

# Bacteriological Qualities of Beef Sold in Abia and Imo States, Nigeria: Implications for the Sustenance of Enteric Diseases

Okechukwu K. Iro<sup>1</sup>, Agwu N. Amadi<sup>2</sup>, Ugo U. Enebeli<sup>3</sup>, Chinasa O. Amadi<sup>4</sup>

<sup>1</sup>Department of Environmental Health Sciences, College of Medicine, Abia State University, Uturu Nigeria

<sup>2, 3, 4</sup>Department of Public Health Technology, School of Public Health, Federal University of Technology, Owerri, Nigeria

**Abstract:** In Nigeria, meat-borne diseases are important contributors to the heavy burden of morbidity and mortality caused by diarrheal diseases. The aim of this research was to assess the bacteriological quality of beef and beef contact surfaces in Abia and Imo States of Nigeria in relation to their implications for sustaining enteric diseases. Two study areas from each State were selected by random sampling: Afor-Ogbe and Owerri in Imo State and Aba and Umuahia in Abia State. Bacteriological quality of the beef and beef contact surfaces was assessed by collecting and analyzing samples at 8 critical sampling locations (CSLs) created at the perceived critical control points. Mean total viable count (TVC) at the study areas were: Afor-Ogbe,  $1.81 \times 10^5$ ; Umuahia,  $1.79 \times 10^5$ ; Aba,  $1.75 \times 10^5$ ; and Owerri,  $1.73 \times 10^5$ ;  $p = 0.00$ . Mean TVC strongly correlated with mean total coliform count (TCC) at the critical sampling locations in the study areas. The mean prevalence of pathogens in the study areas were: Afor-Ogbe, 65.50%; Aba, 54.20%; Owerri, 52.30%; and Umuahia, 48.80%. It is concluded here that the bacteriological quality of the beef sold in the two States is very poor, and this exposes the beef consumers to high risk of enteric diseases. It is recommended here that the government of Nigeria at all levels should urgently enact and enforce laws on meat safety management based on good hygiene principles of Codex Alimentarius Commission.

**Keywords:** Bacteriological; beef; study areas; pathogens; enteric diseases

## 1. Introduction

The safety of meat is intimately connected with safety of its processing environment. Nwanta *et al.* (2008) reviewed the state of Nigeria abattoir operations and waste management; they also discussed the challenges and prospects of the industry with respect to environmental quality and public health. Their findings reveal that the handling of meat in Nigeria is generally unsatisfactory. These findings are in agreement with the findings of Okoliet *al.* (2006) who did a study on animal food product delivery system in Imo State, Nigeria and asserted that official slaughter points in the state were principally low-grade quality slaughter premises consisting of a thin concrete slab; meat handling was very unhygienic with carcasses dressed beside refuse heaps of over 2 years standing; carcasses were dragged on the ground and transported in taxi boots and open trucks. To buttress the above facts Oluwafemi *et al.* (2013) did a review of meat processing practices in Nigeria and concluded that there was a clear indication that the current slaughtering, processing and marketing of meat in many parts of Nigeria are not in compliance with the standard quality and hygiene practices and that it may act as source of contamination and ill health for consumers.

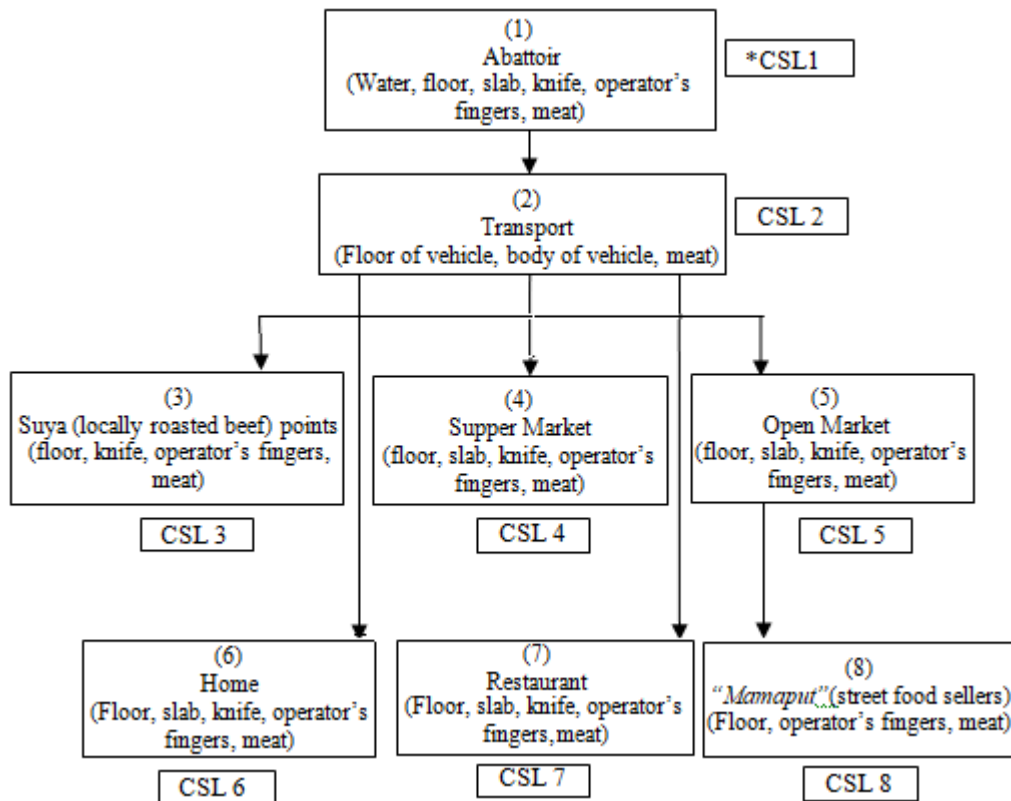
The number, distribution and type of microbiological hazards in meat determine the likelihood of that meat to produce disease in humans when consumed. Several studies have been carried out in the past decade to establish these in order to design a robust food safety management system

that reduce to the barest minimum the incidence and prevalence of meat borne diseases. In a review of challenges to meat safety in the 21<sup>st</sup> century, Sofos (2008) states that the most serious meat safety issues resulting in immediate consumer health problems and recalls from the marketplace of potentially contaminated meat products are associated with microbial hazards, and especially bacterial pathogens. Some recent studies in Nigeria have revealed high meat pathogen prevalence in meat handling locations (Tafida *et al.*, 2013; Eruteya *et al.*, 2014; Okonko *et al.*, 2010; Falola *et al.*, 2011; Clarence *et al.*, 2009). More recent investigators have also consistently found bacteriological meat safety in some parts of Nigeria to be below standard (Chukuet *al.* 2016, Chukwuet *al.* 2016, Azage & Kilbret 2017, Faleke *et al.* 2017, FAO/WHO, 2013)

There has not been any bacteriological assessment of the meat sold in Abia and Imo States. The objective of this study is to assess the bacteriological quality of beef sold in Abia and Imo States of Nigeria.

## 2. Materials and Methods

The study areas were Abia and Imo States of Nigeria. Both States are situated in the southeastern zone of Nigeria. Abia State lies within approximately latitudes  $4^{\circ} 40'$  and  $6^{\circ} 14'$  north and longitudes  $7^{\circ} 10'$  and  $8^{\circ}$  east while Imo State lies between latitudes  $5^{\circ} 4'$  and  $6^{\circ} 3'$  north and longitudes  $6^{\circ} 15'$  and  $7^{\circ} 34'$  east.



**Figure 1:** Conceptual framework for critical sampling locations. Adapted from Jacxsens *et al.* (2009) and ILRI (2011).

\*CSL = Critical Sampling Location

The study population was the beef handling points in Aba and Umuahia in Abia State and Afor-Ogbe and Owerri in Imo State. Five LGAs were selected in the Aba area; namely Aba North, Aba South, Osisioma, Ugwunagbo and Obingwa. Three LGAs were selected in Umuahia Area; namely, Umuahia North, Umuahia South, and Ikwuano. Three LGAs were selected in Owerri area; namely, Owerri West, Owerri North and Owerri Municipal. Also three LGAs were selected in Afor-Ogbe area; namely, Abom-baise, Ahia-Azu-Mbaise and Ngor-Okpala.

The research design was a cross-sectional study that assessed the prevalence of meat-borne pathogens at eight critical control points in the beef chain, which has been called critical sampling locations (CSLs) as adapted from Jacxsens *et al.* (2009) and International Livestock Research Institute (ILRI, 2011). Fig. 1 is a conceptual framework for the CSLs.

## 2.1 Bacteriological Analysis

The microbiological analysis was carried out in the multi-purpose laboratory of Abia State University Teaching Hospital. Culturing was done using Pour plate method outlined by Maturin and Peeler (2001).

Altogether, 480 samples were collected by swab method. This analysis was done by the methods of Serraino *et al.* (2012) and Bhandare *et al.* (2010). Carcass and the meat chain environment were sampled by sterile specimen sponges wetted with 10 ml of buffered peptone water (Oxoid) from sterile Whirl-Pak bags (Sponge-Bag, PBI-International) using a template of 100 cm<sup>2</sup> surface area. Sponging within the area consisted of 5 passes vertically (up

and down was considered one pass) and 5 passes horizontally (side to side was considered one pass) for each large side of the sponge. The sponge was placed into a Stomacher bag and delivered in a cold box (2 – 6 °C) to the laboratory within 4 hours.

Test tubes containing swabs were shaken on a vortex mixer for 30 seconds for uniform distribution of microorganisms. Tenfold serial dilution of all the samples was prepared using sterile normal saline solution (NSS). Then the samples were processed for viable counting. Total viable count (TVC), total coliform count (TCC) and bacteria isolates were determined using nutrient agar medium and MacConkey agar as described by Maturin and Peeler (2001).

The resulting pure cultures were carefully examined and characterized based on colony morphology, microscopic appearance, gram staining reaction and biochemical tests comprising: triple sugar iron Agar (TSI) test, ureas test, indole production, methyl red (MR), Voges-Proscauer (VP), motility, citrate test (Bhandare *et al.*, 2010)

Statistical analysis was performed using Statistical Package for Social Sciences (SPSS) version 25 (International Business Machine, New York) and Microsoft Excel 2007 (Microsoft Corporation, New Mexico, USA).

## 3. Results

The bacteriological quality of meat in each of eight critical sampling locations had the results as shown in Table 3.1. Table 3.1 shows the mean total viable count in Afor-Ogbe (study area 1) by the critical sampling location and meat media (water, floor, slab, knife, operator's finger, and

meat). The transport facility has the highest mean total viable count ( $2.25 \times 10^5 \pm 0.42 \times 10^5$ ). This is followed by the open market ( $2.23 \times 10^5 \pm 0.23 \times 10^5$ ), the abattoir ( $2.12 \times 10^5 \pm 0.25 \times 10^5$ ), restaurant ( $1.65 \times 10^5 \pm 0.13 \times 10^5$ ), supermarket ( $1.58 \times 10^5 \pm 0.17 \times 10^5$ ), *mamaput* ( $1.58 \times 10^5 \pm 0.13 \times 10^5$ ), *suya* vendors ( $1.52 \times 10^5 \pm 0.19 \times 10^5$ ) and home ( $1.51 \times 10^5 \pm 0.13 \times 10^5$ ),  $p < 0.05$ .

Table 3.2 shows the mean total viable count in Aba (study area 2) by the critical sampling location and meat media (water, floor, slab, knife, operator's finger, and meat). The transport facility had the highest mean total viable count ( $2.18 \times 10^5 \pm 0.39 \times 10^5$ ). This was followed by the open market ( $2.08 \times 10^5 \pm 0.24 \times 10^5$ ), the abattoir ( $2.03 \times 10^5 \pm 0.25 \times 10^5$ ), restaurant ( $1.65 \times 10^5 \pm 0.17 \times 10^5$ ), *suya* vendors ( $1.59 \times 10^5 \pm 0.18 \times 10^5$ ), supermarket ( $1.55 \times 10^5 \pm 0.08 \times 10^5$ ), *mamaput* ( $1.49 \times 10^5 \pm 0.10 \times 10^5$ ) and home ( $1.48 \times 10^5 \pm 0.13 \times 10^5$ ),  $p < 0.05$ .

Table 3.3 shows the mean total viable count in Umuahia (study area 3) by the critical sampling location and meat media (water, floor, slab, knife, operator's finger, and meat). The transport facility had the highest mean total viable count ( $2.25 \times 10^5 \pm 0.37 \times 10^5$ ). This is followed by the abattoir ( $2.12 \times 10^5 \pm 0.20 \times 10^5$ ), open market ( $2.09 \times 10^5 \pm 0.14 \times 10^5$ ), restaurant ( $1.64 \times 10^5 \pm 0.15 \times 10^5$ ), *mamaput* ( $1.61 \times 10^5 \pm 0.10 \times 10^5$ ), supermarket ( $1.60 \times 10^5 \pm 0.16 \times 10^5$ ), home ( $1.54 \times 10^5 \pm 0.10 \times 10^5$ ) and *suya* vendors ( $1.50 \times 10^5 \pm 0.19 \times 10^5$ ),  $p < 0.05$ .

Table 3.4 shows the mean total viable count in Owerri (study area 4) by the critical sampling location and meat media (water, floor, slab, knife, operator's finger, and meat). The transport facility had the highest mean total viable count ( $2.13 \times 10^5 \pm 0.36 \times 10^5$ ). This was followed by the open market ( $2.02 \times 10^5 \pm 0.26 \times 10^5$ ), abattoir ( $2.01 \times 10^5 \pm 0.24 \times 10^5$ ), *suya* vendors ( $1.65 \times 10^5 \pm 0.14 \times 10^5$ ), restaurant ( $1.63 \times 10^5 \pm 0.16 \times 10^5$ ), *mamaput* ( $1.53 \times 10^5 \pm 0.11 \times 10^5$ ), supermarket ( $1.51 \times 10^5 \pm 0.08 \times 10^5$ ) and home ( $1.42 \times 10^5 \pm 0.11 \times 10^5$ ),  $p < 0.05$ .

Table 3.5 shows a comparison of the bacterial loads at the critical sampling locations at the study areas with the standard microbiological criteria. The Microbiological criteria states that the total viable count (TVC) for raw meat should be between  $1.00 \times 10^4$  cfu/cm<sup>2</sup> and  $1.00 \times 10^5$  cfu/cm<sup>2</sup>. SA1 = Afor-Ogbe; SA2 = Aba; SA3 = Umuahia; SA4 = Owerri; STD = Standard microbiological criteria. Abattoir had bacteria load of  $2.12 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $2.04 \times 10^5$  cfu in/cm<sup>2</sup> in SA2,  $2.12 \times 10^5$  cfu/cm<sup>2</sup> in SA3 and  $2.01 \times 10^5$  cfu/cm<sup>2</sup> in SA4. Transport facility had  $2.25 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $2.18 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $2.24 \times 10^5$  cfu/cm<sup>2</sup> in SA3 and  $2.13 \times 10^5$  cfu/cm<sup>2</sup> in SA4. *Suya* vendors had  $1.52 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $1.59 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $1.5 \times 10^5$  cfu/cm<sup>2</sup> in SA3 and  $1.65 \times 10^5$  cfu/cm<sup>2</sup> in SA4. Supermarket had  $1.58 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $1.54 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $1.6 \times 10^5$  cfu/cm<sup>2</sup> in SA3, and  $1.51 \times 10^5$  cfu/cm<sup>2</sup> in SA4. Open market had  $2.23 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $2.08 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $2.09 \times 10^5$  cfu/cm<sup>2</sup> in SA3, and  $2.02 \times 10^5$  cfu/cm<sup>2</sup> in SA4. The home had  $1.51 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $1.48 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $1.54 \times 10^5$  cfu/cm<sup>2</sup> in SA3, and  $1.42 \times 10^5$  cfu/cm<sup>2</sup> in SA4. Restaurant had  $1.65 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $1.65 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $1.64 \times 10^5$  cfu/cm<sup>2</sup> in SA3 and  $1.63 \times 10^5$  cfu/cm<sup>2</sup> in SA4. And *Mamaput* had  $1.58 \times 10^5$  cfu/cm<sup>2</sup> in SA1,  $1.49 \times 10^5$  cfu/cm<sup>2</sup> in SA2,  $1.61 \times 10^5$  cfu/cm<sup>2</sup> in SA3 and  $1.53 \times 10^5$  cfu/cm<sup>2</sup> in SA4.

Table 3.6 shows a summary of the bacterial isolates and occurrence in the four study areas of Afor-Ogbe, Aba, Umuahia, and Owerri. In Afor-Ogbe 22 out of 24 samples (91.7%) tested positive for *Staph. aureus*; 19 out of 24 samples (79.2%) tested positive for *E. coli*; 19 out of 24 samples (79.2%) tested positive for *Proteus spp*; 17 out of 24 samples (70.8%) tested positive for *Streptococcus spp*; 12 out of 24 samples (50.0%) tested positive for *Bacillus spp*; 12 out of 24 samples (50.0%) tested positive for *Salmonella spp*; and nine out of 24 samples (37.5%) tested positive for *Klesiella spp*.

In all, 110 of the 168 samples (65.5%) had pathogenic bacteria in them. Chi squared test showed the differences in these bacteria loads to be statistically significant,  $p = 0.00$ .

**Table 3.1:** Mean Total Viable Count (cfu/m<sup>2</sup>) in Study Area 1 (Afor-Ogbe)

| CSL                    | Water              | Floor              | Slab               | Knife              | Operator's Fingers | Meat (Muscle)      | Total               | Mean               | SD                     |
|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|--------------------|------------------------|
| 1. Abattoir            | $2.00 \times 10^5$ | $2.40 \times 10^5$ | $2.10 \times 10^5$ | $1.88 \times 10^5$ | $2.45 \times 10^5$ | $1.88 \times 10^5$ | $12.71 \times 10^5$ | $2.12 \times 10^5$ | $\pm 0.25 \times 10^5$ |
| 2. Trans Fac           | -                  | $2.55 \times 10^5$ | -                  | -                  | -                  | $1.95 \times 10^5$ | $4.5 \times 10^5$   | $2.25 \times 10^5$ | $\pm 0.42 \times 10^5$ |
| 3. <i>Suya</i> Vendors | -                  | $1.65 \times 10^5$ | -                  | $1.45 \times 10^5$ | $1.70 \times 10^5$ | $1.29 \times 10^5$ | $6.09 \times 10^5$  | $1.52 \times 10^5$ | $\pm 0.19 \times 10^5$ |
| 4. Supermarket         | -                  | $1.55 \times 10^5$ | $1.75 \times 10^5$ | $1.35 \times 10^5$ | $1.52 \times 10^5$ | $1.75 \times 10^5$ | $7.92 \times 10^5$  | $1.58 \times 10^5$ | $\pm 0.17 \times 10^5$ |
| 5. Open Market         | -                  | $2.40 \times 10^5$ | $2.10 \times 10^5$ | $2.00 \times 10^5$ | $2.53 \times 10^5$ | $2.10 \times 10^5$ | $11.13 \times 10^5$ | $2.23 \times 10^5$ | $\pm 0.23 \times 10^5$ |
| 6. Home                | -                  | $1.55 \times 10^5$ | $1.65 \times 10^5$ | $1.40 \times 10^5$ | $1.58 \times 10^5$ | $1.35 \times 10^5$ | $7.53 \times 10^5$  | $1.51 \times 10^5$ | $\pm 0.13 \times 10^5$ |
| 7. Restaurant          | -                  | $1.85 \times 10^5$ | $1.68 \times 10^5$ | $1.62 \times 10^5$ | $1.64 \times 10^5$ | $1.48 \times 10^5$ | $8.27 \times 10^5$  | $1.65 \times 10^5$ | $\pm 0.13 \times 10^5$ |
| 8. <i>Mamaput</i>      | -                  | $1.60 \times 10^5$ | -                  | -                  | $1.70 \times 10^5$ | $1.45 \times 10^5$ | $4.75 \times 10^5$  | $1.58 \times 10^5$ | $\pm 0.13 \times 10^5$ |

**Table 3.2:** Mean Total Viable Count (cfu/m<sup>2</sup>) in Study Area 2 (Aba)

| CSL                    | Water              | Floor              | Slab               | Knife              | Operator's Fingers | Meat (Muscle)      | Total               | Mean               | SD                     |
|------------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|---------------------|--------------------|------------------------|
| 1. Abattoir            | $1.88 \times 10^5$ | $2.30 \times 10^5$ | $1.98 \times 10^5$ | $1.90 \times 10^5$ | $2.40 \times 10^5$ | $1.78 \times 10^5$ | $12.16 \times 10^5$ | $2.03 \times 10^5$ | $\pm 0.25 \times 10^5$ |
| 2. Trans Fac           | -                  | $2.45 \times 10^5$ | -                  | -                  | -                  | $1.90 \times 10^5$ | $4.35 \times 10^5$  | $2.18 \times 10^5$ | $\pm 0.39 \times 10^5$ |
| 3. <i>Suya</i> Vendors | -                  | $1.70 \times 10^5$ | -                  | $1.55 \times 10^5$ | $1.75 \times 10^5$ | $1.35 \times 10^5$ | $6.35 \times 10^5$  | $1.59 \times 10^5$ | $\pm 0.18 \times 10^5$ |
| 4. Supermarket         | -                  | $1.50 \times 10^5$ | $1.65 \times 10^5$ | $1.45 \times 10^5$ | $1.50 \times 10^5$ | $1.60 \times 10^5$ | $7.75 \times 10^5$  | $1.55 \times 10^5$ | $\pm 0.08 \times 10^5$ |
| 5. Open Market         | -                  | $2.25 \times 10^5$ | $1.90 \times 10^5$ | $1.89 \times 10^5$ | $2.42 \times 10^5$ | $1.95 \times 10^5$ | $10.41 \times 10^5$ | $2.08 \times 10^5$ | $\pm 0.24 \times 10^5$ |
| 6. Home                | -                  | $1.60 \times 10^5$ | $1.55 \times 10^5$ | $1.40 \times 10^5$ | $1.55 \times 10^5$ | $1.30 \times 10^5$ | $7.4 \times 10^5$   | $1.48 \times 10^5$ | $\pm 0.13 \times 10^5$ |

|               |   |                        |                        |                        |                        |                        |                        |                        |                       |
|---------------|---|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|-----------------------|
| 7. Restaurant | - | 1.90 x 10 <sup>5</sup> | 1.70 x 10 <sup>5</sup> | 1.60 x 10 <sup>5</sup> | 1.60 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 8.25 x 10 <sup>5</sup> | 1.65 x 10 <sup>5</sup> | ±0.17x10 <sup>5</sup> |
| 8. Mamaput    | - | 1.55 x 10 <sup>5</sup> | -                      | -                      | 1.55 x 10 <sup>5</sup> | 1.38 x 10 <sup>5</sup> | 4.48 x 10 <sup>5</sup> | 1.49 x 10 <sup>5</sup> | ±0.10x10 <sup>5</sup> |

Table 3.3: Mean Total Viable Count in Study Area 3 (Umuahia)

| CSL             | Water                  | Floor                  | Slab                   | Knife                  | Operator's Fingers     | Meat (Muscle)          | Total                   | Mean                   | SD                    |
|-----------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|-------------------------|------------------------|-----------------------|
| 1. Abattoir     | 1.99 x 10 <sup>5</sup> | 2.35 x 10 <sup>5</sup> | 2.15 x 10 <sup>5</sup> | 1.96 x 10 <sup>5</sup> | 2.36 x 10 <sup>5</sup> | 1.92 x 10 <sup>5</sup> | 12.73 x 10 <sup>5</sup> | 2.12 x 10 <sup>5</sup> | ±0.20x10 <sup>5</sup> |
| 2. Trans Fac    | -                      | 2.50 x 10 <sup>5</sup> | -                      | -                      | -                      | 1.97 x 10 <sup>5</sup> | 4.47 x 10 <sup>5</sup>  | 2.25 x 10 <sup>5</sup> | ±0.37x10 <sup>5</sup> |
| 3. Suya Vendors | -                      | 1.59 x 10 <sup>5</sup> | -                      | 1.46 x 10 <sup>5</sup> | 1.70 x 10 <sup>5</sup> | 1.25 x 10 <sup>5</sup> | 6.00 x 10 <sup>5</sup>  | 1.50 x 10 <sup>5</sup> | ±0.19x10 <sup>5</sup> |
| 4. Supermarket  | -                      | 1.58 x 10 <sup>5</sup> | 1.80 x 10 <sup>5</sup> | 1.42 x 10 <sup>5</sup> | 1.48 x 10 <sup>5</sup> | 1.70 x 10 <sup>5</sup> | 7.98 x 10 <sup>5</sup>  | 1.60 x 10 <sup>5</sup> | ±0.16x10 <sup>5</sup> |
| 5. Open Market  | -                      | 2.30 x 10 <sup>5</sup> | 2.05 x 10 <sup>5</sup> | 1.95 x 10 <sup>5</sup> | 2.13 x 10 <sup>5</sup> | 2.00 x 10 <sup>5</sup> | 10.43 x 10 <sup>5</sup> | 2.09 x 10 <sup>5</sup> | ±0.14x10 <sup>5</sup> |
| 6. Home         | -                      | 1.53 x 10 <sup>5</sup> | 1.68 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 1.59 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 7.70 x 10 <sup>5</sup>  | 1.54 x 10 <sup>5</sup> | ±0.10x10 <sup>5</sup> |
| 7. Restaurant   | -                      | 1.88 x 10 <sup>5</sup> | 1.65 x 10 <sup>5</sup> | 1.63 x 10 <sup>5</sup> | 1.60 x 10 <sup>5</sup> | 1.46 x 10 <sup>5</sup> | 8.22 x 10 <sup>5</sup>  | 1.64 x 10 <sup>5</sup> | ±0.15x10 <sup>5</sup> |
| 8. Mamaput      | -                      | 1.65 x 10 <sup>5</sup> | -                      | -                      | 1.68 x 10 <sup>5</sup> | 1.50 x 10 <sup>5</sup> | 4.83 x 10 <sup>5</sup>  | 1.61 x 10 <sup>5</sup> | ±0.10x10 <sup>5</sup> |

Table 3.4: Mean Total Viable Count in Study Area 4 (Owerri)

| CSL             | Water                  | Floor                  | Slab                   | Knife                  | Operator's Fingers     | Meat (Muscle)          | Total                   | Mean                   | SD                    |
|-----------------|------------------------|------------------------|------------------------|------------------------|------------------------|------------------------|-------------------------|------------------------|-----------------------|
| 1. Abattoir     | 1.86 x 10 <sup>5</sup> | 2.25 x 10 <sup>5</sup> | 1.97 x 10 <sup>5</sup> | 1.88 x 10 <sup>5</sup> | 2.35 x 10 <sup>5</sup> | 1.72 x 10 <sup>5</sup> | 12.03 x 10 <sup>5</sup> | 2.01 x 10 <sup>5</sup> | ±0.24x10 <sup>5</sup> |
| 2. Trans Fac    | -                      | 2.38 x 10 <sup>5</sup> | -                      | -                      | -                      | 1.87 x 10 <sup>5</sup> | 4.25 x 10 <sup>5</sup>  | 2.13 x 10 <sup>5</sup> | ±0.36x10 <sup>5</sup> |
| 3. Suya Vendors | -                      | 1.72 x 10 <sup>5</sup> | -                      | 1.65 x 10 <sup>5</sup> | 1.78 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 6.35 x 10 <sup>5</sup>  | 1.65 x 10 <sup>5</sup> | ±0.14x10 <sup>5</sup> |
| 4. Supermarket  | -                      | 1.45 x 10 <sup>5</sup> | 1.60 x 10 <sup>5</sup> | 1.40 x 10 <sup>5</sup> | 1.50 x 10 <sup>5</sup> | 1.58 x 10 <sup>5</sup> | 7.53 x 10 <sup>5</sup>  | 1.51 x 10 <sup>5</sup> | ±0.08x10 <sup>5</sup> |
| 5. Open Market  | -                      | 2.20 x 10 <sup>5</sup> | 1.87 x 10 <sup>5</sup> | 1.79 x 10 <sup>5</sup> | 2.38 x 10 <sup>5</sup> | 1.85 x 10 <sup>5</sup> | 10.09 x 10 <sup>5</sup> | 2.02 x 10 <sup>5</sup> | ±0.26x10 <sup>5</sup> |
| 6. Home         | -                      | 1.55 x 10 <sup>5</sup> | 1.50 x 10 <sup>5</sup> | 1.42 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 1.26 x 10 <sup>5</sup> | 7.18 x 10 <sup>5</sup>  | 1.42 x 10 <sup>5</sup> | ±0.11x10 <sup>5</sup> |
| 7. Restaurant   | -                      | 1.88 x 10 <sup>5</sup> | 1.67 x 10 <sup>5</sup> | 1.55 x 10 <sup>5</sup> | 1.62 x 10 <sup>5</sup> | 1.45 x 10 <sup>5</sup> | 8.17 x 10 <sup>5</sup>  | 1.63 x 10 <sup>5</sup> | ±0.16x10 <sup>5</sup> |
| 8. Mamaput      | -                      | 1.60 x 10 <sup>5</sup> | -                      | -                      | 1.58 x 10 <sup>5</sup> | 1.40 x 10 <sup>5</sup> | 4.58 x 10 <sup>5</sup>  | 1.53 x 10 <sup>5</sup> | ±0.11x10 <sup>5</sup> |

Table 3.5: Mean Bacterial Loads in the 8 Critical Sampling Locations (CSL) for the four Study Areas (SA) compared with Standard (STD) Values

| CSL             | SA1 X 10 <sup>5</sup> | SA2 X 10 <sup>5</sup> | SA3 X 10 <sup>5</sup> | SA4 X 10 <sup>5</sup> | STD X 10 <sup>5</sup> |
|-----------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| 1. Abattoir     | 2.12                  | 2.04                  | 2.12                  | 2.01                  | 1                     |
| 2. Trans Fac    | 2.25                  | 2.18                  | 2.24                  | 2.13                  | 1                     |
| 3. Suya Vendors | 1.52                  | 1.59                  | 1.5                   | 1.65                  | 1                     |
| 4. Supermarket  | 1.58                  | 1.54                  | 1.6                   | 1.51                  | 1                     |
| 5. Open Market  | 2.23                  | 2.08                  | 2.09                  | 2.02                  | 1                     |
| 6. Home         | 1.51                  | 1.48                  | 1.54                  | 1.42                  | 1                     |
| 7. Restaurant   | 1.65                  | 1.65                  | 1.64                  | 1.63                  | 1                     |
| 8. Mamaput      | 1.58                  | 1.49                  | 1.61                  | 1.53                  | 1                     |

Table 3.6: Prevalence of Important Meat Pathogens by Study Area

| Study Area | <i>Staphylococcus Spp</i> | <i>E. coli</i> | <i>Bacillus Spp</i> | <i>Proteus Spp</i> | <i>Salmonella Spp</i> | <i>Klebsiella Spp</i> | <i>Streptococcus Spp</i> | Mean Bacterial load |
|------------|---------------------------|----------------|---------------------|--------------------|-----------------------|-----------------------|--------------------------|---------------------|
| Afor-Ogbe  | 91.7%                     | 79.2%          | 50.0%               | 79.2%              | 50.0%                 | 37.5%                 | 70.8%                    | 65.50%              |
| Aba        | 54.2%                     | 58.3%          | 62.5%               | 58.3%              | 62.5%                 | 41.7%                 | 41.7%                    | 54.20%              |
| Umuahia    | 75.0%                     | 41.7%          | 37.5%               | 50.0%              | 45.8%                 | 33.3%                 | 58.3%                    | 48.80%              |
| Owerri     | 75.0%                     | 70.8%          | 29.2%               | 70.8%              | 54.2%                 | 12.5%                 | 54.2%                    | 52.30%              |

In Aba 15 out of 24 samples (62.5%) tested positive for *Bacillus spp*; 15 out of 24 samples (62.5%) tested positive for *Salmonella spp*; 14 out of 24 samples (58.3%) tested positive for *E. coli*; 14 out of 24 samples (58.3%) tested positive for *Proteus spp*; 13 out of 24 samples (54.2%) tested positive for *Staph aureus*; 10 out of 24 samples (41.7%) tested positive for *Klebsiellaspp*; and 10 out of 24 samples (41.7%) tested positive for *Strptococcus spp*. In all, 91 of the 168 samples (54.2%) had pathogenic bacteria in them. Chi squared test showed the differences in these bacteria loads to be statistically significant, p = 0.00

In Umuahia 18 out of 24 samples (75.0%) tested positive for *Staph. aureus*; 14 out of 24 samples (58.3%) tested positive for *Streptococcus spp*; 12 out of 24 samples (50.0%) tested positive for *Proteus spp*; 11 out of 24 samples (45.8%) tested positive for *Salmonella spp*; 10 out of 24 samples (41.7%) tested positive for *E. coli*; 9 out of 24 samples (37.5%) tested positive for *Bacillus spp*; and 8 out of 24

samples (33.33%) tested positive for *Klebsiella spp*. In all, 82 of the 168 samples (48.8%) had pathogenic bacteria in them. Chi squared test showed the differences these bacteria loads not to be statistically significant, p = 0.072

In Owerri 18 out of 24 samples (75.0%) tested positive for *Staph. aureus*; 17 out of 24 samples (70.8%) tested positive for *E. coli*; 17 out of 24 samples (70.8%) tested positive for *Proteus spp*; 13 out of 24 samples (54.2%) tested positive for *Streptococcus spp*; 13 out of 24 samples (54.2%) tested positive for *Salmonella spp*; 7 out of 24 samples (29.2%) tested positive for *Bacillus spp*; and three out of 24 samples (12.5%) tested positive for *Klesiella spp*. In all, 88 of the 168 samples (52.3%) had pathogenic bacteria in them. Chi squared test showed the differences in these bacteria loads to be statistically significant, p = 0.000.

Table 6 also reveals that highest concentration of pathogens were found in study area 1 (Afor-Ogbe), and it is 65.50%.

This was followed by study area 2 (Aba) with pathogen concentration of 54.20%. Study area 4 (Owerri) was the next with mean pathogen concentration of 52.30%. The study area with the least mean concentration of pathogens was study area 3 (Umuahia) with mean pathogen concentration of 48.80%. ( $p = 0.001$ ).

#### 4. Discussion

Tables 3.1 –3.4 reveal that there existed differences in the level of bacterial loads at the critical sampling locations in the study areas. The differences in the bacteria loads in the eight critical sampling locations at the four study areas were statistically significant ( $p < 0.05$ ). This finding is in agreement with the findings Clarence *et al.* (2009), Okonko *et al.* (2010) and Falola *et al.* (2011). There appears to be no significant improvement in the bacteriological qualities of meat sold in Nigeria over the years.

Table 3.5 shows a comparison of the bacterial loads at the critical sampling locations at the study areas with the standard microbiological criteria. The Microbiological criteria states that the total viable count (TVC) for raw meat should be between  $1.00 \times 10^4$  cfu/cm<sup>2</sup> and  $1.00 \times 10^5$  cfu/cm<sup>2</sup>. Any TVC more than  $1.00 \times 10^5$  was unacceptable. All the mean bacterial loads at the critical sampling locations in the study areas (range:  $1.488 \times 10^5$  cfu/cm<sup>2</sup> to  $2.200 \times 10^5$  cfu/cm<sup>2</sup>) were higher than the standard values (range:  $1.00 \times 10^4$  cfu/cm<sup>2</sup> and  $1.00 \times 10^5$  cfu/cm<sup>2</sup>) (Heinz and Hautzinger, 2007; The European Commission, 2005; Turtle and Smith, 2009)  $p = 0.00$ . Therefore the meat sold in those markets in the study areas had the potential to cause enteric diseases and therefore unsafe for human consumption.

There were also differences in the bacteria loads at the four study areas, showing the bacteriological qualities of the study areas. These bacteria loads at the study areas were higher than that found by Clarence *et al.* (2009) in Benin City, Nigeria but lower than that found by Falola *et al.* (2011) in Lagos Mainland Local Government Area, Nigeria, and Oluwafemi and Simisaye (2006) in Abeokuta and Benin City, Nigeria.

Table 3.6 shows that seven pathogens were isolated from the meat and environmental samples: *Staph. aureus*, *E. coli*, *Proteus spp*, *Streptococcus spp*, *Bacillus spp*, *Salmonella spp*, and *Klebsiella spp*. These have prevalence that range from 12.5% to 91.7% in the different study areas. Even the minimum is unacceptable as the meat containing that level of pathogen can cause serious enteric disease outbreak (Heinz and Hautzinger, 2007; Health Protection Agency, 2009; Esemouet *et al.*, 2012).

##### 4.1 Implications for the Sustenance of Enteric Diseases

*Staph. aureus* is notorious for causing enteric diseases (Adams, 2009). This study is in agreement with that of Adesijiet *et al.* (2011) in Oshogbo, Nigeria. Staphylococcal enterotoxins produce the food intoxication (Fisher *et al.*, 2018; Medved'ova, *et al.*, 2017). Transmission is mostly anthroponotic (Argudin *et al.*, 2010; Ercoli, *et al.*, 2017). Its presence in the study samples is therefore due to poor hygiene of the meat handlers.

Isolation of *E. coli* poses a serious enteric disease risk. Although the isolates have not been characterized into their pathogenic strains, a plethora of virulent serotypes of Shiga toxin producing *E. coli* (STEC) and Toxigenic *Escherichia coli* (TEC), have been isolated from human foodborne infections (Balet *et al.*, 2015; Wu *et al.*, 2011; Bell and Kyriakides, 2009). Consumption of the meat sold in the study areas therefore has a very high risk of enteric illness caused by pathogenic *E. coli*.

*Bacillus spp*, such as *B. cereus*, *B. anthracis* and to a lesser extent *B. subtilis*, are pathogenic in humans and other mammals (Blackburn and McClure, 2009). Consumption of meat sold in the study areas also has a high risk enteric disease caused by pathogenic *Bacillus spp* (Carrollet *et al.*, 2019; Bagcioglu *et al.*, 2019).

*Proteus spp* has been suspected of causing acute and chronic gastrointestinal diseases (FDA, 2013, Shi *et al.*, 2016). This reflects the risk of enteric disease inherent in eating the meat sold in these study areas.

Salmonellosis is an important cause of foodborne human gastroenteritis globally and in Nigeria, and meat is an important contributor to the public health disease burden caused by *Salmonella* infection (Møller *et al.*, 2015; EFSA, 2011; van Hoek *et al.*, 2012; Gutema *et al.*, 2019, Fung *et al.*, 2018, Berger *et al.*, 2019). And of greater concern is the recent isolation of multiple drug resistant strains of *Salmonella* from meat (Doyle, 2015).

*Klebsiella spp* is a foodborne pathogen (Zhang *et al.*, 2018; Lu *et al.*, 2017). An outbreak of nosocomial extended - spectrum  $\beta$ -lactamase (ESBL)-producing foodborne disease occurred in Barcelona, Spain in 2008 (Calbo *et al.*, 2011). Eating the meat sold in these study areas has a high risk of enteric disease.

*Streptococcus spp* has pathogenic strains that may produce clinical syndrome similar to staphylococcal intoxication (FDA, 2013, Moris, 2013) including diarrhea, abdominal cramps, nausea, vomiting, fever, chills, and dizziness.

The high prevalence of meat-borne pathogens in all the study areas confirms that consumption of the meat sold in the areas may cause enteric infections with their associated chronic sequelae of irritable bowel syndrome (Haagsma *et al.*, 2010; Schwille-Kiuntke *et al.*, 2011; Thabane *et al.*, 2010; Thabane and Marshall, 2009), inflammatory bowel disease (Ekici & Dümen, 2019), reactive arthritis (Hannu, 2011; Townes, 2010), urological dysfunction (Iwashyna, 2010), and haemolytic uremic syndrome (Mayer *et al.*, 2012; Ekici & Dümen, 2019).

#### 5. Conclusion

The high total viable count which highly correlated with total coliform count and high prevalence of meat pathogens observed at the critical sampling locations depict very poor meat safety management in the two study states which, with all indications, exposes the meat consumers in the study states to high risk of enteric diseases and their chronic sequelae. There is therefore urgent need to improve meat

safety management in the study states through effective public health education, provision of basic infrastructure at the abattoirs, creating enabling environment for meat safety through enactment of relevant laws and policies and their enforcement.

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