

Estimated daily intake of metal (EDI)

Based on the integration of information from the examination of heavy metals, the rate of meat consumption, and the body weight of adult Nigerians, the estimated daily intake (EDI) of metal (mg/kg/day) was determined. The following formula, which is provided by the Human Health Evaluation Manual, was used to obtain the EDI for each metal (US-EPA, 2011). Internationally recommended methods were used for the risk assessment (UNEP, 1996; US-EPA, 1997; 2000). For the estimation of daily intake (EDI), equation 1 was adopted (Copat *et al.*, 2012, 2013),

$$EDI = \frac{C_m \times IR \times EF \times ED}{BW \times AT} \quad (1)$$

Where,

C_m is the concentration of metal in food items (mg/kg)

IR is the ingestion rate (kg/day)
EF is the exposure frequency (days/yr) =365
ED is the exposure duration (yrs)
BW is the average body weight (kg)
AT is the average time (days) = ED × 365

Non-carcinogenic Risk Assessment

Target hazard quotient (THQ)

Target Hazard Quotient (THQ), is defined as the ratio of exposure to the reference dose. It is evaluated using an integrated US-EPA risk analysis. The THQ implies the ratio of exposure rate to the reference dose and can be expressed equation 2.

$$THQ = \frac{EDI}{RfDo} \quad (2)$$

Where,

EDI is the estimated daily intake (mg/kg/day), RfDo is the oral reference dose (mg/kg/day). If THQ risk is greater than 1, it is assumed that there is potential health risk (US-EPA, 2000 and 2000b; Antoine *et al*., 2017; Yahaya *et al*., 2020).

Hazard index (HI)

Hazards index was generated using equation 3

$$HI = \sum_{i=1}^{n} THQ \ \ldots \quad (3)$$

Where i represents each metal analyzed. A THQ and/or HI of > 1 indicate that there is potential risk of the contaminant to human health, whereas a result of ≤ 1 indicates no obvious risk of adverse health effects. This risk assessment method has been used by other researchers (Mt-Isa *et al*., 2016; ; Yahaya *et al.*, 2020; Asomugha *et al.*, 2021).

Carcinogenic Risk Assessment

Incremental lifetime cancer risk (ILCR)

The ILCR is used to estimate the probable carcinogen risk based on the exposure at a dignified dose of pollutant or contaminants using the Cancer Slope Factor (CSF). For the evaluation of incremental lifetime cancer risk (ILCR) equation 4 was applied for the estimation of potential carcinogenic risk.

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

Where: CSF is the cancer Slope Factor (mg/kg/day) for Pb = 0.0085 and Cd = 15 mg/kg (US-EPA, 2000a; Zeng *et al*., 2015; Hossain *et al*., 2018). The USEPA considers acceptable for regulatory purposes a cancer risk in the range of 10^{-6} to 10^{-4} (Sultana *et al*., 2017).

RESULTS AND DISCUSSION

Microbiological Analysis

Total Bacteria count

Total Plate Count

Samples from EG having a total plate count of 3.7 x 10^7 Cfu/g indicates a relatively low microbial load, which is within the recommended limits of 10^5 to 10^6 Cfu/g set by CODEX (2018). This suggests that the sample is within acceptable limits according to the standard. However, the total plate counts (TPC) of samples from BD and SB were too numerous to count, implying an extremely high microbial contamination, exceeding the upper limit of the recommended range. This could raise concerns about the quality and safety of the sample, requiring further investigation and possibly corrective measures. Similarly, sample from NG had 0 Cfu/g which indicates an absence of microbial contamination.

Total Coliform Count

The absence of coliform bacteria in the samples, indicated by a total coliform count of 0 Cfu/g across all samples, meets the recommended limit of less than 10^2 Cfu/g for coliform bacteria in food or water samples (WHO, 2018). This suggests that the samples meet the required threshold for microbiological quality. Coliform bacteria are commonly used as indicators of fecal contamination and overall sanitary quality. The absence of coliform bacteria indicates that the samples have not been contaminated with faecal matter or other sources of microbial contamination.

Total Staphylococcus Count

There was absence of *Staphylococcus* in samples from EG, NG and SB. This aligns closely with the recommended limit of 10^2 to 10^3CFU/g for *Staphylococcus* contamination in food and water (Baidya and Rahman, 2021; Nahla et al., 2023). It indicates that these samples meet the required microbiological safety threshold as they are significantly below the upper limit of the recommended range. However, for sample from BD, the *Staphylococcus* count was 19 x 10^6 CFU/g, which is well above the recommended range. The high *Staphylococcus* count in the BD sample could be due to various factors, such as inadequate sanitation during processing, cross-contamination during storage, or inherent characteristics of the sample itself.

Total Salmonella-Shigella Count

The absence of *Salmonella and Shigella* in all samples meets the limit of these pathogenic bacteria in 25g samples as recommended by WHO/FAO (2016). Ensuring food safety is dependent on the absence of *Salmonella and Shigella*, as they can cause foodborne illnesses when consumed in contaminated food products. Adhering to food safety measures helps to prevent any chances of transmitting foodborne illnesses.

Table 1: Total bacteria count in suya samples from various vendor points in Ibadan

Suya Sample	Total Plate Count		Total Coliform Count		Total *Staphylococcal* Count		Total *Salmonella-Shigella* Count	
Dilution Factor	10^3	10^6	10^3	10^6	10^3	10^6	10^3	10^6
EG	TNTC	29	88	0	72	0	14	0
	TNTC	45	54	0	56	0	27	0
BD	TNTC	TNTC	TNTC	0	TNTC	12	68	0
	TNTC	TNTC	84	0	TNTC	26	42	0
NG	67	0	1	0	21	0	0	0
	45	0	0	0	15	0	0	0
SB	TNTC	TNTC	2	0	24	0	0	0
	243	201	34	0	50	0	0	0

SB: Suya sample from Ibadan North-West LGA; NG: Suya sample from Oluyole LGA; BD: Suya sample from Ibadan North LGA; EG: Suya sample from Egbeda LGA

Isolates Identification

The isolated bacteria were identified and their occurrences were presented in Figures 2 – 5. The occurrence of *Staphylococcus aureus* was observed to be 52%, 24%, 18% and 21% for samples from EG, BD, NG and SB respectively. This pathogenic organism was more prevailing in sample from EG. These levels obtained for all the sample exceeded the recommended limits set by international standard (CODEX 2019, USDA, 2018). A recommendation of absence or very low counts of *Staphylococcus aureus* in ready-to-eat food was set. High concentrations of Staphylococcus aureus were linked to unhygienic handling and preparation procedures, according to research by (Hanson *et al*., 2011). With *Enterobacter* sp present in 80% of the sample from EG, there may be a degree of contamination that precludes the need for remedial measures to enhance sanitation protocols (Akabanda *et al*., 2010; Omemu *et al*., 2018). The occurrence of *Micrococcus* sp at 2% in both EG and BD sample, as well as 4% in NG sample is relatively low and may not pose a significant risk to food safety. *Micrococci* sp are generally considered non-pathogenic and are commonly found in the environment. However, its presence could still indicate environment contamination and may warrant further investigation. This value is lower to 10% occurrence noticeable in sample from SB sample as it may be said to exceed the recommended limit.

The prevalence of *Escherichia coli and Shigella* sp in samples from EG and BD respectively raises significant concerns regarding food safety in street-vended foods. This study indicates a notable occurrence of E. coli, with 19% and 37% prevalence rates in samples from EG and BD respectively. Similarly, *Shigella* sp occurrence in both samples from EG and BD was 3% and 5% respectively. These results align with previous findings documenting the occurrence of pathogenic bacteria in street foods (Alimi, 2016). The co-occurrence of *Pseudomonas aeruginosa and Salmonella typhi* in the Suya sample BD (11% and 13% respectively) raises significant concerns about food safety and public health. The environmental resilience of these pathogens and their connection to foodborne illnesses have been highlighted in earlier research, which offers background for understanding the consequences of this discovery (Jackson and Meah, 2018). The high occurrence of *Salmonella typhi* in the Suya sample BD underscores the potential risk of foodborne illness associated with consumption of contaminated foods. *Salmonella typhi*, the causative agent of typhoid fever, is primarily transmitted through the ingestion of contaminated food or water. In a variety of food matrices, the bacteria can survive for long periods of time, especially in environments that are conducive to its development and multiplication (Crump *et al*., 2004). The global burden of typhoid fever was revealed in a study conducted by (Mogasale *et al*., 2014), which also underlined the significance of strengthening food safety and sanitation protocols to stop the disease's spread.

The coexistence *of Pseudomonas aeruginosa* and *Salmonella typhi* in Suya sample BD indicates various possible sources of contamination in food processing, handling, or storage. Haeghebaert *et al*. (2002) conducted research which revealed that a *Salmonella* outbreak linked to contaminated ready-to-eat foods was caused by inadequate hygiene practices and poor food safety measures. It is crucial to mitigate these risk factors by establishing appropriate food safety measures to minimize contamination and guarantee the safety of food items. Additionally, the presence of both *Pseudomonas aeruginosa* and *Salmonella typhi* in sample from BD emphasizes the significance of strict food safety measures in reducing the dangers linked to harmful bacteria in food. The simultaneous presence of *Pseudomonas aeruginosa* and *Salmonella typhi* in the sample from BD suggests multiple routes of contamination during food preparation, handling, or storage. According to a research by Haeghebaert *et al*. (2002), a *Salmonella* outbreak connected to contaminated ready-to-eat meals was partly caused by ineffective food safety protocols and poor hygiene standards. Reducing the risk of contamination and guaranteeing the safety of food items requires addressing these risk factors through the application of appropriate food safety measures. Also, the co-occurrence of *Pseudomonas aeruginosa* and *Salmonella typhi* in the Suya sample from BD highlights the importance of rigorous food safety practices to mitigate risks associated with foodborne pathogens.

The presence of *Bacillus subtilis* in food, particularly in Ready-to-eat (RTE) food like suya, can indicate improper food handling or hygiene practices, potentially raising concerns about food safety. Although a low occurrence of this pathogen was observed in samples from BD and SB, with 2% and 5% occurrence respectively, this could indicate a potential risk of contamination during preparation, handling, or storage. Factors such as inadequate refrigeration, cross-contamination from raw meat or unsanitary surfaces, or insufficient cooking temperatures could contribute to the presence of Bacillus subtilis in suya samples. Makinde *et al.* (2020) also found that *Bacillus* sp, including *Bacillus subtilis*, were frequently present in RTE foods such as street-vended snacks, which include suya.

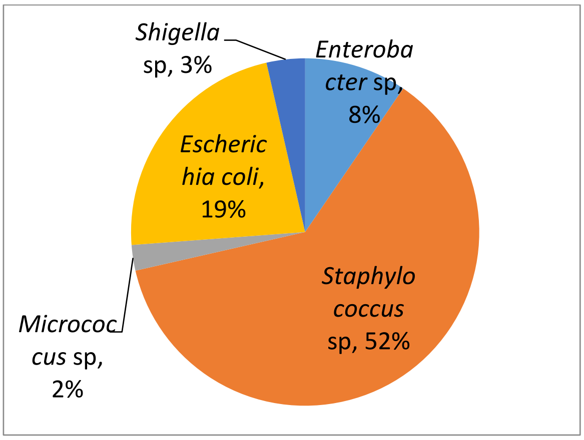

Figure 2: Occurrence of isolated bacteria in suya meat sample from EG

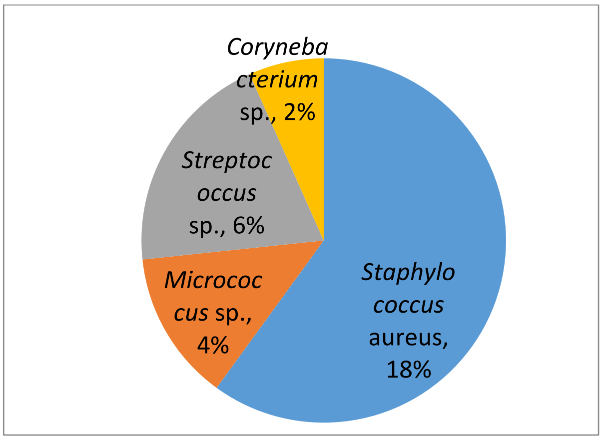

Figure 3: Occurrence of isolated bacteria in suya meat sample from NG

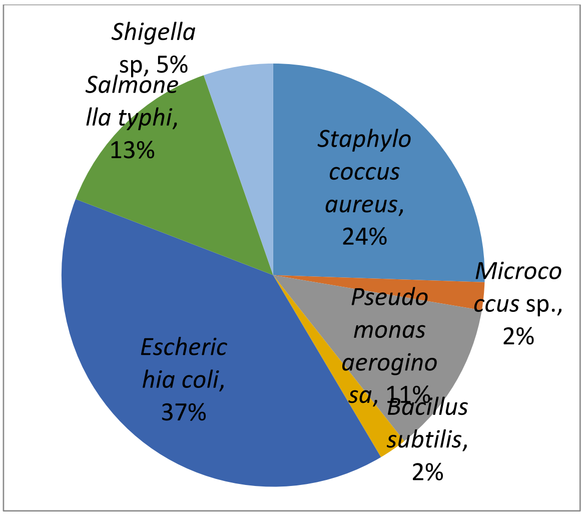

Figure 4: Occurrence of isolated bacteria in suya meat sample from BD

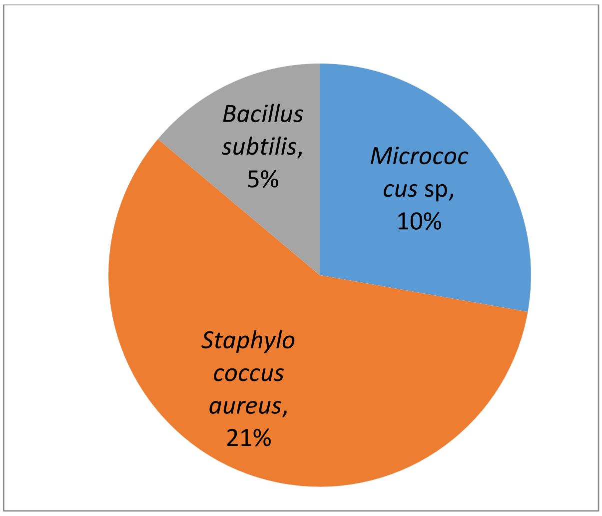

Figure 5: Occurrence of isolated bacteria in suya meat sample from SB

Health Risk Assessment

Concentration of heavy metals in the suya samples

To fully evaluate the effects of heavy metal concentrations in suya meat samples (SB, NG, BD, and EG), it is crucial to compare these concentrations to recommended limits suggested by standard agencies for meat products. The concentrations of the five heavy metals (Zn, Cr, Cd, Pb, and As) in the examined meat samples are shown in Table 2. The ranges of heavy metal contents in the samples are 49.1– 66.59 mg/kg for Zn, 2.54–6.15 mg/kg for Cr, 0.05–0.16 mg/kg for Cd, 0.17–0.36 mg/kg for Pb, and 10.59–17.64 mg/kg for As. The European Food Safety Authority (EFSA) and the U.S. Food Safety and Inspection Service (FSIS) recommend consuming meat products containing zinc at levels under 100 mg/kg. The zinc contents in samples SB, NG, BD, and EG are within the suggested limit, suggesting that consuming zinc from these sources has no harm to one's health. This is consistent with the findings of (Khan *et al*., 2015), which highlighted the safety of zinc concentrations in meat products up to recommended limits. The observed mean concentration of Zn was higher than those reported by Asomugha *et al*. (2021), Ndu and Princess (2018) and Yahaya *et al*. (2020). Zinc (Zn) is one of the valuable multipurpose trace elements with main functions including normal spermatogenesis and maturation, genomic integrity of the sperm, good epithelialization in wound healing as well as the secretion of pancreas and gastric enzymes in human body.

Table 2: Concentration of heavy metals in suya samples from various vendor points in Ibadan

Samples	Concentration of heavy metals (mg/kg)				
	Zn	**Cr**	**Cd**	**Pb**	**As**
SB	58.3	4.78	0.08	0.28	13.65
NG	63.2	5.23	0.11	0.35	15.28
BD	49.1	2.54	0.05	0.17	10.59
EG	66.59	6.15	0.16	0.36	17.64

SB: Suya sample from Ibadan North-West LGA; NG: Suya sample from Oluyole LGA; BD: Suya sample from Ibadan North LGA; EG: Suya sample from Egbeda LGA

Concentrations of chromium (Cr) in the meat samples varied between 2.54 to 5.23 mg/kg. This exceeds the allowed 1.0 mg/kg limit advised by World Health Organization (WHO, 2018; USDA, 2018). Every sample contained chromium levels above the permissible limit for meat products. The levels of this toxic metal found in these samples exceeded the findings of Okeke (2018), Makan-Juola and Olakunle (2016), and Ndu and Princess (2018) for concentration of chromium in suya meat. Excessive levels of chromium in the body may result in several negative consequences (Martin and Griswold, 2009). Health issues caused by exposure to chromium include dermatitis, skin inflammation, chronic allergic reactions, asthma-like conditions in the lungs and respiratory tract, as well as lung cancer and weak carcinogenic infections.

The observed mean concentration of Cadmium (Cd) was in the range of 0.05–0.16 mg/kg which is lower to the permissible limit of 0.5 mg/kg recommended by World Health Organization (WHO, 2011). Sample NG and EG has Cadmium concentrations slightly above the 0.1mg/kg permissible limit by CODEX, (2012). This result aligns with the research conducted by (Njoga *etal*., 2021), which demonstrated the safety of cadmium contents in meat products that are within permissible limits. Although Cd may be present in low concentrations, it is considered to be toxic when absorbed in the human body as it can result in long-term health problems such as brain damage, renal dysfunction and hypertension (González *et al*., 2019). Human nephrotoxicity from cadmium may be caused primarily by anomalies in tubular re-absorption. (Fevrier-Paul *et al*., 2018). According to estimates, the biological half-life of cadmium in the human kidney is lengthy, ranging from 10 to 30 years (Suwazono *et al*., 2009). The mean concentration of lead (Pb) obtained was in the range of 0.17–0.36 mg/kg, which is in accord with the permissible limit of 0.5 mg/kg recommended by USDA (2018) and 0.4 mg/kg by CODEX (2019). Researches carried out by (Tuormaa, 1995) demonstrated that high Lead concentrations cause adverse effects to humans. A high level of Lead in adult's body can generate heart diseases, cancer and infertility. Additional adverse consequences of elevated Pb levels in the body include anemia and hemoglobin biosynthesis, hypertension, renal damage, premature birth, nervous system disorders, brain damage, male infertility, and impaired cognitive function. Washing or cooking won't get rid of this hazardous metal (Sharafi *et al*., 2019).

Due to the severe toxicity of arsenic, meat products are subject to strict regulation restrictions, usually between 0.01 and 0.05 mg/kg, as advised by agencies such as the EFSA and the WHO (EFSA, 2005; WHO, 2017). The arsenic contents in samples SB, NG, BD, and EG greatly exceed these advised limits, putting consumers' health at serious danger. This emphasizes how vital it is to take action to reduce and look into any arsenic contamination in suya meat in order to make sure that meat products are compliant with set limits. This finding is supported by the research conducted by (Okoye *etal*., 2022), which focused on the health risks associated with arsenic concentrations in meat products that exceed allowable limits.

Estimated daily intake of metal (EDI)

The estimated daily intake (EDI) is an important measure used to determine the potential health risks associated with the consumption of various substances, such as contaminants like heavy metals or pesticides in food. This measure helps regulatory authorities ensure food safety and protect public health by establishing appropriate guidelines and limits for exposure to potentially harmful substances. Table 3 provides the estimated daily intake (EDI) of Zinc, Chromium, Cadmium, Lead, and Arsenic for an adult with a body weight of 70kg. The EDI values range from 0.048399 - 0.065639 for Zn, 0.002504 - 0.006062 for Cr, 0.0000789 - 0.000158 for Cd, 0.000168 - 0.000355 for Pb, and 0.010439 – 0.017388 mg/kgbw/day for As (Table 3). The EDI values for Zn, Cd, and Pb are below the recommended provisional tolerable daily intake (PTDI) limits for Zn (0.3 mg/kgbw/day), Cd (0.00014 mg/kgbw/day), and Pb (0.0036 mg/kgbw/day) respectively. However, the EDI of Cr exceeds the recommended PTDI (0.003 mg/kgbw/day) in all samples except in sample BD (0.002504 mg/kgbw/day). Additionally, the EDI for As in all the samples surpasses the recommended PTDI (WHO/FAO, 2016). The excessive EDI of Cr indicates an increased risk of toxicity, which can lead to gastrointestinal issues, dermatitis, or respiratory problems. Furthermore, the high EDI of As signifies an increased risk of arsenic toxicity, posing serious health implications for consumers (Haidar *et al.,* 2023).

Table 3: Estimated daily intake of metal (EDI) of suya samples from various vendor points in Ibadan

Samples	Estimated daily intake of metal (EDI)				
	EDI_Zn	**EDI_Cr**	**EDI_Cd**	**EDI_Pb**	**EDI_As**
SB	0.057467	0.004712	7.89E-05	0.000276	0.013455
NG	0.062297	0.005155	0.000108	0.000345	0.015062
BD	0.048399	0.002504	4.93E-05	0.000168	0.010439
EG	0.065639	0.006062	0.000158	0.000355	0.017388

SB: Suya sample from Ibadan North-West LGA; NG: Suya sample from Oluyole LGA; BD: Suya sample from Ibadan North LGA; EG: Suya sample from Egbeda LGA

Non-carcinogenic Risk Assessment

Target Hazard Quotient (THQ) values of the metals in this study raise public concerns, with THQ > 1 in the suya sample (Table 4). The THQ of Chromium (in all samples except sample BD) and Arsenic was greater than 1 in all samples. These values indicate that the suya meat is unsafe for human consumption. The THQ for Zinc, Cadmium, and Lead can be considered safe for consumers due to their low non-carcinogenic risk, presenting values < 1. Hazard Index (HI) is the total of all THQ values in food samples, with a value >1 indicating a high probability of an adverse health effect associated with such exposure. The HI values were greater than 1 in all samples. The Hazard Index suggests that suya processed in these study areas may pose risks to consumers due to the accumulation of heavy metal contaminants with values greater than one. The highest Hazard Index value, however, was found in suya sample EG. This demonstrates that consumption of suya in these study areas and its environs may pose a potentially great non-carcinogenic risk.

Table 4: Non-carcinogenic Risk Assessment of suya samples from various vendor points in Ibadan

Samples	Target Hazard Quotient (THQ) and Health Index (HI)					
	THQ_Zn	**THQ_Cr**	**THQ_Cd**	**THQ_Pb**	**THQ_As**	**HI**
SB	0.191557	1.570571	0.078857	0.078857	44.85	46.76984
NG	0.207657	1.718429	0.108429	0.098571	50.20571	52.3388
BD	0.161329	0.834571	0.049286	0.047878	34.79571	35.88878
EG	0.218796	2.020714	0.157714	0.101388	57.96	60.45861

SB: Suya sample from Ibadan North-West LGA; NG: Suya sample from Oluyole LGA; BD: Suya sample from Ibadan North LGA; EG: Suya sample from Egbeda LGA

Carcinogenic Risk Assessment

The USEPA considers a cancer risk ranging from 10^{-6} to 10^{-4} acceptable for regulatory purposes (US-EPA, 2009). Any value above 10^{-4} is deemed an unacceptable risk. In this study, all suya meat samples exceeded the acceptable limit for cancer risk due to lead, cadmium, and arsenic. This indicates a significant concern for carcinogenic risk from consuming suya meat. Extended exposure to cadmium in the environment has been associated with a higher risk of death from all cancers (Wang *et al.,* 2011).

Table 5: Incremental lifetime cancer risk (ILCR) of suya sample from various vendor points in Ibadan

Samples	Incremental lifetime cancer risk (ILCR)		
	ILCR_Pb	ILCR_Cd	ILCR_As
SB	0.000488	0.070676	0.020183
NG	0.00053	0.077329	0.022593
BD	0.000411	0.037556	0.015658
EG	0.000558	0.090932	0.026082

SB: Suya sample from Ibadan North-West LGA; NG: Suya sample from Oluyole LGA; BD: Suya sample from Ibadan North LGA; EG: Suya sample from Egbeda LGA

CONCLUSION

There are serious health hazards revealed by thorough examination on the safety and quality of suya meat being sold at various vendor points in Ibadan. Substantial amount of microbial contamination was found, with several cases showing hazardous high bacteria levels exceeding recommended health thresholds. Several samples had harmful bacteria like *Shigella, Pseudomonas aeruginosa, Salmonella typhi*, and *Escherichia coli*, which could cause various health issues, especially gastrointestinal illnesses.

The research also revealed alarming concentrations of heavy metals such as arsenic (As), lead (Pb), zinc (Zn), chromium (Cr), and cadmium (Cd). Long-term exposure to certain metals can have detrimental consequences on health, such as cancer and chronic illnesses. The Estimated Daily Intake (EDI) and Target Hazard Quotient (THQ) values for these metals suggest significant non-carcinogenic and carcinogenic health risks, with some hazard index (HI) values exceeding safe thresholds.

To ensure consumers' safety, it is crucial for suya vendors to implement improved hygiene practices promptly. Stringent food safety laws, continuous monitoring of microbiological and heavy metal contamination, and enhanced sanitation practices among suya vendors are all essential to reduce these threats to public health. These measures are essential to protect consumers, ensuring the safety of suya.

REFERENCES

Adewole, D., Adedeji, B., Bello, S., and Taiwo, J. (2023). Access to healthcare and social determinants of health among female migrant beggars in Ibadan, Nigeria. *Journal of Migration and Health*, *7*: 100-160.

Ades, G., Leith, K., and Leith, P. (2014). Food safety culture: insurance against catastrophe. *Food Safety Magazine*, *20*(5): 44.

Afolabi, F.T. and Odubanjo, O.R. (2012). Microbial assessment of chicken and beef suya samples in Oyo, Nigeria. *Natural Sciences*, *13*(11): 74–77.

Ahmad, A. A., Abdulkarim, I and Usman, H. (2023). Determination of heavy metals accumulation in tilapia fish (Oreochromisniloticus) tissues harvested from Ajiwa dam, Batagarawa, Katsina state. *FUDMA journal of sciences*, *7*(1): 219-223.

Akabanda, F., Owusu-Kwarteng, J., Glover, R.L.K. and Tano-Debrah, K. (2010). Microbiological characteristics of Ghanaian traditional fermented milk product, Nunu. *Nature and Science*, *8*(9): 178–187.

Akpoghelie, O.J. (2018). Assessment of Polycyclic Aromatic Hydrocarbons (PAHs) on Smoked Fish and Suya Meat Consumed in Warri, Nigeria. *Journal of Chemical Society of Nigeria*, *43*(3).

Alimi, B.A. (2016). Risk factors in street food practices in developing countries: A review. *Food Science and Human Wellness*, *5*(3): 141–148.

Antoine, J.M.R., Fung, L.A.H., and Grant, C.N. (2017). Assessment of the potential health risks associated with the aluminium, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. *Toxicology Reports*, *4*:181–187.

Asomugha, R.N., Ilodigwe, E.E., Amedu, J.O., Ogbonnaya, M., and Ifediba, E. (2021). Assessment of selected heavy metal load and identification of bacterial status associated with suya meat sold in Anambra state, Nigeria. *International Journal of Pharmacology and Toxicology, 9 (1): 17-28*

Ayeloja, A.A., George, F.O.A., Jimoh, W.A., Shittu, M.O. and Abdulsalami, S.A. (2018). Microbial load on smoked fish commonly traded in Ibadan, Oyo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, *22*(4): 493–497.

Baidya, S., & Rahman, T. (2021). *A Review On The Prevalence And Detection Of Bacterial Contamination In Common Food And Associated Health Risk* (Doctoral Dissertation, Brac University).

Beyersmann, D., and Hartwig, A. (2008). Carcinogenic metal compounds: recent insight into molecular and cellular mechanisms. *Archives of toxicology*, *82*: 493-512.

Codex Alimentarius. (2019). General Standard for Contaminants and Toxins in Food and Feed.

Copat, C., Conti, G.O., Signorelli, C., Marmiroli, S., Sciacca, S., Vinceti, M. and Ferrante, M. (2013). Risk assessment for metals and PAHs by Mediterranean seafood. *Food Nutr. Sci*., 4: 10-13. http://dx.doi.org/10.4236/fns.2013.47A002 Pu.

Copat, C., Bella, F., Castaing, M., Fallico, R., Sciacca, S. and Ferrante, M. (2012). Heavy Metals Concentrations in Fish from Sicily (Mediterranean Sea) and Evaluation of Possi- ble Health Risks to Consumers. *Bulletin of Environ- mental Contamination and Toxicology*, 88(1): 78-83. doi:10.1007/s00128-011-0433-6

Crump, B. C., Hopkinson, C. S., Sogin, M. L., and Hobbie, J. E. (2004). Microbial biogeography along an estuarine salinity gradient: combined influences of bacterial growth and residence time. *Applied and Environmental Microbiology*, *70*(3): 1494–1505.

Egbebi, A. O., and Seidu, K. T. (2011). Microbiological evaluation of Suya (dried smoked meat) sold in Ado and Akure, South West Nigeria. *European Journal of*

Experimental Biology, *1*(4): 1–5.

Egbebi, O. A., and Muhammad, A. A. (2016). Microbiological analysis of ready-to-eat suya meat sold in Owo, Ondo State. *International Journal of Innovative Biochemistry and Microbiology Research*, *4*: 11–15.

European Food Safety Authority (EFSA). (2005). Opinion of the Scientific Committee on a request from EFSA related to a harmonised approach for risk assessment of substances which are both genotoxic and carcinogenic. *EFSA Journal*, *3*(10): 282.

Falegan, C. R., Akoja, S. O., and Oyarekua, M. A. (2017). Microbiological assessment of suya (sliced roasted beef) in Ado-Ekiti Metropolis, Ekiti State, Nigeria. *MOJ Biology and Medicine*, *2*(3): 266–269.

Fevrier-Paul, A., Soyibo, A. K., Mitchell, S., and Voutchkov, M. (2018). Role of toxic elements in chronic kidney disease. *Journal of Health and Pollution*, *8*(20): 181-202.

Feyereisen, M., Mahony, J., Kelleher, P., Roberts, R. J., O'Sullivan, T., Geertman, J.-M. A., and van Sinderen, D. (2019). Comparative genome analysis of the Lactobacillus brevis species. *BMC Genomics*, *20*: 1–15.

Garba, A., Ibrahim, K. K., Erhabor, O., and Asokan, C. (2017). Lead Content of Three Common Suya Meats Sold on Major Streets in Sokoto Metropolis, Nigeria. *BAOJ Medical and Nursing*, *3*: 1–4.

González, N., Calderón, J., Rúbies, A., Timoner, I., Castell, V., Domingo, J. L., and Nadal, M. (2019). Dietary intake of arsenic, cadmium, mercury and lead by the population of Catalonia, Spain: Analysis of the temporal trend. *Food and Chemical Toxicology*, *132*: 110721.

Haeghebaert, S., Le Querrec, F., Bouvet, P., Gallay, A., Espié, E., and Vaillant, V. (2002). Les toxi-infections alimentaires collectives en France en 2001. *BEH*, *50*: 249–253.

Haidar, Z., Fatema, K., Shoily, S. S., and Sajib, A. A. (2023). Disease-associated metabolic pathways affected by heavy metals and metalloid. *Toxicology Reports*, *10*: 554-570

Hanson, B. M., Dressler, A. E., Harper, A. L., Scheibel, R. P., Wardyn, S. E., Roberts, L. K., Kroeger, J. S., and Smith, T. C. (2011). Prevalence of Staphylococcus aureus and methicillin-resistant Staphylococcus aureus (MRSA) on retail meat in Iowa. *Journal of Infection and Public Health*, *4*(4): 169–174.

Hassan, H. F., and Dimassi, H. (2014). Food safety and handling knowledge and practices of Lebanese university students. *Food Control*, *40*: 127–133.

Hossain, M. T., Hassi, U., and Huq, S. M. I. (2018). Assessment of concentration and toxicological (Cancer) risk of lead, cadmium and chromium in tobacco products commonly available in Bangladesh. *Toxicology Reports*, *5*: 897–902.

Iwar, V. (2017). Hygiene beliefs, attitudes, and practices of suya producers in Nigeria. *Walden University*.

Jackson, P., and Meah, A. (2018). Re-assessing vulnerability to foodborne illness: pathways and practices. *Critical Public Health*, *28*(1): 81–93.

Kelvin, O. C., and Lawrence, E. O. (2015). Heavy metals contamination levels in suya meat marketed in selected towns in Delta State, Nigeria. *IOSR J Environ Sci Toxicol Food Technol*, *9*(11): 110–113.

Khan, A., Khan, S., Khan, M. A., Qamar, Z., and Waqas, M. (2015). The uptake and bioaccumulation of heavy metals by food plants, their effects on plants nutrients, and associated health risk: a review. *Environmental Science and Pollution Research*, *22*: 13772–13799.

Kirk, M., Pires, S., Black, R., Caipo, M., Crump, J., Devleesschauwer, B., Döpfer, D., Fazil, A., Fischer-Walker, C., Hald, T.,

Hall, A., Keddy, K., Lake, R., Lanata, C., Torgerson, P., Havelaar, A., and Angulo, F. (2015). World Health Organization Estimates of the Global and Regional Disease Burden of 22 Foodborne Bacterial, Protozoal, and Viral Diseases, 2010: A Data Synthesis. *PLoS Medicine*, *12*, e1001921. https://doi.org/10.1371/journal.pmed.1001921

Makan-Juola, and Olakunle, M. (2016). Assessment of Heavy Metal in Raw Meat Sold in Some Notable Garages in Ogun State, South West, Nigeria. International Journal of Research Studies in Biosciences (IJRSB); 4(9): 10-13.

Makinde, O. M., Ayeni, K. I., Sulyok, M., Krska, R., Adeleke, R. A., and Ezekiel, C. N. (2020). Microbiological safety of ready-to-eat foods in low-and middle-income countries: A comprehensive 10-year (2009 to 2018) review. *Comprehensive Reviews in Food Science and Food Safety*, *19*(2): 703–732.

Martin, S., and Griswold, W. (2009). Human health effects of heavy metals. *Environmental Science and Technology briefs for citizens*, *15*(5): 1-6

JFECFA and WHO. (2002). Evaluation of Certain Food Additives and Contaminants*: Fifty-seventh Report of the Joint FAO/WHO Expert Committee on Food Additives* (Vol. 57).

Mogasale, V., Maskery, B., Ochiai, R. L., Lee, J. S., Mogasale, V. V, Ramani, E., Kim, Y. E., Park, J. K., and Wierzba, T. F. (2014). Burden of typhoid fever in low-income and middle-income countries: a systematic, literature-based update with risk-factor adjustment. *The Lancet Global Health*, *2*(10), e570–e580.

Mohammad, I. A., Aliyu, G., Tabugbo, B. I., and Rilwan, U. (2023). Determination of Heavy Metals in Some Selected Pastas in Nasarawa State Markets. *Nigeria. Adv. J. Chem. B*, *5*: 306-312.

Mohammadi, A. A., Zarei, A., Majidi, S., Ghaderpoury, A., Hashempour, Y., Saghi, M. H., Alinejad, A., Yousefi, M., Hosseingholizadeh, N., and Ghaderpoori, M. (2019). Carcinogenic and non-carcinogenic health risk assessment of heavy metals in drinking water of Khorramabad, Iran. *MethodsX*, *6*: 1642–1651.

Mt-Isa, S., Ouwens, M., Robert, V., Gebel, M., Schacht, A., and Hirsch, I. (2016). Structured benefit–risk assessment: a review of key publications and initiatives on frameworks and methodologies. *Pharmaceutical Statistics*, *15*(4), 324–332.

Mukhi, S., Rukmini, M. S., Manjrekar, P. A., Iyyaswami, R., and Sindhu, H. (2024). Assessment of Arsenic, Vanadium, Mercury, and Cadmium in Food and Drug Packaging. *F1000Research*, *11*(648), 648.

Nahla, a., Mostafa, s., and Hala, a. A. (2023). Assessment and evaluation of bacteriological hazards from critical points in meat shops concerning some toxigenic and biofilm-forming bacteria. *Assiut veterinary medical journal*, *69*(176).

Ndife, J., Onwuzuruike, U., and Okwunodulu, I. (2022). Influence of meat type on processed meat (Kilishi) quality. *FUDMA Journal of Sciences*, *6*(2): 160-168.

Ndu, D.-O. A., and Princess, T. (2018). Analysis of heavy metals in hawked charcoal roasted beef (suya) within Port Harcourt metropolis. *European Journal of Pure and Applied Chemistry, 5*(2).

Njoga, E. O., Ezenduka, E. V, Ogbodo, C. G., Ogbonna, C. U., Jaja, I. F., Ofomatah, A. C., and Okpala, C. O. R. (2021). Detection, distribution and health risk assessment of toxic heavy metals/metalloids, arsenic, cadmium, and lead in goat carcasses processed for human consumption in South-Eastern Nigeria. *Foods*, *10*(4): 798.

Obadina, A. O., Oyewole, O. B., and Ajisegiri, O. A. (2014). Identification of Hazards and Critical Control Point (CCP) for "Suya" Processing in South-West Nigeria. *Journal of Food Processing and Preservation*, *38*(5): 2057–2060.

Obasi, B. C. and Danladi, G. (2023). Evaluation of microbiological quality and organoleptic properties of smoked dried fish sold in Wukari markets Taraba state, Nigeria. *Magna Scientia Advanced Biology and Pharmacy*, 9(01): 087–093

Obasi, R. A., Madukwe, H. Y., and Nnabo, P. N. (2020). Geochemistry, weathering intensity and paleo-climatic conditions of soils around dumpsites from Ibadan, Oyo state, Nigeria. *European Journal of Basic and Applied Sciences, 7*(1).

Obasi, A., Nwachukwu, S., Ugoji, E., Kohler, C., Göhler, A., Balau, V., Pfeifer, Y., and Steinmetz, I. (2017). Extended-spectrum β-lactamase-producing Klebsiella pneumoniae from pharmaceutical wastewaters in South-Western Nigeria. *Microbial Drug Resistance*, *23*(8): 1013–1018.

Odu, N. N., Akwasiam, B., Osadebe, A. U., and Okonko, I. O. (2020). Potential public health risks associated with suya spice mix in Port Harcourt, Nigeria. *Toxicology and Environmental Health Sciences*, *12*: 315–323.

Ogundiwin, B. A. (2023). Official Maps in Local Administration: A Brief Look at Inner and Outer Local Government Areas (LGAs) of Ibadan, Southwest Nigeria. *Ife Social Sciences Review*, *31*(1): 15-28.

Oguntoyinbo, F. A. (2014). Safety challenges associated with traditional foods of West Africa. *Food Reviews International*, *30*(4): 338–358.

Okeke, O., Aburum, C. M., Ozuah, A. C., & Ezeh, E. (2018). Effect of application of seasonings/spices and heating/processing methods on the levels of polycyclic aromatic hydrocarbons and heavy metals in cooked, fried and roasted meats sold within Enugu metropolis. *International Journal of Environmental Sciences & Natural Resources*, *12*(4): 111-118.

Okoye, E. A., Bocca, B., Ruggieri, F., Ezejiofor, A. N., Nwaogazie, I. L., Frazzoli, C., and Orisakwe, O. E. (2022). Arsenic and toxic metals in meat and fish consumed in Niger delta, Nigeria: employing the margin of exposure approach in human health risk assessment. *Food and Chemical Toxicology*, *159*, 112767.

Omemu, A. M., Okafor, U. I., Obadina, A. O., Bankole, M. O., and Adeyeye, S. A. O. (2018). Microbiological assessment of maize ogi cofermented with pigeon pea. *Food Science and Nutrition*, *6*(5): 1238–1253.

Sharafi, K., Yunesian, M., Mahvi, A. H., Pirsaheb, M., Nazmara, S., and Nodehi, R. N. (2019). Advantages and disadvantages of different pre-cooking and cooking methods in removal of essential and toxic metals from various rice types-human health risk assessment in Tehran households, Iran. *Ecotoxicology and Environmental Safety*, *175*: 128–137.

Sultana, M. S., Rana, S., Yamazaki, S., Aono, T., and Yoshida, S. (2017). Health risk assessment for carcinogenic and non-carcinogenic heavy metal exposures from vegetables and fruits of Bangladesh. *Cogent Environmental Science*, *3*(1): 1291107.

Suwazono, Y., Kido, T., Nakagawa, H., Nishijo, M., Honda, R., Kobayashi, E., Dochi, M., and Nogawa, K. (2009). Biological half-life of cadmium in the urine of inhabitants after cessation of cadmium exposure. *Biomarkers*, *14*(2): 77–81.

Torgerson, P. R., Devleesschauwer, B., Praet, N., Speybroeck, N., Willingham, A. L., Kasuga, F., and de Silva, N. (2015). World Health Organization estimates of the global and regional disease burden of 11 foodborne parasitic diseases, 2010: a data synthesis. *PLoS medicine*, *12*(12), e1001920.

Tuormaa, T. E. (1995). The role of chromium, selenium and copper in human and animal metabolism. *Journal of Orthomolecular Medicine*, *10*(3): 149–164.

UNEP. (1996). Mediterranean Regional Report. Regionally Based Assessment of Persistent Toxic Substances, http://www.chem.unep.ch/

USDA (2018) USDA food composition databases: National Nutrient Database for Standard Reference. United States Department of Agriculture Agricultural Research Service, Washington, DC. https://ndb.nal.usda.gov/ndb/foods.

USEPA (2011) Recommended use of BW3/4 as the default method in derivation of the oral reference dose. EPA/100/R11/001. Office of the Science Advisor.

US-EPA. (2009) Risk-Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual. Part A. Interim Report (Final). https://www.epa.gov/sites/default/files/2015-09/documents/partf_200901_final.pdf

US-EPA. (2000). Risk-Based Concentration Table. http://www.epa.gov/spc/pdfs/rchandbk.pdf

Walker, N., Gupta, R., and Cheesbrough, J. (2006). Blood pressure cuffs: friend or foe? *Journal of Hospital Infection*, *63*(2): 167–169.

Wang, M., Xu, Y., Pan, S., Zhang, J., Zhong, A., Song, H., and Ling, W. (2011). Long-term heavy metal pollution and mortality in a Chinese population: an ecologic study. *Biological Trace Element Research*, *142*: 362–379.

World Health Organization. (2018). *Understanding the Codex Alimentarius*. Food & Agriculture Org..

World Health Organization. (2017). *Inheriting a sustainable world? Atlas on children's health and the environment*. World Health Organization.

WHO, (2011), Cadmium, In: Safety Evaluation of Certain Food Additives and Contaminants, Fifty-Fifth Meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), Geneva: WHO Food Additives Series, 46, World Health Organization, Geneva.

WHO, (2000), Lead, In: Safety Evaluation of Certain Food Additives and Contaminants, FiftyFifth Meeting of the Joint FAO/WHO Expert Committee on Food Additives (JECFA), Geneva: WHO Food Additives Series, 44, World Health Organization, Geneva, 273-312.

WHO/FAO (2016) General standard for contaminants and toxins in food and feed. Food and Agriculture Organization, World Health Organization, Rome, Geneva

Wongsasuluk, P., Chotpantarat, S., Siriwong, W., and Robson, M. (2014). Heavy metal contamination and human health risk assessment in drinking water from shallow groundwater wells in an agricultural area in Ubon Ratchathani province, Thailand. *Environmental Geochemistry and Health*, *36*: 169–182.

Yahaya, A., Abdulbasit, A. A., Onoja, A. D., Abdulkareem, A., Idowu, O. L., Odoma, J., Omale, V. F., Onuche, D., Nayo, R. O., and Abimaje, J. S. (2020). Analysis of Heavy Metals in Roasted Meat (Suya) in Anyigba, Kogi State, Nigeria and their Health Risk Assessment. *Communication in Physical Sciences*, *6*(1).

Yakubu, M. M., and Ngueku, B. B. (2015). Quality assessment of smoked-dried fish from five different markets in Lafia, Nigeria. *International Journal of Fisheries and Aquatic Studies*, *2*(4): 135–139.

Zeng, F., Wei, W., Li, M., Huang, R., Yang, F., and Duan, Y. (2015). Heavy metal contamination in rice-producing soils of Hunan province, China and potential health risks. *International Journal of Environmental Research and Public Health*, *12*(12): 15584–15593.