Article

PAMJ One Health

Research

Antimicrobial resistance profile of *Escherichia coli isolates* and antibiotic use practices in pig farms in Ebonyi State, Southeast Nigeria

Amelia Eleazar, Samuel Nsikan Akpan, Theophilus Chibueze Muoka, Cromat Joseph Okoh, Peace Ifunanya Edokwe, Uduak Akpabio

Corresponding author: Samuel Nsikan Akpan, Department of Veterinary Public Health and Preventive Medicine, Joseph Sarwuan Tarkaa University, Makurdi, Nigeria. iykesamuel187@gmail.com

Received: 11 Mar 2025 - **Accepted:** 04 Oct 2025 - **Published:** 31 Oct 2025

Keywords: Antimicrobial resistance, *Escherichia coli*, antibiotic use, pig farms, zoonotic pathogens, public health

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Cite this article: Amelia Eleazar et al. Antimicrobial resistance profile of *Escherichia coli isolates* and antibiotic use practices in pig farms in Ebonyi State, Southeast Nigeria. PAMJ-One Health. 2025;18(13). 10.11604/pamj-oh.2025.18.13.47133

Available online at: https://www.one-health.panafrican-med-journal.com/content/article/18/13/full

Antimicrobial resistance profile of *Escherichia coli*isolates and antibiotic use practices in pig farms in Ebonyi State, Southeast Nigeria

Amelia Ndidi Eleazar[1], Samuel Nsikan Akpan[2,&], Theophilus Chibueze Muoka[1], Cromat Joseph Okoh[1], Peace Ifunanya Edokwe[3], Uduak Akpabio[4]

[1]Department of Animal Science, Alex Ekwueme Federal University, Ndufu-Alike, Ebonyi State, Nigeria, [2]Department of Veterinary Public Health and Preventive Medicine, Joseph Sarwuan Tarkaa University, Makurdi, Nigeria, [3]Department of Community Medicine, Faculty of Health Sciences, Ahmadu Bello University, Zaria, Nigeria, [4]Department of Veterinary Public Health and Preventive Medicine, Michael Okpara University of Agriculture, Umudike, Nigeria

[&]Corresponding author

Samuel Nsikan Akpan, Department of Veterinary Public Health and Preventive Medicine, Joseph Sarwuan Tarkaa University, Makurdi, Nigeria

Abstract

Introduction: *antimicrobial resistance (AMR) is a growing public health concern driven by the indiscriminate use of antibiotics in livestock production. This study aimed to assess the prevalence of AMR in Escherichia coli isolates from pig farms in Ebonyi State, Nigeria, and evaluate pig farmers' knowledge, attitudes, and practices (KAP) regarding antibiotic use.* ***Methods:*** *a cross-sectional study was conducted across pig farms, where fecal samples were collected from pigs (13 finishers, 36 piglets) and analyzed for bacterial isolates and antibiotic susceptibility. A structured questionnaire was also administered to assess pig farmers' KAPs on antibiotic use.* ***Results:*** *results showed the E. coli isolates exhibited multiple antibiotic resistance, with high resistance rates seen for Oxytetracycline (94.7%), Chloramphenicol (62.1%), and Colistin (59.5%). Furthermore, farmers showed poor knowledge of AMR (54%), negative attitudes toward responsible use (68%), and also administered antibiotics to pigs without veterinary consultation (92%). The chi-square analysis revealed significant associations between AMR prevalence and farmers' education level (χ^2= 7.72, p= 0.005), years of experience (χ^2= 30.52, p= 0.000), use of professional veterinary services (χ^2= 5.75, p= 0.016), overall attitude (χ^2= 6.05, p= 0.013), and antibiotic use (χ^2= 16.73, p= 0.000). Farms with higher antibiotic usage had significantly ($p < 0.05$) higher AMR prevalence.* ***Conclusion:*** *our findings highlight the need for stricter antibiotic use regulations, and targeted AMR education programs for pig farmers in Nigeria. We recommend improved funding for molecular studies to investigate antibiotic resistance genes (ARGs) of zoonotic pathogens in the animal health sector. Given the transboundary nature of AMR, enhanced surveillance is also critical for mitigating it's spread, to safeguard global public health.*

Introduction

Antimicrobial resistance (AMR) has emerged as a global health crisis with profound implications for both human and veterinary medicine [1,2]. The World Health Organization (WHO) has recognized AMR as one of the most pressing public health challenges, warning that if left unaddressed, it could lead to a post-antibiotic era where common infections become untreatable [3]. The widespread and often indiscriminate use of antibiotics in food animal production is a significant driver of AMR, as inappropriate antibiotic use exerts selective pressure on bacterial populations, facilitating the emergence and dissemination of resistant strains [4,5]. Pig production, a major component of global animal agriculture, is particularly associated with high antibiotic usage due to intensive farming practices, which often necessitate the use of antimicrobials for disease prevention, growth promotion, and treatment [6,7]. In Nigeria, particularly in Ebonyi State, pig farming plays a crucial role in rural livelihoods and food security [8,9]. However, the indiscriminate use of antibiotics, including self-prescription by farmers, poor adherence to withdrawal periods, and the absence of veterinary regulation, raises concerns regarding the emergence and spread of antimicrobial-resistant pathogens within pig farms and beyond [10,11]. The unregulated access to antibiotics further increases this problem, as farmers frequently procure antibiotics from open markets without prescriptions or professional guidance, thereby increasing the likelihood of suboptimal dosing, prolonged usage, and the emergence of multidrug-resistant bacterial strains [12,13].

The increasing burden of AMR poses a significant threat to public health, food safety, and animal productivity [14,15]. Bacteria such as *Escherichia coli, Salmonella spp.* and *Staphylococcus aureus*, commonly found in pigs, have been reported to exhibit resistance to multiple antibiotics, raising concerns about their potential transmission to humans through occupational exposure or consumption of contaminated pork products [16,17]. *Escherichia coli* is a common commensal bacterium in the gastrointestinal tract of animals and humans, but certain strains have developed resistance to multiple antibiotics, posing a significant public health threat [18,19]. Antibiotic-resistant *E. coli*, particularly those producing extended-spectrum beta-lactamases (ESBLs) and carrying resistance genes such as *mcr-1* for colistin resistance, have been increasingly detected in livestock, including pigs [20]. These resistant strains can spread through direct contact, contaminated food products, and the environment, facilitating the transmission of resistance genes to other bacterial pathogens [21]. Despite the global recognition of this issue, there remains a paucity of data on the prevalence of AMR in pig farms in Nigeria, particularly in Ebonyi State. Additionally, while various studies have documented the knowledge, attitudes, and practices (KAP) of livestock farmers regarding antibiotic use, few have focused specifically on pig farmers, whose production systems and management practices may differ from those of poultry and cattle farmers [22]. Without empirical data on the prevalence of AMR and the factors influencing antibiotic use among pig farmers, it is difficult to formulate targeted intervention strategies to combat the risks associated with antimicrobial misuse [23].

This study aims to bridge the knowledge gap by assessing the prevalence of antimicrobial resistance in pig production systems in Ebonyi State and evaluating the KAP of pig farmers regarding antibiotic usage. The findings of this study will contribute to ongoing national and global efforts to combat AMR by providing region-specific data that can inform regulatory frameworks and public health interventions. The global relevance of this study cannot be overemphasized, as AMR is a transboundary issue that extends beyond individual farms or countries [24]. Resistant bacterial strains have the potential to spread across borders through international trade, travel, and environmental pathways, necessitating a concerted, One Health approach to tackling the problem [25,26]. Sub-Saharan Africa has been identified as a high-risk region for AMR due to the widespread misuse of antibiotics, weak enforcement of regulations, and limited surveillance systems [7]. Given that Nigeria is one of the largest producers and consumers of livestock in Africa [27], addressing antibiotic misuse in pig production will be instrumental in reducing the risk of drug-resistant infections in both animals and humans [28].

Methods

Study area

The study was carried out across pig farms in Ebonyi State, South-Eastern Nigeria, geographically located between latitude 6.2649°N and longitude 8.0137°E. The vegetation of the region is predominantly derived from the savannah, with mean annual low temperature of 25.87°C and relative humidity between 42.84-70.53% [29].

The study was conducted in two phases: 1) bacteriological study; 2) questionnaire survey.

Bacteriological study

Study design: a cross-sectional study design was used, where pigs were purposively selected, based on the population sizes of the production stages available in each herd. A total of 49 pigs (13 finishers and 36 piglets) were sampled.

Sample collection and processing: faecal samples were collected from selected pigs, labeled appropriately and transported to the Microbiology laboratory of the Department of Microbiology, Alex Ekwueme Federal University, Ebonyi State. Samples were inoculated and incubated at 37°C overnight for pre-enrichment, after which suspected organisms were isolated and preserved in slopes at 4°C to 8°C [30].

Bacterial identification: streak method was used to get discrete colonies of the bacteria growth on Eosin Methylene Blue agar. The inoculated plates were incubated at 37°C for 24 hours. *Escherichia coli* growth was identified and isolated from the primary culture based on its characteristic metallic green sheen appearance [30].

Antibiotic susceptibility testing: the isolated organisms were streaked onto a nutrient agar plate for susceptibility testing. Antibiotic discs were placed on the plates at different intervals to monitor zones of inhibition. The plates were incubated at 37°C for 24 h. The zones of inhibition were measured using a meter rule and quantified as either (+), (+), or (+) based on the size of the clearance [30].

Questionnaire survey

The survey was carried out in 11 Local Government Areas which were purposively selected based on the availability and accessibility of pig farms.

Data collection: pig farmers (n= 50) were purposively selected based on their willingness to allow themselves and their farms to be included in the study. Data was collected using structured questionnaires administered to farmers. Also, focus group discussions (FGD) and in-depth interviews were used to triangulate and clarify the points that appeared not to have been sufficiently addressed by the respondents.

Data analysis: data were coded and entered into Microsoft Excel spread sheets. Descriptive data were computed to define farm characteristics and to determine AMR knowledge, attitudes, and practices. Herd sizes were classified into small (1-100 pigs), medium (101- 200 pigs), and large-scale farmers (>200 pigs). Each question had either zero or one point, resulting in the maximum obtainable points of four, distributed according to the number of questions. Respondents that had 0-1 point and 2-3 points were rated inadequate and adequate respectively. Same process was used to assess the farmers' attitude to AMR. The maximum obtainable points of seven (7) was distributed according to the number of questions. Respondents that had 0-3 points and 4-7 points were rated negative and positive respectively. Pearson's Chi-square tests were used to examine possible associations between farm characteristics, level of knowledge and attitude of farmers on AMR, antimicrobial use, and prevalence of resistance to different types of antibiotics. Data was analysed using IBM SPSS Statistics (version 25.0) software, and p-value of < 0.05 was considered significant.

Results

The prevalence of resistant *E. coli* isolates to tested antibiotics

The *E. coli* isolates were resistant to eight (8) antibiotics, with a prevalence of resistance greater than 20%. These included Clarithromycin (35.7%), Nitrofurantoin (44.7%), Chloramphenicol (62.1%), Amoxicillin (41.2%), Streptomycin (32.4%), Oxytetracycline (94.7%), Tylosin (48.6%), Colistin (59.5%), and multiple drug resistant (MDR) (59.2%) (Figure 1).

Farm and respondents' demographic characteristics

Majority of respondents (88%) were farm owners, while 12% were farm workers. Amongst them, 58% were males, with 42% as females. For occupational engagement, 52% were solely into pig farming, 26% combined pig farming with trading, and 20% combined pig farming with public service. The age distribution showed that 62% were between 25-45 years, while 38% were > 45 years. Majority (76%) had obtained tertiary education, while 24% had education below the tertiary levels. Pig farming experience varied, with 68% respondents having 1-10 years of experience and 32%) having >10 years of experience. Farm classification based on herd size showed that 40% respondents were small-scale farmers (1-100 pigs), 38%) were medium-scale farmers (101-200 pigs), and 11 22% were large-scale farmers (more than 200 pigs). Only 38% of the farms used regular professional veterinary services, while 62% did not (Table 1).

Assessment of farmer's knowledge on antibiotics use and AMR

This is presented in Table 2. A significant proportion of farmers (42%) reported they had heard of AMR, while (58%) said they had not. Among those who were aware, 36% heard through seminars/workshops, 14% through pig farmers' forums and social media, and 22% through radio/TV programs. Also, 46% had received training on antibiotic use, and 46% were aware of the risks and consequences of antibiotic misuse and AMR. Overall, 54% respondents were rated as having inadequate knowledge of antibiotic use and AMR.

Farmers' attitudes toward antibiotic use and AMR in pig farms

Out of 50 respondents, 78% believed that pigs grow better and healthier when given antibiotics, and 62% respondents said it was important for their pigs to receive antibiotics when sick. Additionally, 68% believed antibiotics improved pig production, and 52% believed it did not matter who prescribed and administered antibiotics. Cost concerns also influenced veterinary consultation, with 58% respondents considering professional veterinary services too expensive and opting for alternatives, whereas 42% preferred professional veterinary services. It was not economical for 60% respondents to take samples from sick pigs before administering antibiotics. Furthermore, 78% respondents considered antibiotic susceptibility testing a waste of time and resources, whereas 22% disagreed. Overall, 68% respondents exhibited a negative attitude toward antibiotic use and AMR (Table 2).

Pig farmers' practice on antibiotics use and antimicrobial resistance

Majority of respondents (92%) acknowledged they used antibiotics for their pigs, while 8% did not. Decision-making on antibiotic type and dosage varied: 30% decided themselves, 24% relied on other farmers, 16% followed drug vendors' recommendations, and 30% consulted veterinarians. Regarding the initiation of antibiotic administration, 14% respondents started from 1 week of age, while 38%, 28%, and 20% began at 2, 3, and > 4 weeks of age, respectively. Most respondents (76%) used antibiotics for disease prevention and weight gain, whereas 24% used them strictly for treating observed diseases. On withdrawal periods before selling pigs for slaughter, 24% waited 0-14 days after antibiotic administration, while 76% waited > 14 days.

Antibiotics commonly used by the pig farmers

Six (6) injectable antibiotics were used by the farmers. These were oxytetracycline (34%) and gentamycin (24%), followed by penicillin/streptomycin combination (18%), enrofloxacin (12%), tylosin (8%), and colistin (4%) (Figure 2).

Effect of farmers' characteristics, knowledge, attitude, and practices on the prevalence of AMR in pig farms

Age: thirty-one (31) of the forty-nine (49) resistant *E. coli* isolates were from farms owned by farmers aged 25-45 years, with 64.5% classified under the low-prevalence (0-20%) AMR group, while 35.5% were in the high-prevalence (>20%) group. The remaining 18 isolates were from farms owned by farmers over 45 years, all of which (100%) fell into the high-prevalence (>20%) antimicrobial resistance group, with none in the low-prevalence category. Antimicrobial resistance was significantly influenced by farmers' age, as farms owned by those over 45 years exhibited a significantly higher resistance rate (100%) compared to farms owned by farmers aged 25-45 years (35.5%) (χ^2= 17.04, df = 1, p = 0.000).

Gender: out of the 49 *E. coli* resistant isolates studied, 41 were from farms managed by males, with 41.5% classified under the low-prevalence (0-20%) AMR group, while 58.5% were in the high-prevalence (>20%) group. Among the 8 isolates from farms managed by females, 25.0% belonged to the low-prevalence (0-20%) group, and 75.0% were in the high-prevalence (>20%) group. Antimicrobial resistance was not significantly different (χ^2= 0.23, *df*= 1, p= 0.63) between farms managed by male and female pig farmers.

Level of education: out of the 49 *E. coli* resistant isolates examined, 11 were from farms managed by farmers with education below the tertiary level, all of which (100%) belonged to the high-prevalence (>20%) AMR group, with none in the low-prevalence (0-20%) category. Among the 38 isolates from farms owned by farmers with tertiary education, 52.6% were in the low-prevalence (0-20%) group, while 47.4% were in the high-prevalence (>20%) group. Antimicrobial resistance was significantly influenced by farmers' education level (χ^2= 7.72, *df*= 1, *p*= 0.005).

Years of pig farming experience: results showed thirty-four (34) resistant *E. coli* isolates were from farms managed by farmers with 1-10 years of pig farming experience, with 11.8% classified under the low-prevalence (0-20%) AMR group, while 88.2% were in the high-prevalence (>20%) group. Among the 15 isolates from farms owned by farmers with >10 years of experience, all (100%) belonged to the low-prevalence (0-20%) group, with none in the high-prevalence category. Antimicrobial resistance was significantly influenced by farmers' years of experience (χ^2= 30.52, *df*= 1, *p*= 0.000).

Level of knowledge: out of the 49 *E. coli* resistant isolates studied, 27 were from farms owned by farmers with inadequate knowledge of antibiotic use and AMR, with 29.6% classified under the low-prevalence (0-20%) AMR group, while 19 (70.4%) were in the high-prevalence (>20%) group. Among the 22 isolates from farms owned by farmers with adequate AMR knowledge, 54.5% belonged to the low-prevalence (0-20%) group, while 45.5% were in the high-prevalence (>20%) group. However, antimicrobial resistance did not differ significantly (χ^2= 2.17, *df*= 1, *p*= 0.14).

Overall attitude: a substantial number of *E. coli* resistant isolates studied (33) were from farms where farmers had a negative overall attitude toward antimicrobial use and AMR. Among these, 27.3% belonged to the low-prevalence (0-20%) AMR group, while 72.7% were in the high-prevalence (>20%) group. Conversely, among the 16 isolates from farms where farmers had a positive overall attitude, 68.8% were in the low-prevalence (0-20%) group, while 31.2% were in the high-prevalence (>20%) group. Antimicrobial resistance was significantly influenced by farmers' overall attitude (χ^2= 6.05, *df*= 1, *p*= 0.013).

Herd size: analysis revealed twelve (12) resistant *E. coli* isolates were from small-scale farms (1-100 pigs), with 8.3% classified under the low-prevalence (0-20%) AMR group, while 11 (91.7%) were in the high-prevalence (>20%) group. The remaining 37 isolates were from medium-scale and large-scale farms, where 12 (44.4%) and 4 (40.0%) belonged to the low-prevalence group, respectively. Antimicrobial resistance was not significantly associated with herd size (χ^2= 4.94, *df*= 2, *p*= 0.08).

Regular use of professional veterinary services: results revealed twenty-four (24) resistant *E. coli* isolates were from farms that did not use professional veterinary services regularly, with 12.5% classified under the low-prevalence (0-20%) group, and 87.5% in the high-prevalence (>20%) group. Among the 25 isolates from farms that used regular professional veterinary services, 64.0% belonged to the low-prevalence (0-20%) group, while 36.0% were in the high-prevalence (>20%) group. Antimicrobial resistance was significantly influenced by the use of regular professional veterinary services (χ^2= 5.75, *df*= 1, *p*= 0.016).

Production group: results showed that thirty-six (36) resistant *E. coli* isolates were from finishers, with 44.4% classified under the low-prevalence (0-20%) AMR group, while 20 (55.6%) were in the high-prevalence (>20%) group. Among the 13 isolates obtained from piglets, 23.1% belonged to the low-prevalence (0-20%) group, while 76.9% were in the high-prevalence (>20%) group. Antimicrobial resistance was not significantly different (χ^2= 1.05, *df*= 1, *p*= 0.30) between finishers and piglets.

Antibiotic use: ten (10) resistant isolates were from pig farms that did not use antibiotics, all of which (100.0%) belonged to the low-prevalence (0-20%) AMR group. Among the 39 isolates from farms that used antibiotics, 23.1% were in the low-prevalence group, while 76.9% were in the high-prevalence group. Antimicrobial resistance was significantly influenced by antibiotic use [χ^2 = 16.73, *df*= 1, *p*= 0.000] (Table 3).

Discussion

The emergence of AMR in *E. coli* is a growing public health concern, particularly in livestock production, where extensive antibiotic use exerts selective pressure, leading to the proliferation of resistant strains [14]. Multidrug-resistant *E. coli* strains have been reported in food animals, with resistance to critical antibiotics such as beta-lactams, tetracyclines, and fluoroquinolones [19]. The high prevalence of AMR in *E. coli* isolates to Oxytetracycline (94.7%), Chloramphenicol (62.1%), and Colistin (59.5%) shows the growing AMR threat in animal production systems. This result aligns with global concerns about the misuse of antibiotics in livestock farming, which has been identified as a major driver of AMR in both developed and developing nations [4,5]. The resistance to Oxytetracycline, one of the most frequently used antibiotics in livestock farming, is consistent with reports from other studies in Nigeria [31,32], South Africa [33] and Thailand [34]. Tetracyclines are often misused due to their affordability, broad-spectrum activity, and easy accessibility without prescription [35,36].

This trend is alarming because tetracyclines are frequently used in human medicine, indicating its declining efficacy in veterinary settings could have far-reaching consequences for human health [37]. The resistance to Chloramphenicol, an antibiotic restricted in food animal production due to its potential to cause aplastic anemia in humans, also calls for concern. The presence of resistant *E. coli* strains suggests that farmers may still be using Chloramphenicol illegally or that environmental contamination from past use is sustaining resistant bacterial populations [38]. Similarly, the resistance to Colistin is particularly worrisome, as it is considered a last-resort antibiotic for treating multidrug-resistant infections in humans. The global spread of Colistin-resistant bacteria, particularly those carrying the *mcr*-1 gene, has been a major public health concern, as it limits treatment options for life-threatening infections [39]. Overall, there are concerns about the potential for transmission of these resistant strains to humans through direct contact, environmental exposure, or consumption of contaminated pork products [40].

The study's findings on the KAP of pig farmers reveal significant gaps in knowledge and attitudes toward antibiotic use and AMR. Despite the growing global awareness of AMR, more than half (54%) of the respondents had inadequate knowledge of AMR, while 68% exhibited negative attitudes toward responsible antibiotic use. This suggests that many pig farmers do not fully understand the consequences of antibiotic misuse or the mechanisms through which resistance develops. In many low- and middle-income countries, including Nigeria, the unregulated access to antibiotics allows farmers to purchase and administer these drugs without proper guidance [41-43]. This practice leads to inappropriate dosing, extended treatment durations, and increased selection pressure for resistant bacteria [22]. In contrast, high-income countries have stricter regulations on antibiotic use in animal farming, with mandatory veterinary oversight and restrictions on medically important antibiotics [44]. The lack of such controls in Nigeria highlights the need for strict regulatory frameworks to prevent the risks of AMR. Furthermore, the finding that 78% of farmers considered antibiotic susceptibility testing a waste of time and money is a perception which supports empirical antibiotic use without laboratory confirmation [22]. In many developed countries, routine antibiotic sensitivity testing is standard practice prior to prescription, ensuring targeted treatment and minimizing resistance development [45,46]. The absence of this practice in Nigeria reflects systemic gaps in veterinary healthcare infrastructure and highlights the need for educational interventions to change farmers' perceptions.

Farmers with tertiary education had a lower prevalence of AMR on their farms compared to those with lower education levels. This suggests that formal education enhances awareness of antimicrobial stewardship, and the risks associated with antibiotic misuse [47-49]. Similar findings have been reported, indicating that investing in farmer education could be a key strategy in AMR mitigation [50]. Furthermore, farmers with >10 years of experience had lower AMR prevalence on their farms. This finding could be attributed to their accumulated knowledge of best practices in disease prevention and biosecurity. However, it also raises questions about whether younger farmers are more reliant on antibiotics due to changes in farming intensification and commercialization. Farms that regularly used professional veterinary services had significantly lower AMR prevalence. Hence, making veterinary services more accessible to farmers could be a viable intervention for reducing AMR.

Farmers with inadequate knowledge had a higher prevalence of resistant *E. coli* isolates on their farms. This aligns with previous research [22,43] which stated that a lack of awareness about AMR and antibiotic stewardship contributes to the misuse of antimicrobials, leading to selective pressure for resistant bacterial strains. Farmers with limited knowledge may fail to recognize the consequences of inappropriate antibiotic uses, such as subtherapeutic dosing, prolonged treatment duration, and the routine use of antibiotics for non-therapeutic purposes (eg. growth promotion), all of which accelerates the development of resistance. However, the lack of a statistically significant association in this study suggests that while knowledge could play a role, it was not a sufficient determinant of AMR prevalence.

Furthermore, farmers with negative attitude toward antibiotic stewardship had significantly higher AMR prevalence on their farms. This indicates that farmers' beliefs and perceptions significantly influence their antibiotic usage patterns [47]. For example, a large proportion (78%) of farmers in this study believed that antibiotic susceptibility testing was a waste of time and money, which likely contributed to the empirical and indiscriminate use of antibiotics. Additionally, many farmers relied on personal experience or peer recommendations rather than professional veterinary advice, reinforcing the cycle of irrational antibiotic use. Similar trends have been reported in sub-Saharan Africa, where economic constraints and cultural practices influence farmers' willingness to adopt responsible antibiotic use practices [23]. This underscores the need for behavior-change interventions that not only improve knowledge but also shift perceptions regarding AMR.

The association between herd size and AMR prevalence was not statistically significant ($p = 0.08$). While some studies suggest that larger herds may have higher AMR prevalence due to increased antibiotic usage for disease prevention and growth promotion [34], the lack of significance in this study suggests that factors such as management practices, biosecurity measures, and access to veterinary services may play a more dominant role in determining AMR levels. Hence, our finding that small-scale farms had a higher percentage of resistant *E. coli* isolates compared to medium and large-scale farms may be due to weaker biosecurity measures and the frequent use on antibiotics as a primary disease control strategy.

The high resistance to oxytetracycline, chloramphenicol, and colistin observed in this study further supports the notion that prolonged exposure to these antibiotics contributes to the persistence and spread of resistant bacterial strains. Non-adherence to withdrawal periods was another critical factor influencing AMR prevalence. However, economic pressures often drive farmers to disregard withdrawal periods, prioritizing quick market returns over long-term health implications. The rise of resistant *E. coli* strains in Nigerian pig farms as also seen in our study results has direct implications for public health, given their potential for transmission to humans through contaminated food products, occupational exposure, or environmental contamination.

Conclusion

There is a strong association between pig farmers' perceptions and attitudes to antibiotic use, and the multiple antimicrobial resistance status of *E. coli* isolates from the farms. These findings emphasize the need for increased monitoring of antibiotic use, and farmer education to curb AMR in the livestock sector. Given the global nature of AMR, addressing this issue at the local level is also crucial for preventing the eventual spread of novel resistant *E. coli* strains internationally. A One Health approach is essential in tackling AMR to safeguard public health in Nigeria.

What is known about this topic

- *Multidrug-resistant E. coli strains have been reported in food animals, with resistance to critical antibiotics such as beta-lactams, tetracyclines, and fluoroquinolones; which poses significant challenges to human and animal health;*
- *In many low- and middle-income countries, including Nigeria, the unregulated access to antibiotics allows farmers to purchase and administer these drugs without proper veterinary guidance.*

What this study adds

- *Our study showed significant associations between AMR prevalence and several farmers' characteristics, signifying the complex interplay between knowledge, experience, and antibiotic use;*
- *While it plays a role, knowledge alone is not a sufficient determinant of AMR prevalence; hence, other behavioral and systemic drivers must also be considered.*

Competing interests

The authors declare no competing interests.

Authors' contributions

Conceptualization and data curation: Amelia Ndidi Eleazar. Investigation: Amelia Ndidi Eleazar, Theophilus Chibueze Muoka, Cromat Joseph Okoh. Writing-original draft: Amelia Ndidi Eleazar, Theophilus Chibueze Muoka, Cromat Joseph Okoh. Funding: Amelia Ndidi Eleazar, Samuel Nsikan Akpan. Visualization: Amelia Ndidi Eleazar, Samuel Nsikan Akpan. Formal analysis: Samuel Nsikan Akpan, Uduak Akpabio, Peace Ifunanya Edokwe, Theophilus Chibueze Muoka, Cromat Joseph Okoh. Writing-review and editing: Uduak Akpabio, Peace Ifunanya Edokwe. All authors have read and agreed to the final manuscript.

Acknowledgments

The authors wish to thank all the farmers who participated in this study and those that own the farms where samples were collected. Also, we thank the laboratory staff of the Department of Microbiology, Alex Ekwueme Federal University, Ebonyi State, for their technical expertise and assistance.

Tables and figures

Table 1: demographic characteristics of selected farms and respondents

Table 2: attitudes of pig farmers to antibiotics use and antimicrobial resistance

Table 3: effect of farmers' characteristics and their overall knowledge, attitude and practice on the prevalence of AMR

Figure 1: prevalence of resistant *E. coli* isolates to tested antibiotics

Figure 2: proportion of commonly used antibiotics by the pig farmers

References

1. Caneschi A, Bardhi A, Barbarossa A, Zaghini A. The Use of Antibiotics and Antimicrobial Resistance in Veterinary Medicine, a Complex Phenomenon: A Narrative Review. Antibiotics (Basel). 2023 Mar 1;12(3): 487. **PubMed**| **Google Scholar**
2. Ahmed SK, Hussein S, Qurbani K, Ibrahim RH, Fareeq A, Mahmood KA *et al*. Antimicrobial resistance: Impacts, challenges, and future prospects. Journal of Medicine, Surgery, and Public Health. 2024 Apr 1;2: 100081. **Google Scholar**
3. World Health Organization. **Antimicrobial resistance**. WHO. November 2023. Accessed 14 February 2025.
4. Samtiya M, Matthews KR, Dhewa T, Puniya AK. Antimicrobial Resistance in the Food Chain: Trends, Mechanisms, Pathways, and Possible Regulation Strategies. Foods. 2022 Sep 22;11(19): 2966. **PubMed**
5. Irfan M, Almotiri A, AlZeyadi ZA. Antimicrobial Resistance and Its Drivers-A Review. Antibiotics (Basel). 2022 Oct 5;11(10): 1362. **PubMed**| **Google Scholar**
6. Lekagul A, Tangcharoensathien V, Yeung S. Patterns of antibiotic use in global pig production: A systematic review. Vet Anim Sci. 2019 Apr 6;7: 100058. **PubMed**| **Google Scholar**
7. Mulchandani R, Wang Y, Gilbert M, Van Boeckel TP. Global trends in antimicrobial use in food-producing animals: 2020 to 2030. PLOS Glob Public Health. 2023 Feb 1;3(2): e0001305. **PubMed**| **Google Scholar**
8. Okoronkwo MO, Okechukwu SO. Economics of Pig Production in Ezza North Local Government Area of Ebonyi State, Nigeria. Asian Journal of Agricultural Extension, Economics & Sociology. 2018 Dec 20;29(1): 1-1. **Google Scholar**
9. Omodele T, Okere IA, Oladele-Bukola MO, Omole AJ, Oyegbami A. Application of GIS in pig production system in Nigeria. African Journal of Agricultural Research. 2019 Aug 14;14(25): 1042-50. **Google Scholar**
10. Oloso NO, Fagbo S, Garbati M, Olonitola SO, Awosanya EJ, Aworh MK *et al*. Antimicrobial Resistance in Food Animals and the Environment in Nigeria: A Review. Int J Environ Res Public Health. 2018 Jun 17;15(6): 1284. **PubMed**| **Google Scholar**
11. Arama UO, Oduoye MO, Akanbi-Hakeem B, Khan M, Wechuli P, Aliyu A. A systematic review of One Health perspective on the use of antimicrobials in Nigeria. CABI One Health. 2025 Jan 28;4(1): 0004. **Google Scholar**
12. Loosli K, Nasuwa F, Melubo M, Mnzava K, Matthews L, Mshana SE *et al*. Exploring drivers of self-treatment with antibiotics in three agricultural communities of northern Tanzania. Antimicrob Resist Infect Control. 2024 Aug 29;13(1): 94. **PubMed**| **Google Scholar**
13. Otaigbe II, Elikwu CJ. Drivers of inappropriate antibiotic use in low- and middle-income countries. JAC Antimicrob Resist. 2023 May 31;5(3): dlad062. **PubMed**| **Google Scholar**

14. Samreen, Ahmad I, Malak HA, Abulreesh HH. Environmental antimicrobial resistance and its drivers: a potential threat to public health. J Glob Antimicrob Resist. 2021 Dec;27: 101-111. **PubMed**| **Google Scholar**
15. Almansour AM, Alhadlaq MA, Alzahrani KO, Mukhtar LE, Alharbi AL, Alajel SM. The Silent Threat: Antimicrobial-Resistant Pathogens in Food-Producing Animals and Their Impact on Public Health. Microorganisms. 2023 Aug 22;11(9): 2127. **PubMed**| **Google Scholar**
16. Ikwap K, Gertzell E, Hansson I, Dahlin L, Selling K, Magnusson U *et al*. The presence of antibiotic-resistant Staphylococcus spp. and Escherichia coli in smallholder pig farms in Uganda. BMC Vet Res. 2021 Jan 18;17(1): 31. **PubMed**| **Google Scholar**
17. Lunha K, Leangapichart T, Jiwakanon J, Angkititrakul S, Sunde M, Järhult JD *et al*. Antimicrobial Resistance in Fecal *Escherichia coli*from Humans and Pigs at Farms at Different Levels of Intensification. Antibiotics (Basel). 2020 Sep 30;9(10): 662. **PubMed**| **Google Scholar**
18. Gambushe SM, Zishiri OT, El Zowalaty ME. Review of *Escherichia coli*O157: H7 Prevalence, Pathogenicity, Heavy Metal and Antimicrobial Resistance, African Perspective. Infect Drug Resist. 2022 Aug 23;15: 4645-4673. **PubMed**| **Google Scholar**
19. Puvača N, de Llanos Frutos R. Antimicrobial resistance in Escherichia coli strains isolated from humans and pet animals. Antibiotics. 2021; 10(1): 69. **PubMed**| **Google Scholar**
20. Valiakos G, Kapna I. Colistin resistant mcr genes prevalence in livestock animals (swine, bovine, poultry) from a multinational perspective. A systematic review. Vet Sci. 2021; 8(11): 265. **PubMed**| **Google Scholar**
21. Trongjit S, Assavacheep P, Samngamnim S, My TH, An VTT, Simjee S, Chuanchuen R. Plasmid-mediated colistin resistance and ESBL production in Escherichia coli from clinically healthy and sick pigs. Sci Rep. 2022; 12(1): 2466. **PubMed**| **Google Scholar**
22. Adebowale OO, Adeyemo FA, Bankole N, Olasoju M, Adesokan HK, Fasanmi O *et al*. Farmers' Perceptions and Drivers of Antimicrobial Use and Abuse in Commercial Pig Production, Ogun State, Nigeria. Int J Environ Res Public Health. 2020 May 20;17(10): 3579. **PubMed**| **Google Scholar**
23. Caudell MA, Dorado-Garcia A, Eckford S, Creese C, Byarugaba DK, Afakye K *et al*. Towards a bottom-up understanding of antimicrobial use and resistance on the farm: A knowledge, attitudes, and practices survey across livestock systems in five African countries. PLoS One. 2020 Jan 24;15(1): e0220274. **PubMed**| **Google Scholar**
24. Cella E, Giovanetti M, Benedetti F, Scarpa F, Johnston C, Borsetti A *et al*. Joining Forces against Antibiotic Resistance: The One Health Solution. Pathogens. 2023 Aug 23;12(9): 1074. **PubMed**| **Google Scholar**
25. Patel J, Harant A, Fernandes G, Mwamelo AJ, Hein W, Dekker D *et al*. Measuring the global response to antimicrobial resistance, 2020-21: a systematic governance analysis of 114 countries. Lancet Infect Dis. 2023 Jun;23(6): 706-718. **PubMed**| **Google Scholar**
26. Zhang T, Nickerson R, Zhang W, Peng X, Shang Y, Zhou Y *et al*. The impacts of animal agriculture on One Health-Bacterial zoonosis, antimicrobial resistance, and beyond. One Health. 2024 May 8;18: 100748. **PubMed**| **Google Scholar**

27. Tyohen BI, Mbakpenev TJ. Impact of livestock farming on economic growth in Nigeria. UMM Journal of Accounting and Financial Management. 2023 Oct 15;3(1): 124-50. **Google Scholar**
28. Raufu IA, Ahmed OA, Aremu A, Ameh JA, Timme RE, Hendriksen RS *et al*. Antimicrobial and Genomic Characterization of Salmonella Nigeria from Pigs and Poultry in Ilorin, North-central, Nigeria. J Infect Dev Ctries. 2021 Dec 31;15(12): 1899-1909. **PubMed**| **Google Scholar**
29. Obiahu OH, Yan Z, Uchenna UB. Spatiotemporal analysis of land use land cover changes and built-up expansion projection in predominantly dystric nitosol of Ebonyi state, Southeastern, Nigeria. Environmental Challenges. 2021 Aug 1;4: 100145. **Google Scholar**
30. CLSI. Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animal; Approved standards-Fourth edition. Wayne, Pennsylvania, USA. 2013.
31. Adenipekun EO, Jackson CR, Oluwadun A, Iwalokun BA, Frye JG, Barrett JB, Hiott LM, Woodley TA. Prevalence and antimicrobial resistance in Escherichia coli from food animals in Lagos, Nigeria. Microb Drug Resist. 2015; 21(3): 358-365. **PubMed**| **Google Scholar**
32. Olorunleke SO, Kirchner M, Duggett N, AbuOun M, Okorie-Kanu OJ, Stevens K, Card RM, Chah KF, Nwanta JA, Brunton LA, Anjum MF. Molecular characterization of extended spectrum cephalosporin resistant Escherichia coli isolated from livestock and in-contact humans in Southeast Nigeria. Front Microbiol. 2022; 13: 937968. **PubMed**| **Google Scholar**
33. Abdalla SE, Abia ALK, Amoako DG, Perrett K, Bester LA, Essack SY. From Farm-to-Fork: *E. coli* from an Intensive Pig Production System in South Africa Shows High Resistance to Critically Important Antibiotics for Human and Animal Use. Antibiotics (Basel). 2021 Feb 10;10(2): 178. **PubMed**| **Google Scholar**
34. Ström G, Halje M, Karlsson D, Jiwakanon J, Pringle M, Fernström LL *et al*. Antimicrobial use and antimicrobial susceptibility in Escherichia coli on small- and medium-scale pig farms in north-eastern Thailand. Antimicrob Resist Infect Control. 2017 Jul 17;6: 75. **PubMed**| **Google Scholar**
35. Aceijas C, Selvaraj DH. Global availability and use of over the counter antibiotics (OTCA): a systematic literature review. Acta Sci Dental Sci. 2019;3: 92-104. **Google Scholar**
36. Chandra P, Mk U, Ke V, Mukhopadhyay C, U DA, M SR, V R. Antimicrobial resistance and the post antibiotic era: better late than never effort. Expert Opin Drug Saf. 2021 Nov;20(11): 1375-1390. **PubMed**| **Google Scholar**
37. Ifedinezi OV, Nnaji ND, Anumudu CK, Ekwueme CT, Uhegwu CC, Ihenetu FC *et al*. Environmental Antimicrobial Resistance: Implications for Food Safety and Public Health. Antibiotics (Basel). 2024 Nov 14;13(11): 1087. **PubMed**| **Google Scholar**
38. Okaiyeto SA, Sutar PP, Chen C, Ni JB, Wang J, Mujumdar AS *et al*. Antibiotic resistant bacteria in food systems: current status, resistance mechanisms, and mitigation strategies. Agric Commun. 2024;2: 100027. **Google Scholar**
39. Hussein NH, Al-Kadmy IMS, Taha BM, Hussein JD. Mobilized colistin resistance (mcr) genes from 1 to 10: a comprehensive review. Mol Biol Rep. 2021 Mar;48(3): 2897-2907. **PubMed**| **Google Scholar**

40. Anyanwu MU, Marrollo R, Paolucci M, Brovarone F, Nardini P, Chah KF *et al*. Isolation and characterisation of colistin-resistant Enterobacterales from chickens in Southeast Nigeria. J Glob Antimicrob Resist. 2021; 26: 93-100. **PubMed**| **Google Scholar**
41. Ajekiigbe VO, Ogieuhi IJ, Odeniyi TA, Ogunleke PO, Olatunde JT, Babalola AV *et al*. Understanding Nigeria's antibiotic resistance crisis among neonates and its future implications. Discov Public Health. 2025; 22(1): 28. **Google Scholar**
42. Iskandar K, Molinier L, Hallit S, Sartelli M, Catena F, Coccolini F *et al*. Drivers of Antibiotic Resistance Transmissionin Low- and Middle-Income Countriesfrom a "One Health" Perspective-A Review. Antibiotics (Basel). 2020 Jul 1;9(7): 372. **PubMed**| **Google Scholar**
43. Wilkinson A, Ebata A, MacGregor H. Interventions to Reduce Antibiotic Prescribing in LMICs: A Scoping Review of Evidence from Human and Animal Health Systems. Antibiotics (Basel). 2018 Dec 22;8(1): 2. **PubMed**
44. Pitchforth E, Gemma-Clare A, Smith E, Taylor J, Rayner T, Lichten C *et al*. What and how can we learn from complex global problems for antimicrobial resistance policy? A comparative study combining historical and foresight approaches. J Glob Antimicrob Resist. 2023 Dec;35: 110-121. **PubMed**| **Google Scholar**
45. Muteeb G, Rehman MT, Shahwan M, Aatif M. Origin of Antibiotics and Antibiotic Resistance, and Their Impacts on Drug Development: A Narrative Review. Pharmaceuticals (Basel). 2023 Nov 15;16(11): 1615. **PubMed**| **Google Scholar**
46. van Belkum A, Bachmann TT, Lüdke G, Lisby JG, Kahlmeter G, Mohess A *et al*. Developmental roadmap for antimicrobial susceptibility testing systems. Nat Rev Microbiol. 2019; 17(1): 51-62. **PubMed**| **Google Scholar**
47. Akande-Sholabi W, Ajamu AT. Antimicrobial stewardship: Assessment of knowledge, awareness of antimicrobial resistance and appropriate antibiotic use among healthcare students in a Nigerian University. BMC Med Educ. 2021 Sep 10;21(1): 488. **PubMed**| **Google Scholar**
48. Satterfield J, Miesner AR, Percival KM. The role of education in antimicrobial stewardship. J Hosp Infect. 2020 Jun;105(2): 130-141. **PubMed**| **Google Scholar**
49. Mallah N, Orsini N, Figueiras A, Takkouche B. Education level and misuse of antibiotics in the general population: a systematic review and dose-response meta-analysis. Antimicrob Resist Infect Control. 2022 Feb 3;11(1): 24. **PubMed**| **Google Scholar**
50. Fuller W, Kapona O, Aboderin AO, Adeyemo AT, Olatunbosun OI, Gahimbare L *et al*. Education and awareness on antimicrobial resistance in the WHO African region: a systematic review. Antibiotics. 2023; 12(11): 1613. **PubMed**| **Google Scholar**

Table 1: demographic characteristics of selected farms and respondents		
Variables	**Frequency**	**Percentage (%)**
Status		
Farm owner	44	88
Farm worker	6	12
Gender		
Male	29	58
Female	21	42
Occupation		
Pig farming only	26	52
Pig farming cum trading	13	26
Pig farming cum public servant	10	20
Other	1	2
Age (Years)		
26 –35	10	20
36 – 45	21	42
46 – 55	19	38
Highest level of education		
Primary	8	16
Secondary	17	34
Tertiary	25	50
Years of experience		
1 – 5	12	24
6 – 10	20	40
Above 10	18	36
Herd size		
1 – 100	20	40
101 – 200	19	38
Over 200	11	22
Farm has regular professional veterinary services		
Yes	19	38
No	31	62

Table 2: pig farmers' attitude on antibiotics used and AMR		
Variables	**Frequency**	**Percentage (%)**
Do you believe your pigs grow better and healthier when given antibiotics?		
No	11	22
Yes	39	78
Is it important that your pigs receive antibiotics once they are sick?		
No	19	38
Yes	31	62
Do you feel that your pigs produce more when given antibiotics?		
No	16	32
Yes	34	68
Does it matter to you who prescribes and administers antibiotics to your pigs?		
No	26	52
Yes	24	48
Do you feel that consulting a professional vet is so expensive that you use other options?		
No	21	42
Yes	29	58
Do you think that it's economical to take samples from sick pigs for laboratory diagnosis?		
No	30	60
Yes	20	40
Do you feel that requesting for antibiotic sensitivity tests before prescribing and administering to your pigs is time wasting?		
No	11	22
Yes	39	78
Overall rating on Attitude		
Negative	34	68
Positive	16	32

Table 3: effect of farmers' characteristics and their overall knowledge, attitude and practice on the prevalence of AMR									
Prevalence of antimicrobial resistant E coli isolates									
			Low prevalence (0-20%)		**High prevalence (>20%)**				
Variables		**Total**	**Number**	**Percentage**	**Number**	**Percentage**	**df**	**χ²**	**p value**
Age (Years)	25-45	31	20	64.5	11	35.5	1	17.04	0.000*
	over 45	18	0	0	18	100			
Gender	Male	41	17	41.5	24	58.5	1	0.23	0.63
	Female	8	2	25.0	6	75.0			
Education level	Below tertiary	11	0	0	11	100	1	7.72	0.005*
	Tertiary	38	20	52.6	18	47.4			
Years of experience	1-10	34	4	11.8	30	88.2	1	30.52	0.000*
	Over 10	15	15	100	0	0			
Level of knowledge	Inadequate	27	8	29.6	19	70.4	1	2.17	0.14
	Adequate	22	12	54.5	10	45.5			
Overall attitude	Negative	33	9	27.3	24	72.7	1	6.05	0.013*
	Positive	16	11	68.8	5	31.2			
Herd size	Small-scale (1-100)	12	1	8.3	11	91.7	2	4.94	0.08
	Medium-scale (101-200)	27	12	44.4	15	55.56			
	Large Scale >200	10	4	40.0	6	60.0			
Use of Vet Services	No	24	3	12.5	21	87.5	1	5.75	0.016*
	Yes	25	16	64.0	19	36.0			
Production group	Finisher	36	16	44.4	20	55.6	1	1.05	0.30
	Piglet	13	3	23.1	10	76.9			
Antibiotics use	No	10	10	100.0	0	0.0	1	16.73	0.000*
	Yes	39	9	23.1	30	76.9			
Antibiotic withdrawal period	0-14 days	39	9	23.1	30	76.9		16.73	0.000*
	>14 days	10	10	100.0	0	0.0			
Key: χ²; Chi-square, >; greater than, df; degree of freedom, p; probability, %; percentage									

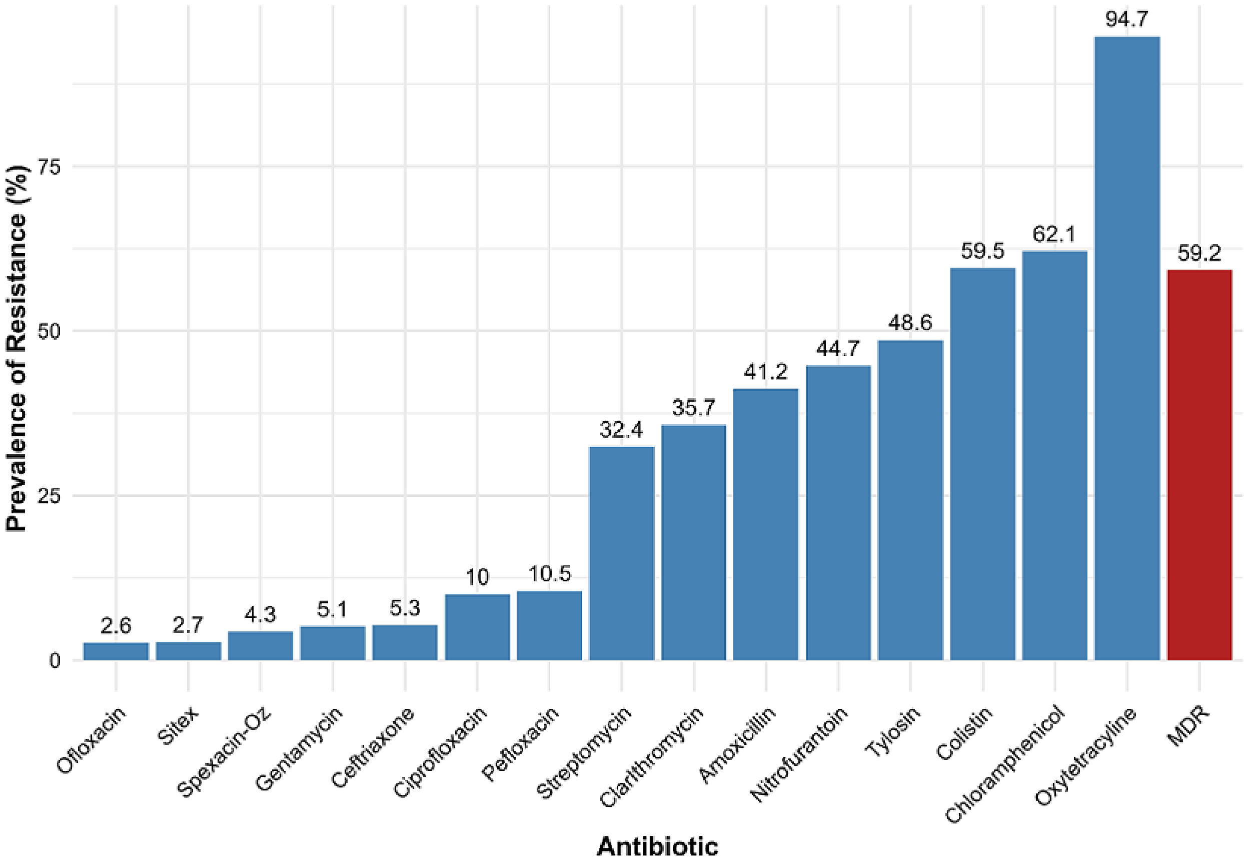

Figure 1: prevalence of resistant *E. coli* isolates to tested antibiotics

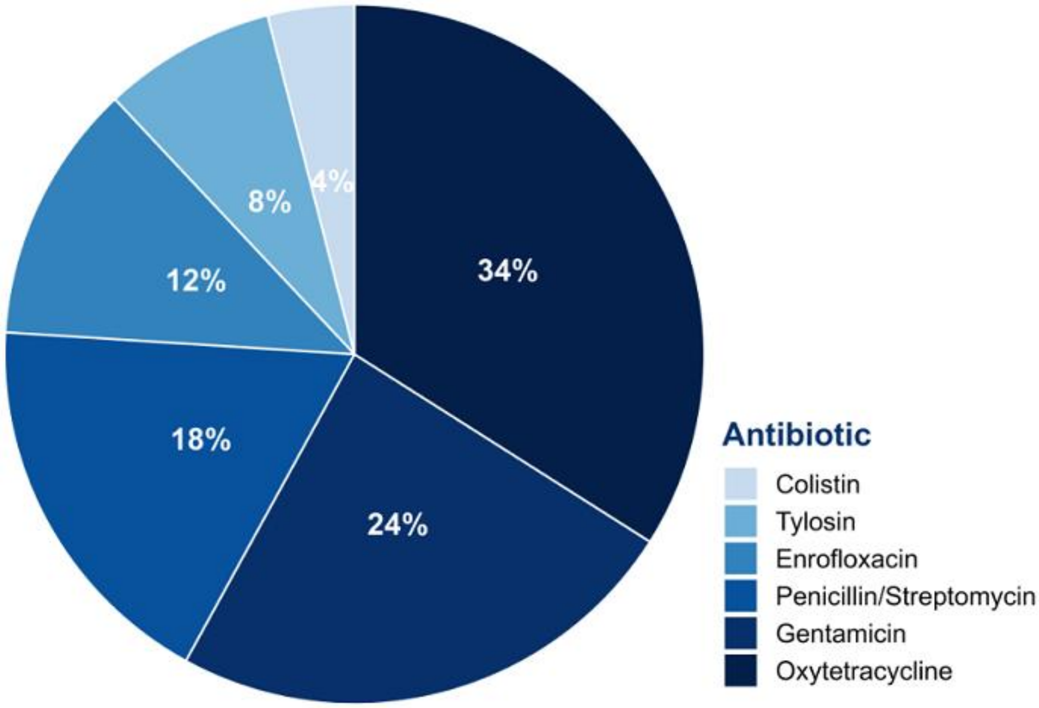

Figure 2: proportion of commonly used antibiotics by the pig farmers