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Research Article

Occurrence of *Staphylococcus aureus* and their Resistant Strains in Raw Meat sold at a Metropolitan Abattoir in Maiduguri, Borno State, Nigeria

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ABSTRACT
Staphylococcus aureus is a major foodborne pathogen associated with raw meat contamination and an emerging public health concern due to increasing antimicrobial resistance. This study assessed the occurrence and antimicrobial susceptibility profile of *Staphylococcus aureus* isolated from raw meat sold at a metropolitan abattoir in Maiduguri, Borno State, Nigeria. A total of 80 raw meat samples, comprising beef, chevon, and mutton, were analyzed using standard microbiological methods. Isolation was carried out using Mannitol Salt Agar and confirmed by biochemical tests, while antimicrobial susceptibility was determined using the Kirby–Bauer disc diffusion method. Out of the samples analyzed, 26 (32.5%) were positive for *Staphylococcus aureus*. Beef recorded the highest prevalence (40%), followed by chevron (32%) and mutton (24%), with no significant association between animal species and contamination ($p > 0.05$). The isolates showed high resistance to oxacillin (46.2%), erythromycin (42.3%), and penicillin (38.5%), while all the isolates were susceptible to vancomycin (100%). The presence of antimicrobial-resistant *Staphylococcus aureus* in raw meat highlights a potential route for transmission of resistant pathogens to humans through the food chain.

Keywords: Abattoir; Antimicrobial resistance; Food safety; Raw meat; S*taphylococcus aureus*

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INTRODUCTION

Foodborne diseases continue to pose a serious global public health challenge, particularly in developing countries where food safety systems are still evolving. Among the important bacterial agents associated with food contamination, *Staphylococcus aureus* is widely recognized due to its frequent occurrence in meat and meat products (Kadariya *et al.,* 2014).

Staphylococcus aureus is a Gram-positive bacterium that is commonly present on the skin and in the nasal cavities of humans and animals. Although it may exist without causing harm, it has the potential to cause a variety of infections, including skin infections, pneumonia, septicaemia, and food poisoning (Tong *et al.*, 2015; Foster & Geoghegan, 2014; Taylor & Unakal, 2019). The relatively high rate of human carriage makes it easy for the organism to be introduced into

food during handling and processing (Tesso *et al.*, 2025).

One of the major concerns associated with *S. aureus* in food is its ability to produce heat-stable toxins that remain active even after cooking. These toxins are responsible for food poisoning symptoms such as vomiting, diarrhoea, and abdominal discomfort. In addition, the organism can survive under a wide range of environmental conditions, which enhances its ability to persist in raw meat and other food products (Hennekinne *et al.,* 2012).

In many abattoirs, contamination of meat with *S. aureus* is often linked to inadequate hygiene practices during slaughtering, processing, transportation, and sale. Contact with contaminated surfaces, equipment, or handlers can easily introduce the organism into meat, making raw meat an important route through which humans may be exposed to *S. aureus* (Grace, 2015).

Another growing concern is the increasing resistance of *S. aureus* to commonly used antimicrobial agents. The emergence of methicillin-resistant *Staphylococcus aureus* (MRSA) has made treatment more challenging and has increased the risk of severe infections (Turner *et al.,* 2019). Antimicrobial resistance (AMR) is now recognized as a major global health threat, with *S. aureus* listed among priority pathogens requiring urgent attention (WHO, 2017).

Recent reports have shown that resistant strains of *S. aureus* are increasingly being detected in food-producing animals and meat products, with some isolates exhibiting resistance to multiple classes of antibiotics (Malik *et al.,* 2023; EFSA, 2022). This situation is often associated with the misuse and overuse of antibiotics in livestock production, which facilitates the spread of resistant bacteria through the food chain.

In countries like Nigeria, the problem is further compounded by poor hygiene practices, weak enforcement of food safety regulations, and limited surveillance systems. Despite the public health importance of *S. aureus*, there is still a paucity of data on its prevalence and antimicrobial susceptibility patterns in raw meat within Maiduguri metropolis.

Therefore, this study aimed to determine the prevalence and antimicrobial susceptibility profile of *Staphylococcus aureus* in raw meat obtained from Maiduguri abattoir, with the aim of assessing potential public health risks and providing recommendations for improving food safety practices.

MATERIALS AND METHODS

Study Area and Design

This study was conducted in Maiduguri metropolis, Borno State, Nigeria, located in the northeastern region within the Sahelian Savannah zone. The area is characterized by a hot, semi-arid climate with low annual rainfall and high temperatures. A cross-sectional study design was employed to determine the prevalence and antimicrobial susceptibility profile of *Staphylococcus aureus* in raw meat samples obtained from the Maiduguri abattoir. Laboratory analyses were carried out at the Veterinary Public Health Laboratory, University of Maiduguri, between July and August, 2023.

Determination of Sample Size

The sample size was determined using the Cochran formula:

$$n = \frac{z^2 \mathrm{x}\, p(1-p)}{e^2}$$

where *n* is the required sample size, *Z* is the standard normal deviate at 95% confidence level (1.96), *p* is the estimated prevalence 50%, and *e* is the margin of error (0.05). Although the calculated sample size was higher, a total of 80 samples were analyzed due to logistical and financial constraints. A total of 80 meat samples were obtained from Maiduguri Metropolitan Abattoir based on convenience

Collection and Processing of Samples

A total of 80 raw meat samples comprising beef (cattle), chevron (goat), and mutton (sheep) were aseptically collected from different retail points within Maiduguri abattoir. Approximately, 5 g of each sample was collected into sterile sampling bags and transported immediately to the laboratory in an insulated cooler containing ice packs. All samples were processed within 24 hours of collection, and about 1 g of each sample was aseptically transferred into 9 mL of sterile buffered peptone water to obtain a 1:10 dilution and homogenized using a vortex mixer to ensure uniform distribution of microorganisms, in accordance with standard microbiological methods (ISO, 2017; FDA, 2020).

Isolation and Identification of *Staphylococcus aureus*

An aliquot of the homogenized sample was directly streaked onto Mannitol Salt Agar (MSA) and blood agar plates and incubated at 37°C for 24 hours. Mannitol Salt Agar, a selective and differential medium containing 7.5% sodium chloride, was used for the selective isolation of staphylococci. Presumptive *Staphylococcus aureus* colonies were identified based on mannitol fermentation, indicated

by yellow colonies with surrounding yellow zones on MSA.

Further identification was performed on blood agar, where colonies typically appeared golden-yellow, with or without beta-haemolysis. Presumptive isolates were confirmed using Gram staining, catalase, and coagulase tests. Gram-positive cocci that were catalase-positive and coagulase-positive were identified as *Staphylococcus aureus* (Murray *et al.,* 2003)

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was performed using the Kirby–Bauer disc diffusion method on Mŭeller–Hinton agar following Clinical and Laboratory Standards Institute guidelines (CLSI, 2023). A standardized bacterial suspension equivalent to 0.5 McFarland standard was prepared and uniformly inoculated onto Mŭeller–Hinton agar plates using a sterile swab. Commercial antibiotic discs were aseptically placed on the inoculated plates, followed by incubation at 37°C for 24 hours. The antimicrobial agents tested and their respective disc concentration were as follows: penicillin (10 IU), oxacillin (1 µg), cefoxitin (30 µg), erythromycin (15 µg), clindamycin (2 µg), gentamicin (10 µg), tetracycline (30 µg), trimethoprim-sulfamethoxazole (1.25/23.75 µg), and vancomycin (30 µg), in accordance with CLSI guidelines and zones of inhibition were measured in millimetres and interpreted as susceptible, intermediate, or resistant according to CLSI breakpoints.

Data Analysis

Data obtained were analyzed using SPSS version 20 statistical software package. The overall occurrence of *S. aureus* was calculated as the proportion of positive samples. Chi-square (χ^2) test was used to assess associations between categorical variables, with statistical significance set at $p \leq 0.05$. Results were presented as frequencies and percentages using tables.

RESULTS

A total of 80 raw meat samples were examined, out of which 26 (32.5%) tested positive for *Staphylococcus aureus*. When the results were analysed based on animal species, beef samples showed the highest level of contamination at 40% (12/30), followed by goat meat at 32% (8/25), and sheep meat at 24% (6/25). There was no statistically significant association between the type of animal and the occurrence of *Staphylococcus aureus* (χ^2 = 0.821, p = 0.687) as shown in Table 1.

The antimicrobial susceptibility results showed different levels of resistance among the isolates (Table 2). The highest resistance was observed against oxacillin (46.2%), followed by erythromycin (42.3%) and penicillin (38.5%). Moderate resistance was seen with cefoxitin (30.8%) and trimethoprim-sulfamethoxazole (26.9%), while lower resistance levels were recorded for tetracycline (19.3%), gentamicin (15.4%), and clindamycin (11.5%). All the isolates were found to be completely susceptible to vancomycin (100%).

Table 1: Distribution of *Staphylococcus* species in different Meat among Slaughtered Animals in Maiduguri Abattoir

Species	Number sampled	Positive Isolates (%)	95% CI	χ2	P-value
Cattle	30	12 (40.0)		0.821	0.687
Goat	25	8 (32.0)	0.4-3.5		
Sheep	25	6 (24.0)	0.5-5.1		
Total	**80**	**26 (32.5)**			

Table 2: Antimicrobial susceptibility profile for *Staphylococcus aureus* in Beef, Mutton and chevron in Maiduguri Abattoir

Class of Antimicrobials	Antimicrobials	Susceptibility (%)	Resistance (%)
Beta-lactam	Methicillin	20 (76.9)	6 (23.1)
	Oxacillin	14 (53.8)	12(46.2)
	Cefoxitin	18 (69.2)	8 (30.8)
	Penicillin	16 (61.5)	10 (38.5)
Tetracycline	Tetracycline	21 (80.7)	5 (19.3)
Sulfonamide	Sulfamethoxazole/Trimethoprim	19 (73.1)	7 (26.9)
Aminoglycosides	Gentamycin	22 (84.6)	4 (15.4)
Glycopeptide	Vancomycin	26 (100)	00
Macrolides	Erythromycin	15 (57.7)	11(42.3)
	Clindamycin	23 (88.5)	3 (11.5)

DISCUSSION

The overall occurrence of *Staphylococcus aureus* observed in this study (32.5%) indicates a considerable level of contamination of raw meat in Maiduguri abattoir. This finding is consistent with reports from other studies conducted in Nigeria. For instance, Okorie-Kanu *et al.* (2020) reported the occurrence of *Staphylococcus aureus* in chicken and pig carcasses and among carcass handlers, with an overall prevalence of approximately 29.4%, which is comparable to the value obtained in the present study.

Similarly, a meta-analysis by Ezeh *et al.* (2023) reported prevalence estimates of approximately 31.1% and 32.1% in meat and meat-related samples in Nigeria. The finding in this study therefore falls within the reported national range. More broadly, *S. aureus* prevalence in Nigeria has been reported to vary widely between 1.3% to 72.5%, depending on factors such as sampling methods, hygiene practices, and environmental conditions (Odetokun *et al.,* 2023). These variations highlight the influence of abattoir hygiene, handling practices, and environmental exposure on contamination levels.

The antimicrobial susceptibility profile observed in this study revealed notable resistance among *Staphylococcus aureus* isolates, particularly to oxacillin (46.2%), erythromycin (42.3%), and penicillin (38.5%). This pattern is consistent with reports from other studies conducted in Nigeria, where *S. aureus* isolates showed high resistance to commonly used antibiotics, especially β-lactams (Ezeh *et al.,* 2023). The high resistance to penicillin observed in this study may be attributed to the production of β-lactamase enzymes, which render the antibiotic ineffective.

The resistance observed to oxacillin and cefoxitin suggests the possible presence of methicillin-resistant *Staphylococcus aureus* (MRSA). Similar findings had been reported in Nigeria, where resistant strains have been isolated from meat and animal sources (Okorie-Kanu *et al.,* 2020). The presence of MRSA in food products is of significant public health concern, as these strains are associated with limited treatment options and increased risk of infection.

Resistance to erythromycin (42.3%) observed in this study is also in agreement with previous reports, which indicate increasing resistance to macrolides among *S. aureus* isolates (Ezeh *et al.,* 2023). This may be due to the widespread use of these antibiotics in both human medicine and livestock production, resulting in increased selective pressure.

Despite the observed resistance, all isolates were susceptible to vancomycin (100%), indicating that this antibiotic remains effective against *S. aureus* in this setting. Similar findings had been reported in other studies, where vancomycin retained high efficacy against *S. aureus* isolates (Ezeh *et al.,* 2023). However, reliance on such last-resort antibiotics is not sustainable and highlights the need for prudent antimicrobial use.

The presence of resistance across multiple antibiotic classes observed in this study suggests the emergence of multidrug-resistant (MDR) strains. This finding is of significant concern, as MDR *Staphylococcus aureus* limits treatment options and increases the risk of treatment failure. The observed resistance patterns may be linked to the misuse and overuse of antibiotics in livestock production, a practice commonly reported in developing countries (European Food Safety Authority [EFSA], 2022).

CONCLUSION

This study demonstrated a notable occurrence of 32.5% *Staphylococcus aureus* in raw meat from Maiduguri abattoir, indicating substantial

contamination within the meat processing environment. The isolates showed considerable resistance to commonly used antibiotics, particularly β-lactams and macrolides. These findings underscore the potential public health risk associated with contaminated meat and highlight the growing concern of antimicrobial resistance in foodborne pathogens.

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Conflict of Interest
The authors declared that there are no conflicts of interest

Authors Declaration
The author(s) affirm that the content of this manuscript is original and accept full responsibility for any issues, dispute arising from its publication.

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