IPS Journal of Applied Microbiology and Biotechnology
ISSN: 3115-5685
IPS J Appl Microbiol Biotech, 4(4): 265-270 (2025)
DOI: https://doi.org/10.54117/ijamb.v4i4.101

Vancomycin-Resistant *Staphylococcus aureus* in Abattoir Workers in Jos, Nigeria: Prevalence and Public Health Implications

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Abstract

Background: *Staphylococcus aureus*, including vancomycin-resistant strains (VRSA), poses treatment challenges. Abattoir workers, due to animal contact, risk carrying resistant strains, but VRSA prevalence in Nigerian abattoirs is understudied. **Aim**: This study aimed to determine the prevalence of *S. aureus* and VRSA among abattoir workers in Jos, Nigeria, to assess occupational and public health risks. **Methods**: A cross-sectional study was conducted from January to June 2024 at three major abattoirs in Jos, Plateau State. Hand swabs (n=180) were collected from 60 workers (20 each from pork, beef, and mutton/chevon sections) during working hours. Swabs were cultured on Mannitol Salt Agar, and *S. aureus* was identified using Gram staining, catalase, coagulase, and DNase tests. Antibiotic susceptibility was assessed via Kirby-Bauer disk diffusion, and vancomycin minimum inhibitory concentrations (MICs) were determined by broth macrodilution. **Results**: Of 180 swabs, 84 (46.7%, 95% CI: 39.2–54.3%) were positive for *S. aureus*, with prevalence highest among pork handlers (33/60, 55.0%, 95% CI: 41.6–67.9%), followed by beef (30/60, 50.0%, 95% CI: 36.8–63.2%) and mutton/chevon handlers (21/60, 35.0%, 95% CI: 23.1–48.4%). Among 84 isolates, 36 (42.9%) were methicillin-resistant (MRSA), with 18 (50.0%) from pork, 12 (33.3%) from beef, and 6 (16.7%) from mutton/chevon handlers. Vancomycin testing revealed 9 (10.7%) VRSA isolates (MIC ≥ 16 µg/mL), predominantly from pork handlers (5/9, 55.6%), 12 (14.3%) vancomycin-intermediate (VISA, MIC 4–8 µg/mL), and 63 (75.0%) vancomycin-susceptible (VSSA, MIC ≤ 2 µg/mL). MRSA prevalence was significantly higher in pork handlers ($\chi^2 = 8.14$, $p = 0.017$). **Conclusion**: The high prevalence of *S. aureus*, MRSA, and VRSA among abattoir workers underscores significant occupational and public health risks. Enhanced infection control and antibiotic stewardship are critical in Nigerian abattoirs.

Keywords: *Staphylococcus aureus*, Vancomycin-resistant, MRSA, Abattoir workers, Zoonotic transmission, Antibiotic resistance

Article History
Received: 15 Oct 2025
Accepted: 04 Nov 2025
Published: 07 Nov 2025

Scan QR code to view

How to cite this paper: Okojokwu, O. J., Cirfat, N. A., Gwan, I. J., & Orah, I. C. (2025). Vancomycin-Resistant Staphylococcus aureus in Abattoir Workers in Jos, Nigeria: Prevalence and Public Health Implications. *IPS Journal of Applied Microbiology and Biotechnology*, *4*(4), 265–270. https://doi.org/10.54117/ijamb.v4i4.101

Introduction

Staphylococcus aureus (*S. aureus*) is a versatile bacterium commonly residing in the human respiratory tract and on the skin, with approximately 20% of individuals as persistent carriers and 20–90% as transient carriers (Taylor and Unakal, 2022). While typically a benign component of the human microbiota, *S. aureus* can turn pathogenic when it breaches the bloodstream or internal tissues, leading to a range of infections from minor skin and soft tissue infections to severe conditions like bacteremia, endocarditis, and osteomyelitis (Cong *et al*., 2020). Its pathogenicity is driven by an arsenal of virulence factors, including coagulase, which promotes clotting to shield the bacterium from phagocytosis, and enzymes such as hyaluronidase, DNase, and staphylokinase, which facilitate tissue invasion and systemic dissemination (Foster *et al*., 2014; Cheung *et al*., 2021). These factors enable *S. aureus* to cause significant morbidity, particularly in vulnerable populations (Turner *et al.*, 2019).

The emergence of antibiotic-resistant strains has posed substantial challenges to treatment. Since the identification of methicillin-resistant *S. aureus* (MRSA) in 1961, vancomycin has been a cornerstone for managing severe infections caused by this resistant strain (Lowy, 1998). However, the subsequent rise of vancomycin-intermediate *S. aureus* (VISA) and vancomycin-resistant *S. aureus* (VRSA), characterized by elevated minimum inhibitory concentrations (MICs) to vancomycin, has heightened global concern (Hiramatsu, 1997;

Gardete andTomasz, 2014; Shariati *et al.*, 2020). These resistant strains, though reported sporadically worldwide, underscore a growing public health threat due to their potential to limit therapeutic options (Shariati *et al.*, 2020).

Abattoirs are high-risk environments for zoonotic transmission due to the intimate contact between workers and animal tissues, creating opportunities for *S. aureus* transmission between animals and humans (Pal *et al.*, 2020; Mourabit *et al.*, 2020). Studies have identified *S. aureus* in various animals, including cattle, pigs, and poultry, with some isolates exhibiting antibiotic resistance, including to vancomycin (Weese, 2010; Sharma *et al.*, 2014; Al-Amery *et al.*, 2019). In Nigeria, while hospital-associated VRSA has been documented (Akanbi and Mbe, 2013; Olufunmiso *et al.*, 2017), community-acquired VRSA in occupational settings like abattoirs remains understudied. This study aims to determine the prevalence of *S. aureus* and vancomycin-resistant strains among abattoir workers in Jos, Nigeria, to evaluate occupational risks and their broader public health implications.

Materials and Methods

Study Design and Setting

This cross-sectional study was conducted from January to June 2024 at three major abattoirs in Jos, Plateau State, Nigeria, selected for their high livestock processing volume and representation of typical slaughterhouse environments. Ethical approval was obtained from the Ethics and Research Committee of the University of Jos Teaching Hospital (approval number NHREC/05/01/2010b and Ref. No. PSSH/ETH. CO/2019/006). Informed consent was secured from all participants, ensuring confidentiality throughout the study (WHO, 2011).

Sample Collection

A total of 180 hand swabs were collected from 60 abattoir workers (20 per abattoir section: pork, beef, and mutton/chevon handlers) during working hours. Participants were instructed not to wash their hands prior to sampling to reflect occupational exposure (Burton *et al.*, 2011). Swabs, moistened with sterile saline, were used to sample a 1 cm^2 area of each palm, with both hands swabbed perpendicularly to ensure uniform collection (Schweizer *et al.*, 2012). Sterile gloves were worn to prevent cross-contamination, and moistened swabs placed in sterile 15-mL polypropylene tubes served as negative controls. Samples were transported in an icebox to the Microbiology Laboratory, University of Jos, within 4 hours for analysis (Abera *et al.*, 2010).

Isolation and Identification of *Staphylococcus aureus*

Swabs were streaked onto Mannitol Salt Agar (MSA; Oxoid, UK) and incubated aerobically at 37°C for 24–48 hours. Yellow, mannitol-fermenting colonies were presumptively identified as *S. aureus* and sub-cultured onto nutrient agar for purification. Confirmation was performed using standard biochemical tests as described by Cheesbrough (2010), including Gram staining, catalase, coagulase (using rabbit plasma), DNase, and sugar fermentation tests, following protocols outlined by Cowan and Steel (2003).

Antimicrobial Susceptibility Testing

Antibiotic susceptibility was determined using the Kirby-Bauer disk diffusion method on Mueller-Hinton Agar (Oxoid, UK), according to Clinical and Laboratory Standards Institute (CLSI) guidelines (CLSI, 2023). Isolates were standardized to 0.5 McFarland turbidity (1.5×10^8 CFU/mL) using a 1% barium chloride and 1% sulfuric acid solution. Tested antibiotics included penicillin (10 µg), cefoxitin (30 µg), vancomycin (30 µg), erythromycin (15 µg), clindamycin (2 µg), gentamicin (10 µg), tetracycline (30 µg), ciprofloxacin (15 µg), ofloxacin (5 µg), and co-trimoxazole (1.25/23.75 µg). Plates were incubated at 35°C for 18 hours, and inhibition zone diameters were measured and interpreted per CLSI standards. Isolates with cefoxitin inhibition zones ≤21 mm were classified as methicillin-resistant *S. aureus* (MRSA) (Ali *et al.*, 2015).

Vancomycin Minimum Inhibitory Concentration (MIC)

Vancomycin MICs were determined using the broth macrodilution method in Mueller-Hinton broth (Oxoid, UK) (Andrew, 2001; Chakraborty *et al.*, 2012). Standardized inocula (0.5 McFarland) were added to tubes containing vancomycin concentrations (0.5–128 µg/mL). After incubation at 37°C for 18 hours, the MIC was recorded as the lowest concentration with no visible turbidity. Isolates were classified as vancomycin-susceptible (VSSA, MIC ≤ 2 µg/mL), vancomycin-intermediate (VISA, MIC 4–8 µg/mL), or vancomycin-resistant (VRSA, MIC ≥ 16 µg/mL) per CLSI (2023) guidelines (Hasan *et al.*, 2016).

Statistical Analysis

Data were analyzed using SPSS version 25.0 (IBM, USA). Prevalence of *S. aureus* and vancomycin resistance was expressed as percentages with 95% confidence intervals. Differences in resistance patterns across abattoir sections were assessed using chi-square tests, with a p-value < 0.05 indicating statistical significance (Klein *et al.*, 2017).

Results

A total of 180 hand swabs were collected from 60 abattoir workers across three sections (pork, beef, and mutton/chevon handlers; 60 swabs per section) in Jos, Nigeria, from January to June 2024. Of these, 84 samples were culture-positive for *Staphylococcus aureus*, confirmed by Gram staining, catalase, coagulase, and DNase tests, yielding an overall prevalence of 46.7% (84/180, 95% CI: 39.2–54.3%). By abattoir section, *S. aureus* was isolated from 33 of 60 swabs (55.0%, 95% CI: 41.6–67.9%) from pork handlers, 30 of 60 swabs (50.0%, 95% CI: 36.8–63.2%) from beef handlers, and 21 of 60 swabs (35.0%, 95% CI: 23.1–48.4%) from mutton/chevon handlers (Table 1). The prevalence was significantly higher among pork and beef handlers compared to mutton/chevon handlers ($\chi^2 = 6.72$, $p = 0.035$).

Table 1: Prevalence of *Staphylococcus aureus* by Abattoir Section

Section	Total Swabs	Positive Swabs	Prevalence (%)	95% CI
Pork Handlers	60	33	55.0	41.5 – 67.9
Beef Handlers	60	30	50.0	36.8 – 63.2
Mutton/Chevon	60	21	35.0	23.1 – 48.4
Total	180	84	46.7	39.2 – 54.3

The 84 *S. aureus* isolates were tested for susceptibility to 10 antibiotics using the Kirby-Bauer disk diffusion method, following CLSI (2023) guidelines (Table 2). Resistance was highest to penicillin (79/84, 94.0%, 95% CI: 86.7–98.0%), followed by cefoxitin (36/84, 42.9%, 95% CI: 32.1–54.1%), indicating 36 methicillin-resistant *S. aureus* (MRSA) isolates. Resistance to erythromycin (33/84, 39.3%, 95% CI: 28.8–50.5%), clindamycin (30/84, 35.7%, 95% CI: 25.6–46.9%), and chloramphenicol (27/84, 32.1%, 95% CI: 22.4–43.2%) was also notable. High susceptibility was observed for ciprofloxacin (75/84, 89.3%, 95% CI: 80.6–94.9%), ofloxacin (72/84, 85.7%, 95% CI: 76.4–92.4%), gentamicin (69/84, 82.1%, 95% CI: 72.3–89.7%), tetracycline (66/84, 78.6%, 95% CI: 68.3–86.8%), and co-trimoxazole (63/84, 75.0%, 95% CI: 64.4–83.8%).

Table 2: Antibiotic Susceptibility Profile of *Staphylococcus aureus* Isolates (n = 84)

Antibiotic	Resistance (n, %)	Intermediate (n, %)	Susceptible (n, %)
Penicillin	79 (94.0)	0 (0.0)	5 (6.0)
Cefoxitin	36 (42.9)	0 (0.0)	48 (57.1)
Erythromycin	33 (39.3)	3 (3.6)	48 (57.1)
Clindamycin	30 (35.7)	6 (7.1)	48 (57.1)
Chloramphenicol	27 (32.1)	9 (10.7)	48 (57.1)
Ciprofloxacin	6 (7.1)	3 (3.6)	75 (89.3)
Ofloxacin	9 (10.7)	3 (3.6)	72 (85.7)
Gentamicin	12 (14.3)	3 (3.6)	69 (82.1)
Tetracycline	15 (17.9)	3 (3.6)	66 (78.6)
Co-trimoxazole	18 (21.4)	3 (3.6)	63 (75.0)

Of the 84 *S. aureus* isolates, 36 (42.9%) were identified as MRSA based on cefoxitin resistance (inhibition zone ≤ 21 mm). The distribution of MRSA isolates across abattoir sections was as follows: 18 from pork handlers (50.0% of MRSA isolates), 12 from beef handlers (33.3%), and 6 from mutton/chevon handlers (16.7%) (Table 4). The proportion of MRSA was significantly higher among pork handlers compared to mutton/chevon handlers ($\chi^2 = 8.14$, $p = 0.017$).

Antibiotic resistance patterns were compared across the three abattoir sections for all 10 antibiotics (Table 3). Pork handler isolates exhibited the highest MRSA prevalence (18/33, 54.5%), followed by beef (12/30, 40.0%) and mutton/chevon (6/21, 28.6%), with a significant difference ($\chi^2 = 8.14$, $p = 0.017$). Penicillin resistance was consistently high across all sections, with no significant variation ($\chi^2 = 0.11$, $p = 0.946$). Differences in resistance to erythromycin, clindamycin, chloramphenicol, ciprofloxacin, ofloxacin, gentamicin, tetracycline, and co-trimoxazole were not statistically significant ($p > 0.05$).

Table 3: Antibiotic Resistance of *Staphylococcus aureus* Isolates by Abattoir Section

Antibiotic	Pork (n = 33)	Beef (n = 30)	Mutton/Chevon (n = 21)	χ^2	*p*-value
Penicillin	31 (93.9)	28 (93.3)	20 (95.2)	0.11	0.946
Cefoxitin	18 (54.5)	12 (40.0)	6 (28.6)	8.14	0.017*
Erythromycin	15 (45.5)	12 (40.0)	6 (28.6)	3.81	0.149
Clindamycin	13 (39.4)	11 (36.7)	6 (28.6)	2.97	0.226
Chloramphenicol	12 (36.4)	10 (33.3)	5 (23.8)	2.45	0.294
Ciprofloxacin	2 (6.1)	2 (6.7)	2 (9.5)	0.54	0.763
Ofloxacin	3 (9.1)	3 (10.0)	3 (14.3)	0.82	0.664
Gentamicin	5 (15.2)	4 (13.3)	3 (14.3)	0.22	0.896
Tetracycline	6 (18.2)	5 (16.7)	4 (19.0)	0.19	0.910
Co-trimoxazole	7 (21.2)	6 (20.0)	5 (23.8)	0.35	0.839

Table 4: Distribution of MRSA Isolates by Abattoir Section

Section	Total *S. aureus* Isolates	MRSA Isolates (n, %)	95% CI for MRSA (%)
Pork Handlers	33	18 (54.5)	36.4 – 71.9
Beef Handlers	30	12 (40.0)	22.7 – 59.4
Mutton/Chevon	21	6 (28.6)	11.3 – 52.2
Total	**84**	**36 (42.9)**	**32.1 – 54.1**

The 36 MRSA isolates were tested for vancomycin susceptibility using disk diffusion and broth macrodilution methods (Figure 2). Of these, 9 isolates (25.0%, 95% CI: 12.1–42.2%) were resistant (inhibition zone diameter [IZD] ≤ 14 mm), 12 (33.3%, 95% CI: 18.6–51.0%) were sensitive (IZD ≥ 17 mm), and 15 (41.7%, 95% CI: 25.5–59.2%) were intermediate (IZD 15–16 mm). Broth macrodilution confirmed that the 9 resistant isolates had MICs ≥ 16 µg/mL, classifying them as vancomycin-resistant *S. aureus* (VRSA), representing 10.7% (9/84) of total *S. aureus* isolates. Among all 84 isolates, 63 (75.0%) were vancomycin-susceptible (VSSA, MIC ≤ 2 µg/mL), 12 (14.3%) were vancomycin-intermediate (VISA, MIC 4 – 8 µg/mL), and 9 (10.7%) were VRSA (MIC ≥ 16 µg/mL). VRSA was most prevalent among pork handlers (5/9, 55.6%), followed by beef (3/9, 33.3%) and mutton/chevon (1/9, 11.1%) handlers, with no significant difference across sections ($\chi^2 = 2.89$, $p = 0.236$).

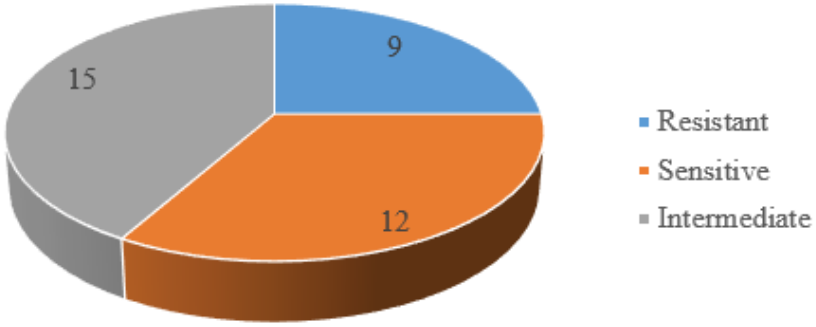

Figure 2: Vancomycin Susceptibility of MRSA Isolates

Discussion

This study highlights the alarming prevalence of *Staphylococcus aureus* and its antibiotic-resistant strains among abattoir workers in Jos, Nigeria, underscoring significant occupational and public health challenges. The high carriage rate of *S. aureus* (46.7%) reflects the elevated risk in abattoir settings, where close contact with livestock facilitates zoonotic transmission (Pal *et al.*, 2010; Mourabit *et al.*, 2020). The variation in prevalence across sections – highest in pork handlers (55%), followed by beef (50%) and mutton/chevon (35%) – suggests differences in animal-specific microbial loads or hygiene practices. Notably, the lower prevalence among mutton/chevon handlers may be attributed to more frequent handwashing, which reduces bacterial colonization (Burton *et al.*, 2011). This aligns with studies in Ethiopia (55%) and China (54.8%), which report comparable *S. aureus* carriage in livestock-related settings, though it exceeds the 29.7% reported in other Nigerian animal-contact environments (Al-Amery *et al.*, 2019; Mai-Siyama *et al.*, 2014). These disparities likely stem from variations in biosecurity measures and antibiotic use practices across regions.

The detection of methicillin-resistant *S. aureus* (MRSA) in 42.9% of isolates, particularly among pork handlers (50%), is concerning, as it mirrors global trends of livestock-associated MRSA (LA-MRSA) in pig farming (Abdullahi *et al.*, 2019). This high MRSA prevalence suggests that abattoir workers may serve as vectors for community transmission, especially in settings with limited infection control (El-Gamal *et al.*, 2022). The emergence of vancomycin-resistant *S. aureus* (VRSA) in 10.7% of isolates (25% of MRSA) is particularly alarming, given vancomycin's role as a last-line treatment for MRSA infections (Gardete and Tomasz, 2014). This VRSA rate exceeds global estimates of 1.5% but aligns with African studies reporting 19 – 54% prevalence in specific contexts (Shariati *et al.*, 2020; Bhattacharyya *et al.*, 2024). The presence of vancomycin-intermediate *S. aureus* (VISA, 14.3%) further indicates a potential trajectory toward increased resistance, complicating treatment options (Shrestha *et al.*, 2020).

The findings point to systemic issues in Nigerian abattoirs, including inadequate hygiene infrastructure and widespread antibiotic misuse in livestock farming, which likely drive resistance (Anyanwu and Okorie-Kanu, 2016; Odetokun *et al.*, 2018). The absence of routine surveillance and infection control measures in these settings heightens the risk of resistant strains spreading to the broader community, a concern echoed in global antimicrobial resistance reports (WHO, 2014). The predominance of VRSA among pork handlers may reflect higher antibiotic exposure in pig farming, a known reservoir for resistant *S. aureus* (Weese, 2010).

Limitations of this study include the modest sample size (180 swabs from 60 workers), which may limit generalizability, and the lack of molecular characterization (e.g., vanA/vanB gene detection) to confirm resistance mechanisms (McGuinness *et al.*, 2017). Additionally, the study did not sample livestock directly, which could clarify zoonotic transmission pathways (Klein *et al.*, 2017). Future research should prioritize multi-center studies, incorporate genomic analysis to identify resistance genes, and investigate antibiotic use patterns in Nigerian livestock farming to inform targeted interventions (Chinnambedu *et al.*, 2020). Implementing stricter biosecurity measures, such as mandatory handwashing stations and personal protective equipment, could mitigate occupational risks and curb the spread of resistant strains (WHO, 2011).

Conclusion

The high prevalence of *S. aureus*, MRSA, and VRSA among abattoir workers in Jos underscores the urgent need for enhanced infection control and antibiotic stewardship in Nigerian abattoirs. These findings advocate for integrated surveillance systems and public health policies to address the

growing threat of antimicrobial resistance in occupational and community settings.

Conflict of Interests

No conflict of interest.

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