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MICROBIOLOGICAL QUALITY AND OCCURRENCE OF METHICILLIN-RESISTANT STAPHYLOCOCCUS AUREUS AND ESCHERICHIA COLI IN STREET-VENDED WHITE RICE AND SPAGHETTI IN ILORIN METROPOLIS, NIGERIA

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ABSTRACT

Foodborne infections caused by antimicrobial-resistant bacteria pose a major public health challenge, particularly in developing countries where street-vended foods are widely consumed. This study assessed the microbiological quality of street-vended cooked white rice and spaghetti sold in Ilorin metropolis, Nigeria, with emphasis on the occurrence of methicillin-resistant Staphylococcus aureus and methicillin-resistant Escherichia coli. Ten food samples were collected from five vending locations and analyzed using standard microbiological techniques, including culture, Gram staining, and biochemical tests. Antibiotic susceptibility was determined using the Kirby–Bauer disk diffusion method with cefoxitin. Physicochemical parameters (pH, titratable acidity, and moisture content) were also evaluated. The results showed that methicillin-resistant Staphylococcus aureus was present in 60% of the samples, while methicillin-resistant Escherichia coli was detected in 10%. Total bacterial counts ranged from 0.30×10^4 to 2.20×10^4 CFU/g. Physicochemical values ranged from pH 5.65–7.68, titratable acidity 316.76–789.68 mg/L, and moisture content 11.67–14.19%. These findings indicate poor hygienic practices in street food handling and highlight the public health risks associated with antimicrobial-resistant bacteria in ready-to-eat foods. Improved regulatory enforcement, vendor hygiene training, and routine food safety monitoring are recommended to reduce foodborne infections and limit the spread of antimicrobial resistance.

Keywords: Food safety, Ready-to-eat foods, Antibiotic resistance, Public health risk, Vendor hygiene

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INTRODUCTION

Food safety is a fundamental component of public health that ensures that the food people consume does not pose any risk of disease or harm. In developing countries, especially Nigeria, food safety remains a significant challenge due to limited enforcement of food regulations, lack of vendor training, and inadequate sanitation infrastructure (Adeyanju *et al*., 2025).

In Nigeria, meals like street-vended rice and spaghetti are popular choices for many people because they are both affordable and easy to find. Unfortunately, these foods are often prepared and sold in less-than-ideal sanitary conditions, which increases the risk of harmful microbes getting into the food (Bichi and Hamza, 2024). Several studies have found dangerous and drug-resistant bacteria in ready-to-eat foods, raising concerns that these foods could help spread antimicrobial resistance (Sinha, 2025).

Among the various microbial agents found in contaminated foods, *Staphylococcus aureus* and *Escherichia coli* are major contributors to foodborne illness. Both have increasingly acquired resistance to multiple antibiotics, including methicillin. The emergence of Methicillin-Resistant *Staphylococcus aureus* (MRSA) and Methicillin-Resistant *Escherichia coli* (MREC) complicates treatment, increases costs, and poses a global health threat (Algammal *et al.*, 2020).

Staphylococcus aureus is associated with a wide range of infections, from skin diseases to life-threatening systemic illnesses. Methicillin-resistant *Staphylococcus aureus* (MRSA) strains, which carry the mecA gene encoding altered penicillin-binding protein (PBP2a), are resistant to β-lactam antibiotics and present a major therapeutic challenge (Algammal *et al*., 2020). *Escherichia coli*, a Gram-negative bacterium commonly found in the gut, serves as an indicator of faecal contamination when detected in food. While many strains are harmless, pathogenic variants such as enterotoxigenic (ETEC) and enterohemorrhagic (EHEC) can cause severe gastroenteritis. Increasing reports of methicillin-resistant E. coli (MREC) in foods highlight its emerging role in the dissemination of antimicrobial resistance (Farrukh *et al*., 2025).

The rise of antimicrobial resistance (AMR) in foodborne bacteria is no longer restricted to clinical settings; food and environmental pathways are now recognized as major drivers of resistance gene transmission. Street foods, often exposed to poor handling, inadequate cooking, and cross-contamination, provide favourable conditions for resistant bacteria to persist and spread (Grudlewska-Buda *et al*., 2023).

Despite the growing body of literature on foodborne pathogens and antimicrobial resistance globally, studies specific to MRSA and MREC contamination in street-vended cooked rice and spaghetti in Nigeria are limited. Ilorin, a bustling city with many informal food markets and vendors, is an ideal setting to investigate this issue. Understanding the microbiological profile and resistance patterns of organisms in these foods is essential for risk assessment and the development of effective safety policies (Khan *et al*., 2020).

This study aimed to isolate and characterize MRSA and MREC from street-vended rice and spaghetti in Ilorin and to evaluate physicochemical parameters that may influence bacterial survival and proliferation.

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Materials and Methods

Sample Collection

Ten samples of cooked rice and spaghetti were collected aseptically from vendors. Samples were transported in sterile polyethylene bags within insulated boxes containing ice packs to maintain integrity.

Microbiological Analysis

Twenty-five grams of each sample were homogenized in 225 ml sterile peptone water. Serial dilutions up to 10^{-5} were prepared, and 0.1 mL aliquots were plated on Mannitol Salt Agar (MSA) for S. aureus and Eosin Methylene Blue (EMB) agar for E. coli. Plates were incubated at 37°C for 24–48 hours.

Biochemical Identification

Presumptive isolates were subjected to biochemical tests: *Staphylococcus aureus* was confirmed using catalase, coagulase, and mannitol fermentation tests, while E. coli was confirmed using indole, citrate utilization, and lactose fermentation tests.

Antibiotic Susceptibility Testing

Resistance was evaluated using the Kirby–Bauer disk diffusion method with cefoxitin (30 µg) on Mueller–Hinton agar. Zone diameters were interpreted using CLSI (2021) standards.

Physicochemical Analysis

pH was measured using a calibrated digital pH meter, titratable acidity by titration with NaOH, and moisture content using the oven-drying method (AOAC, 2019).

RESULT

Bacterial Counts

The total bacterial load of the rice and spaghetti samples ranged from 0.30×10^4 to 2.20×10^4 CFU/g (Table 1). The highest bacterial count was recorded in Sample I (2.20×10^4 CFU/g), while the lowest was observed in Sample B (0.30×10^4 CFU/g) (Table 1)

Morphological and Biochemical Characteristics of Isolates

Colonies on MSA appeared golden yellow (*Staphylococcus aureus*), while EMB plates showed green metallic sheen colonies (*Escherichia coli*). Biochemical tests confirmed identities (Table 3)

Prevalence of MRSA and MREC

MRSA was detected in six samples (60%), while *MREC* was detected in one sample (10%) (Table 3)

Physicochemical Properties of Rice and Spaghetti Samples

The physicochemical analysis of the food samples is presented in Table 4. The pH values ranged from 5.65 ± 0.03 to 7.68 ± 0.03, titratable acidity from 316.76 ± 6.76 to 789.68 ± 6.76 mg/L, and moisture content from 11.67 ± 0.05% to 14.19 ± 0.05%. Statistically significant differences ($p < 0.05$) were observed among samples for all parameters (Table 5)

Discussion

The findings of this study reveal a substantial prevalence of *Methicillin-Resistant Staphylococcus aureus* (MRSA) and *Escherichia coli* in street-vended white rice and spaghetti samples sold in Ilorin markets. The 60% detection rate for MRSA aligns with previous studies identifying street-vended foods as significant reservoirs for antibiotic-resistant pathogens due to poor hygienic conditions and improper food handling (Igbinosa and Beshiru, 2019; Suleiman *et al.,* 2020). This widespread detection of MRSA may be attributed to poor vendor hygiene, unsanitary environmental conditions, and the handling practices common in open market environments (Kurtz *et al.,* 2021).

In addition, the isolation of *Escherichia coli* in 10% of the samples further underscores the public health risks associated with street foods. The presence of *E. coli* is a well-established indicator of fecal contamination and inadequate sanitation (Zhao *et al.*, 2022), consistent with findings from other studies (Andoh *et al.,* 2022).

Physicochemical analysis of the samples revealed significant associations between MRSA presence and moisture content, as well as titratable acidity. This implies that higher water activity and moderate acidity create favourable conditions for MRSA survival and possibly growth. These findings agree with the conclusions of Gould *et al.*, (2021) that moist foods, if not properly stored, are more susceptible to microbial spoilage and contamination.

Moreover, the moderate positive correlation with titratable acidity supports the adaptability of MRSA to moderately acidic environments (Hübschle *et al.,* 2022). Conversely, the weak negative correlation with pH suggests that mildly acidic pH alone may not be sufficient to inhibit MRSA growth, which aligns with the findings of Argudín *et al.* (2019).

Antibiotic susceptibility testing confirmed phenotypic resistance to cefoxitin in both MRSA and methicillin-resistant *E. coli* (MREC) isolates, consistent with CLSI guidelines (CLSI, 2021). The detection of multidrug resistance in both organisms supports the global concern regarding the role of contaminated foods in spreading antibiotic-resistant bacteria (Holmes *et al.,* 2016; WHO, 2021).

The findings of this study have important implications for food safety and public health within Ilorin metropolis and similar urban settings. The high occurrence of methicillin-resistant *Staphylococcus aureus* in commonly consumed street-vended foods suggests that these foods may serve as silent vehicles for the transmission of antimicrobial-resistant bacteria to the general population. Continuous exposure through regular consumption may lead to colonization of consumers, thereby increasing the risk of infections that are difficult to treat due to limited antibiotic options (Fusaro *et al*., 2024). This situation places additional pressure on already overstretched healthcare systems in developing countries such as Nigeria.

Furthermore, the detection of methicillin-resistant *Escherichia coli*, though at a lower prevalence, indicates faecal contamination and poor sanitary conditions during food preparation and handling. This has broader implications for environmental hygiene and water quality used in food processing. The presence of resistant *E. coli* in ready-to-eat foods raises concerns about the potential spread of resistance genes through horizontal gene transfer within the human gut microbiota, thereby contributing to the wider antimicrobial resistance burden in the community (Zhao *et al*., 2022). This observation aligns with reports from other low- and middle-income countries where inadequate hygiene practices among street food vendors have been linked to contamination with antimicrobial resistant foodborne pathogens (Bichi and Hamza, 2024).

From a regulatory perspective, these results highlight the urgent need for strengthened food safety surveillance and enforcement of hygiene standards among street food vendors. Routine monitoring of ready-to-eat foods for antimicrobial-resistant pathogens, alongside vendor education on proper hygiene and safe food handling practices, could significantly reduce contamination risks. Addressing these issues is essential not only for preventing foodborne infections but also for limiting the community level dissemination of antimicrobial resistance (Fusaro *et al*., 2024).

Conclusion

This study revealed a high prevalence of Methicillin-Resistant *Staphylococcus aureus* (MRSA) and the presence of Methicillin-Resistant *Escherichia coli* in street-vended white rice and spaghetti sold in Ilorin. A significant relationship was observed between MRSA and MREC occurrence and physicochemical parameters such as moisture content and titratable acidity, suggesting these factors influence the survival of MRSA in food. The phenotypic resistance of MRSA and MREC isolates to cefoxitin highlights the threat of antimicrobial resistance in ready-to-eat foods. These findings emphasize the need for strict hygiene practices, routine food safety monitoring, and public health interventions to reduce the risk of foodborne infections and the spread of antibiotic-resistant bacteria through street foods.

Recommendation

To reduce the risks related to contaminated street-vended foods, regulatory agencies should enforce strict hygiene standards with regular inspections. Food handlers need proper training on safe practices and the dangers of antibiotic-resistant germs. Public awareness campaigns are also important to inform consumers about the risks of eating improperly handled foods. Finally, more research using molecular techniques is needed to better understand the genetic basis of antibiotic resistance in these isolates.

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Appendices

Table 1: Bacterial Load in Rice and Spaghetti Samples (CFU/g)

Sample Code	**Total Plate Count (CFU/g)**	***S. aureus* Count (CFU/g)**	***E. coli* Count (CFU/g)**
A	2.10×10^4	1.60×10^3	ND
B	0.30×10^4	ND	ND
C	1.50×10^4	0.92×10^3	2.4×10^2
D	1.70×10^4	1.20×10^3	ND
E	1.90×10^4	1.50×10^3	ND
F	0.38×10^4	ND	ND
G	1.40×10^4	0.80×10^3	ND
H	0.40×10^4	ND	ND
I	2.20×10^4	1.80×10^3	ND
J	0.35×10^3	ND	ND

ND: Not Detected.

Table 2: Morphological Characteristics of Bacterial Isolates

ISOLATES	SHAPE	EGDE	ELEVATION	OPTICAL	CONSISTENCY	COLONY SURFACE	PIGMENTATION
Staphylococcus aureus	Circular	Entire	Raised	Opaque	Butyrous	Smooth	Deep yellow
Escherichia coli	Circular	Entire	Convex	Translucent	Butyrous	Smooth	Dark colonies with a green metallic sheen

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Table 3: Morphological and Biochemical Characteristics of Bacterial Isolates

Organism	Catalase Test	Coagulase Test	Mannitol Fermentation	Indole Test	Citrate Test	TSI Reaction (Slant/Butt Gas,H_2S)
Staphylococcus aureus	+	+	+	-	-	-
Escherichia coli	-	-	-	+	+	A/A, Gas +, H_2S –

Keys: + Present

- Absent

Table 4: Prevalence of MRSA and *Escherichia coli* in Rice and Spaghetti Samples

Sample Code	MRSA Positive	*E. coli* Positive
A	+	-
B	-	-
C	+	+
D	+	-
E	+	-
F	-	-
G	+	-
H	-	-
I	+	-
J	-	-

Keys: + Present

- Absent

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Table 5: Physicochemical Properties of Rice Samples with Significant Differences

Sample Code	pH	Titratable Acidity (mg/L)	Moisture Content (%)
A	$7.68^{a} \pm 0.03$	$610.82^{b} \pm 6.76$	$12.38^{c} \pm 0.05$
B	$7.00^{b} \pm 0.03$	$316.76^{d} \pm 6.76$	$11.67^{d} \pm 0.05$
C	$7.37^{a} \pm 0.03$	$438.82^{c} \pm 6.76$	$12.96^{b} \pm 0.05$
D	$7.51^{a} \pm 0.03$	$350.76^{d} \pm 6.76$	$13.46^{b} \pm 0.05$
E	$6.97^{b} \pm 0.03$	$395.12^{d} \pm 6.76$	$12.82^{c} \pm 0.05$
F	$6.68^{b} \pm 0.03$	$644.96^{b} \pm 6.76$	$11.96^{d} \pm 0.05$
G	$6.42^{c} \pm 0.03$	$566.93^{b} \pm 6.76$	$13.81^{a} \pm 0.05$
H	$6.80^{c} \pm 0.03$	$787.65^{a} \pm 6.76$	$14.19^{a} \pm 0.05$
I	$5.65^{d} \pm 0.03$	$469.56^{c} \pm 6.76$	$14.00^{a} \pm 0.05$
J	$5.65^{d} \pm 0.03$	$789.68^{a} \pm 6.76$	$13.99^{a} \pm 0.05$

Note:
Values are presented as mean ± standard deviation. Different superscript letters within the same column indicate statistically significant differences ($p < 0.05$) according to Tukey's HSD test.