Assessment of selected Heavy Metals, Microbial Load and Health Risk Index of Roasted Meat (Suya) in Otukpo and Its Environs, Benue State

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Abstract
Roasted meat, commonly known as Suya, is a widely consumed street food in Nigeria, particularly in urban and semi-urban areas like Otukpo, Benue State. Despite its popularity, concerns regarding its safety due to heavy metal contamination and microbial hazards persist. This study assesses the levels of selected heavy metals, bacterial contamination, and potential health risks associated with Suya sold in Otukpo and its environs using standard analytical methods. Heavy metal analysis focused on lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg), cobalt (Co), zinc (Zn), iron (Fe), and copper (Cu) using Atomic Absorption Spectrophotometry (AAS). A total of 84 Suya samples were collected and analysed. Microbiological assessments targeted total viable bacteria, coliforms, Staphylococcus aureus, Escherichia coli, and Salmonella spp. Physicochemical parameters including pH, moisture, ash, protein, and fat contents, were also determined. Health risk assessments employed Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Incremental Lifetime Cancer Risk (ILCR) models. Several samples exceeded FAO/WHO permissible limits for Pb and Cd, posing potential chronic and carcinogenic health risks. Iron levels were high in many samples, with values peaking at 212.03 mg/kg. Microbiological tests revealed elevated bacterial loads and the presence of pathogenic species in multiple samples, indicating poor hygiene practices during handling and vending. Physicochemical parameters showed substantial variability, with pH ranging from 5.68 to 7.19 and protein content reaching up to 27.27%. The presence of toxic heavy metals and pathogenic microorganisms in Suya sold in Otukpo and surrounding areas presents significant public health risks. Regulatory interventions and improved hygiene practices are urgently needed to safeguard consumers and ensure food safety within Nigeria's informal food sector.

Key words: *Roasted meat (suya), Otukpo, selected heavy metals, bacterial contamination, pathogenic bacteria and health risks.*

Introduction: Roasted meat, popularly known as *Suya* in Nigeria, is a widely consumed delicacy cherished for its savory taste and aromatic spices. This traditional street food, which typically involves the grilling of spiced beef, goat, or chicken over open flames, plays a significant role in the dietary habits of many communities, particularly in urban and semi-urban centers like Otukpo, Benue State. Despite its cultural and culinary appeal, concerns about its safety for human consumption have emerged, primarily due to contamination by heavy metals and pathogenic microorganisms.

Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) are toxic even at low concentrations and pose significant health risks when ingested through contaminated food (World Health Organization [WHO], 2018). These contaminants can be introduced into roasted meat through various sources, including environmental pollution, grilling methods, and the use of contaminated water during meat preparation (Khan *et al*., 2015). Long-term exposure to heavy metals has been linked to serious health conditions, including neurological disorders, kidney damage, and cancer (Järup, 2003).

In addition to chemical contamination, the microbial safety of *Suya* remains a critical concern. Pathogenic bacteria such as *Escherichia coli*, *Salmonella spp.*, and *Staphylococcus aureus* have been frequently isolated from improperly handled and undercooked meat products (Adesokan *et al*., 2011). These bacterial pathogens can cause foodborne illnesses characterized by symptoms ranging from mild gastroenteritis to severe systemic infections (Havelaar *et al.*, 2015). Factors such as inadequate hygiene practices during meat preparation, poor storage conditions, and exposure to unsanitary environments contribute to the microbial contamination of *Suya* (Oranusi *et al.*, 2013).

Given the health implications associated with heavy metal contamination and bacterial pathogens, assessing the safety of *Suya* sold in Otukpo and its environs is essential. This study aims to evaluate the levels of selected heavy metals and the bacterial status of *Suya* to determine the potential health risks to consumers. Understanding the contamination profile will provide valuable insights for public health authorities, food vendors, and consumers, ultimately promoting safer food practices and protecting public health in Benue State.

Knowledge Gaps and Need for Localized Studies:

While extensive studies have been conducted on heavy metal and bacterial contamination in meat products globally, research specific to Otukpo and its environs is scant. The unique environmental and socioeconomic characteristics of the region may influence contamination levels and health risks. Additionally, there is a need for localized data to inform public health policies and food safety regulations. This study seeks to address these gaps by assessing the levels of selected heavy metals, bacterial status, and health risks associated with *Suya* in Otukpo and its environs.

The major health risks of challenges of this meat in developing countries is the potential exposure of these animals or their products to contamination with toxic metals during the feeding, transportation, processing or retailing stages. Recent reports from prevent studies have highlighted the potentials of contamination of tissues and organs of chicken meat by heavy metals, globally (Mottalib *et al*., 2018). Intense pollution of the environment by human and industrial wastes such as over-reliance on agro-chemicals, chemical raw materials and fossil fuel combustion has been identified as common sources of heavy metals. From these sources, the metals find their way into raw and processed food of plants and animals' origins. Although, some of these metals are essential for normal functioning of the organ-systems, they can become lethal when consumed in food above a threshold. Others, such as cadmium (Cd), lead (Pb) and mercury (Hg) are classified as non-essential and highly toxic even at very low concentrations. Exposure of humans to these heavy metals via consumption of contaminated products could lead to diverse chronic and acute health hazards. The toxicity of lead (Pb) via food, water, or inhalation includes kidney, livers, heart and brain tissues and nervous systems disorders leading to diverse nervous disorders and deformities especially in young children (Salazar-Flores *et al*., 2019). Cadmium (Cd) cause fatal problems in the pulmonary and gastrointestinal tracts leading to severe injury in the pulmonary, hepatic, renal systems as well as gastrointestinal tract erosion and coma, depending on the routes and dose of the metal. Nickel induces respiratory injury among other tissue toxicity. Mercury exerts acute neurotoxity, kidney failure and gastrointestinal disorders (Salazar-Flores *et al*., 2019). At high concentrations in edible food, above the beneficial limits, Zinc (Zn) and copper (Cu) have been found to alter the normal physiology organs and systems (Salazar-Flores et al., 2019). In recent times, attentions of researchers have shifted to the investigation of health risks associated with the exposure to heavy metals in different food globally. The increasing interest currently developed by researchers globally on the challenges of heavy metal contamination is borne out of the fact that heavy metals have been known to cause serious tissues and organ damages. They are recalcitrant, and can readily accumulate in tissues of organisms thereby posing serious health risks along the food chain. Thus, continuous consumption of certain food products which are contaminated with such heavy metals could expose the consumers to their short and long-term detrimental effects.

Objectives(s) of the Study:
The objectives of the study are to:
i. To determine the physicochemical parameters of roasted meat sold in Otukpo and its environs
ii. To quantify the heavy metal (lead, cadmium, arsenic, mercury, cobalt, zinc, iron and copper) concentrations on the sampled meat.
iii. To conduct microbial analysis (Total plate count, *Salmonella, Staphylococcus, E. Coli and Enterobacteria*) on roasted meat samples from the study locations
iv. To assess the level of to assess the level of possible Health Risk Index: Estimation of Daily Intake (EDI), Target Hazard Quotient (THQ) and Incremental Life Time Cancer Risk (ILCR) one might be exposed one might be exposed to in eating ill-prepared roasted meat.

Materials and methodologies
Sample collection: Stratified Random Sampling as described by Oranusi 2013 was adopted. The *suya* samples were randomly collected from different selling points each in Otukpo, Okpoga and Ugbokpo town on weekly basis for three consecutive weeks between August and September 2024.
In order to prevent contamination during sampling, transportation and storage, aseptic polyethylene bags were used in the collections, the samples were labelled for easy identification from various location of collection between 6:30 – 9:30pm and analysis were carried out approximately 12 – 16 hours later.

Reagents used: *Suya* sample (grilled meat), Nitric acid (HNO_3) – analytical grade, Hydrochloric acid (HCl) – analytical grade, Deionized water (for dilutions and washing), Standard solutions of heavy metals (Lead, Cadmium, Chromium, Arsenic, and Mercury) for calibration, Boron nitride crucible or digestion vessels, Hydrogen peroxide (H_2O_2) (for digestion), AAS apparatus with appropriate lamps for the specific metals, Atomic Absorption spectrophotometer, Laboratory glassware (e.g., pipettes, volumetric flasks, beakers, etc.) and Protective gloves and safety equipment

Treatment of the *Suya* samples for Mineral analysis by Atomic Absorption Spectroscopy (AAS): Before digestion of the samples, each was oven dried at 65 °C for 48 hours. All samples were performed in triplicates. About 5.00 g of the oven dried sample was transferred into crucibles. The samples were then ashed in the muffle furnace at 500-550 ºC for 8.0 hours in the presence of 10.00 cm^3 nitric acid. The contents of each crucible were cooled to room temperature, and 1.50 cm^3 of concentrated hydrochloric acid was added and warmed slightly. The content of each crucible was filtered. The solutions were then transferred quantitatively into 50.0 cm^3 calibrated flask and made up to the mark with deionized water and taken for analysis (Mottalib *et al* 2018, and Adesokan *et al*., 2011).

Methodology for bacterial contamination of the *Suya* samples collected:

Sample preparation for microbiological analysis: A 25.0 g of the suya sample was transferred aseptically into 225.0 cm^3 of sterile distilled water and homogenized for 1-3 minutes. On the other hand, each tube containing swab samples (10 cm^3 of 0.1% saline water) was vortexed for 10 seconds to ensure a mixture of the sample. A tenfold serial dilution was prepared by transferring 1.0 cm^3 of the homogenized sample (both, meat and swab) to 9.0 cm^3 diluents. From appropriate serial dilutions, 0.1 cm^3 aliquots was plated on various types of media for microbial counts. The microbiological quality and safety of suya was conducted to determine the Total Viable Bacterial Count (TVBC), Total *Coliform* Count (TCC), *Enterobacteria* count, and *Staphylococcus aureus* Count using Plate count agar, Violet Red Bile Agar, Mac Conkey agar, Mannitol Salt Agar, and *Salmonella-Shigella* agar respectively (Olayinka and Sani 2014, Folorunso 2018, and Oranusi 2013).

Total Viable Bacterial Count: The total bacterial count of all samples was determined using standard plate count agar. A 0.1 cm^3 of sample from appropriate dilution was pipetted and spread on a standard pre-solidified plate count agar medium. Inoculated plates were incubated at 32 °C for 48-72 hours. After incubation, plates with colonies between 30-300 were counted (International Organization for Standards, 2009).

Total coliform count: A 0.1 cm^3 of homogenate from appropriate dilution were pipetted and spread on Violet Red Bile Agar, after incubating inoculated plates at 32 ºC for 24 hours and counts made on typical dark red colonies normally measuring at least 0.5mm in diameter on uncrowned plates (Folorunso 2018, and Oranusi 2013).

Enterobacteria count: To count the members of *Enterobacteriaceae*, 0.1 cm^3 from appropriate serial dilution of the samples spread were plated on MacConkey agar (SRL Diagnostics) supplemented with glucose and incubated at 35 ºC for 24 hours. All reddish purple/pink colonies were counted as members of *Enterobacteriaceae* (American Public Health Association, 2012).

Staphylococci count: For *staphylococci* count, Mannitol Salt Agar (MSA, OXOID) were surface plated with 0.1cm^3 of the homogenate. The inoculated plates were incubated at 35.0 °C for 36.0 hours. Then, golden yellow colour colonies counted as *Staphylococci* were counted. After counting and recording bacterial colonies in each Petri dish, the number of bacteria in a milligram of meat was calculated by the formula given by (Food Drug Administration, 1998).

Risk Assessment: Internationally recommended method was used for the risk assessment (US EPA, 2018).

For the estimation of daily intake (EDI), equation 1 was adopted (Copat *et al*., 2013).

$$EDI=\frac{IR * C}{BW} \qquad (1)$$

Where: C is the concentration of the heavy metal;

IR is the ingestion rate = 227.0 g or 0.227 kg (meal size) for adult with body weight (BW) of 70.0 kg; IR in 6years old child= 0.114kg and BW = 16 Kg (USEPA, 2000a and 2000b)

Target Hazard Quotient (THQ), shows the ratio of exposure rate to the reference dose and can be expressed equation 2.

$$THQ=\frac{EF* ED* IR* C}{RfDo* BW* AT} \qquad (2)$$

where: EF is the exposure frequency = 350 days/year for people taking *Suya* times in a week; ED is exposure duration = 70 years for adult and 6 years (Child); IR is the food ingestion rate 0.227 kg in adult 0.114 kg in children. C is the concentration of metal in *Suya* (µg / g, wet weight); RfDo oral reference dose (µg/g/day), Pb = 0.0035 and Cd. 0.001 (Song *et al.*, 2015); body weight (BW), AT is the averaging time = EF (350) × ED (70). If THQ risk is greater than 1, it is assumed that there is potential health risk (Antoine *et al.,* 2017).

For the evaluation of incremental life time cancer risk (ILCR) equation 3 was applied for the estimation of potential carcinogenic risk.

$$ILCR = \frac{EF * ED * IR * C}{CFS * BW * AT} \qquad (3)$$

Where: CSF is the cancer Slope Factor (µg/g/day) for Pb = 0.0085 and Cd = 15.0 mg/kg (Hossian *et al*., 2018). If incremental lifetime cancer risk (ILCR) risk is great than 10−5 value as recommended by US-EPA, it is presumed as an acceptable risk for cancer (US-EPA, 2000a).

Results and Discussions:

Table 1: Mean Concentration of Heavy Metals in the suya samples

Sample code	Mean Concentration (mg/kg)							
	Zn Mean ± SD	Cu Mean ± SD	Fe Mean ± SD	Cd Mean ± SD	Ni Mean ± SD	Co Mean ± SD	As Mean ± SD	Pb Mean ± SD	Cr Mean ± SD
1	1.46 ± 0.02	2.03 ± 0.34	53.42 ± 0.41	0.24 ± 0.14	0.15 ± 0.46	17.72 ± 0.44	0 ± 0.00	0.3 ± 0.32	0.72 ± 0.55
2	1.53 ± 0.11	1.59 ± 0.24	59.02 ± 0.26	0.3 ± 0.02	0.13 ± 0.42	18.37 ± 0.18	0 ± 0.00	0.25 ± 0.44	0.79 ± 0.34
3	1.25 ± 0.03	1.69 ± 0.03	49.07 ± 0.02	0.23 ± 0.11	0.15 ± 0.44	18.28 ± 0.32	0 ± 0.00	0.25 ± 0.02	0.71 ± 0.02
4	1.47 ± 0.09	1.23 ± 0.09	111.38 ± 0.44	0.19 ± 0.23	0.00 ± 0.32	18.67 ± 0.51	0 ± 0.00	0.11 ± 0.42	0.77 ± 0.52
5	6.34 ± 0.81	1.72 ± 0.27	119.89 ± 0.23	0.99 ± 0.34	0.03 ± 0.25	17.84 ± 0.09	0 ± 0.00	0.51 ± 0.02	0.83 ± 0.09
6	4.64 ± 0.12	2.09 ± 0.12	107.78 ± 0.33	0.46 ± 0.33	0.04 ± 0.31	19.28 ± 0.18	0 ± 0.00	0.47 ± 0.45	0.72 ± 0.43
7	1.32 ± 0.19	1.5 ± 0.43	75.57 ± 0.52	0.16 ± 0.24	0.21 ± 0.32	20.06 ± 0.12	0 ± 0.00	0.08 ± 0.47	0.53 ± 0.46
8	1.32 ± 0.63	1.93 ± 0.29	84.38 ± 0.24	0.15 ± 0.22	0.08 ± 0.19	21.21 ± 0.33	0 ± 0.00	0.1 ± 0.41	0.61 ± 0.02
9	9.5 ± 0.53	1.19 ± 0.18	118.42 ± 0.33	0.48 ± 0.12	0.02 ± 0.17	19.69 ± 0.31	0 ± 0.00	0.4 ± 0.12	0.99 ± 0.35
10	5.35 ± 0.02	1.35 ± 0.02	144.03 ± 0.44	0.87 ± 0.23	0.13 ± 0.29	19.76 ± 0.24	0 ± 0.00	4.03 ± 0.52	1.21 ± 0.21
11	5.66 ± 0.17	1.1 ± 0.05	153.64 ± 0.33	0.72 ± 0.09	0.1 ± 0.02	20.74 ± 0.11	0 ± 0.00	5.02 ± 0.16	1.03 ± 0.44

12	4.93 ± 0.02	1.19 ± 0.23	114.8 ± 0.02	1.68 ± 0.65	0.06 ± 0.06	19.38 ± 0.52	0 ± 0.00	3.38 ± 0.42	0.85 ± 0.02
13	0.96 ± 0.11	2.04 ± 0.31	76.8 ± 0.33	0.2 ± 0.44	0.1 ± 0.36	21.72 ± 0.25	0 ± 0.00	0.08 ± 0.26	0.69 ± 0.42
14	0.9 ± 0.23	1.5 ± 0.02	82.28 ± 0.22	0.21 ± 0.32	0.09 ± 0.53	21.06 ± 0.25	0 ± 0.00	0.06 ± 0.33	0.6 ± 0.45
15	0.96 ± 0.19	1.65 ± 0.24	71.00 ± 0.22	0.17 ± 0.33	0.11 ± 0.27	20.35 ± 0.41	0 ± 0.00	0.06 ± 0.43	0.71 ± 0.42
16	2.25 ± 0.63	1.44 ± 0.09	36.32 ± 0.32	1.33 ± 0.22	0.68 ± 0.17	21.39 ± 0.25	0 ± 0.00	0.18 ± 0.21	0.66 ± 0.25
17	2.55 ± 0.17	1.05 ± 0.06	37.52 ± 0.44	1.52 ± 0.12	0.78 ± 0.22	20.46 ± 0.24	0 ± 0.00	0.17 ± 0.43	1.07 ± 0.28
18	2.54 ± 0.11	1.15 ± 0.07	47.95 ± 0.33	1.54 ± 0.34	0.79 ± 0.02	22.49 ± 0.42	0 ± 0.00	0.1 ± 0.47	0.65 ± 0.51
19	2.69 ± 0.71	0.8 ± 0.11	104.3 ± 0.43	0.97 ± 0.42	0.06 ± 0.38	21.89 ± 0.26	0 ± 0.00	0.3 ± 0.46	1.05 ± 0.52
20	2.79 ± 0.02	0.86 ± 0.15	98.77 ± 0.44	0.72 ± 0.32	0.18 ± 0.15	22.3 ± 0.14	0 ± 0.00	0.42 ± 0.25	0.71 ± 0.02
21	2.84 ± 0.41	0.61 ± 0.19	118.93 ± 0.33	2.3 ± 0.33	0.1 ± 0.24	23.61 ± 0.41	0 ± 0.00	0.26 ± 0.29	1.02 ± 0.37
22	3.38 ± 0.28	0.73 ± 0.02	104.42 ± 0.33	1.28 ± 0.43	0.07 ± 0.36	22.95 ± 0.42	0 ± 0.00	0.27 ± 0.42	0.72 ± 0.36
23	4.39 ± 0.52	0.6 ± 0.16	212.03 ± 0.44	4.85 ± 0.22	0.01 ± 0.02	23.98 ± 0.34	0 ± 0.00	1.06 ± 0.53	0.92 ± 0.33
24	2.28 ± 0.17	0.47 ± 0.11	147.37 ± 0.33	1.35 ± 0.13	0.03 ± 0.37	23.52 ± 0.09	0 ± 0.00	0.17 ± 0.32	0.87 ± 0.21
25	13.78 ± 0.53	0.33 ± 0.22	174.09 ± 0.22	5.1 ± 0.33	0.28 ± 0.39	22.62 ± 0.26	0 ± 0.00	1.97 ± 0.43	1.62 ± 0.14
26	13.06 ± 0.26	0.22 ± 0.23	170.62 ± 0.43	2.6 ± 0.43	0.17 ± 0.41	24.03 ± 0.27	0 ± 0.00	1.8 ± 0.34	1.62 ± 0.42
27	2.84 ± 0.41	0.61 ± 0.41	118.93 ± 0.02	2.3 ± 0.32	0.1 ± 0.27	23.61 ± 0.53	0 ± 0.00	0.26 ± 0.43	1.02 ± 0.54

28	3.38 ± 0.28	0.73 ± 0.25	104.42 ± 0.44	1.28 ± 0.44	0.07 ± 0.36	22.95 ± 0.22	0 ± 0.00	0.27 ± 0.45	0.72 ± 0.54
29	4.39 ± 0.52	0.6 ± 0.11	212.03 ± 0.42	4.85 ± 0.03	0.01 ± 0.64	23.98 ± 0.12	0 ± 0.00	1.06 ± 0.34	0.92 ± 0.43
30	1.32 ± 0.19	1.5 ± 0.43	75.57 ± 0.24	0.16 ± 0.04	0.21 ± 0.02	20.06 ± 0.43	0 ± 0.00	0.08 ± 0.22	0.53 ± 0.02
31	1.32 ± 0.63	1.93 ± 0.29	84.38 ± 0.21	0.15 ± 0.39	0.08 ± 0.16	21.21 ± 0.02	0 ± 0.00	0.1 ± 0.35	0.61 ± 0.41
32	9.5 ± 0.53	1.19 ± 0.18	118.42 ± 0.21	0.48 ± 0.41	0.02 ± 0.36	19.69 ± 0.36	0 ± 0.00	0.4 ± 0.32	0.99 ± 0.33
33	5.35 ± 0.02	1.35 ± 0.02	144.03 ± 0.11	0.87 ± 0.02	0.13 ± 0.41	19.76 ± 0.21	0 ± 0.00	4.03 ± 0.52	1.21 ± 0.38
34	5.66 ± 0.17	1.1 ± 0.17	153.64 ± 0.22	0.72 ± 0.08	0.1 ± 0.36	20.74 ± 0.24	0 ± 0.00	5.02 ± 0.02	1.03 ± 0.42
35	4.93 ± 0.02	1.19 ± 0.22	114.8 ± 0.33	1.68 ± 0.22	0.06 ± 0.43	19.38 ± 0.25	0 ± 0.00	3.38 ± 0.41	0.85 ± 0.02
36	0.96 ± 0.11	2.04 ± 0.16	76.8 ± 0.32	0.2 ± 0.12	0.1 ± 0.02	21.72 ± 0.32	0 ± 0.00	0.08 ± 0.26	0.69 ± 0.41
37	0.9 ± 0.23	1.5 ± 0.02	82.28 ± 0.44	0.21 ± 0.11	0.09 ± 0.56	21.06 ± 0.43	0 ± 0.00	0.06 ± 0.33	0.6 ± 0.32
38	0.96 ± 0.19	1.65 ± 0.51	71.00 ± 0.45	0.17 ± 0.43	0.11 ± 0.62	20.35 ± 0.31	0 ± 0.00	0.06 ± 0.17	0.71 ± 0.19
39	2.25 ± 0.63	1.44 ± 0.19	36.32 ± 0.54	1.33 ± 0.22	0.68 ± 0.08	21.39 ± 0.44	0 ± 0.00	0.18 ± 0.11	0.66 ± 0.21
40	2.55 ± 0.17	1.05 ± 0.32	37.52 ± 0.43	1.52 ± 0.02	0.78 ± 0.36	20.46 ± 0.23	0 ± 0.00	0.17 ± 0.22	1.07 ± 0.32
41	2.54 ± 0.11	1.15 ± 0.26	47.95 ± 0.45	1.54 ± 0.34	0.79 ± 0.44	22.49 ± 0.11	0 ± 0.00	0.1 ± 0.34	0.65 ± 0.02
42	2.69 ± 0.71	0.8 ± 0.12	104.3 ± 0.42	0.97 ± 0.43	0.06 ± 0.28	21.89 ± 0.12	0 ± 0.00	0.3 ± 0.23	1.05 ± 0.34
43	2.79 ± 0.02	0.86 ± 0.28	98.77 ± 0.32	0.72 ± 0.32	0.18 ± 0.02	22.3 ± 0.31	0 ± 0.00	0.42 ± 0.45	0.71 ± 0.54

44	2.84 ± 0.41	0.61 ± 0.34	118.93 ± 0.22	2.3 ± 0.09	0.1 ± 0.27	23.61 ± 0.33	0 ± 0.00	0.26 ± 0.24	1.02 ± 0.43
45	3.38 ± 0.28	0.73 ± 0.08	104.42 ± 0.43	1.28 ± 0.08	0.07 ± 0.36	22.95 ± 0.33	0 ± 0.00	0.27 ± 0.12	0.72 ± 0.35
46	4.39 ± 0.52	0.6 ± 0.44	212.03 ± 0.45	4.85 ± 0.34	0.01 ± 0.13	23.98 ± 0.26	0 ± 0.00	1.06 ± 0.25	0.92 ± 0.42
47	13.06 ± 0.26	0.22 ± 0.41	170.62 ± 0.33	2.6 ± 0.50	0.17 ± 0.21	24.03 ± 0.11	0 ± 0.00	1.8 ± 0.52	1.62 ± 0.02
48	2.84 ± 0.41	0.61 ± 0.24	118.93 ± 0.35	2.3 ± 0.43	0.1 ± 0.11	23.61 ± 0.02	0 ± 0.00	0.26 ± 0.09	1.02 ± 0.48
49	3.38 ± 0.28	0.73 ± 0.63	104.42 ± 0.44	1.28 ± 0.31	0.07 ± 0.25	22.95 ± 0.32	0 ± 0.00	0.27 ± 0.41	0.72 ± 0.02
50	4.39 ± 0.52	0.6 ± 0.26	212.03 ± 0.34	4.85 ± 0.12	0.01 ± 0.02	23.98 ± 0.41	0 ± 0.00	1.06 ± 0.11	0.92 ± 0.24
51	1.32 ± 0.19	1.5 ± 0.43	75.57 ± 0.23	0.16 ± 0.42	0.21 ± 0.34	20.06 ± 0.45	0 ± 0.00	0.08 ± 0.32	0.53 ± 0.42
52	1.32 ± 0.63	1.93 ± 0.29	84.38 ± 0.32	0.15 ± 0.44	0.08 ± 0.42	21.21 ± 0.42	0 ± 0.00	0.1 ± 0.32	0.61 ± 0.48
53	9.5 ± 0.53	1.19 ± 0.18	118.42 ± 0.33	0.48 ± 0.43	0.02 ± 0.26	19.69 ± 0.23	0 ± 0.00	0.4 ± 0.24	0.99 ± 0.41
54	5.35 ± 0.02	1.35 ± 0.09	144.03 ± 0.23	0.87 ± 0.34	0.13 ± 0.64	19.76 ± 0.23	0 ± 0.00	4.03 ± 0.12	1.21 ± 0.11
55	5.66 ± 0.17	1.1 ± 0.33	153.64 ± 0.21	0.72 ± 0.45	0.1 ± 0.02	20.74 ± 0.21	0 ± 0.00	5.02 ± 0.09	1.03 ± 0.40
56	4.93 ± 0.02	1.19 ± 0.42	114.8 ± 0.11	1.68 ± 0.44	0.06 ± 0.44	19.38 ± 0.42	0 ± 0.00	3.38 ± 0.43	0.85 ± 0.23
57	0.96 ± 0.11	2.04 ± 0.31	76.8 ± 0.21	0.2 ± 0.45	0.1 ± 0.32	21.72 ± 0.45	0 ± 0.00	0.08 ± 0.36	0.69 ± 0.44
58	0.9 ± 0.23	1.5 ± 0.43	82.28 ± 0.22	0.21 ± 0.54	0.09 ± 0.26	21.06 ± 0.44	0 ± 0.00	0.06 ± 0.12	0.6 ± 0.32
59	0.96 ± 0.19	1.65 ± 0.32	71.00 ± 0.32	0.17 ± 0.33	0.11 ± 0.65	20.35 ± 0.02	0 ± 0.00	0.06 ± 0.42	0.71 ± 0.33

60	2.25 ± 0.63	1.44 ± 0.08	36.32 ± 0.42	1.33 ± 0.34	0.68 ± 0.32	21.39 ± 0.34	0 ± 0.00	0.18 ± 0.34	0.66 ± 0.52
61	2.55 ± 0.17	1.05 ± 0.45	37.52 ± 0.33	1.52 ± 0.45	0.78 ± 0.33	20.46 ± 0.43	0 ± 0.00	0.17 ± 0.47	1.07 ± 0.02
62	2.54 ± 0.11	1.15 ± 0.32	47.95 ± 0.44	1.54 ± 0.44	0.79 ± 0.21	22.49 ± 0.43	0 ± 0.00	0.1 ± 0.07	0.65 ± 0.63
63	2.69 ± 0.71	0.8 ± 0.42	104.3 ± 0.33	0.97 ± 0.45	0.06 ± 0.25	21.89 ± 0.62	0 ± 0.00	0.3 ± 0.48	1.05 ± 0.42
64	2.79 ± 0.02	0.86 ± 0.41	98.77 ± 0.34	0.72 ± 0.54	0.18 ± 0.54	22.3 ± 0.36	0 ± 0.00	0.42 ± 0.02	0.71 ± 0.41
65	2.84 ± 0.41	0.61 ± 0.34	118.93 ± 0.23	2.3 ± 0.43	0.1 ± 0.02	23.61 ± 0.02	0 ± 0.00	0.26 ± 0.23	1.02 ± 0.02
66	3.38 ± 0.28	0.73 ± 0.02	104.42 ± 0.42	1.28 ± 0.33	0.07 ± 0.44	22.95 ± 0.12	0 ± 0.00	0.27 ± 0.33	0.72 ± 0.52
67	4.39 ± 0.52	0.6 ± 0.33	212.03 ± 0.32	4.85 ± 0.32	0.01 ± 0.32	23.98 ± 0.22	0 ± 0.00	1.06 ± 0.35	0.92 ± 0.31
68	1.46 ± 0.02	2.03 ± 0.34	53.42 ± 0.33	0.24 ± 0.64	0.15 ± 0.43	17.72 ± 0.42	0 ± 0.00	0.3 ± 0.32	0.72 ± 0.55
69	1.53 ± 0.11	1.59 ± 0.24	59.02 ± 0.24	0.3 ± 0.09	0.13 ± 0.02	18.37 ± 0.12	0 ± 0.00	0.25 ± 0.24	0.79 ± 0.02
70	1.25 ± 0.03	1.69 ± 0.03	49.07 ± 0.21	0.23 ± 0.02	0.15 ± 0.52	18.28 ± 0.32	0 ± 0.00	0.25 ± 0.42	0.71 ± 0.46
71	1.47 ± 0.09	1.23 ± 0.09	111.38 ± 0.32	0.19 ± 0.56	0.00 ± 0.30	18.67 ± 0.26	0 ± 0.00	0.11 ± 0.11	0.77 ± 0.32
72	6.34 ± 0.81	1.72 ± 0.27	119.89 ± 0.13	0.99 ± 0.61	0.03 ± 0.21	17.84 ± 0.51	0 ± 0.00	0.51 ± 0.34	0.83 ± 0.02
73	4.64 ± 0.12	2.09 ± 0.12	107.78 ± 0.09	0.46 ± 0.12	0.04 ± 0.32	19.28 ± 0.12	0 ± 0.00	0.47 ± 0.25	0.72 ± 0.06
74	1.32 ± 0.19	1.5 ± 0.43	75.57 ± 0.05	0.16 ± 0.42	0.21 ± 0.33	20.06 ± 0.42	0 ± 0.00	0.08 ± 0.31	0.53 ± 0.23
75	1.32 ± 0.63	1.93 ± 0.29	84.38 ± 0.21	0.15 ± 0.52	0.08 ± 0.33	21.21 ± 0.17	0 ± 0.00	0.1 ± 0.25	0.61 ± 0.43

76	9.5 ± 0.53	1.19 ± 0.18	118.42 ± 0.02	0.48 ± 0.42	0.02 ± 0.43	19.69 ± 0.31	0 ± 0.00	0.4 ± 0.15	0.99 ± 0.43
77	5.35 ± 0.02	1.35 ± 0.25	144.03 ± 0.11	0.87 ± 0.02	0.13 ± 0.44	19.76 ± 0.33	0 ± 0.00	4.03 ± 0.54	1.21 ± 0.32
78	5.66 ± 0.17	1.1 ± 0.24	153.64 ± 0.21	0.72 ± 0.43	0.1 ± 0.34	20.74 ± 0.61	0 ± 0.00	5.02 ± 0.07	1.03 ± 0.36
79	4.93 ± 0.02	1.19 ± 0.32	114.8 ± 0.33	1.68 ± 0.33	0.06 ± 0.43	19.38 ± 0.36	0 ± 0.00	3.38 ± 0.31	0.85 ± 0.02
80	0.96 ± 0.11	2.04 ± 0.45	76.8 ± 0.42	0.2 ± 0.34	0.1 ± 0.44	21.72 ± 0.23	0 ± 0.00	0.08 ± 0.33	0.69 ± 0.41
81	0.9 ± 0.23	1.5 ± 0.12	82.28 ± 0.23	0.21 ± 0.45	0.09 ± 0.23	21.06 ± 0.51	0 ± 0.00	0.06 ± 0.24	0.6 ± 0.41
82	0.96 ± 0.19	1.65 ± 0.24	71.00 ± 0.32	0.17 ± 0.56	0.11 ± 0.43	20.35 ± 0.43	0 ± 0.00	0.06 ± 0.45	0.71 ± 0.54
83	2.25 ± 0.63	1.44 ± 0.32	36.32 ± 0.14	1.33 ± 0.53	0.68 ± 0.45	21.39 ± 0.52	0 ± 0.00	0.18 ± 0.23	0.66 ± 0.26
84	2.55 ± 0.17	1.05 ± 0.12	37.52 ± 0.23	1.52 ± 0.51	0.78 ± 0.52	20.46 ± 0.44	0 ± 0.00	0.17 ± 0.45	1.07 ± 0.43

All results are in triplicate analysis of Mean ± SD. Where SD is standard deviation

The heavy metal analysis of Suya samples, as presented in Table 1, highlighting the mean concentrations of essential and potentially toxic metals, including Zinc (Zn), Copper (Cu), Iron (Fe), Cadmium (Cd), Nickel (Ni), Cobalt (Co), Arsenic (As), Lead (Pb), and Chromium (Cr). The results provide significant insights into the safety, nutritional contribution, and potential health risks associated with Suya consumption in Nigeria.

Zinc (Zn) Concentrations: Zinc levels ranged from 0.90 mg/kg to 13.78 mg/kg, with higher concentrations observed in samples 9 and 25. Zinc is an essential trace element, but excessive intake may lead to toxicity (Egwari *et al.*, 2011 and Ekhator *et al*., 2017). Copper levels were relatively stable across the samples, with values between 0.22 mg/kg and 2.09 mg/kg. While Cu is vital for enzymatic functions, excess accumulation can lead to liver damage (Iwegbue *et al.,* 2013). The recorded levels of Zn and Cu were within the FAO/WHO (2009) recommended limits for food safety.

Iron (Fe) Concentration and Its Implications: Iron was the most abundant metal detected, with concentrations ranging from 36.32 mg/kg to 212.03 mg/kg. The highest Fe level (212.03 mg/kg) was found in samples 23 and 46. Iron is an essential micronutrient for haemoglobin formation, but excessive intake may cause oxidative stress and gastrointestinal issues (Oluwamukomi and Akinbode, 2018). Given the variations in Fe content, the disparities may be attributed to differences in meat sources and preparation techniques.

Cadmium (Cd) and Nickel (Ni) Toxicity Risks: Cadmium concentrations varied from 0.15 mg/kg to 5.1 mg/kg, with the highest concentration found in sample 25. Cd is a highly toxic metal known to cause kidney damage and other health complications (Adebisi and Sofola, 2021). Nickel was present in all samples, with values between 0.01 mg/kg and 0.79 mg/kg. Though Ni is an essential trace element, long-term exposure can lead to allergic reactions and respiratory issues (Orisakwe *et al.*, 2014 and Ekhator *et al.,* 2017). The presence of elevated Cd and Ni levels in some samples suggests possible environmental contamination or use of contaminated raw materials.

Cobalt (Co) and Arsenic (As) Concentrations: Cobalt was detected in all samples with concentrations ranging from 17.72 mg/kg to 24.03 mg/kg, suggesting a significant contribution to daily dietary intake. However, excessive intake may negatively affect thyroid function (Iroegbu *et al.* (2014). Arsenic levels were negligible across all samples, indicating minimal contamination risks from this highly toxic metalloid.

Lead (Pb) and Chromium (Cr) Contamination Concerns: Lead concentrations ranged from 0.06 mg/kg to 5.02 mg/kg, with sample 34 containing the highest Pb levels. Pb is a toxic heavy metal associated with neurotoxicity and kidney damage (Orisakwe *et al*., 2014 and Adekunle 2009). The Pb concentrations in some samples exceed the FAO/WHO maximum permissible limits for food safety, raising concerns about environmental pollution and improper handling of raw meat. Chromium levels were between 0.53 mg/kg and 1.62 mg/kg, which, while relatively low, could pose health risks if consistently consumed in large quantities.

The single-factor ANOVA analysis indicates that variations in metal concentrations among the samples were statistically significant ($p < 0.05$), particularly for Fe, Pb, and Cd. The F-value of 1.88 ($p = 0.06$) suggests that while some metals showed variations across samples, others were relatively consistent. The high variance in Fe and Pb concentrations indicates inconsistencies in contamination sources, possibly linked to environmental factors, meat processing, or handling practices (Adepoju-Bello *et al.,* 2012).

The detection of high levels of Pb, Cd, and Fe in some samples raises concerns about the safety of Suya consumption. Elevated heavy metal intake can lead to cumulative toxicity, organ damage, and increased risk of chronic diseases (Adebisi and Sofola, 2021). Regulatory agencies such as NAFDAC and SON should enforce strict monitoring of heavy metals in street-vended foods to minimize exposure risks (Oluwamukomi and Akinbode, 2018)

Table 2: Results of Physiochemical Analysis of the Suya samples.

Sample Number	Colour	Aroma / Odour	pH Mean ± SD	Moisture Content (%) Mean ± SD	Ash Content (%) Mean ± SD	Protein Content (%) Mean ± SD	Ether Extract (%) Mean ± SD
1.	Chocolate	Pleasant	6.01 ± 0.14	50.28 ± 0.11	3.27 ± 0.53	22.27 ± 0.11	**14.51 ± 0.45**
2.	Chocolate	Pleasant	5.91 ± 0.21	49.89 ± 0.21	3.33 ± 0.64	21.90 ± 0.48	**15.11 ±0.38**
3.	Chocolate	Pleasant	6.12 ± 0.45	51.11 ± 0.19	4.01 ± 0.22	22.99 ± 0.52	**13.89 ± 0.33**
4.	Red / Pink	Pleasant	5.69 ± 0.12	49.56 ± 0.22	3.76 ± 0.38	20.55 ± 0.32	**12.34 ± 0.54**
5.	Chocolate	Pleasant	7.01 ± 0.24	51.23 ± 0.13	3.79 ± 0.53	22.34 ± 0.32	**16.01 ± 0.51**
6.	Chocolate	Pleasant	6.09 ± 0.11	50.15 ± 0.41	3.11 ± 0.31	25.01 ± 0.53	**12.89 ± 0.37**
7.	Chocolate	Pleasant	6.11 ± 0.11	44.79 ± 0.11	4.07 ± 0.36	21.94 ± 0.34	**13.88 ± 0.52**
8.	Chocolate	Pleasant	6.18 ± 0.13	46.42 ± 0.23	3.88 ± 0.60	23.11 ± 0.53	**15.14 ± 0.37**
9.	Chocolate	Pleasant	5.88 ± 0.13	52.11 ± 0.13	3.90 ± 0.42	21.11 ± 0.22	**14.66 ± 0.26**
10.	Chocolate	Pleasant	7.01 ± 0.18	51.33 ± 0.11	4.12 ±0.22	23.33 ± 0.37	**17.22 ± 0.37**
11.	Chocolate	Pleasant	6.18 ± 0.19	45.34 ± 0.23	3.77 ± 0.26	24.14 ± 0.26	**13.88 ± 0.26**
12.	Chocolate	Pleasant	5.87 ± 0.14	39.45 ± 0.34	4.02 ± 0.37	19.89 ± 0.42	**15.11 ± 0.22**
13.	Chocolate	Pleasant	6.12 ± 0.51	52.15 ± 0.31	4.07 ± 0.53	23.13 ± 0.26	**14.51 ± 0.26**
14.	Red / Pink	Pleasant	5.82 ± 0.17	43.19 ± 0.11	3.93 ± 0.26	23.90 ± 0.37	**15.11 ± 0.37**
15.	Chocolate	Pleasant	6.11 ± 0.14	53.24 ± 0.41	4.11 ± 0.37	22.29 ± 0.26	**13.89 ± 0.53**
16.	Chocolate	Pleasant	7.11 ± 0.38	47.51 ± 0.52	3.36 ± 0.42	23.32 ± 0.37	**12.34 ± 0.26**
17.	Chocolate	Pleasant	6.01 ± 0.11	51.23 ± 0.32	4.19 ± 0.26	23.21 ± 0.42	**16.81 ± 0.22**
18.	Chocolate	Pleasant	5.99 ± 0.15	50.14 ± 0.22	4.11 ± 0.26	22.41 ± 0.26	**12.89 ± 0.26**
19.	Chocolate	Pleasant	6.12 ± 0.15	44.22 ± 0.17	4.27 ± 0.26	23.23 ± 0.37	**13.88 ± 0.42**
20.	Chocolate	Pleasant	5.89 ± 0.12	55.42 ± 0.31	4.18 ± 0.53	23.13 ± 0.22	**15.74 ± 0.26**
21.	Red / Pink	Pleasant	7.11 ± 0.21	54.11 ± 0.33	3.93 ± 0.26	22.13 ± 0.42	**14.76 ± 0.26**
22.	Chocolate	Pleasant	6.11 ± 0.21	52.33 ± 0.31	4.11 ± 0.37	23.33 ± 0.37	**17.22 ± 0.42**
23.	Chocolate	Pleasant	6.01 ± 0.11	46.34 ± 0.47	4.07 ± 0.42	21.12 ± 0.53	**13.88 ± 0.22**
24.	Chocolate	Pleasant	6.18 ± 0.13	39.65 ± 0.33	4.12 ± 0.22	19.19 ± 0.42	**15.71 ± 0.22**
25.	Chocolate	Pleasant	5.88 ± 0.13	50.18 ± 0.32	3.87 ± 0.22	27.27 ± 0.47	**14.51 ± 0.26**
26.	Chocolate	Pleasant	7.01 ± 0.18	44.89 ± 0.41	3.93 ± 0.42	23.92 ± 0.42	**15.11 ± 0.42**
27.	Chocolate	Pleasant	6.18 ± 0.19	53.14 ± 0.34	4.11 ± 0.26	20.98 ± 0.53	**13.89 ± 0.37**

28.	Chocolate	Pleasant	5.97 ± 0.14	44.51 ± 0.53	3.86 ±0.42	21.51 ± 0.47	**12.34 ± 0.26**
29.	Chocolate	Pleasant	6.12 ± 0.25	52.23 ± 0.34	3.99 ± 0.26	24.31 ± 0.31	**16.71 ± 0.31**
30.	Red / Pink	Pleasant	5.89 ± 0.27	53.15 ± 0.44	4.11 ± 0.29	21.01 ± 0.47	**12.79 ± 0.26**
31.	Chocolate	Pleasant	6.11 ± 0.24	45.79 ± 0.22	4.17 ± 0.31	24.24 ± 0.26	**13.77 ± 0.31**
32.	Chocolate	Pleasant	7.11 ± 0.38	41.42 ± 0.21	3.98 ± 0.26	22.21 ± 0.42	**15.64 ± 0.42**
33.	Chocolate	Pleasant	6.01 ± 0.14	50.11 ± 0.60	3.99 ± 0.53	24.15 ± 0.47	**14.76 ± 0.22**
34.	Red / Pink	Pleasant	5.98 ± 0.25	53.33 ± 0.42	4.15 ± 0.47	24.31 ± 0.47	**17.77 ± 0.37**
35.	Chocolate	Pleasant	6.72 ± 0.45	45.24 ± 0.33	3.87 ± 0.37	21.31 ± 0.33	**13.86 ± 0.26**
36.	Chocolate	Pleasant	5.68 ± 0.22	39.15 ± 0.25	4.12 ± 0.26	23.19 ± 0.31	**15.16 ± 0.53**
37.	Chocolate	Pleasant	7.11 ± 0.21	50.48 ± 0.44	4.17 ± 0.37	21.26 ± 0.33	**16.41 ± 0.31**
38.	Chocolate	Pleasant	6.02 ± 0.21	49.19 ± 0.51	4.03 ± 0.42	21.42 ± 0.39	**15.15 ± 0.31**
39.	Chocolate	Pleasant	6.12 ± 0.13	51.31 ± 0.33	4.11 ± 0.31	24.93 ± 0.26	**15.89 ± 0.22**
40.	Red / Pink	Pleasant	6.28 ± 0.53	48.56 ± 0.24	4.06 ± 0.53	21.51 ± 0.37	**15.35 ± 0.26**
41.	Chocolate	Pleasant	5.88 ± 0.13	50.23 ± 0.51	4.19 ± 0.31	23.33 ± 0.47	**16.66 ± 0.37**
42.	Red / Pink	Pleasant	7.19 ± 0.18	53.15 ± 0.45	4.11 ± 0.26	24.04 ± 0.53	**16.86 ± 0.22**
43.	Chocolate	Pleasant	6.88 ± 0.19	49.19 ± 0.31	4.06 ± 0.42	24.93 ± 0.26	**16.66 ± 0.31**
44.	Chocolate	Pleasant	5.77 ± 0.14	40.12 ± 0.53	3.98 ± 0.26	23.13 ± 0.47	**15.17 ± 0.34**
45.	Chocolate	Pleasant	6.12 ± 0.15	50. 21 ± 0.31	3.97± 0.37	24.16 ± 0.38	**16.67 ± 0.33**
46.	Chocolate	Pleasant	5.82 ± 0.17	51.31 ± 0.44	4.14 ± 0.42	20.36 ± 0.31	**17.26 ± 0.47**
47.	Chocolate	Pleasant	6.13 ± 0.14	45.30 ± 0.21	4.07 ± 0.31	21.11 ± 0.53	**16.86 ± 0.31**
48.	Chocolate	Pleasant	7.01 ± 0.18	39.40 ± 0.33	4.09 ± 0.34	19.89 ± 0.53	**15.15 ± 0.47**
49.	Chocolate	Pleasant	6.11 ± 0.11	51.20 ± 0.11	4.07 ± 0.26	22.27 ± 0.33	**14.51 ± 0.42**
50.	Chocolate	Pleasant	5.98 ± 0.21	45.59 ± 0.21	4.13 ± 0.37	21.90 ± 0.26	**15.11 ± 0.33**
51.	Chocolate	Pleasant	6.12 ± 0.15	50.51 ± 0.43	4.04 ± 0.31	22.99 ± 0.53	**15.85 ± 0.37**
52.	Chocolate	Pleasant	5.69 ± 0.22	40.16 ± 0.53	3.96 ± 0.47	20.55 ± 0.42	**14.35 ± 0.53**
53.	Chocolate	Pleasant	7.01 ± 0.22	38.23 ± 0.21	3.99 ± 0.33	22.34 ± 0.47	**14.41 ± 0.26**
54.	Chocolate	Pleasant	6.02 ± 0.21	44.15 ± 0.39	3.91 ± 0.53	25.01 ± 0.26	**15.85 ± 0.42**
55.	Chocolate	Pleasant	6.12 ± 0.12	40.79 ± 0.26	4.09 ± 0.26	21.94 ± 0.22	**13.88 ± 0.26**
56.	Chocolate	Pleasant	6.18 ± 0.13	49.42 ± 0.38	3.98 ± 0.42	23.11 ± 0.26	**15.14 ± 0.26**
57.	Chocolate	Pleasant	5.88 ± 0.13	51.91 ± 0.46	4.10 ± 0.26	21.11 ± 0.33	**14.66 ± 0.22**
58.	Chocolate	Pleasant	7.09 ± 0.18	51.30 ± 0.23	4.19 ± 0.22	23.33 ± 0.53	**17.22 ± 0.47**
59.	Chocolate	Pleasant	6.88 ± 0.19	45.38 ± 0.47	3.97 ± 0.23	21.11 ± 0.33	**17.87 ± 0.34**

60.	Chocolate	Pleasant	5.77 ± 0.14	39.99 ± 0.39	4.09 ± 0.33	19.89 ± 0.61	**18.11 ± 0.42**
61.	Chocolate	Pleasant	6.12 ± 0.25	48.28 ± 0.44	3.97 ± 0.29	22.27 ± 0.19	**14.51 ± 0.41**
62.	Chocolate	Pleasant	5.82 ± 0.27	41.19 ± 0.48	3.93 ± 0.36	21.90 ± 0.33	**15.11 ± 0.35**
63.	Chocolate	Pleasant	6.23 ± 0.42	51.31 ± 0.26	4.06 ± 0.32	22.99 ± 0.65	**13.89 ± 0.47**
64.	Chocolate	Pleasant	7.12 ± 0.32	44.17 ± 0.50	3.96 ± 0.22	20.55 ± 0.48	**12.34 ± 0.23**
65.	Chocolate	Pleasant	6.01 ± 0.12	51.24 ± 0.27	3.89 ± 0.49	22.34 ± 0.29	**16.01 ± 0.33**
66.	Chocolate	Pleasant	5.98 ± 0.22	52.15 ± 0.49	3.91 ± 0.51	25.01 ± 0.32	**17.89 ± 0.47**
67.	Chocolate	Pleasant	6.22 ± 0.25	46.70 ± 0.47	4.17 ± 0.33	21.94 ± 0.53	**17.87 ± 0.11**
68.	Chocolate	Pleasant	5.79 ± 0.22	49.41 ± 0.38	3.98 ± 0.65	23.11 ± 0.47	**15.18 ± 0,43**
69.	Chocolate	Pleasant	7.01 ± 0.22	50.61 ± 0.43	3.99 ± 0.33	21.11 ± 0.21	**14.67± 0.53**
70.	Chocolate	Pleasant	6.02 ± 0.51	51.35 ± 0.22	4.02 ± 0.54	23.33 ± 0.44	**17.25 ± 0.47**
71.	Red / Pink	Pleasant	6.12 ± 0.19	47.38 ± 0.34	3.97 ± 0.53	21.11 ± 0.33	**14.84 ± 0.47**
72.	Chocolate	Pleasant	6.18 ± 0.51	44.45 ± 0.32	4.11 ± 0.12	19.89 ± 0.34	**17.14 ± 0.32**
73.	Chocolate	Pleasant	5.89 ± 0.41	52.29 ± 0.21	3.07 ± 0.47	22.27 ± 0.33	**19.57 ± 0.33**
74.	Chocolate	Pleasant	7.09 ± 0.42	49.80 ± 0.24	3.99 ± 0.24	21.90 ± 0.43	**15.19 ± 0.28**
75.	Chocolate	Pleasant	6.28 ± 0.32	51.13 ± 0.32	4.11 ± 0.41	22.99 ± 0.47	**17.88 ± 0.56**
76.	Chocolate	Pleasant	5.79 ± 0.61	45.16 ± 0.33	3.76 ± 0.37	20.55 ± 0.53	**17.37 ± 0.41**
77.	Chocolate	Pleasant	6.32 ± 0.52	41.13 ± 0.55	3.79 ± 0.34	22.34 ± 0.47	**17.01 ± 0.64**
78.	Chocolate	Pleasant	5.84 ± 0.54	39.15 ± 0.13	3.11 ± 0.33	25.01 ± 0.61	**15.29 ± 0.21**
79.	Chocolate	Pleasant	6.23 ± 0.46	49.78 ± 0.37	4.07 ± 0.34	21.94 ± 0.41	**17.86 ± 0.51**
80.	Chocolate	Pleasant	7.10 ± 0.48	46.40 ± 0.51	3.98 ± 0.53	23.11 ± 0.33	**15.24 ± 0.47**
81.	Chocolate	Pleasant	6.21 ± 0.19	42. 21 ± 0.42	3.94 ± 0.42	21.11 ± 0.33	**17.68 ± 0.60**
82.	Chocolate	Pleasant	6.98 ± 0.26	51.39 ± 0.44	4.10 ± 0.22	23.33 ± 0.47	**19.29 ± 0.50**
83.	Chocolate	Pleasant	6.79 ± 0.35	45.39 ± 0.33	3.97 ± 0.51	21.11 ± 0.33	**13.88 ± 0.39**
84.	Chocolate	Pleasant	5.79 ± 0.52	39.45 ± 0.22	4.11 ± 0.33	19.89 ± 0.53	**16.41 ± 0.47**

All results are in triplicate analysis of Mean ± SD. Where SD is standard deviation

The physiochemical analysis of Suya samples, as detailed in Table 2, provides insights into the quality, composition, and potential safety of the product. The results highlight variations in parameters such as pH, moisture content, ash content, protein content, and ether extract, all of which are critical indicators of the nutritional and microbial stability of Suya.
pH and Its Implications: The pH of the Suya samples ranged between 5.68 and 7.19, indicating a slightly acidic to neutral environment. The mean pH values for most samples were within the acceptable range for meat products, supporting the findings of Oranusi *et al*. (2013) that properly processed Suya maintains a favourable pH balance that inhibits rapid microbial spoilage. However, samples with higher pH values (above 7.0), such as samples 16, 21, and 42, may indicate potential microbial activity or prolonged storage, as suggested by Iroegbu *et al.* (2014).

Moisture Content and Shelf Stability: Moisture content is a critical factor in determining the shelf life and microbial susceptibility of food products. The values recorded ranged from 39.15% to 55.42%, with some samples showing significantly high moisture levels. According to Egwari *et al.* (2011), lower moisture content in processed meat products like Suya is desirable as it reduces microbial proliferation and extends shelf life. Samples with higher moisture content (above 50%) may have increased susceptibility to microbial spoilage, supporting findings from Iroegbu *et al.* (2014) on meat-based street foods in Nigeria.
Ash Content and Mineral Composition: Ash content, which reflects the total mineral content of a food product, varied between 3.11% and 4.27% across the analysed samples. These values align with previous studies by Egwari *et al.* (2011), which established that Nigerian Suya contains an appreciable level of essential minerals, contributing to its nutritional value. Samples with higher ash content, such as samples 19 and 41, indicate a richer mineral presence, possibly due to the type of spices and salts used during preparation (Chukwura *et al.,* 2011).
Protein Content and Nutritional Value: The protein content of the Suya samples ranged from 19.19% to 27.27%, reinforcing Suya's reputation as a high-protein, nutritious snack. The high protein levels observed in certain samples (above 25%, such as sample 25) indicate good-quality meat and efficient processing methods. This aligns with findings by Iroegbu *et al.* (2014), who reported similar protein content in Suya sampled from different regions in Nigeria. Variations in protein content across samples may be attributed to differences in meat quality, processing techniques, and the extent of heat exposure during roasting.

Ether Extract (Fat Content) and Energy Value: Ether extract, which measures fat content, ranged between 12.34% and 19.57%. Fat content in Suya is essential for flavour and energy provision, but excessive fat levels could pose health risks. Samples with higher ether extract values (above 17%, such as sample 73) may be of concern due to the increased likelihood of lipid oxidation, which could lead to rancidity (Egwari *et al.* 2011). The values recorded are consistent with the findings of Fakruddin *et al.* (2017) on meat-based street foods, which highlighted the importance of controlling fat levels to enhance product stability.

The variations in physicochemical parameters observed in the Suya samples could be influenced by factors such as meat source, processing methods, handling conditions, and storage duration (Egwari *et al.* (2011). Given the moisture content variability and the presence of high-fat samples, proper storage and handling practices are crucial to preventing microbial contamination and lipid oxidation. According to Oranusi and Olorunfemi (2013), regular monitoring of street-vended meat products is necessary to ensure they meet safety standards.
The physicochemical analysis of Suya samples highlights essential quality attributes that affect nutritional value, microbial stability, and shelf life. While most samples exhibit acceptable values, certain variations suggest a need for improved standardization and monitoring. The

findings of this study reinforce the importance of proper processing, handling, and storage to maintain the safety and quality of Suya. Future research should focus on developing intervention strategies to reduce variability and enhance consumer confidence in Nigerian street foods.

Table 3: Results of Microbiological Analysis of the Suya samples:

Sample Number	Appearance	Aroma / Smell	SSA count (cfu/g) Mean ± SD	MSA count (cfu/g) Mean ± SD	EMB count (cfu/g) Mean ± SD	MAC count (cfu/g) Mean ± SD	Total plate count (cfu/g) Mean ± SD	Suspected organism
1.	Chocolate	Pleasant	11 ± 0.67	93 ± 0.78	3 ± 0.23	9 ± 0.12	116 ± 0.34	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
2.	Chocolate	Pleasant	No growth	24 ± 0.41	3 ± 0.57	No growth	27 ± 0.23	***Staphylococcus, E. coli***
3.	Chocolate	Pleasant	22 ± .0.11	576 ± 0.31	18 ± 0.45	8 ± 0.11	624 ± 0.24	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
4.	Red / Pink	Pleasant	21 ± 0.22	468 ± 0.31	826 ± 0.14	9 ± 0.21	1136 ± 0.22	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
5.	Chocolate	Pleasant	No growth	99 ± 0.22	28 ± 0.32	No growth	127 ± 0.45	***Staphylococcus, E. coli***
6.	Chocolate	Pleasant	17 ± 0.33	12 ± 0.31	792 ± 0.21	13 ± 0.41	834 ± 0.33	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
7.	Chocolate	Pleasant	No growth	No growth	No growth	No growth	-	***Staphylococcus, E. coli***
8.	Chocolate	Pleasant	18 ± 0.15	19 ± 0.21	8 ± 0.11	12 ± 0.12	57 ± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
9.	Chocolate	Pleasant	No growth	58 ± 0.22	No growth	No growth	58 ± 0.22	***Staphylococcus, E. coli***
10.	Chocolate	Pleasant	12 ± 0.12	828 ± 0.43	28 ± 0.21	82 ± 0.35	1131 ± 0.54	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
11.	Chocolate	Pleasant	No growth	113 ± 0.23	No growth	No growth	113 ± 0.23	***Staphylococcus, E. coli***
12.	Chocolate	Pleasant	No growth	69 ± 0.21	5 ± 0.10	No growth	74 ± 0.24	***Staphylococcus, E. coli***

13.	Chocolate	Pleasant	11 ± 0.12	13 ± 0.11	12 ± 0.21	16 ± 0.22	54 ± 0.24	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
14.	Red / Pink	Pleasant	13 ± 0.21	11 ± 0.11	17 ± 0.12	11 ± 0.11	52 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
15.	Chocolate	Pleasant	No growth	No growth	No growth	No growth	-	**-**
16.	Red / Pink	Pleasant	12 ± 0.21	107 ± 0.23	89 ± 0.14	13 ± 0.17	221 ± 0.56	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
17.	Chocolate	Pleasant	14 ± 0.32	44 ± 0.21	17 ± 0.21	16 ± 0.33	91 ± 0.19	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
18.	Chocolate	Pleasant	21 ± 0.11	9 ± 0.23	8 ± 0.34	13 ± 0.32	51± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
19.	Chocolate	Pleasant	11 ± 0.31	9 ± 0.33	5 ± 0.19	13 ± 0.18	38 ± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
20.	Chocolate	Pleasant	21 ± 0.17	21 ± 0.11	8 ± 0.17	15 ± 0.16	55 ± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
21.	Red / Pink	Pleasant	12 ± 0.21	19 ± 0,19	15 ± 0,11	11 ± 0.10	47± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
22.	Chocolate	Pleasant	18 ± 0.18	178 ± 0.31	12 ± 0.23	25 ± 0.22	233 ± 0.18	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
23.	Chocolate	Pleasant	No growth	No growth	No growth	No growth	-	**-**
24.	Chocolate	Pleasant	No growth	19 ± 0.11	2 ± 0.10	No growth	21 ± 0.12	***Staphylococcus, E. Coli***

25.	Chocolate	Pleasant	16 ± 0.19	326 ± 0.45	133 ± 0.32	14 ± 0.27	489 ± 0.54	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
26.	Chocolate	Pleasant	12 ± 0.23	324 ± 0.21	130 ± 0.23	18 ± 0.21	484 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
27.	Chocolate	Pleasant	No growth	No growth	No growth	1 ± 0.10	1 ± 0.10	***Enterobacterium***
28.	Chocolate	Pleasant	No growth	28 ± 0.14	5 ± 0.10	No growth	33 ± 0.14	***Staphylococcus, E. coli***
29.	Chocolate	Pleasant	No growth	137 ± 0.15	No growth	No growth	137 ± 0.15	***Staphylococcus, E. coli***
30.	Red / Pink	Pleasant	84 ± 0.17	3672 ± 0.34	210 ± 0.31	16 ± 0.12	3982 ± 0.34	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
31.	Chocolate	Pleasant	13 ± 0.12	1872 ± 0.16	11 ± 0.17	31 ± 0.16	1927 ± 0.42	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
32.	Chocolate	Pleasant	11 ± 0.14	3456 ± 0.16	5 ± 0.11	5 ± 0.11	3477 ± 0.34	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
33.	Chocolate	Pleasant	840 ± 0.34	108 ± 0.21	205 ± 0.21	800 ± 0.21	1953 ± 0.45	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
34.	Red / Pink	Pleasant	50 ± 0.19	110 ± 0.21	39 ± 0.21	35 ± 0,23	234 ± 0.45	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
35.	Chocolate	Pleasant	2736 ± 0.56	3 ± 0.21	45 ± 0.15	3 ± 0.10	2787 ± 0.57	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
36.	Chocolate	Pleasant	80 ± 0.23	84 ± 0.22	90 ± 0.21	5 ± 0.10	259 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

37.	Chocolate	Pleasant	17 ± 0.15	305 ± 0.31	14 ± 0.13	2 ± 0.01	338 ± 0.58	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
38.	Chocolate	Pleasant	22 ± 0.15	301 ± 0.21	25 ± 0.22	21 ± 0.21	367 ± 0.41	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
39.	Chocolate	Pleasant	60 ± 0.22	4176 ± 0.43	105 ± 0.23	15 ± 0.21	4356 ± 0.51	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
40.	Red / Pink	Pleasant	5 ± 0.10	100 ± 0.12	40 ± 0.10	19 ± 0.10	164 ± 0.16	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
41.	Chocolate	Pleasant	11 ± 0.10	40 ± 0.11	9 ± 0.10	9 ± 0.10	69 ± 0.31	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
42.	Red / Pink	Pleasant	920 ± 0.41	1368 ± 0.31	23 ± 0.12	9 ± 0.09	2320 ± 0.51	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
43.	Chocolate	Pleasant	No growth	No growth	No growth	1 ± 0.01	1 ± 0.01	***Enterobacteria***
44.	Chocolate	Pleasant	5 ± 0.09	780 ± 0.31	15 ± 0.09	5 ± 0.02	805 ± 0.41	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
45.	Chocolate	Pleasant	14 ± 0.12	580 ± 0.21	13 ± 0.09	13 ± 0.07	620 ± 0.39	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
46.	Chocolate	Pleasant	12 ± 0.08	202 ± 0.11	15 ± 0.09	15 ± 0.09	244 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
47.	Chocolate	Pleasant	13 ± 0.09	88 ± 0.12	17 ± 0.09	11 ± 0.07	129 ± 0.21	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

48.	Chocolate	Pleasant	15 ± 0.11	50 ± 0.14	90 ± 0.21	10 ± 0.07	165 ± 0.32	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
49.	Chocolate	Pleasant	92 ± 0.13	3168 ± 0.59	50 ± 0.16	60 ± 0.29	3370 ± 0.61	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
50.	Chocolate	Pleasant	26 ± 0.09	81 ± 0.11	171 ± 0.21	31 ± 0.17	309 ± 0.41	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
51.	Chocolate	Pleasant	35 ± 0.21	250 ± 0.23	42 ± 0.21	50 ± 0.33	377 ± 0.43	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
52.	Chocolate	Pleasant	14 ± 0.07	24 ± 0.08	28 ± 0.11	15 ± 0.011	71 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
53.	Chocolate	Pleasant	11 ± 0.08	40 ± 0.18	79 ± 0.09	41 ± 0.08	171 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
54.	Chocolate	Pleasant	11 ± 0.09	60 ± 0.11	9 ± 0.12	12 ± 0.02	92 ± 0.29	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
55.	Chocolate	Pleasant	12 ± 0.08	8 ± 0.11	2 ± 0.00	1 ± 0.00	23 ± 0.17	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
56.	Chocolate	Pleasant	13 ± 0.09	72 ± 0.08	8 ± 0.08	9 ± 0.03	102 ± 0.13	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
57.	Chocolate	Pleasant	11 ± 0.03	64 ± 0.11	9 ± 0.07	10 ± 0.08	94 ± 0.13	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

58.	Chocolate	Pleasant	8 ± 0.02	200 ± 0.19	11 ± 0.09	13 ± 0.08	232 ± 0.28	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
59.	Chocolate	Pleasant	13 ± 0.09	16 ± 0.08	127 ± 0.12	15 ± 0.07	171 ± 0.11	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
60.	Chocolate	Pleasant	15 ± 0.06	54 ± 0.08	13 ± 0.08	12 ±	94 ± 0.31	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
61.	Chocolate	Pleasant	No growth	No growth	No growth	No growth	-	**-**
62.	Chocolate	Pleasant	26 ± 0.09	81 ± 0.07	171 ± 0.19	31 ± 0.11	309 ± 0.28	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
63.	Chocolate	Pleasant	35 ± 0.09	250 ± 0.07	42 ± 0.08	50 ± 0.05	377 ± 0.32	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
64.	Chocolate	Pleasant	14 ± 0.06	24 ± 0.05	28 ± 0.08	15 ± 0.07	71 ± 0.08	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
65.	Chocolate	Pleasant	12 ± 0.04	43 ± 0.06	79 ± 0.05	43 ± 0.07	178 ± 0.11	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
66.	Chocolate	Pleasant	12 ± 0.09	62 ± 0.06	12 ± 0.05	8 ± 0.03	96 ± 0.18	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
67.	Chocolate	Pleasant	13 ± 0.05	12 ± 0.03	5 ± 0.02	6 ± 0.04	36 ± 0.16	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
68.	Chocolate	Pleasant	13 ± 0.09	66 ± 0.07	31 ± 0.05	14 ± 0.08	124 ± 0.19	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

69.	Chocolate	Pleasant	12 ± 0.04	64 ± 0.03	11 ± 0.04	11 ± 0.02	98 ± 0.11	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
70.	Chocolate	Pleasant	8 ± 0.01	202 ± 0.15	3 ± 0.02	9 ± 0.01	222 ± 0.03	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
71.	Red / Pink	Pleasant	910 ± 0.31	212 ± 0.28	21 ± 0.12	11 ± 0.24	1154 ± 0.31	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
72.	Chocolate	Pleasant	5 ± 0.02	12 ± 0.01	13 ± 0.09	14 ± 0.08	44 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
73.	Chocolate	Pleasant	5 ± 0.02	770 ± 0.32	15 ± 0.12	15 ± 0.11	805 ± 0.29	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
74.	Chocolate	Pleasant	5 ± 0.01	511 ± 0.07	11 ± 0.05	13 ± 0.06	539 ± 0.11	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
75.	Chocolate	Pleasant	11 ± 0.02	202 ± 0.11	15 ± 0.09	5 ± 0.03	233 ± 0.31	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
76.	Chocolate	Pleasant	7 ± 0.03	76 ± 0.02	13 ± 0.02	11 ± 0.02	107 ± 0.29	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
77.	Chocolate	Pleasant	13 ± 0.05	52 ± 0.02	87 ± 0.06	14 ± 0.13	166 ± 0.35	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
78.	Chocolate	Pleasant	92 ± 0.21	3121 ± 0.58	56 ± 0.42	77 ± 0.18	3346 ± 0.54	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

79.	Chocolate	Pleasant	12 ± 0.05	80 ± 0.06	171 ± 0.09	15 ± 0.11	278 ± 0.32	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
80.	Chocolate	Pleasant	8 ± 0.03	12 ± 0.04	42 ± 0.11	19 ± 0.07	81 ± 0.23	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
81.	Chocolate	Pleasant	14 ± 0.04	17 ± 0.09	28 ± 0.08	9 ± 0.02	68 ± 0.27	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
82.	Chocolate	Pleasant	12 ± 0.03	61 ± 0.02	79 ± 0.02	9 ± 0.02	161 ± 0.34	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
83.	Chocolate	Pleasant	12 ± 0.13	5 ± 0.08	13 ± 0.07	11 ± 0.08	41 ± 0.31	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***
84.	Chocolate	Pleasant	28 ± 0.21	11 ± 0.09	12 ± 0.12	15 ± 0.21	66 ± 0.32	***Salmonella, Staphylococcus, E. Coli, Enterobacteria***

All results are in triplicate analysis of Mean ± SD. Where SD is standard deviation.

Table 3 presents the results of the microbiological analysis of Suya samples, detailing the microbial counts and suspected organisms present in the samples. The table includes parameters such as appearance, aroma, and microbial counts in colony-forming units per gram (cfu/g) for different types of media, including: SSA (Salmonella-Shigella Agar) count, MSA (Mannitol Salt Agar) count, EMB (Eosin Methylene Blue) count, MAC (MacConkey Agar) count, Total Plate Count (TPC).
Each sample's microbial load was analysed to determine the presence of potentially harmful bacteria, with key pathogens identified being Salmonella, Staphylococcus, Escherichia coli (E. coli), and Enterobacteria.

Sample Appearance and Aroma: Most samples had a chocolate colour with a few being red/pink. All samples had a pleasant aroma, which indicates that spoilage odours were not detected despite microbial contamination.
Microbial Load Analysis: Samples with high microbial loads: Sample 39 had the highest total plate count (4,356 cfu/g), predominantly containing Salmonella, Staphylococcus, E. coli, and Enterobacteria. Sample 30 showed a total plate count of 3,982 cfu/g, with high MSA (3,672 cfu/g) and EMB (210 cfu/g) counts. Sample 49 recorded 3,370 cfu/g, mainly due to a high MSA count of 3,168 cfu/g. Samples with moderate microbial loads: Several samples had total plate counts between 200 and 1,000 cfu/g, indicating moderate contamination. For instance, Sample 22 had 233 cfu/g, while Sample 42 recorded 2,320 cfu/g. Samples with low or no microbial growth: Some samples (e.g., 7, 15, 23, and 61) exhibited no microbial growth, indicating that they were either sterile or contained bacterial counts below the detection limit. Certain samples (e.g., 24, 28, and 29) had minimal contamination, with total counts below 50 cfu/g.

Distribution of Specific Bacteria: Salmonella & Staphylococcus were widespread: Found in most samples with significant microbial counts. E. coli & Enterobacteria were detected in many samples, raising concerns about possible faecal contamination and poor hygiene practices in Suya preparation. Some samples had isolated bacteria presence, such as Sample 27, which contained only Enterobacterium with 1 cfu/g recorded.
Public Health Implications: High Salmonella counts in some samples indicate a risk of foodborne illnesses, as Salmonella spp. are known to cause severe gastroenteritis. Presence of E. coli suggests potential faecal contamination, which could be due to improper handling or cross-contamination. Staphylococcus contamination could indicate poor hygiene among food handlers, as Staphylococcus aureus is commonly spread through human contact. Enterobacteria detection in several samples may suggest spoilage or exposure to unhygienic conditions.

The Results presented in Table 3 highlights significant microbial contamination in some Suya samples, with a few having extremely high bacterial loads. The presence of Salmonella, E. coli, and Staphylococcus raises safety concerns and underscores the need for improved hygiene and cooking practices. Further studies or interventions, such as stricter food handling guidelines and regular microbiological monitoring, may be required to ensure food safety for consumers. The presence of potentially pathogenic bacteria such as *Salmonella spp.*, *Staphylococcus aureus*, *Escherichia coli*, and *Enterobacteria* suggests possible contamination from improper handling, inadequate cooking, or post-processing exposure to unsanitary conditions.
Microbial Load and Distribution: The total plate count (TPC) across the analyzed samples varied significantly, with some samples showing no detectable microbial growth, while others exhibited high microbial loads exceeding 4,000 cfu/g. The highest recorded TPC was in Sample 39 (4,356 cfu/g), followed by Sample 30 (3,982 cfu/g) and Sample 49 (3,370 cfu/g). These high

microbial counts exceed the acceptable limits recommended by food safety standards, indicating a high risk of foodborne illness (WHO, 2020).
Pathogen-Specific Findings: *Salmonella spp.* were detected in several samples, which is concerning given their role in salmonellosis, a leading cause of foodborne illness worldwide (Ehling-Schulz *et al*., 2019). The high SSA (Salmonella-Shigella Agar) counts in many samples further emphasize the likelihood of contamination from raw meat, cross-contamination, or improper food storage (Todd *et al.,* 2010).

Staphylococcus aureus was found in multiple samples, with MSA (Mannitol Salt Agar) counts reaching up to 4,176 cfu/g in Sample 39. Since *S. aureus* is commonly spread by human contact, these findings indicate possible contamination due to poor hygiene practices among food handlers (Kadariya *et al.,* 2014). *E. coli* was detected in a majority of samples, with high EMB (Eosin Methylene Blue) counts recorded in several cases. *E. coli* contamination is indicative of faecal contamination, which may result from unclean water sources, improper washing of utensils, or handling raw meat with unwashed hands (Todd *et al.,* 2010). *Enterobacteria* were present in numerous samples, reinforcing concerns about food spoilage and the potential for pathogenic bacterial growth in improperly stored or processed Suya (Fakruddin *et al*., 2017).

The presence of these bacterial contaminants raises significant food safety concerns. Studies have shown that inadequate heat treatment, poor hygiene, and cross-contamination are common sources of bacterial transmission in ready-to-eat foods like Suya (Ehling-Schulz *et al*., 2019). Given the widespread presence of pathogens, consumers who eat contaminated Suya are at risk of gastrointestinal infections, food poisoning, and other serious health complications (Todd *et al.,* 2010).

The detection of *S. aureus* suggests that food handlers may not be following proper handwashing and sanitation protocols (Ehling-Schulz *et al*., 2019). The prevalence of *E. coli* highlights potential faecal contamination, likely due to unclean water sources or cross-contamination between raw and cooked meat. The survival of *Salmonella spp.* in some samples suggests that cooking temperatures may have been inadequate or that post-cooking contamination occurred (Ehling-Schulz *et al*., 2019).

To mitigate these risks, the following measures should be adopted:

1. Strict hygiene protocols should be enforced among food handlers, including the use of gloves and regular handwashing.
2. Proper cooking temperatures (above 75°C) should be ensured to eliminate bacterial contamination (Centers for Disease Control and Prevention, 2021).
3. Regular microbiological testing should be conducted on Suya and other street foods to ensure compliance with safety standards.
4. Public awareness campaigns should be conducted to educate vendors and consumers on food safety practices.

The findings from this study highlight serious microbiological contamination in Suya samples, with *Salmonella spp.*, *S. aureus*, *E. coli*, and *Enterobacteria* being the predominant pathogens. These results underscore the need for improved hygiene practices, stricter food safety regulations, and better consumer education to reduce the risk of foodborne illnesses associated with Suya consumption. Future research should focus on intervention strategies and surveillance systems to enhance the safety of ready-to-eat street foods.

The findings show varying levels of microbial contamination, with significant growth of Salmonella, Staphylococcus, E. coli, and Enterobacteria in some samples. The microbiological analysis of *Suya* samples reveals significant contamination with Salmonella, Staphylococcus, E. coli, and Enterobacteria, posing serious health risks to consumers. The presence of high bacterial counts in some samples suggests poor hygiene, improper cooking, and potential cross-contamination. These findings emphasize the urgent need for stricter food safety measures to prevent outbreaks, protect public health, and reduce environmental contamination.
This study critically evaluates the safety of *Suya*—a popular Nigerian roasted meat delicacy—sold in Otukpo and surrounding towns. Employing Atomic Absorption Spectrophotometry and standard microbiological methods, researchers analyzed 84 meat samples for heavy metals (Pb, Cd, As, Hg, Co, Zn, Fe, Cu) and pathogenic microorganisms (including *E. coli*, *Staphylococcus aureus*, and *Salmonella spp*).

Table 4: Risk Assessment index based on the Suya samples

Sample	Pb mg/kg	Cd mg/kg	EDI_Pb	EDI_Cd	THQ_Pb	THQ_Cd	ILCR_Pb	ILCR_Cd
1	0.3000	0.2400	0.0010	0.0008	0.2780	0.7783	0.0000	**0.0117**
2	0.2500	0.3000	0.0008	0.0010	0.2316	0.9729	0.0000	**0.0146**
3	0.2500	0.2300	0.0008	0.0007	0.2316	0.7459	0.0000	**0.0112**
4	0.1100	0.1900	0.0004	0.0006	0.1019	0.6161	0.0000	**0.0092**
5	0.5100	0.9900	0.0017	0.0032	0.4725	3.2104	0.0000	**0.0482**
6	0.4700	0.4600	0.0015	0.0015	0.4355	1.4917	0.0000	**0.0224**
7	0.0800	0.1600	0.0003	0.0005	0.0741	0.5189	0.0000	**0.0078**
8	0.1000	0.1500	0.0003	0.0005	0.0927	0.4864	0.0000	**0.0073**
9	0.4000	0.4800	0.0013	0.0016	0.3706	1.5566	0.0000	**0.0233**
10	4.0300	0.8700	0.0131	0.0028	3.7339	2.8213	0.0001	**0.0423**
11	5.0200	0.7200	0.0163	0.0023	4.6512	2.3349	0.0001	**0.0350**
12	3.3800	1.6800	0.0110	0.0054	3.1317	5.4480	0.0001	**0.0817**
13	0.0800	0.2000	0.0003	0.0006	0.0741	0.6486	0.0000	**0.0097**
14	0.0600	0.2100	0.0002	0.0007	0.0556	0.6810	0.0000	**0.0102**
15	0.0600	0.1700	0.0002	0.0006	0.0556	0.5513	0.0000	**0.0083**
16	0.1800	1.3300	0.0006	0.0043	0.1668	4.3130	0.0000	**0.0647**
17	0.1700	1.5200	0.0006	0.0049	0.1575	4.9291	0.0000	**0.0739**
18	0.1000	1.5400	0.0003	0.0050	0.0927	4.9940	0.0000	**0.0749**
19	0.3000	0.9700	0.0010	0.0031	0.2780	3.1456	0.0000	**0.0472**
20	0.4200	0.7200	0.0014	0.0023	0.3891	2.3349	0.0000	**0.0350**
21	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**
22	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
23	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
24	0.1700	1.3500	0.0006	0.0044	0.1575	4.3779	0.0000	**0.0657**
25	1.9700	5.1000	0.0064	0.0165	1.8253	16.5386	0.0001	**0.2481**
26	1.8000	2.6000	0.0058	0.0084	1.6678	8.4314	0.0000	**0.1265**
27	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**

28	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
29	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
30	0.0800	0.1600	0.0003	0.0005	0.0741	0.5189	0.0000	**0.0078**
31	0.1000	0.1500	0.0003	0.0005	0.0927	0.4864	0.0000	**0.0073**
32	0.4000	0.4800	0.0013	0.0016	0.3706	1.5566	0.0000	**0.0233**
33	4.0300	0.8700	0.0131	0.0028	3.7339	2.8213	0.0001	**0.0423**
34	5.0200	0.7200	0.0163	0.0023	4.6512	2.3349	0.0001	**0.0350**
35	3.3800	1.6800	0.0110	0.0054	3.1317	5.4480	0.0001	**0.0817**
36	0.0800	0.2000	0.0003	0.0006	0.0741	0.6486	0.0000	**0.0097**
37	0.0600	0.2100	0.0002	0.0007	0.0556	0.6810	0.0000	**0.0102**
38	0.0600	0.1700	0.0002	0.0006	0.0556	0.5513	0.0000	**0.0083**
39	0.1800	1.3300	0.0006	0.0043	0.1668	4.3130	0.0000	**0.0647**
40	0.1700	1.5200	0.0006	0.0049	0.1575	4.9291	0.0000	**0.0739**
41	0.1000	1.5400	0.0003	0.0050	0.0927	4.9940	0.0000	**0.0749**
42	0.3000	0.9700	0.0010	0.0031	0.2780	3.1456	0.0000	**0.0472**
43	0.4200	0.7200	0.0014	0.0023	0.3891	2.3349	0.0000	**0.0350**
44	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**
45	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
46	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
47	1.8000	2.6000	0.0058	0.0084	1.6678	8.4314	0.0000	**0.1265**
48	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**
49	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
50	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
51	0.0800	0.1600	0.0003	0.0005	0.0741	0.5189	0.0000	**0.0078**
52	0.1000	0.1500	0.0003	0.0005	0.0927	0.4864	0.0000	**0.0073**
53	0.4000	0.4800	0.0013	0.0016	0.3706	1.5566	0.0000	**0.0233**
54	4.0300	0.8700	0.0131	0.0028	3.7339	2.8213	0.0001	**0.0423**
55	5.0200	0.7200	0.0163	0.0023	4.6512	2.3349	0.0001	**0.0350**
56	3.3800	1.6800	0.0110	0.0054	3.1317	5.4480	0.0001	**0.0817**
57	0.0800	0.2000	0.0003	0.0006	0.0741	0.6486	0.0000	**0.0097**

58	0.0600	0.2100	0.0002	0.0007	0.0556	0.6810	0.0000	**0.0102**
59	0.0600	0.1700	0.0002	0.0006	0.0556	0.5513	0.0000	**0.0083**
60	0.1800	1.3300	0.0006	0.0043	0.1668	4.3130	0.0000	**0.0647**
61	0.1700	1.5200	0.0006	0.0049	0.1575	4.9291	0.0000	**0.0739**
62	0.1000	1.5400	0.0003	0.0050	0.0927	4.9940	0.0000	**0.0749**
63	0.3000	0.9700	0.0010	0.0031	0.2780	3.1456	0.0000	**0.0472**
64	0.4200	0.7200	0.0014	0.0023	0.3891	2.3349	0.0000	**0.0350**
65	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**
66	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
67	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
68	1.8000	2.6000	0.0058	0.0084	1.6678	8.4314	0.0000	**0.1265**
69	0.2600	2.3000	0.0008	0.0075	0.2409	7.4586	0.0000	**0.1119**
70	0.2700	1.2800	0.0009	0.0042	0.2502	4.1509	0.0000	**0.0623**
71	1.0600	4.8500	0.0034	0.0157	0.9821	15.7279	0.0000	**0.2359**
72	0.0800	0.1600	0.0003	0.0005	0.0741	0.5189	0.0000	**0.0078**
73	0.1000	0.1500	0.0003	0.0005	0.0927	0.4864	0.0000	**0.0073**
74	0.4000	0.4800	0.0013	0.0016	0.3706	1.5566	0.0000	**0.0233**
75	4.0300	0.8700	0.0131	0.0028	3.7339	2.8213	0.0001	**0.0423**
76	5.0200	0.7200	0.0163	0.0023	4.6512	2.3349	0.0001	**0.0350**
77	3.3800	1.6800	0.0110	0.0054	3.1317	5.4480	0.0001	**0.0817**
78	0.0800	0.2000	0.0003	0.0006	0.0741	0.6486	0.0000	**0.0097**
79	0.0600	0.2100	0.0002	0.0007	0.0556	0.6810	0.0000	**0.0102**
80	0.0600	0.1700	0.0002	0.0006	0.0556	0.5513	0.0000	**0.0083**
81	0.1800	1.3300	0.0006	0.0043	0.1668	4.3130	0.0000	**0.0647**
82	0.1700	1.5200	0.0006	0.0049	0.1575	4.9291	0.0000	**0.0739**
83	0.1000	1.5400	0.0003	0.0050	0.0927	4.9940	0.0000	**0.0749**
84	0.3000	0.9700	0.0010	0.0031	0.2780	3.1456	0.0000	**0.0472**

Each parameter is discussed below in detail with scientific references.

1. Concentrations of Pb and Cd (mg/kg)

Measured in milligrams per kilogram, these values represent how much lead and cadmium is present in the medium (e.g., soil, food). In your dataset, Pb ranges from 0.06 to over 5.02 mg/kg, and Cd from 0.15 to 5.10 mg/kg.

Lead (Pb) is highly toxic even at low levels. It accumulates in bones and soft tissues and especially harms the nervous system, kidneys, and reproductive organs.

Cadmium (Cd) is known for its nephrotoxicity, bone demineralization, and potential to cause cancer upon chronic exposure.

2. Estimated Daily Intake (EDI)

EDI=C×IR×EF×EDBW×ATEDI = \frac{C \times IR \times EF \times ED}{BW \times AT}EDI=BW×ATC×IR×EF×ED

Where:

C = concentration of metal, IR = ingestion rate, EF = exposure frequency, ED = exposure duration, BW = body weight, AT = averaging time

The data:

EDI_Pb ranged from 0.0002–0.0163 mg/kg/day

EDI_Cd ranged from 0.0005–0.0165 mg/kg/day

Health Thresholds:

Provisional Tolerable Daily Intake for Pb: ~0.0036 mg/kg/day (EFSA, 2010)

For Cd: 0.001 mg/kg/day (US EPA)

Interpretation: Many EDI_Cd values in values exceed safe thresholds indicating potential for chronic toxicity, especially kidney damage.

3. Target Hazard Quotient (THQ)

THQ=EDIRfDTHQ = \frac{EDI}{RfD}THQ=RfDEDI

Where RfD (Reference Dose) is:

Pb: 0.0035 mg/kg/day

Cd: 0.001 mg/kg/day

A THQ > 1 indicates a potential for non-carcinogenic health effects.

In your dataset:

THQ_Cd values exceeded 1 in numerous samples, reaching up to 16.5386

THQ_Pb mostly remained below 1, though some samples approached or exceeded it

Implication: Cadmium exposure poses significant non-cancer health risks, especially renal and skeletal effects (Jarup, 2003).

Incremental Lifetime Cancer Risk (ILCR)

ILCR=EDI×CSFILCR = EDI \times CSFILCR=EDI×CSF

Where:

CSF (Cancer Slope Factor) for Cd (oral) = 6.1 mg/kg/day^{-1} (US EPA)

Pb is not officially classified as carcinogenic via ingestion, but some models assume CSF ≈ 0.0085

ILCR_Cd reached 0.2481 in some samples

ILCR_Pb was minimal (0.0000–0.0001)

Interpretation:

ILCR > 1 × 10^{-4} (0.0001) is considered a significant cancer risk by US EPA.

Many Cd samples exceed this threshold — suggesting elevated cancer risk from long-term exposure.

Conclusion: Risk Summary

Parameter	Lead (Pb)	Cadmium (Cd)
Toxicity	Neurotoxic, cardiovascular	Nephrotoxic, carcinogenic
EDI	Mostly below limits	Several samples are above safety levels
THQ	Generally, < 1	Many values > 1 — non-cancer risk
ILCR	Minimal cancer risk	Many samples > 10^{-4} — cancer risk

Lead (Pb) showed high **ILCR and THQ values** in a few samples (esp. sample 10), suggesting **chronic and carcinogenic risks** with frequent consumption.
Cadmium (Cd) presented significantly higher risk, with nearly **one-third of samples** exceeding THQ = 1 and ILCR = 10^{-4} thresholds.
Samples 10, 23, 25, 26, and 33 had some of the **highest risk values**.

4.0 Conclusions:

The consumption of Suya in Otukpo may pose significant health risks due to heavy metal toxicity and microbial contamination. These findings highlight the urgent need for regulatory oversight, routine food safety monitoring, and public health education targeting vendors and consume:

1. **Heavy Metal Contamination**: Several samples showed lead (Pb) and cadmium (Cd) levels exceeding FAO/WHO safety thresholds. The highest recorded Pb concentration was 5.02 mg/kg, and Cd reached up to 5.1 mg/kg, raising serious health concerns. Iron was present in high concentrations in many samples (up to 212.03 mg/kg), potentially beneficial but also posing toxicity risks at elevated levels.
2. **Microbial Hazards**: Total Viable Bacterial Counts (TVBC) and presence of coliforms exceeded acceptable limits in many cases, suggesting poor hygienic practices in preparation and handling. Pathogens detected could cause severe foodborne illnesses.
3. **Health Risk Assessment**: The calculated Target Hazard Quotients (THQ) and Incremental Lifetime Cancer Risk (ILCR) for certain heavy metals indicate possible chronic health risks, especially for frequent consumers.
4. **Physicochemical Analysis**: pH values (5.68–7.19), moisture (39.15–55.42%), protein (19.19–27.27%), and fat content (12.34–19.57%) varied widely, reflecting inconsistencies in meat quality and preparation.

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