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Risk Assessment of Heavy Metals and Microbial Quality of Beef at Slaughter Houses and Butchers' Shops in Benue South

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Abstract
Meat samples were collected from ten shops at Otukpo main and Tiv market. The objective of the study is to assess heavy metals (HM) concentration, the hygienic practices and microbial quality of meat at slaughterhouses and butchers' shops in Benue South. The HMs' concentration was determined using AAS while the safety of meat products was determined by counting Total Viable Bacterial, Total Coliform, Enterobacter, and Staphylococcus spp. From the result of this study, the mean total aerobic mesophilic bacteria range between 2.16-5.43 log10 cfu/g. The cultural characteristics reveal a preponderance of Escherichia coli, E. faecalis, Klebsiella pneumonia, Salmonella enterica and Staphylococcus aureus in most of the study locations. Total coliform count on meat samples from this study in some locations exceeds the recommended set standard of coliform bacteria counts (< 3.0 log cfu/g) according to (FAO, 2007). The concentration of Cd range 0.0010-0.100ppm. Most of the concentrations are below the (FAO) permissible limit of 0.005ppm. Similarly, the concentration of Cr range between < LOD and 0.270 ppm. The concentration of Mn is between <LOD and- 0.070 ppm. The results are below the FAO of 5.00ppm. The concentration of Ni is between 0.00ppm and 0.030ppm while that of Pb is between 0.0309 - 0.185 ppm. The study reveals high microbial load in the meat samples which pose considerable risks to the consuming public.

Key Words: *Meat, slaughter/butcher house, microbial analysis, heavy metals, permissible limit.*

Introduction

Microbiological quality of meat and meat products is of great public health significance since the consumption of contaminated meat has been reported as one of the major causes of food-related diseases. The quality of livestock products in Nigeria especially red meat is substandard. This is due to poor handling, transportation, production practice in slaughterhouses and unhygienic butcher house facilities, and inadequate hygiene of workers. Poor quality meat results in defects in processing properties, functional and eating qualities and is less likely to be accepted by consumers. Besides, the major factor for the emergence of food borne illness is eating habits of the community, poor handling, unsanitary slaughterhouse facilities, unsafe food storage conditions, and transportation [1]

Heavy metals in meat and eggs may result from industrial activities and agricultural practices, including using contaminated fertilizers or pesticides to produce feed ingredients [2]. Non-biodegradable heavy metals possess extended biological half-lives and have the potential to accumulate in various human body tissues due to the limited mechanisms to eliminate these toxic substances [3].

To understand the safety of meat consumed by the public, there is a need for its risk assessment. Risk assessment is the scientific process that systematically evaluates food safety hazards that pose deleterious effects to health. The risk assessment models can adopt quantitative, semi-quantitative or qualitative approaches [4]. The process entails four different steps namely hazard identification (the first step in risk assessment and entails qualitative elucidation of a hazard that is of public health importance; hazard characterization (details the adverse effects resulting from exposure to a specific hazard, and entails establishing the dose-response relationship if the data is available [5]; exposure assessment (the qualitative and/or quantitative estimation of the probability of the consumption and amounts of hazard ingested from intake of a given quantity of food [6]; and risk characterization (the three steps are integrated to generate a risk estimate [7].

Because of continuous consumer demand for meat products, especially the consumption of raw meat as part of the culture, it is necessary to ensure good quality, safe meat products through regular assessments of hygienic production practices, the microbial quality of meat products, and adequate waste management systems.

Literature indicates that Pb enters the body through inhalation or ingestion, disrupting multiple organs, while Co enters the food chain via fertilizers, reaching animals and affecting lung, heart, and thyroid function [8]. Ni interferes with respiratory, circulatory, and neurological systems. Cr VI is a known carcinogen that has a severe impact on human health. It is mainly food-borne, water borne, or workplace-borne. Cr VI is known to be a potent carcinogen to humans, and the IARC categorizes it in group 1[9]. The main cancer risk associated with Cr VI is lung cancer, which is mostly due to inhalation. Consumption of Cr VI through meat or water also has the potential to cause gastrointestinal cancers, particularly stomach cancer. The cumulative effects of Cr in food or water are known to induce DNA damage, oxidative stress, and carcinogenicity, which constitute a major health risk in contaminated environments [10].

The current research study assessed the hygiene status and microbial quality of meat at slaughterhouses and butchers' shops in Benue South senatorial district.

Materials and Methods

Study Area

Benue State has a landmass of 34,059 square kilometres and a population of about 4,253,641 as from the 2006 census (Federal Republic of Nigeria [Frong], 2009). The State lies within longitude 7° 47` and 10° 0` East and Latitude 6° 25` and 8° 8` North.; and shares boundaries with five other states namely: Cross-River to the south, Enugu to the south-west, Kogi to the west and Nassarawa to the north with Taraba to the east, The State also shares a common boundary with the Republic of Cameroun on the south-east. The study locations for this work include: Ogbadibo-Otukpa, Oju-Oju, Otukpo-Otukpo.

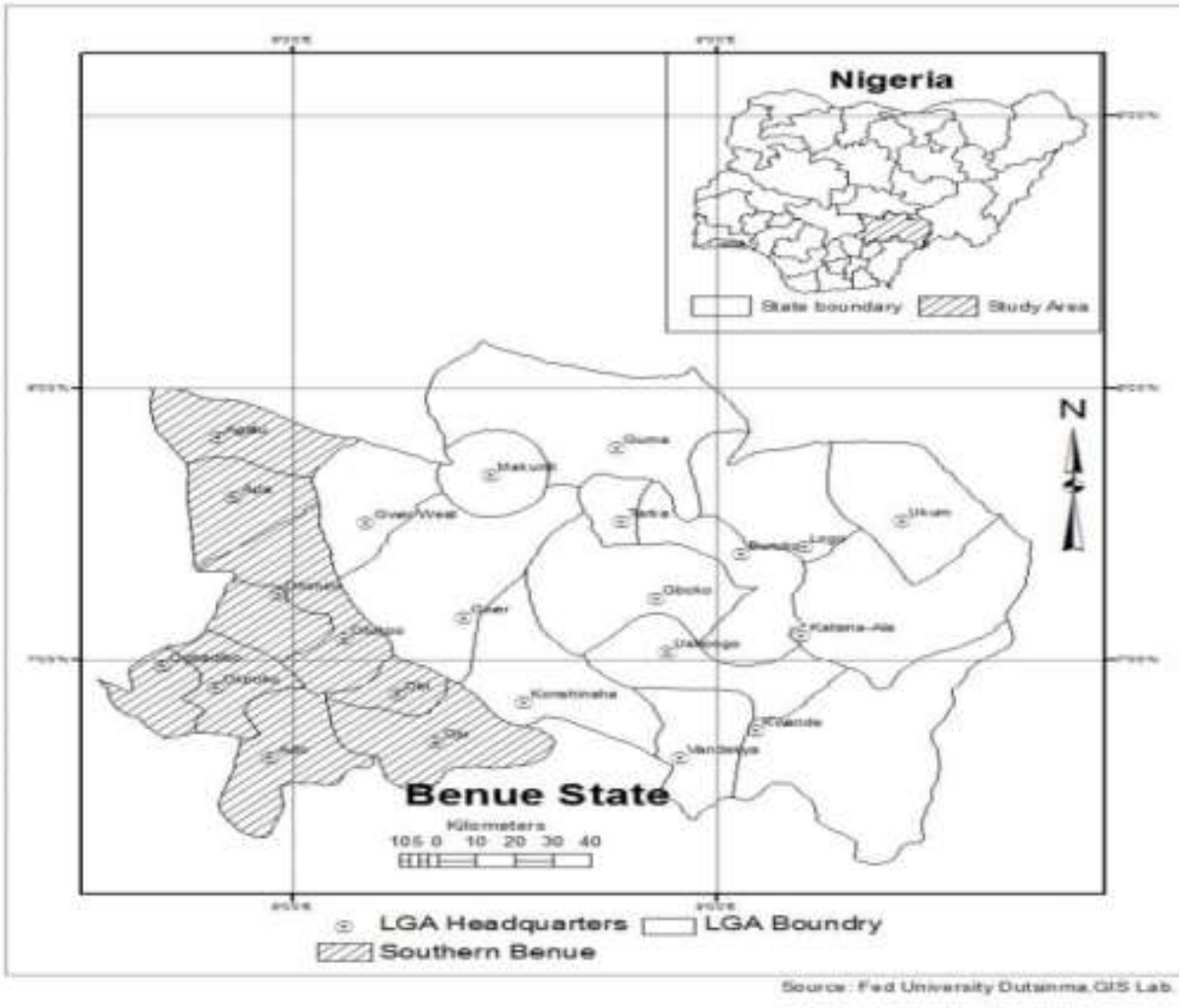

Fig 1: Map of Benue State Showing the Study Location

Sample Size Determination

Sample size was derived using the formula [11] for estimating a single population proportion, where the target population was retail beef sold in selected outlets and abattoirs across, Oju, Okpokwu and Otukpo LGAs.

$$n = \frac{z^2 p(1-p)}{d^2}$$

where

- n = sample size
- Z = Critical value and a standard value for the desired confidence level of the prevalence estimate; 1.96
- P = the estimated prevalence (0.50 or 50%)
- d = sampling error that can be tolerated (0.05 or 5%)

Sample Collection

A total of thirty 100g fresh beef samples were collected randomly in September, 2025, 1 each from 10 different registered retail meat outlets/abattoirs in Oju, Okpokwu and Otukpo LGA. Meat samples were collected in sterile polythene bags, packed in a container embedded with ice packs and transported to the laboratory. The samples were processed within 24 hours of arrival in the laboratory.

Sample Preparation

Total, 10 grams of meat sample were taken and homogenized into 90mL of sterile normal saline using a meat grinder under sterile conditions. Ten-fold dilutions of the homogenates up to 10-5 in normal saline were made using sterile pipettes.

Total Mesophilic Aerobic Counts: Total mesophilic aerobic counts was assessed in accordance with the method described by [12]. After incubation at 37°C for 24h, plates containing 30 and above colonies were enumerated. The mean number of colonies was multiplied by the inverse of the dilution, and the bacterial counts obtained. Results are reported as colony-forming units per gram of samples (cfu/g).

Isolation and Identification of Bacteria: To obtain pure bacterial isolates, a distinct colony from mixed culture were picked using a sterile wire loop and placed on a fresh nutrient agar medium. After streaking, the petri dishes were incubated at 37°C for 24 hours. All isolates from this pure culture were maintained in an agar slant for further analyses. All bacterial isolates were identified according to their physical (colonial) characteristics (shape, colour, odour, pigmentation) and biochemical tests such as Gram's staining, Coagulase, Catalase, Indole, Urea, Citrate, Bacterial Spore stain, Motility test, Voges Proskauer test, Methyl red test and Oxidase test. Additional selective/differential plating was employed to further identify the isolates [13].
Presumptive Staphylococcus aureus isolates were inoculated on mannitol salt agar and incubated at 37°C for 48 hours. Colonies characterized by yellowish pigmentation are considered as *S. aureus*. Presumptive *Pseudomonas aeruginosa* isolates would be inoculated on cetrimide selective agar at 37°C for 24 hours. Colonies characterized by bluegreen and yellow-green shall be considered as *P. aeruginosa*. Presumptive *E. coli* and *Salmonella spp.* colonies based on biochemical reactions were further inoculated on Eosin methylene blue (EMB) and incubated at 37°C for 24 hours. Colonies characterized by metallic green sheen are considered as *E. coli* whereas grey colonies are regarded as *Salmonella spp*. In addition, bacterial isolates were further confirmed using a combination of Analytical Properties Index API 20E, API STAPH test system and API 50CHB (BioMerieux, Marcy l'Etoile, France).

Preparation and Analysis

Using the wet digestion method, the collected samples were decomposed for the determination of heavy metals. Samples were cut into very small fragments using a stainless-steel dissection instrument. A weighed 1 g of representative meat from each sample was washed with distilled water and transferred into 50 mL beakers. Measured 15 mL of aqua regia (1 part of HNO3 (65%) to 3 parts of HCl (35%) was added to each sample. Afterwards, samples were heated in a water bath at 100ºC until brown fumes were given off. After cooling, H2 O2 (30%) was added dropwise into each beaker to obtain a clear solution. Then, the content of the beaker was filtered into a 100 mL volumetric flask and made up to the mark with distilled water. Using a modified analytical

procedure based on (27), processed samples were analyzed for Cr, Pb, Ni, Mn and Cd, using a Perkin Elmer Analyst 700 Atomic Absorption Spectrophotometer-Gemini BV.

Result and Discussion

Result

Table 1: Total viable bacterial count of the meat samples

	OGBADIBO		OJU		OTUKPO	
Shop Code	**Log_{10}cfu/g on Nutrient Agar**	**Log_{10}cfu/g on MacConkey Agar**	**Log_{10}cfu/g on Nutrient Agar**	**Log_{10}cfu/g on MacConkey Agar**	**Log_{10}cfu/g on Nutrient Agar**	**Log_{10}cfu/g on MacConkey Agar**
A	2.80	2.10	6.24	5.34	1.53	1.42
B	2.80	2.41	5.26	4.92	4.35	4.33
C	2.61	2.15	2.36	2.33 ±0	1.44	1.34
D	2.52	2.41	5.32	4.62	1.82	1.25
E	2.81	2.51	4.33	4.21	5.32	4.32
F	3.41	2.81	6.03	5.61	4.46	4.33
G	2.21	1.8.2	7.23	7.11 4	5.43	4.87
H	5.43	3.71	3.52	3.34	4.82	4.02
I	2.11	1.86	6.22	5.96	3.21	4.01
J	5.63	4.22	4.82	5.43	5.33	4.45

Table 2: Biochemical characteristics of bacteria isolated from meat samples from the study area

Isolate	Cell	Cell	Gra	Cata	Oxid	Coag	Urea	Citra	Indol	Hem	Gluc	Lact	Sucr	Arab.	Malt	TSI	H_2S	Meth	Gas	Most probable bacteria
01	+	R	-	+	-	-	-	-	+	-	+	+		+	+	Y	-	+	+	*Escherichia coli*
02	-	C	+	-	-		-	-	-	-	+	+		-	+		-			*Enterococcus faecalis*
03	-	R	-	+	-		+	+	-		+	+	+	+	+	Y	-	-	+	*Klebsiella pneumoniae*
04	+	R	-	+	-		-	-	-		+	-	-	-	+	B	+			*Salmonella enterica*
05	-	C	+	+	-	+	+	-	-	+	+	+	+	-	+		-	+	-	*Staphylococcus aureus*

Table 3: Cultural characteristics of bacteria isolated from meats in Ogbadibo markets on selected and differential media

Shop Code	Manitol Salt Agar	Salmonella Shigella Agar	Simon citrate Agar	MacConkey Agar	Isolates Code implicated
A	Yellow and red colony	Pink and pale colonies	No	Pink and pale colonies	01 and 05
B	Yellow colonies	Pink, cream and black colonies	Tiny yellow colonies	Pink and mucoid colonies	01, 03, 04 and 05
C	Yellow colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	04 and 05
D	Red colonies	Black colonies	Muccoid colonies change green to pink	Large pink mucoid colonies	01, 03, and 05
E	Yellow colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	04 and 05
F	Yellow colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	04 and 05
G	Yellow colonies	Black colonies	Growth changed green to blue background	Pink and pale colonies	02, 04 and 05
H	Yellow colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	04 and 05
I	Red colonies	Black colonies	Yellow and pink colonies	Pink and pale	01, 03, 04 and 05

Table 4: Cultural characteristics of bacteria isolated from meats in Oju markets on selected and differential media

Shop Code	Manitol Salt Agar	Salmonella Shigella Agar	Simon citrate Agar	MacConkey Agar	Isolates Code implicated
A	No growth	Black colonies	Mucoid colonies turned green blue	Pink and pale colonies	01, 03 and 04
B	Yellow colonies	Pink, cream and black colonies	Mucoid colonies turned yellow to green	Pink and mucoid colonies	01, 02, 03, 04 and 05
C	Tiny cream colonies	Black and cream colonies	No growth	Pink colonies	01, 04 and 05
D	Tiny cream and red colonies	Black colonies	No growth	Large pink mucoid colonies	04 and 05
E	Cream colonies	Black and cream colonies	No growth	Pink colonies	01 and 05
F	Cream and red colonies	Pink and black colonies	No growth	Pink colonies	01 and 05
G	cream colonies	Pink and black colonies	No growth	Pink and pale colonies	01, 04 and 05
H	Cream colonies	Black and pink colonies	No growth	Pink colonies	01, 04 and 05
I	Pink and cream colonies	Pink and black colonies	Mucoid colonies turned green to blue	Pink and pale	01, 03, 04 and 05

Table 5: Cultural characteristics of bacteria isolated from meats in Otukpo markets on selected and differential media

Shop Code	Manitol Salt Agar	Salmonella Shigella Agar	Simon citrate Agar	MacConkey Agar	Isolates Code implicated
A	Yellow and red colony	Pink and pale colonies	No growth	Pink and pale colonies	01 and 05
B	Red colonies	Black colonies	No growth	Pink and mucoid colonies	03 and 05
C	Yellow colonies	Black and cream colonies	Muccoid and slightly raised colonies	Pink colonies	01 and 03
D	Yellow colonies	Black colonies	Muccoid colonies change green to blue	Large pink mucoid colonies	02, 03, 04 and 05
E	Yellow and red colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	01, 04 and 05
F	Yellow colonies	Black and cream colonies	Growth turn green to blue background	Pink colonies	01, 03, 04 and 05
G	Yellow and red colonies	Black colonies	Muccoid growth turn green to blue background	Pink and pale colonies	03, 04 and 05
H	Yellow and tiny pink colonies	Black and cream colonies	Growth turn green to blue background	Pink colonies	01, 02, 03, 04 and 05
I	Red colonies	Black colonies	Yellow and pink colonies	Pink and pale	01, 03 and 05
J	Yellow colonies	Black and cream colonies	Growth changed green to blue background	Pink colonies	01,02 and 05

Table 6: Result of Heavy Metal Analysis

Sample code	OJU					OKPOKWU					OTUKPO				
	Concentration (ppm)					Concentration (ppm)					Concentration (ppm)				
	Cd	Cr	Mn	Ni	Pb	Cd	Cr	Mn	Ni	Pb	Cd	Cr	Mn	Ni	Pb
A	0.0018	0.004	0.010	0.100	0.0370	0.0018	0.008	0.070	0.100	0.0679	0.0055	0.004	0.010	0.100	0.0309
B	0.0037	0.009	0.020	0.100	0.0617	0.0055	0.018	0.020	0.100	0.0309	0.0073	0.006	0.070	0.100	0.1240
C	0.0037	0.005	0.030	0.000	0.0494	0.0018	0.006	0.050	0.000	0.0988	0.1100	0.003	0.260	0.000	0.1850
D	0.0018	0.002	0.030	0.100	0.0309	0.0037	0.002	0.020	0.200	0.0247	0.0037	0.006	0.020	0.100	0.0247
E	0.0073	0.004	0.040	0.100	0.0494	0.0055	0.005	0.020	0.200	0.1240	0	0	0.010	0.200	0.0247
F	0.0018	0.003	0.030	0.200	0.1240	0.0073	0.002	0.030	0.100	0.1850	0.0055	0.008	0	0.100	0.1240
G	0.0038	0.007	0.030	0.000	0.1850	0.0037	0.010	0.030	0.100	0.0741	0.0073	0.004	0.070	0.300	0.0309
H	0.0019	0.006	0.060	0.100	0.0309	0.0037	0.004	0.040	0.100	0.0370	0.0037	0.004	0.270	0.100	0.0620
I	0.0165	0.006	0.070	0.200	0.0370	0.0018	0.004	0.050	0.000	0.0247	0.0055	0.005	0.030	0.200	0.1850
J	0.0020	0.024	0.040	0.100	0.0556	0.0055	0.008	0.040	0.100	0.0556	0.0010	0.001	0.030	0.100	0.0247

Discussion

Table 1 reveals the total viable bacterial count of the meat samples in the study locations. Biochemical characteristics of bacteria isolated from the meat samples are presented in Table 2.

The mean of total aerobic mesophilic bacteria in Okpokwu, Oju and Otukpo were respectively 3.23, 5.16, 2.64 log10 cfu/g. This may indicate similarity of sanitary and hygienic practices between the three locations. The study showed, there were highly significant differences ($P<0.005$ across the locations). The mean count of total aerobic mesophilic bacteria at Otukpo (G) was the highest- 5.43cfu/g. High level of total aerobic bacteria might indicate, the possibility of oxygen demanding microorganism on raw beef.

Table 3 reveals the cultural characteristics of bacteria isolated from meat samples in Ogbadibo markets on selected and differential media. *Escherichia coli* was implicated in sample location A, B, D, I while *Escherichia coli* was found only in sample G. *Klebsiella pneumonia* was seen in sample B, D, I while *Salmonella enterica* was found in samples B, C, E, F, G, H, I, J. *Staphylococcus aureus* was found in all the sample locations.

Among the most concerning pathogens in cow meat is *S. aureus*. *S. aureus* and other staphylococci are associated with cross-contamination of beef, with the primary reservoir being the bovine nasopharyngeal tract. Therefore, most contamination events are attributed to the slaughter and carcass-cutting processes [14]. Several studies have reported the presence of *S. aureus* in a wide range of beef samples, with prevalence rates ranging from 6% to 100% [15]. A particularly alarming aspect of this pathogen is its resistance to methicillin, which gives rise to methicillin-resistant *S. aureus* (MRSA). These strains pose a major challenge to both human and animal health due to the severity of the infections they can cause, as they produce toxins and enterotoxins capable of inducing food poisoning, as well as urinary, respiratory, and bloodstream infections [16].

Table 4 also shows the cultural characteristics of bacteria isolated from meat in Oju markets on selected and differential media. E. coli was found in all the samples except D while *E. faecalis* was seen in only sample B. *Klebsiella pneumonia* is reported in samples A, B, and I. *Salmonella enterica* and *Staphylococcus aureus* were found in all the samples except E, F; and A respectively.

Table 5 shows the cultural characteristics of bacteria isolated from meat samples in Otukpo markets on selected and differential media. Using the identity codes, it can be seen that *E. coli* was found in all the samples except B, D, G. On the other hand, *E. faecalis* was seen only in samples D,H, J while *Klebsiella pneumonia* was absent only in A, E, I. *Salmonella enterica* were in D, E, F, G, H. while *Staphylococcus aureus* was absent only in sample C.

Total coliform count on meat samples from this study in some locations exceeds the recommended set standard of coliform bacteria counts (< 3.0 log cfu/g) according to FAO [17].

Escherichia coli was isolated in the meat samples which implies that the meat were probably not well washed in water free from Escherichia coli and may have come in contact with faucal matter.

Staphylococcus count was detected in the meat samples and this agrees with studies by other researchers that found a high prevalence of *Staphylococcus aureus* in raw meat and abattoir [18].

Klebsiella pneumonia is a leading cause of multi-drug resistant human infections. It is regarded as a critical priority pathogen [19] given the depletion of therapeutic options to treat multi drug resistance *K. pneumoniae* infections. Its presence in a good number of the meat samples calls for caution.

Salmonella enterica is an important source of food borne disease, resulting in morbidity and mortality worldwide [20]. In China, 70-80% of bacterial food poisoning cases are due to Salmonella that originates in poultry, eggs, beef and pork [21]. Direct and indirect spread of

Salmonella between animals and humans are threats to human health. The preponderance of this bacterium in meat samples may be responsible for the surge in cases of food poising in recent times.

Table 6 presents result of the heavy metal analysis in the various samples on the various meat samples. The concentration of Cd range 0.0010(Otukpo sample code J)-0.100ppm (Otukpo sample code C). The concentrations of Cd are above the (FAO) permissible limit of 0.005ppm at most locations.

Similarly, the concentration of Cr is at a minimum of 0.01-Otukpo 'J' while the maximum of 0.009ppm was recorded at Oju-'B'. The concentration of chromium at Otukpo-'E' is < LOD. The FAO permissible limit of Cr is 0.05 showing that results in this study are still within the safety threshold.

In the same vein, the concentration of Mn is at a minimum of 0.010 Oju- 'A' while the maximum concentration of 0.270 ppm at Otukpo-'H'. The concentration of Mn at Otukpo 'F' is <LOD. The results are below the FAO of 5.00ppm.

The concentration of Ni is at a minimum of 0.00ppm at Oju 'C', G' while the maximum concentration of 0.030ppm is at Otukpo 'G'. The concentration of Ni are mostly below the FAO MRL of 0.20ppm except at Otukpo 'G' where it is 0.030ppm.

The minimum Pb concentration of lead; 0.0309 was reported at Otukpo 'A' 'G', Okpokwu 'B', Oju 'D' while the maximum concentration was 0.185 ppm at Otukpo 'C', 'I' Okpokwu 'F',
Oju 'G'. A few locations have concentration values above 0.10ppm, the FAO MRL for Pb in meat. This calls for caution and continuous monitoring.

The importance of determining the amounts of heavy metals in meat and meat product has been pointed out in several studies as a result of the growing concern on the rise of environmental pollution. The various literature in this regard reveals that the heavy metals enter into the human body through inhalation or ingestion (Tripathi et al in Mumbai India) [22]. It is noted that the meat becoming a part of diet day by day hence it become necessary to make proper study in this field too. The study conducted in Turkey and in China, which reveals, the presence of cadmium in fish (0.8367 meg/100g) in meat (0.8167 meg/100g) chromium in fish (8.61meg/100g) in meat (8.94meg/100g) and in china it reveals that the dietary intake of heavy metals in adult per day meat accounted 6.05% lead 4.93 meg/day cadmium (o.319meg/day).

Salmonella enterica is a leading cause of enteric diseases in human and animal with millions of illness worldwide, whereas the non-typhoidal *Salmonella* species as a zoonotic agent are also predominantly associated with foodborne infections[23]. *Salmonella* species in foods of animal origin are most frequently considered to be associated with the foodborne pathogen outbreaks. Improper cooking, inadequate storage, cross-contamination and use of raw ingredients in the preparation of food are the most common factors contributing to outbreaks [23].

In the majority of foodborne infections, it is not possible to identify the food vehicle. Poultry meat is considered as the most commonly reported foodborne pathogens vehicle followed by the red meat [24]. *S. aureus* is responsible for causing a variety of animal diseases such as mastitis, arthritis and urinary tract infections and a prominent cause of food poisoning due to poor hygienic practices. *S. aureus* related food poisoning is the third largest cause of food related illness worldwide [25].

Pathogenic bacteria like *Salmonella* and *S. aureus* from food sources have been confirmed by different authors all over the world. Ellerbroek *et al.* reported 13% prevalence of *Salmonella* isolates from imported chicken carcass in Bhutan [26]. While Minami *et al.* reported 25% prevalence in different types of meat including chicken in Thailand [27]. Their

study shows that *Salmonella* is more prevalent in the case of chicken or poultry meat. Fernández *et al.* in their study in 1993 and 2006 recorded 22.7% prevalence of *Salmonella* in poultry meat samples in Spain. Zhao *et al.* reported 4.2% prevalence of *Salmonella* contamination in chicken meat in a similar study in USA [28]. That is in agreement with our findings.

S. aureus has a wide range of habitats including human body parts, which may contaminate the food. It is considered being one of the most important foodborne illnesses causing pathogenic species. It's present in food indicates poor hygiene and improper storage conditions[29]. De Boer *et al.* reported 11.9% MRSA prevalence in meat whereas 16% in chicken meat alone [30]. Gundogan *et al.* reported 53% of *S. aureus* contamination of meat and chicken samples [29]. Atanassova *et al.* found 51.1% *S. aureus* contamination in raw pork meat by PCR detection while he claimed 57.7% *S. aureus* contamination by using classical microbiological procedures [31]. Heo *et al.* reported 11% *S. aureus* prevalence in meat, while Lee reported 13% *S. aureus* presence in poultry meat of Korea [32]. These results are in agreement with result emanating from this current study.

Health Risk Assessment

Risk Assessment

To calculate the estimated daily intake (EDI), total hazard quotient (THQ), chronic daily intake (CDI), and incremental lifetime cancer risk (ILCR), Eqs 1 to 4 were used as shown.

$$EDI = \frac{CXIR}{BW} = \quad (1)$$

$$THQ = \frac{CDI}{RfD} \quad (2)$$

$$CDI \ \frac{EDI \ x \ EFg \ x \ EDtot}{AT} \quad (3)$$

$$ILCR = CDI \ x \ CSF \quad (4)$$

Where C stands for concentration of HMs, IR for ingestion rate at 120 g and 60 g for adults and children per day, respectively, and BW for body weight at 60.7 and 20.5 kg for adults and children, respectively, compared to the WHO recommendations. The hazard index and target hazard quotient (THQ), CDI, EDI, reference dose (RfD) for each hazard, and the cancer slope factors (CSF) were used according to [33]. The recommended ingestion rate and body weight by the WHO provide significant changes in muscle mass with age, particularly in older persons, which could be detected in short-term balance studies. The results showed THQ valued >1 in Pb which clearly showed the risk of lead poisoning while consuming this meat. The elevated levels of lead can be attributed to the feeds the animals are exposed to and the method of preparation. In addition, a systematic review on the methods, pollution levels, and policy implications of heavy metal contamination in soils, water, and food in Nigeria from 2000 to 2019 revealed that concentrations of heavy metals in food crops, meat, and milk consistently surpassed the WHO/FAO safety thresholds across all urban areas studied. The findings underscore the widespread contamination of key food sources, including plant-based crops, livestock (meat), and dairy products, posing significant risks to public health [34] However, according to another study [35] the general limitations of EDI, CDI, THQ, and ILCR are that risk is assumed to be from a specific source rather than being estimated from aggregate exposures. The use of THQ and ILCR does not indicate specific effects on target organs; hence, it may not correspond to real-life exposure scenarios. Therefore, for comparative purposes, further studies can adopt emerging proposals for calculating aggregate exposures, as the consensus among regulatory toxicologists regarding dietary estimations has not yet been established.

Statistical analysis

Data was analyzed using Statistical Analysis Software (SAS Inc., Cary, USA, version 9) and ANOVA was applied to compare the means of study sites Post Hoc test on the concentration of heavy metals except with lead where the Post Hoc test revealed that there were significant differences between the concentrations at OJU F, G, OKPOKWU E, F and OTUKPO C, F, I and other measured concentrations of lead. The analysis of the microbial counts showed, that at $P<0.005$ there were no significant differences in the total mesophilic aerobic counts.

Conclusion and Recommendation

Based on the present results, microbial load of meat in the study locations is high which can be traced to poor conditions in the slaughter houses, transportation and butcher shops. Hence, consuming raw meat has a health risk for consumers. Selling raw meat in open places and unhygienic environment, lack of cold storage transportation, lack of awareness on food safety and poor sanitation level of slaughtering houses can be major risk factors for elevated contamination level of meat for bacteria. To minimize the risk of foodborne bacterial infections, it is essential to promote awareness of proper sanitation and handling practices, ensure regular monitoring of safety standards, and enforce food safety regulations. These measures are vital for safeguarding public health and promoting the safe production of meat.

Conclusion and Recommendation

The findings of this study show that the microbial load of meat in the surveyed locations is significantly high. This contamination can be attributed to poor hygiene conditions in slaughterhouses, unsafe transportation methods, and unhygienic practices in butcher shops. As a result, the consumption of raw or improperly handled meat poses substantial health risks to consumers.

Selling raw meat in open and unsanitary environments, the absence of cold-chain transportation, limited awareness of food safety, and inadequate sanitation in slaughtering facilities all contribute to the elevated bacterial contamination observed.

To reduce the risk of foodborne bacterial infections, it is crucial to promote proper sanitation and safe meat-handling practices among all stakeholders. Regular monitoring and enforcement of food safety standards should be strengthened, alongside awareness campaigns to educate meat handlers and consumers. Implementing these measures is essential for safeguarding public health and ensuring the safe production, distribution, and consumption of meat.

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Conflict of Interest

The authors declare that there is no conflict of interest in the course of executing this project**.**