Colistin-Resistant *Escherichia coli* from Hospital and Community Nexus: Public and Environmental Health Concern

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Abstract

Antimicrobial resistance (AMR) is one of the greatest encounters for human health globally, which is associated with elevated morbidity and increased economic burdens. Colistin represents an important resort in treating severe infections caused by multidrug-resistant difficult-to-treat Gram-negative bacteria, including *Escherichia coli*. The study aimed to investigate the prevalence of colistin-resistant *E. coli* (CREC) in community and hospital sources and their associated risk factors. Eighty-five samples from hospital and community sources were screened using cultural and biochemical techniques and confirmed via Analytical Profile Index 20E. The antimicrobial susceptibility profile was determined using disc diffusion procedure and the phenotypic virulence factors were determined using standard culture protocols. The occurrence of CREC based on sample types includes cow carcass (26.7%), abattoir effluents (20%) and hospital effluents (8.6%). Pumpkin leaf, carrots and smoked fish were negative for CREC. The percentage distribution of CREC positive samples based on sample sources were slaughterhouses (77%) and hospital environment (33%) with open markets showing no case of CREC. Overall, CREC positive samples were 9/85 (10.6%). CREC demonstrated 100% ampicillin and trimethoprim/sulfamethoxazole resistance. The multiple antibiotics resistance profile of the *Escherichia coli* in this study ranged from 0.83 – 0.46. The phenotypic virulence distribution of CREC were lipase activity (33.3%), β-hemolytic activity (22.2%) and gelatinase activity (22.2%). The detection of CREC in both community and hospital environment allays a notable threat to human and animal health. Public enlightenment campaign and proper education against indiscriminate antibiotics usage as animal feed and growth promoters coupled with routine antibiotic resistance monitoring is crucial to curtail the dissemination of superbugs.

Keywords: Colistin, *E. coli*, Drug resistance, Virulence, Superbugs.

INTRODUCTION

Antimicrobial resistance (AMR) represents one of the utmost encounters for human health globally. AMR is an evolving health menace that linked with elevated morbidity and increased economic burdens (Phodha et al., 2019). Bacterial resistance especially the Gram-negative bacteria to multiple antibiotics have been associated to several infections worldwide and is predominantly significant in low and middle income countries where antibiotics misuse is high (Beshiru et al., 2017; Imanah et al., 2017; Igbinosa & Beshiru, 2019; Igbinosa et al., 2020a). Globally, the estimate of deaths linked to AMR stands at 700,000, and...
projected to reach ten million by the year 2050 (O’Neill, 2014). However, the deaths attributable to AMR is projected to reach 4,150,000 by 2050 in Africa (O’Neill, 2014). Indiscriminate prescription and usage of antibiotics in veterinary and human medicine have been attributed to the spread of multidrug-resistant (MDR) bacteria as they demonstrate resistance to almost all commercially available antimicrobials (Igbinosa et al., 2022a; Beshiru & Igbinosa, 2023).

This rise in AMR translates to longer hospital stays, therapeutic complications, difficult-to-treat infections and amplified mortality in animals and human (Beshiru et al., 2016). The risk associated with AMR is more worrisome in nations with limited resources such as sub-Saharan Africa where common infections exist and last-resort antimicrobials are relatively unaffordable and scarce (Igbinosa et al., 2022b). In view of the enormous lack of novel antimicrobials active in the treatment of infections arising from MDR Gram-negative bacteria, there have been renewed interest in polymyxin antibiotics especially polymyxin E (colistin) whose usage were initially discontinued in human medicine in several countries (Karaikos et al., 2019). Colistin acts by competitively disrupting the cell membrane integrity thereby resulting in leakage of important cellular components and ultimately bacterial cell death (Ma et al., 2022). The restriction of colistin a last-resort antibiotics in human medicine despite its effectiveness is due to patient safety concerns as it has been linked to nephrotoxicity and neurotoxicity potential (Falagas et al., 2010).

The therapeutic use of colistin regained global interest after the emergence of MDR Enterobacteriaceae (Igbinosa et al., 2020b; Ma et al., 2022). Colistin represent an important resort in treating severe, infections caused by MDR difficult-to-treat Gram-negative bacteria, including Escherichia coli (Igbinosa & Beshiru, 2018). Colistin was relatively reintroduced recently in human medicine within formation on colistin-resistant bacteria already on the rise (Falagas et al., 2010). The unfortunate increase of colistin resistance can be notably attributed to its misuse in veterinary medicine as therapeutics and growth promoters (El-Mokhtar et al., 2021). Several studies have implicated food animals and their products as a notable foundation of colistin resistance genes of zoonotic importance (Poirel et al., 2018). Resistance to colistin can be disseminated zoonotically or indirectly through the food platforms and subsequently cause difficult-to-treat diseases in human (Marshall & Levy, 2011).

*E. coli* is reported as one amongst other bacterial species liable for the horizontal spread of antimicrobial resistance genes (Tang et al., 2021). Over the years, colistin acquired resistance has been frequent consequent of chromosomal mutation in regulatory pathways or via amplified capsular polysaccharide production (Olaitan et al., 2014). However, resistance to antibiotic agents is further complicated and spread faster via antimicrobial resistance gene encoded on transferable plasmids (Ma et al., 2022). Most antimicrobial resistant genes of *E. coli* are plasmid-mediated hence they have high potential of being transferred horizontally (Beshiru et al., 2023). *E. coli* can cause infections in animals from the environment or other infected populations (Poirel et al., 2018). The transferable plasmid encoding colistin resistance (mobilized colistin resistance-mcr) emerged in China in late 2015 (Poirel et al., 2018). This global emergence of CREC from different nexus has evoked public health attention. Hence, it is important to concurrently surveil and monitor the spread of CREC from diverse sources and environment. The study aimed to investigate the prevalence of CREC from community and hospital sources and their associated risk factors.
MATERIALS AND METHODS

Study Area
This study was conducted within Oghara town, Ethiope West Local Government Area, Delta State, Nigeria (Latitude: 5.63314, Longitude: 6.02819 5° 37′ 59″ North, 6° 1′ 41″ East). Oghara community is a home to various educational and health institutions which include Delta State Polytechnic in Otefe-Oghara, Western Delta University, Oghara, Nigeria Naval Logistic Headquarters, Oghara and Delta State University teaching hospital, Oghara.

Samples Collection
A total of 85 samples were collected and analyzed in this study. These include community samples \((n=25)\) gotten from open markets [pumpkin leaf - *Telfaria occidentalis* \((n=10)\), carrots - *Daucus carota* \((n=10)\), smoked fish \((n=5)\)] and slaughterhouses samples \((n=25)\) [cow carcass \((n=15)\), abattoir effluents \((n=10)\)]. Hospital-related samples were gotten from Delta State University teaching hospital, Oghara [Hospital effluents \((n=35)\)]. Sample collection did not require ethical approval as samples were not directly obtained from animals and humans. However, permission and informed consent were gotten from the abattoir workers and clinic institutions before sampling. The effluent specimens were collected in sterile sampling plastic containers at a depth approximately 500 mm and other samples were collected in sterile polythene bags. The samples were conveyed immediately on ice packs to the laboratory for analysis.

Isolation of Colistin-Resistant *Escherichia coli*
Twenty-five grams of pumpkin leaf, carrots and fish samples were weighed, severed into pieces and transferred to 225 mL sterile distilled water. The effluent samples were homogenized by shaking the sampling containers slightly before opening and 10 mL was transferred into 90 mL sterile distilled water. An aliquot of 1 mL from the stock samples was cultured in 10 mL Tryptone Soy Broth (TSB) (Merck, Darmstadt, Germany) at 37 °C for 24 hours. After incubation, 100 µL of each TSB culture was inoculated onto a Chromocult Coliform Agar (CCA) (Merck, Darmstadt, Germany) agar plate supplemented with 4 µg/mL colistin to screen for colistin resistance as recommended by European Committee on Antimicrobial Susceptibility Testing (EUCAST) and adopted in previous studies (El-Mokhtar et al., 2021). Plates were incubated at 37 °C for 24 hours. Distinct blue or violet colonies were considered presumptive CREC isolates. The presumptive *Escherichia coli* isolates were purified on nutrient agar (Lab M, Lancashire UK) and stored on nutrient agar slants until ready for further use.

Biochemical Characterization and Identification of Colistin-Resistant *Escherichia coli*
Colonies were presumptively identified by colony pigmentation and Gram reactions using 3% potassium hydroxide (3% KOH) (Gram-negative) characteristics. Pure cultures were obtained by streaking a portion of an isolated colony on nutrient agar and incubated aerobically at 37 °C for 24 hours. The isolates were confirmed by oxidase test, catalase test, indole test, urease test, and hydrogen sulphide test. Isolates were further characterized biochemically using Analytical Profile Index (API) 20E (Biomérieux, France). The tests were performed according to the manufacturer’s instruction for use. Data interpretation was performed using the Analytical profile index (API) database (V4.1) with the apiweb™ identification software.
Antimicrobial Susceptibility Testing
The confirmed CREC isolates were subjected to antimicrobial susceptibility testing to determine the AMR patterns using the Kirby-Bauer disc diffusion method. Suspension containing approximately $10^5$ colony forming units (CFU)/mL was prepared accordingly and 50 μL of the suspension were deposited and aseptically spread on Mueller-Hinton agar (MHA) plates (Lab M, Lancashire, United Kingdom). The antibiotics disc tested include ceftazidime (30 μg), aztreonam (30 μg), ampicillin (10 μg), amoxicillin-clavulanate (20/10 μg), meropenem (10 μg), gentamicin (10 μg), tetracycline (30 μg), ciprofloxacin (5 μg), chloramphenicol (30 μg), nitrofurantoin (300 μg) and trimethoprim/sulfamethoxazole (1.25/23.75 μg) (Oxoid, Basingstoke, Hampshire, United Kingdom). Plates were incubated for 24 hours at 37 °C. Diameter of zones of inhibition were measured and interpreted according to Clinical Laboratory Standards Institute (CLSI) (2020).

Multiple Antibiotic Resistance Index
Multiple antibiotic resistance index (MARI) of CREC was elucidated as follows:

$$\text{MARI} = \frac{a}{b}$$

where “a” represents total antibacterial agents that an isolate is resistant and “b” is represents, antibacterial agents that an isolate was exposed (Igbinosa et al., 2023a). Isolates with MAR index ≥0.2 was considered to be of high risk. Isolates resistant to ≥3 antibiotic class were considered multidrug-resistant (Igbinosa et al., 2023b).

Determination of Phenotypic Virulence
Colistin-resistant E. coli isolates were cultivated on tryptone soy agar (TSA) (Merck, Darmstadt, Germany). The recovered colonies on TSA were suspended in 3.0 mL of TSB (Merck, Darmstadt, Germany). The turbidity of colonies suspension was adjusted to 0.5 McFarland standards approximately $10^8$ cells/mL. Lipase activity was determined by inoculating 5.0 mL of the sample suspension on TSA and incubated for 48 h at 37 °C. Positive lipase activity was indicated by a clear halo surrounding the growth of lipase producing bacterium. Gelatinase activity was determined by inoculating 5.0 mL sample of the suspension on gelatin medium and incubated for 48 h at 37 °C. Zones of clearance in the media indicated the proliferation of gelatin-liquefying microorganisms. Haemolytic activity was determined by inoculating 5.0 mL sample suspension on sheep blood agar plate and incubated for 48 h at 37 °C. Haemolytic activity was spotted by clear colourless zones surrounding the colonies which indicate lyses of the red blood cells. Phenotypic virulence was determined using the protocol adapted from previous studies of Beshiru et al. (2018; Beshiru et al. (2022).

Data Analysis
All data were analyzed using Microsoft Excel 2013 and SPSS 21.0. The prevalence and occurrence of the bacteria were expressed in percentage (%).

RESULTS AND DISCUSSION

The Occurrence and Distribution of Colistin-Resistant E. coli
Suspected isolates that were Gram negative, catalase positive, indole positive, oxidase negative, urease negative and hydrogen sulphide negative were confirmed as E coli using API-20E. The occurrence of CREC based on API-20E identification is shown in Table 1. The occurrence of CREC based on sample types were cow carcass (26.7%), abattoir effluents (20%) and hospital effluents (8.6%). Pumpkin leaf, carrots, and smoked fish had no CREC. The highest prevalence occurred in cow carcass samples while there was no occurrence
observed in smoked fish and carrots samples. The percentage distribution of CREC positive samples based on sample types is shown in Figure 1. The distribution observed were cow carcass (44.3%), abattoir effluents (22.7%) and hospital effluents (33%).

**Table 1:** Occurrence of colistin-resistant *E. coli* based on sample types

<table>
<thead>
<tr>
<th>Samples</th>
<th>Samples assessed</th>
<th>Colistin-resistant <em>E. coli</em> positive samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pumpkin leaf</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Carrots</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Smoked fish</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Cow carcass</td>
<td>15</td>
<td>4</td>
</tr>
<tr>
<td>Abattoir effluents</td>
<td>10</td>
<td>2</td>
</tr>
<tr>
<td>Hospital effluents</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td>9 (10.6%)</td>
</tr>
</tbody>
</table>

**Figure 1:** Percentage distribution of colistin-resistant *E. coli* positive samples based on sample types.

Over the years, there has been substantial increase in the spread of MDR Gram-negative bacteria and resulting upsurge of colistin usage as last resort drugs. Previous studies have adopted similar protocol to ours by supplementing culture media with 4 μg/mL colistin concentrations in screening CREC (El-Mokhtar *et al*., 2021). Similarly, other authors have agreed that the colistin resistance gene is mainly detected in *Enterobacteriaceae* and has a moderate level of resistance with minimum inhibitory concentration values varying from 4 to 16 mg/L (Skov *et al*., 2016). The prevalence (10.6%) CREC in this study is higher in comparison to the prevalence (0.09%) of CREC strains detected in Tunisia (Mezghani-Maalej *et al*., 2012) and the prevalence (8.3%) of CREC previously reported in Nigeria (Olowe *et al*., 2018). However, higher prevalence of CREC (26.5%, 14.0% and 0.9%) has been detected in pigs, chickens, and cattle respectively (Zhuge *et al*., 2019). This high prevalence agrees with this study as most of the resistant isolates observed were from environments related to farm animals.

The distribution of CREC based on sample sources is shown in Table 2 with slaughterhouses (24%) and hospital environment (8.6%) having the bulk of distributions. The highest occurrence was observed in slaughterhouses (24%) while no occurrence was observed at open market. The percentage distribution of CREC positive samples based on sample sources is shown in Figure 2. The distribution for open market recorded 0%,
slaughterhouses (77%) and hospital environment (33%). Overall, the total CREC positive samples was (10.6%).

### Table 2: Occurrence of colistin-resistant *E. coli* based on sample sources

<table>
<thead>
<tr>
<th>Samples</th>
<th>Samples assessed</th>
<th>Colistin-resistant <em>E. coli</em> positive samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open markets</td>
<td>25</td>
<td>0</td>
</tr>
<tr>
<td>Slaughterhouses</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>Hospital environment</td>
<td>35</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>85</strong></td>
<td><strong>9 (10.6%)</strong></td>
</tr>
</tbody>
</table>

![Figure 2](image_url): Percentage distribution of colistin-resistant *E. coli* positive samples based on sample sources

Our findings agree with comparable studies, which reported a higher prevalence of CREC in livestock’s (0.02% to 20.6%) as compared to the 1.3% to 19% in retail meat and 0.08% to 2% in hospital settings (Hasman *et al.*, 2015; Kluytmans *et al.*, 2016). Higher CREC in our study could be probably due to the continuous and increasing exposure of animals to colistin as feed additives (particularly bacteria colonized in the gastrointestinal tract of animals), growth promoter and therapeutic purposes. These bacteria could contaminate animal products and meat during slaughterhouse processing and spread to humans via food chain or to workers through direct animal contact. In further agreement with this study, previous study has reported a noteworthy upsurge in the prevalence of colistin resistance over a period of a 3 years surveillance (El-Mokhtar *et al.*, 2021). The differences observed among the studies can be attributed to differences in study location, geographical conditions, and climate. Additionally, the relatively high prevalence of colistin resistance in livestock and retail meat could be ascribed to the influence of mcr-1 mediated resistance making food animals a notable reservoir for transmission to humans (Skov & Monnet, 2016) and possible transmission within the food chain. This poses significant health threat to humans that largely consume the products, animal and workers. This makes routine colistin resistance surveillance crucial in both community and hospital environment.
Antimicrobial Resistance Profile of Colistin-Resistant *E. coli* Isolates

The AMR profile of CREC is shown in Table 3. The observed resistance profile was ceftazidime (88.9%), aztreonam (66.7%), ampicillin (100%), amoxicillin-clavulanate (66.7%), meropenem (22.2%), gentamicin, tetracycline (77.8%), chloramphenicol (55.6%), nitrofurantoin (66.7%) and trimethoprim/sulfamethoxazole (77.8%). The highest resistance was demonstrated towards ampicillin with a resistance rate of 100%. No resistance was observed towards ciprofloxacin and gentamicin.

Table 3: Antimicrobial resistance profile of colistin-resistant *E. coli*

<table>
<thead>
<tr>
<th>Antimicrobial class</th>
<th>Antibiotics</th>
<th>Resistance profile of CREC*(n=9)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sensitive (%)</td>
<td>Intermediate (%)</td>
</tr>
<tr>
<td>Cephalosporins</td>
<td>CAZ</td>
<td>1 (11.1)</td>
</tr>
<tr>
<td>Monobactams</td>
<td>AZT</td>
<td>3 (33.3)</td>
</tr>
<tr>
<td>Penicillins</td>
<td>AMP</td>
<td>0 (0)</td>
</tr>
<tr>
<td>B-lactam combination agents</td>
<td>AMC</td>
<td>1 (11.1)</td>
</tr>
<tr>
<td>Carbapenems</td>
<td>MEM</td>
<td>6 (66.7)</td>
</tr>
<tr>
<td>Aminoglycosides</td>
<td>GEN</td>
<td>8 (88.9)</td>
</tr>
<tr>
<td>Tetracyclines</td>
<td>TET</td>
<td>2 (22.2)</td>
</tr>
<tr>
<td>Fluoroquinolones</td>
<td>CIP</td>
<td>8 (0)</td>
</tr>
<tr>
<td>Phenicols</td>
<td>CHL</td>
<td>4 (44.4)</td>
</tr>
<tr>
<td>Nitrofurans</td>
<td>NIT</td>
<td>3 (33.3)</td>
</tr>
<tr>
<td>Folate pathway inhibitors</td>
<td>SXT</td>
<td>0 (0)</td>
</tr>
</tbody>
</table>

Key: CAZ: ceftazidime (30 µg), AZT: aztreonam (30 µg), AMP: ampicillin (10 µg), AMC: amoxicillin-clavulanate (20/10 µg), MEM: meropenem (10 µg), GEN: gentamicin (10 µg), TET: tetracycline (30 µg), CIP: ciprofloxacin (5 µg), CHL: chloramphenicol (30 µg), NIT: nitrofurantoin (300 µg) and SXT: trimethoprim/sulfamethoxazole (1.25/23.75 µg).

Substantial proportion of the isolates were highly resistant to commercially available antibiotics with 100% resistance demonstrated towards ampicillin comparable to previous study (Ma *et al.*, 2022). These authors reported higher resistance profile of 90.9% towards amoxicillin/clavulanate and ceftazidime while lower resistance towards meropenem (33.3%) and gentamicin (11.1%) was equally reported. However, in this study all the isolates were susceptible to ciprofloxacin. In agreement with our study, high resistance rates of CREC isolates to antibiotics commonly used in veterinary therapy including ampicillin, tetracycline and chloramphenicol have been reported (Zhang *et al.*, 2021). The high resistance rates correlate with other reports on isolates in Nigeria (Shettima *et al.*, 2020).

Table 4: Multiple antimicrobial resistance index of colistin-resistant *E. coli*

<table>
<thead>
<tr>
<th>Isolate code</th>
<th>Number of antibiotics</th>
<th>Resistance phenotype</th>
<th>MAR Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>AES1</td>
<td>9</td>
<td>CAZ/AZT/AMP/AMC/MEM/TET/CHL/NIT/SXT</td>
<td>0.82</td>
</tr>
<tr>
<td>HES4</td>
<td>8</td>
<td>CAZ/AZT/AMP/AMC/TET/CHL/NIT/SXT</td>
<td>0.73</td>
</tr>
<tr>
<td>HES30</td>
<td>8</td>
<td>CAZ/AZT/AMP/MEM/TET/CHL/NIT/SXT</td>
<td>0.73</td>
</tr>
<tr>
<td>CCS6</td>
<td>7</td>
<td>CAZ/AZT/AMP/AMC/TET/NIT/SXT</td>
<td>0.64</td>
</tr>
<tr>
<td>CCS11</td>
<td>7</td>
<td>CAZ/AMP/AMC/TET/CHL/NIT/SXT</td>
<td>0.64</td>
</tr>
<tr>
<td>HES15</td>
<td>7</td>
<td>CAZ/AMP/AMC/TET/CHL/NIT/SXT</td>
<td>0.64</td>
</tr>
<tr>
<td>CCS4</td>
<td>5</td>
<td>CAZ/AZT/AMP/AMC/SXT</td>
<td>0.46</td>
</tr>
<tr>
<td>AES8</td>
<td>5</td>
<td>AZT/AMP/AMC/TET/SXT</td>
<td>0.46</td>
</tr>
<tr>
<td>CCS10</td>
<td>5</td>
<td>CAZ/AMP/AMC/MEM/SXT</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Key: CAZ: ceftazidime (30 µg), AZT: aztreonam (30 µg), AMP: ampicillin (10 µg), AMC: amoxicillin-clavulanate (20/10 µg), MEM: meropenem (10 µg), TET: tetracycline (30 µg), CHL: chloramphenicol (30 µg), NIT: nitrofurantoin (300 µg) and SXT: trimethoprim/sulfamethoxazole (1.25/23.75 µg).
The multiple antibiotics resistance (MAR) profile of CREC is shown in Table 4. It was observed that 1/9 (11.1%) was resistant to nine antibiotics, 2/9 (22.2%) was resistant to eight antibiotics, 3/9 (33.3%) was resistant to seven antibiotics, and 3/9 (33.3%) was resistant to five antibiotics. The MAR profile of the CREC in this study ranged from 0.83 – 0.46. All the isolates demonstrated resistance to at least five antibiotics and demonstrated an MAR index ≥ 0.46.

Mishra et al. (2013) reported that MAR index ≥0.2 designates high-risk contamination sources while MAR index ≥0.4 is allied with fecal contamination source. Furthermore, MAR index >0.2 portrays isolate from high-risk sources of contamination with antibiotic misuse. Therefore, high MAR index in this study necessitates adequate surveillance and measures to curb the spread of AMR.

**Distribution of Phenotypic Virulence Factors**

The phenotypic virulence distribution of CREC was shown in Figure 3. In total the virulence factors observed were lipase activity 3/9 (33.3%), β-hemolytic activity 2/9 (22.2%) and gelatinase activity 2/9 (22.2%).

![Figure 3: Distribution of colistin-resistant E. coli phenotypic virulence factors.](image)

Lower rate of hemolysin production has been reported in previous studies (Mittal et al., 2014). Similarly, El-Mosallamy et al. (2015) have reported lower gelatinase activity. Hemolysin is a crucial virulence factor, which targets multiple pathways of the host and significantly influences infection (Beshiru & Igbinosa, 2018). Gelatinases are critical virulence factor of *E. coli* liable for numerous disease pathogenicity. Therefore, the linkage of isolates in this study to virulence factors further aggravates public and environmental health concern other than solely the spread of AMR.

**CONCLUSION**

The detection of CREC in both community and hospital environment allays a notable threat to public and environmental health. Therefore, routine AMR monitoring and surveillance towards critical antibiotics such as colistin classes of clinically relevant antimicrobials should
be implemented. These findings also highlight on the necessity for continuous studies to ascertain the factors that promote colistin resistance and the requisite to reinforce regulations specific to antimicrobial usage among farm personnel to reduce colistin resistance in the community. Public enlightenment campaign and proper education against indiscriminate antibiotics usage as animal feed and growth promoters is crucial to curtail the spread of AMR.

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CONFLICT OF INTEREST
The authors declare no competing interest.

REFERENCES


