

Review Article

One Health Bulletin

Pig farming: A neglected pathway for antimicrobial resistance in Nigeria

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ABSTRACT

Antimicrobial resistance (AMR) represents a major global health threat, heightened by extensive and often indiscriminate use of antibiotics in livestock production. In Nigeria, pig farming constitutes a significant yet underexamined pathway for the emergence and spread of AMR. This review aimed to examine the role of pig farming in the development and spread of AMR, evaluate the associated public health and economic risks, and propose evidence-based strategies to curb its spread. A comprehensive literature search was conducted across PubMed, Scopus, Web of Science, Google Scholar, and African Journals Online (AJOL) for studies published between January 2000 to May 2025 and in English language. Relevant publications were screened, and data were extracted on antimicrobial use patterns, resistance prevalence, and associated risk factors. Studies were synthesized narratively and comparatively to identify key trends and policy gaps. The routine administration of antibiotics for therapeutic, prophylactic, and growth-promoting purposes, coupled with insufficient veterinary oversight, inadequate biosecurity measures, and limited regulatory enforcement, has facilitated the proliferation of multidrug-resistant bacteria including *Escherichia coli*, *Salmonella* spp., *Staphylococcus aureus* (including methicillin-resistant *Staphylococcus aureus*), and *Enterococcus* spp. The persistence of antibiotic residues in pork products further increases public health risks by increasing the incidence of treatment failures and prolonging infections in humans. Beyond the health implications, AMR in pig farming has profound economic consequences, including reduced livestock productivity, increased production costs, and potential trade restrictions. Addressing this multifaceted challenge requires stringent antibiotic regulations, enhanced veterinary regulation, improved farm hygiene, and targeted farmer education on antimicrobial stewardship. A comprehensive One Health approach integrating veterinary, environment, and public health professionals is imperative to reduce the impact of AMR locally and globally.

KEYWORDS: Antimicrobial resistance; Antibiotics; Nigeria; One Health; Pig farming; Public health

1. Introduction

Antimicrobials (medicines used to prevent and treat infectious diseases in humans, animals and plants, which include antibiotics, antivirals, antifungals, and antiparasitics) play a crucial role in the treatment and prevention of infectious diseases in animals, and humans[1,2]. Their discovery was hailed as a major breakthrough in managing infectious diseases, leading to a significant reduction

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How to cite this article: Akpan SN, Jolayemi KO, Ahmed AN, Offiong UP, Akpabio U. Pig farming: A neglected pathway for antimicrobial resistance in Nigeria. One Health Bull 2026; 6(2): 59-71. doi: 10.4103/ohbl.ohbl_40_25

Article history: Received 9 May 2025 Revision 26 August 2025
Accepted 10 November 2025 Available online 22 November 2025

in illness and death rates among both humans and animals[3]. In livestock production, antimicrobials have been particularly valuable, contributing to a decline in economic losses and shorter treatment periods[4,5]. Over the past century, antimicrobials (natural, synthetic, or semi-synthetic agents that kill or inhibit the growth of microorganisms, including bacteria, viruses, fungi, and parasites) have also become integral to livestock production systems, being used not only for treatment but also for disease prevention and growth promotion[6,7]. Experts believe that the global use of antimicrobial agents in animals is twice as much as that in humans, although there is limited standardized data from the veterinary sector to support these claims[8]. Developing countries, including Myanmar, Indonesia, and Nigeria, are expected to experience a substantial increase of over 200% in antimicrobial consumption[9,10]. While high-income and some middle-income countries track antimicrobial consumption in humans and animals including pigs, low-income countries have paid less attention to this issue[11–13].

Antimicrobial resistance (AMR) constitutes a significant worldwide health challenge of the 21st century[14,15]. The rapid emergence and spread of antibiotic-resistant bacteria pose a significant risk to public health, animal health, and environmental sustainability[16]. The World Health Organization (WHO) has consistently warned about the increasing burden of AMR, particularly in low- and middle-income countries (LMICs) such as Nigeria, where antibiotic (a type of antimicrobial that specifically kill or inhibit the growth of bacteria) use remains largely unregulated[17,18]. Among the various agricultural sectors contributing to AMR, pig farming in Nigeria represents a critical yet neglected pathway through which resistant bacterial strains evolve and disseminate[19,20]. The intensive nature of pig production, characterized by the prophylactic and therapeutic use of antibiotics coupled with suboptimal biosecurity measures and a lack of veterinary oversight, creates a breeding ground for multidrug-resistant (MDR) pathogens[21–23]. This review critically examines the factors driving AMR in Nigerian pig farming, the associated risks, and the strategies needed to mitigate its impact.

2. Methods

2.1. Search strategy

A comprehensive literature search was conducted across multiple electronic databases, including PubMed, Scopus, Web of Science, Google Scholar, and African Journals Online (AJOL). The search covered studies published between January 2000 and May 2025. Searches combined free-text keywords and controlled vocabulary (*e.g.*, MeSH terms in PubMed) using Boolean operators as follows: [“antimicrobial resistance”(MeSH Terms) OR “antibiotic resistance”OR “drug resistance, bacterial”] AND (“pig” OR “swine”OR “porcine”) AND (“antimicrobial use” OR “antibiotic use” OR “antimicrobial consumption” OR “AMU”) AND (“Nigeria" OR “West Africa”) AND (“One Health” OR “veterinary public health” OR “public health”). To ensure comprehensive coverage, additional records were retrieved by manually searching the websites and repositories of relevant international agencies such as the World Health Organization (WHO), Food and Agriculture Organization (FAO), and the National Agency for Food and Drug Administration and Control (NAFDAC). Only studies and reports published in English were considered eligible.

2.2. Inclusion and exclusion criteria

Studies were included if they reported data on antimicrobial or antibiotic use, resistance patterns, or resistance gene detection in pig farming systems in Nigeria or comparable low- and middle-income countries (LMICs). Eligible studies focused on bacterial isolates from pigs, pig farm environments, pork products, or individuals working within pig value chains. Publications that examined biosecurity practices, veterinary regulation, or antimicrobial stewardship relevant to pig production were also considered. Only peer-reviewed articles, conference proceedings, and credible institutional or technical reports published in English between 2000 and 2025 were included. Studies were excluded if they focused exclusively on other livestock species such as poultry, cattle, or aquaculture, or if they were experimental pharmacological or toxicological investigations unrelated to AMR. Review papers, commentaries, and studies lacking clear methodological descriptions, AMR data, or accessible full texts were also excluded from the final analysis.

2.3. Data extraction and synthesis

All identified articles were screened for relevance based on their titles and abstracts, followed by full-text review of eligible studies. Data were systematically extracted into a structured matrix that captured key variables, including study location, publication year, sample type, bacterial species, antibiotics tested, prevalence and patterns of resistance, and major findings. The extraction process was carried out independently by two reviewers, and discrepancies were resolved through discussion and consensus to ensure consistency and accuracy. Extracted data were synthesized narratively to identify recurring themes, patterns of antimicrobial use, resistance trends, and associated risk factors. Quantitative information was summarized and presented in tables to facilitate comparison of antimicrobial use and resistance patterns between Nigeria and other LMICs. All data and references were organized using Mendeley Reference Manager (version 2.118.0) and Microsoft Excel (version 2016) for traceability and consistency.

2.4. Quality assessment

Although this review was not conducted as a formal systematic review, each included study underwent methodological appraisal using adapted elements of the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for prevalence and cross-sectional studies. The appraisal focused on sampling strategy, laboratory testing methodology, clarity of antimicrobial susceptibility testing standards, and data reporting transparency. Two reviewers independently assessed study quality, and discrepancies were resolved through consensus to ensure objectivity. Studies judged to have limited methodological rigor were retained only to provide contextual or descriptive insight, while higher-quality studies contributed more substantially to the synthesis and interpretation of findings.

3. Results

3.1. Pig production in Nigeria

Pig production in Nigeria is a rapidly growing sector of the livestock industry, contributing significantly to food security, employment, and economic development[24,25]. The increasing demand for pork, particularly in urban region has led to intensified pig farming[24,26]. Pig farming in Nigeria is primarily concentrated in the southern and central regions, where pork consumption is culturally acceptable[25,27,28]. The production systems range from extensive, where pigs scavenge for food, to semi-intensive and intensive systems that involve confined housing and controlled feeding[29]. While indigenous pig breeds, such as the West African Dwarf pig, are disease-resistant and well-adapted to harsh environments, commercial pig farmers predominantly rear exotic breeds like Large White, Landrace, and Duroc due to their superior growth performance and reproductive efficiency[30]. With more than 9.5 million farmed pigs as of 2022, Nigeria had the highest population of domesticated pigs in Africa (Figure 1). Following with about 8.1 million and 3.6 million heads, respectively, were Malawi and Angola. The pigs were raised for their meat or kept for breeding[31].

3.2. Pig farming, antibiotic usage, and AMR in Nigeria

Pig farming in Nigeria, like in many other LMICs, relies heavily on antibiotics to sustain productivity and profitability[32]. The use of antimicrobials in pig production can be classified into three main categories: Therapeutic use (to treat bacterial infections), Prophylactic use (to prevent infections in healthy animals) and Growth promotion (to enhance feed efficiency and weight gain)[33–35]. A major issue in Nigeria is the unregulated use of antibiotics without accurate diagnosis, frequently attributed to the scarcity of veterinary doctors in rural farming areas[36,37]. Studies indicate that small- and medium-scale pig farmers commonly administer antibiotics such as penicillin, tetracyclines, fluoroquinolones, and aminoglycosides without veterinary prescriptions[38,39]. The widespread practice of using these drugs as growth promoters is particularly alarming, as it exerts continuous selective pressure on bacterial populations, fostering the emergence of resistant strains[40,41].

A study conducted in Ogun State, a major pig-producing region,

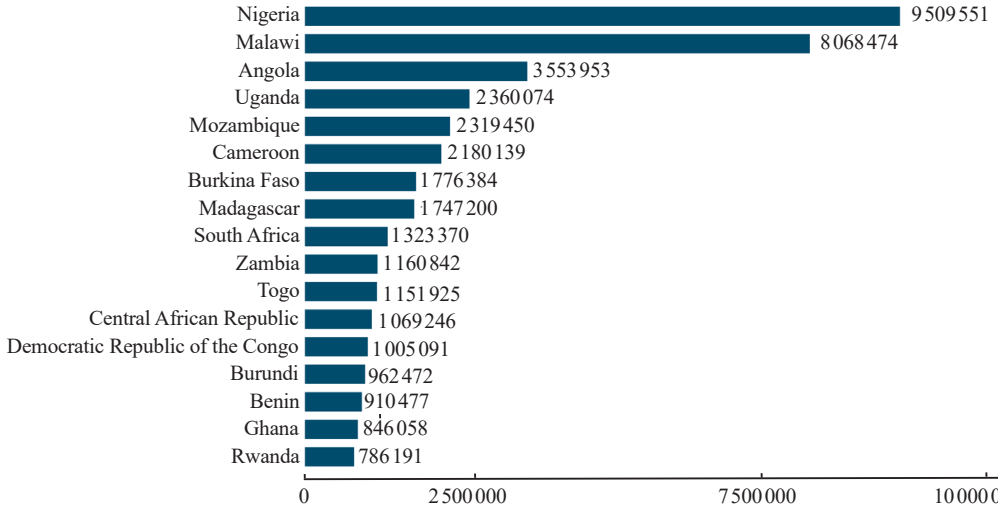


Figure 1. Number of domesticated pigs in Africa as of 2022, by country[31].

found that over 90% of pig farmers used antibiotics routinely, with many relying on informal sources such as open markets and unlicensed vendors to procure veterinary drugs[42]. The lack of proper dosage regulation, coupled with poor adherence to withdrawal periods before slaughter, contributes to antibiotic residues in pork products, facilitating the transfer of resistant bacteria to humans through the food chain[43–45]. Additionally, farmers sometimes rely on metaphylactic treatments, where entire herds are given antibiotics regardless of the infection status of individual animals, further accelerating resistance development[46,47]. AMR has significantly increased worldwide over the past two decades, prompting the United Nations to identify it as a critical global health issue[48]. This issue is particularly severe in developing countries, including Nigeria, where poor regulatory enforcement and inadequate surveillance contribute to the widespread prevalence of AMR[49,50].

3.3. Occurrence of antimicrobial–resistant pathogens in Nigerian pig farms

Numerous studies have documented the establishment and propagation of antimicrobial resistance genes associated with antibiotic abuse in Nigerian swine populations[51–54]. Research has detected multidrug-resistant *Escherichia* (*E.*) *coli*, *Salmonella* spp., *Staphylococcus aureus* (including MRSA), *Enterococcus* spp., and other resistant pathogens in pig faeces, farm environments, and pork products[55–58]. These findings raise serious public health concerns, as resistant bacteria can spread from pigs to humans through direct contact, contaminated meat, and environmental exposure. A study conducted in Ibadan[59] identified 21 different antibiotic resistance genes in bacteria isolated from pig faecal samples, highlighting the role of Nigerian pig farms as reservoirs for resistant determinants. Many of these genes conferred resistance to critically important antibiotics, such as beta-lactams, fluoroquinolones, and macrolides, which are essential for treating human infections.

Within the microbiome of pigs, bacteria can exchange genetic material through processes such as conjugation, transformation, and transduction[60]. This horizontal gene transfer enables the rapid dissemination of resistance genes among different bacterial species. The presence of mobile genetic elements, such as plasmids and integrons, facilitates this genetic exchange, leading to the emergence of multidrug-resistant bacterial populations[61]. Understanding these mechanisms is crucial for developing strategies to mitigate the spread of AMR from pig farming operations. Environmental pollution with antibiotic residues may alter the soil microbiota composition, enriching soils with bacteria capable of degrading these compounds, which can further propagate resistance genes[62]. Further studies have also detected AMR bacteria in rivers receiving effluents from pig slaughter facilities, posing risks to nearby communities that rely on these water sources[43,63]. The use of pig manure as fertilizer contributes to the spread of resistance genes into soil and water systems, amplifying the environmental impact of AMR[64]. In response to the growing AMR crisis, the National Agency for Food and Drug Administration and Control[65] has released a list of prohibited antimicrobials for livestock production, aligning with the best global practices (Supplementary Table 1). However, enforcement remains a challenge, necessitating stronger regulatory frameworks and improved compliance mechanisms.

3.4. Risk factors driving AMR in pig farming

The WHO claims that the excessive use of antibiotics for prophylactic, therapeutic, and growth-promoting uses in livestock production will increase the likelihood of AMR bacteria emerging and spreading[66]. While AMR continues to represent a challenge, the pipeline for new antimicrobial is running dry[67,68]. The overuse of antimicrobials in pig farming hence contributes to the spread of resistant bacteria and increases the risk of treatment failure[16,34]. Inadequate veterinary oversight allows for the unchecked use of antibiotics, often driven by farmers' lack of awareness regarding proper antimicrobial stewardship[69]. The absence of national policies regulating antibiotic use in livestock exacerbates the problem, leading to the easy accessibility of antibiotics without prescriptions[70]. Poor biosecurity measures in many pig farms create an environment conducive to the spread of infectious diseases, prompting farmers to overuse antibiotics as a preventive measure[41]. Inadequate sanitation, overcrowding, and improper waste disposal are common issues in pig production, further increasing the risk of disease outbreaks and encouraging excessive antibiotic usage. Another significant factor is the socio-economic aspect of pig farming (Table 1). Many smallholder pig farmers in Nigeria operate on limited financial resources, prioritizing immediate economic gains over long-term sustainability[71]. The reliance on antibiotics as a cost-effective strategy to maintain herd health and productivity discourages the adoption of alternative disease management strategy like improved husbandry practices[17,25]. The attention on AMR in recent times has centred on nosocomial settings, and the poultry sector[72,73]. The role of pigs in spread and transmission of AMR genes via the environment and pork products have not received required attention. A systematic review of AMR in the animal health sector reports that only 17.9% of studies conducted on AMR topics in livestock in the country were on pigs. Antibiotic residues and resistant bacteria from pig farms can enter the environment through various pathways, notably

via manure application on agricultural lands[74]. In Nigeria, the lack of stringent waste management practices means that these contaminants can leach into soil and water systems, promoting the spread of AMR in the broader ecosystem[75]. Studies have reported high levels of antibiotic residues in animal products, which not only affect human health but also contribute to environmental pollution[76,77]. This environmental dissemination underscores the need for sustainable waste management practices in pig farming.

The close interaction between pigs, farm workers, and the surrounding environment facilitates the transfer of resistant bacteria to humans and other animals[78]. Direct contact with livestock, as well as the consumption of contaminated pork products, are primary routes of transmission[75]. Additionally, the use of manure as fertilizer can introduce resistant bacteria into the food chain, affecting crops and subsequently human consumers[64]. This zoonotic transmission highlights the interconnectedness of animal and human health concerning AMR. Studies in Nigeria revealed that farm workers had a low level of awareness about the correct use of antibiotics and the implications of resistance, which exacerbates the risk of transmission[79,80].

At the systemic level, weak regulatory frameworks and poor enforcement remain major barriers to effective AMR control in pig farming. Despite NAFDAC's ban on certain veterinary drugs[65], enforcement at the farm level is inconsistent, and over-the-counter antibiotic sales continue unchecked. Furthermore, Nigeria lacks a robust national surveillance infrastructure for tracking antimicrobial use and resistance patterns in livestock[43]. The absence of coordinated monitoring systems limits data availability and hinders timely policy interventions, perpetuating uncontrolled antibiotic use and resistance spread.

Table 1. Categorization of risk factors contributing to AMR in pig farming.

Category	Risk factors
Animal-level	Frequent prophylactic/metaphylactic antibiotic use
	Low herd immunity
Farm-level	Poor sanitation
	Overcrowded pens
	Inadequate biosecurity
	Insufficient veterinary oversight
Human behavior	Misuse of antibiotics by farmers
	Lack of AMR awareness
	Over-the-counter antibiotic access
Systemic/Policy	Weak regulatory frameworks
	Lack of enforcement
	Limited surveillance infrastructure

AMR: Antimicrobial resistance.

3.5. Public health and economic implications of AMR in pig farming

The implications of AMR arising from pig farming extend far beyond the farm gates[81]. Resistant bacteria from pigs can easily spread to humans through direct contact, consumption of contaminated pork, and environmental exposure[82]. Farm workers and slaughterhouse personnel are at high risk of acquiring resistant infections, which can subsequently be transmitted to the broader community[83]. The presence of antibiotic residues in pork products further increases the risk of consumers developing antibiotic-resistant infections, potentially leading to treatment failures and prolonged illness[82]. From an economic perspective, AMR threatens the viability of the livestock sector by reducing the effectiveness of antibiotics, leading to higher mortality rates and increased production costs[84,85]. The reduced efficacy of antibiotics necessitates the use of more expensive drugs, further straining the financial capacity of smallholder farmers[86]. Additionally, trade restrictions on antibiotic-laden meat products could impact Nigeria's

Table 2. Summary of antimicrobial use and AMR in pig farming: Nigeria and selected LMICs.

Country	Antibiotic use (%)	Most common antibiotics	MDR bacteria prevalence	Notable trends/findings
Nigeria	90% of pig farmers use antibiotics routinely[42]	Oxytetracycline (31%), Sulfadimidine (17%), Gentamicin (12%)[87]	MDR *E. coli* prevalence: 20–100%[98,99]	Farmers often self-prescribe; poor withdrawal compliance; no national surveillance system
Ghana	98% of pig farmers use antibiotics[41]	Penicillin-streptomycin (98%), Tetracyclines (70%)	Not specified	High antibiotic access; awareness varies by region.
Tanzania	87.6% use antibiotics prophylactically[88]	Not specified	Not specified	Drivers include weak regulation and limited vet access
Vietnam	98.1% of pig farmers use antibiotics[90]	Mainly for treatment (81.3%), also prophylaxis	100% MDR in some *E. coli* isolates[100]	Common use for growth promotion; better tracking via surveillance systems.
China	89% of households access antibiotics easily[91]	Tetracyclines, Sulfonamides[96]	91% MDR in *E. coli* (2018–2019)[101]	Genomic surveillance in place; extensive use tied to intensive systems
Timor-Leste	Only 3.6% of farmers use antibiotics[92]	Used only for treatment	Very limited data	Low antimicrobial usage due to subsistence-level pig farming

MDR: Multidrug-resistant. LMICs: Low- and middle-income countries.

agricultural exports, limiting market access for pig farmers and exacerbating food insecurity[85].

3.6. Quantitative trends in antibiotic use and AMR in pig farming

Antimicrobial use in pig farming in Nigeria and similar LMICs is widespread, driven by therapeutic, prophylactic, and growth-promoting purposes (Table 2). In Nigeria, a study in Ogun State found that 36.9% of pig farmers used antibiotics prophylactically, and 29.2% used them for growth promotion, with tetracyclines (*e.g.*, oxytetracycline), gentamicin, and tylosin being the most common[42]. A study assessed antibiotic use and awareness among pig farmers. It found that oxytetracycline (31%), sulfadimidine (17%), and gentamicin (12%) were the most commonly used antibiotics[87]. A survey in Ghana's Ashanti region reported that 98% of pig farmers administered antibiotics, with penicillin-streptomycin (98%), sulfadimidine (72%), and tetracyclines (70%) dominating usage[41]. In Tanzania, research revealed high prophylactic antibiotic use (87.6%) among pig farmers with factors such as limited access to veterinary services and weak regulatory enforcement contributing to this trend[88]. In Togo, 84% of the farmers who reported antimicrobial use, utilized them as prophylaxis in the production of pigs[89]. In Vietnam, a survey involving 540 pig farmers found that 98.1% used antimicrobials, primarily for treatment (81.3%), disease prevention, and growth promotion[90]. In a survey of 404 pig farming households in Yunnan province of China, 89% reported easy access to antibiotics, and 83.7% had experience self-purchasing them. About 40.3% used antibiotics mainly for disease prevention and treatment[91]. However, among smallholder pig farmers in Timor-Leste, only 3.6% reported using antibiotics, exclusively for treatment purposes[92]. Globally, Van Boeckel[93] estimated that livestock consumed 131,109 tons of antimicrobials in 2013, with pigs accounting for a significant share due to intensive production systems. In LMICs, antimicrobial consumption is projected to increase by 67% by 2030[94,95]. In China, pig farming accounts for a substantial portion of the country's high veterinary antibiotic use, with tetracyclines and sulfonamides being prevalent[96] (Table 2).

The intensive use of antimicrobials in pig farming has led to significant AMR prevalence in Nigeria and similar LMICs. A global analysis by Van Boeckel[97] of 901 point-prevalence surveys across LMICs showed that the proportion of antimicrobials with resistance rates above 50% (P50) in pigs rose from 0.13 in 2000 to 0.34 in 2018. In Nigeria, multidrug-resistant (MDR) *E. coli* isolates from pig farms ranged from 20% to 100%, with high resistance to tetracyclines, sulfonamides, and penicillins[98,99]. In other LMICs, similar patterns emerge. In Vietnam, some pig-derived *E. coli* isolates exhibited 100% MDR[100]. In China, a 2018–2019 surveillance study found that 91% of *E. coli* isolates from pig farms were MDR, with resistance to critical drugs like colistin and carbapenems[101]. The quantitative data reveal a clear link between high antimicrobial use and rising AMR in pig farming. Tetracyclines and sulfonamides, commonly used across Nigeria and LMICs, consistently show high resistance rates, reflecting selective pressure from overuse. However, data gaps hinder precise estimates. Nigeria lacks national AMR surveillance for livestock, and studies are often small-scale and region-specific. In contrast, countries like China provide more robust data through large-scale genomic studies, highlighting a disparity in research capacity.

3.7. AMR prevention strategies and policy recommendations

Addressing the AMR crisis in Nigerian pig farming requires a multifaceted approach involving regulatory interventions, improved farming practices, and enhanced public awareness. One of the most critical steps is strengthening national policies on antibiotic use in livestock, including stricter regulations on antibiotic sales and mandatory veterinary prescriptions for antimicrobial use[102]. The enforcement of withdrawal periods before slaughter should also be emphasized to reduce antibiotic residues in meat products[103]. Investing in farmer education programs is another essential strategy. Training pig farmers on responsible antibiotic use, disease prevention through improved hygiene, and alternative treatment methods such as probiotics and vaccination can significantly reduce reliance on antimicrobials[104–106]. Collaboration between veterinary professionals, public health authorities, and agricultural stakeholders can facilitate the implementation of effective antimicrobial stewardship programs at the farm level[107,108]. Promoting good biosecurity practices is also crucial. Implementing measures such as improved waste management, controlled farm access, and regular disease surveillance can help prevent infections and minimize the need for antibiotic use[109]. Encouraging the adoption of precision livestock farming technologies, such as automated health monitoring systems, can further aid in early disease detection and targeted treatment, reducing unnecessary antibiotic administration[110].

At the research level, continuous surveillance of antimicrobial resistance patterns in pig farms is needed to monitor emerging resistance trends and inform policy decisions[111]. Establishing a national AMR surveillance network that integrates data from veterinary, agricultural, and human health sectors will enhance Nigeria's ability to tackle the AMR challenge effectively[112].

Future research direction can focus on assessing the effectiveness of alternative disease prevention strategies, such as probiotics, in reducing antibiotic dependence, investigating the role of wildlife and environmental reservoirs in the transmission of antimicrobial-resistant bacteria and exploring the socioeconomic barriers to responsible antibiotic use in pig farming.

4. Conceptual framework: A One Health Model of AMR in pig farming

Figure 2 presents a One Health conceptual model illustrating the interconnected pathways through which AMR emerges, spreads, and persists within Nigeria's pig farming system. Integrating the animal, human, and environmental health domains, the model identifies key leverage points that represent nodes of origin, amplification, and transmission, each offering strategic opportunities for intervention. Central to the model is the widespread use of antibiotics in pigs for therapeutic, prophylactic, and growth-promotion purposes, which constitutes the primary selection pressure for the emergence of resistant bacterial strains. Poor veterinary oversight, particularly among smallholder farmers with limited knowledge of AMR, further exacerbates indiscriminate antibiotic use. Frequent and often unprotected contact between pigs and farm workers facilitates zoonotic transmission, while environmental dissemination through manure application and waste runoff introduces resistance genes into broader ecosystems. The informal and poorly regulated veterinary drug market, characterized by easy access to counterfeit or substandard antibiotics, perpetuates misuse and undermines control efforts. Additionally, the absence of an integrated surveillance system hampers the timely detection and containment of resistant strains across animal, human, and environmental reservoirs. Policy recommendations stemming from this model include enforcing prescription-only antibiotic use, strengthening veterinary public health systems, promoting farm-level biosecurity, regulating environmental waste disposal, controlling pharmaceutical supply chains, and establishing a national One Health AMR surveillance network. This conceptual framework not only serves as a diagnostic tool but also provides a strategic blueprint for AMR policy development in Nigeria. It enables the identification of high-risk nodes for targeted intervention, facilitates intersectoral collaboration among veterinary, environmental, and public health stakeholders, guides efficient resource allocation, and supports the development of measurable indicators to assess the effectiveness of national AMR strategies over time.

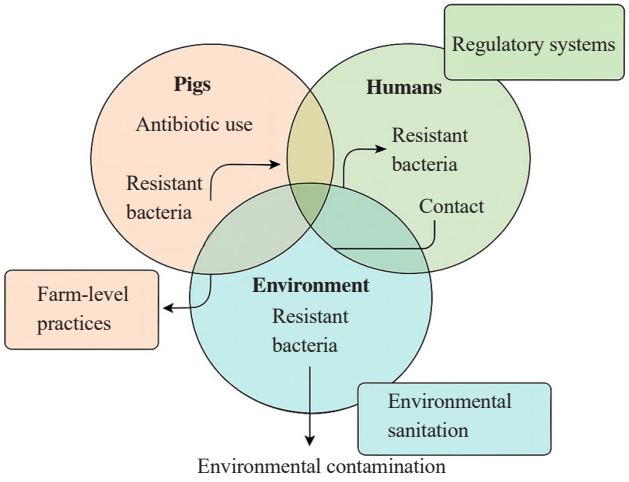


Figure 2. One Health conceptual model of AMR dynamics in pig production.

5. Novel insights and global comparisons

The findings of this review reveal that Nigeria's pig farming sector is a significant but underappreciated contributor to the national AMR burden. Compared to global counterparts, particularly in high-income and some middle-income countries (*e.g.*, China, Vietnam, and even Ghana), Nigeria exhibits a unique set of challenges that amplify AMR risks and limit effective response strategies.

5.1. Disparity in surveillance and data infrastructure

Globally, countries like China and Vietnam have invested heavily in AMR surveillance in livestock, enabling data-driven interventions. China's routine genomic surveillance of resistant bacteria in swine allows early detection of MDR strains and guides policy decisions[101,113]. In contrast, Nigeria lacks a national AMR surveillance program specific to the livestock sector, and existing studies are often small-scale and region-specific. This impedes trend analysis, resistance forecasting, and coordinated responses. It is suggested that establishing a national livestock AMR surveillance network, integrating veterinary, environmental, and human health data. Such a platform should be supported by molecular laboratories and digital reporting systems to detect and monitor resistance genes in real-time.

5.2. Unregulated antibiotic access

Unlike nations with stringent prescription policies such as Sweden and Denmark where veterinary antibiotics are tightly controlled[114,115], Nigeria still permits over-the-counter sales of critical antimicrobials without prescription. This creates an environment where misuse is rampant, especially for growth

promotion or metaphylactic purposes. Enforcing mandatory veterinary prescription laws for antimicrobial sales and implementing point-of-sale digital tracking systems to monitor antibiotic distribution and use across farms and veterinary outlets is suggested.

5.3. Knowledge and awareness gaps among stakeholders

Evidence suggests that in Nigeria, many farmers have low awareness of AMR and less formal education, compared to interventions in Ghana and Vietnam which have shown measurable improvements in awareness and practices following structured training programs[116,117]. This educational gap fuels inappropriate usage, lack of adherence to withdrawal periods, and resistance to behavioral change. Developing localized, farmer-targeted AMR education programs using vernacular languages, radio campaigns, and extension agents is paramount. Also, linking AMR education to incentive programs (*e.g.*, subsidized veterinary services or biosecurity inputs) can improve awareness.

5.4. Biosecurity deficits and farm hygiene

In high-performing systems in Europe and East Asia, stringent biosecurity protocols (*e.g.*, controlled access, disinfection barriers, farm zoning) are core to minimizing infection risks and antibiotic dependence[118–120]. Nigerian pig farms, particularly small and medium enterprises, often operate in overcrowded, unhygienic environments with limited veterinary input, thereby increasing infection pressure and routine antibiotic use. Promoting low-cost, scalable biosecurity models tailored to smallholder farms and introducing regulatory biosecurity minimum standards and offering microgrants or tax incentives for farms meeting them can be a way of ensuring biosecurity and farm hygiene.

5.5. Lack of alternatives to antibiotics

Countries like the Netherlands and Denmark have successfully transitioned from prophylactic antibiotic use to alternatives like vaccination, improved nutrition, and probiotics[5]. In Nigeria, such options remain poorly understood, inaccessible, or unaffordable to many pig farmers. Funding pilot trials and scale-up studies of alternative therapies, including locally producible probiotics, herbal extracts with antimicrobial activity can be a way of providing alternatives, hence reducing antimicrobial use.

The convergence of poor regulation, insufficient data, and low awareness in Nigeria's pig sector contrasts starkly with the strategic, evidence-led AMR mitigation observed in several other LMICs and high-income countries. Yet, this disparity also presents an opportunity: Nigeria can leverage these global lessons to design context-specific, cost-effective interventions within a One Health framework. By addressing these structural and behavioral gaps, Nigeria can not only curb the local impact of AMR but also contribute to the global fight against AMR especially as its livestock sector grows. A strategic shift that combines national policy reform, community education, and technology-enabled surveillance will be crucial in aligning Nigeria's pig farming practices with international AMR containment goals.

6. Conclusions

Pig farming in Nigeria represents a significant yet largely neglected driver of AMR. The excessive and often indiscriminate use of antibiotics in pig production, coupled with inadequate biosecurity measures and weak regulatory enforcement, has facilitated the emergence and spread of resistant bacterial strains. The public health and economic consequences of AMR in pig farming are far-reaching, necessitating urgent action to curb this growing crisis. By implementing stringent antibiotic regulations, promoting responsible antibiotic use, and investing in sustainable livestock management practices, Nigeria can mitigate the impact of AMR and safeguard both animal and human health. A One Health approach, integrating veterinary, environment, and public health, is essential to achieving long-term success in the fight against AMR.

Conflict of interest statement

The authors claim there is no conflict of interest.

Funding

The study received no extramural funding.

Data availability statement

The data supporting the findings of this study are available from the corresponding author upon request.

Authors' contributions

Akpan SN, Jolayemi KO conceived the study. Akpan SN, Jolayemi KO, Ahmed AN, Offiong UB, and Akpabio U participated in the study design and manuscript review. Akpan SN, Jolayemi KO did the data analysis and manuscript writing. All authors read and approved the final manuscript.

References

[1] World Health Organization (WHO). *Antimicrobial resistance. 2023.* [Online] Available from: https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance. [Accessed on 6 September 2025].

[2] Endale H, Mathewos M, Abdeta D. Potential causes of spread of antimicrobial resistance and preventive measures in one health perspective—A review. *Infect Drug Resist* 2023; **16**: 7515-7545.

[3] Faizan ALI, Ahmed A, Maqsood S, Fatima M, Hussain M, Rehman SU, et al. The never-ending battle: Strategies for infectious disease control in the face of emerging pathogens. *Curr Stud Health Life Sci* 2024; **240**: 240-264.

[4] Lhermie G, Gröhn YT, Raboisson D. Addressing antimicrobial resistance: An overview of priority actions to prevent suboptimal antimicrobial use in food-animal production. *Front Microbiol* 2017; **7**: 2114.

[5] Tiseo K, Huber L, Gilbert M, Robinson TP, Van Boeckel TP. Global trends in antimicrobial use in food animals from 2017 to 2030. *Antibiotics* 2020; **9**(12): 918.

[6] Sharma C, Rokana N, Chandra M, Singh BP, Gulhane RD, Gill JPS, et al. Antimicrobial resistance: Its surveillance, impact, and alternative management strategies in dairy animals. *Front Vet Sci* 2018; **4**: 237.

[7] Lees P, Pelligand L, Giraud E, Toutain PL. A history of antimicrobial drugs in animals: Evolution and revolution. *J Vet Pharmacol Ther* 2021; **44**(2): 137-171.

[8] EMA Committee for Medicinal Products for Veterinary Use (CVMP), EFSA Panel on Biological Hazards (BIOHAZ), Murphy D, Ricci A, Auce Z, Beechinor JG, et al. EMA and EFSA Joint Scientific Opinion on measures to reduce the need to use antimicrobial agents in animal husbandry in the European Union, and the resulting impacts on food safety (RONAFA). *EFSA J* 2017; **15**(1): 04666.

[9] Iskandar K, Molinier L, Hallit S, Sartelli M, Catena F, Coccolini F, et al. Drivers of antibiotic resistance transmission in low- and middle-income countries from a "One Health" perspective—A review. *Antibiotics* 2020; **9**(7): 372.

[10]Hlaing T, Lat TW, Myint ZM. Prevalence and possible causes of antibiotic self-medication among rural dwellers and volunteer health workers in Nattalin Township, Bago region, Myanmar. *Int J Community Med Public Health* 2022; **9**(4): 1592.

[11]van Boeckel TP, Gandra S, Ashok A, Caudron Q, Grenfell BT, Levin SA, et al. Global antibiotic consumption 2000 to 2010: An analysis of national pharmaceutical sales data. *Lancet Infect Dis* 2014; **14**(8): 742-750.

[12]Food and Agriculture Organization of the United Nation (FAO). *Antimicrobial resistance. 2025.* [Online] Available from: https://www.fao.org/antimicrobial-resistance/key-sectors/animal-production/en/. [Accessed on 10 October 2025].

[13]Olaru ID, Walther B, Schaumburg F. Zoonotic sources and the spread of antimicrobial resistance from the perspective of low- and middle-income countries. *Infect Dis Poverty* 2023; **12**(3): 73-87.

[14]Aijaz M, Ahmad M, Ansari MA, Ahmad S. Antimicrobial resistance in a globalized world: Current challenges and future perspectives. *Int J Pharm Drug Des* 2023; **1**(1): 7-22.

[15]Tang KWK, Millar BC, Moore JE. Antimicrobial resistance (AMR). *Br J Biomed Sci* 2023; **80**: 11387.

[16]Serwecińska L. Antimicrobials and antibiotic-resistant bacteria: A risk to the environment and to public health. *Water* 2020; **12**(12): 3313.

[17]Pieri A, Aschbacher R, Fasani G, Mariella J, Brusetti L, Pagani E, et al. Country income is only one of the tiles: The global journey of antimicrobial resistance among humans, animals, and environment. *Antibiotics* 2020; **9**(8): 473.

[18]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.

[19]Okorie-Kanu OJ, Anyanwu MU, Ezenduka EV, Mgbeahuruike AC, Thapaliya D, Gerbig G, et al. Molecular epidemiology, genetic diversity and antimicrobial resistance of *Staphylococcus aureus* isolated from chicken and pig carcasses, and carcass handlers. *PLoS One* 2020; **15**(5): 0232913.

[20]Iwu CD, Korsten L, Okoh AI. The incidence of antibiotic resistance within and beyond the agricultural ecosystem: A concern for public health. *Microbiol Open* 2020; **9**(9): 1035.

[21]Barton MD. Impact of antibiotic use in the swine industry. *Curr Opin Microbiol* 2014; **19**: 9-15.

[22]Dawangpa A, Lertwatcharasarakul P, Boonsoongnern A, Ratanavanichrojn N, Sanguankiat A, Pinniam N, et al. Multidrug resistance problems targeting piglets and environmental health by *Escherichia coli* in intensive swine farms. *Emerg Contam* 2022; **8**: 123-133.

[23]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* 2023; **12**(3): 487.

[24]Nwachukwu CU, Udegbunam C. Rural pig production and pork consumption in Imo State, Nigeria. *Niger J Anim Sci* 2020; **22**(1):165-185.

[25]Adesehinwa AO, Boladuro BA, Dunmade AS, Idowu AB, Moreki JC, Wachira AM. Pig production in Africa: Current status, challenges, prospects and opportunities. *Anim Biosci* 2024; **37**(4): 730.

[26]Gilbert M, Conchedda G, van Boeckel TP, Cinardi G, Linard C, Nicolas G, et al. Income disparities and the global distribution of intensively farmed chicken and pigs. *PLoS One* 2015; **10**(7): 0133381.

[27]Aminu FO, Akhigbe-Ahonkhai CE. Profitability and technical efficiency of pig production in Nigeria: The case of Ekiti State. *Agric Trop Subtrop*

2017; **50**(1): 27-35.

[28]Edo FA, Ihejirika CE, Okoli CG, Okoli IC. Socio-cultural and environmental impacts of pig farming on nearby residents in Imo State, Nigeria. *Niger J Anim Sci Technol* 2021; **4**(3): 93-104.

[29]Adebiyi OA, Adejumo IO, Oluyemi AA, Onarinde OE, Adebiyi FG. Understanding pig production. Ibadan: Emperor Inno Creative, Nigeria; **2023**.

[30]Pius L, Huang S, Wanjala G, Bagi Z, Kusza S. African local pig genetic resources in the context of climate change adaptation. *Animals* 2024; **14**(16): 2407.

[31]Sasu DD. *Pig stock in Africa 2022, by country*. *Statista*. [Online] Available from: https://www.statista.com/statistics/1498108/pig-population-in-africa-by-country. [Accessed on 18 February 2025].

[32]Akinbobola JS, Kumuyi OA, Olusoji JA, Omeje JN, Dare TA, Jolayemi KO. Antibiotics use and ethnoveterinary practices in pig farming: An insight from federal capital territory, Nigeria. *BMC Vet Res* 2025; **21**(1): 418.

[33]Lekagul A, Tangcharoensathien V, Yeung S. Patterns of antibiotic use in global pig production: A systematic review. *Vet Anim Sci* 2019; **7**: 100058.

[34]Albernaz-Gonçalves R, Olmos Antillón G, Hötzel MJ. Linking animal welfare and antibiotic use in pig farming—A review. *Animals* 2022; **12**(2): 216.

[35]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; **3**(2): 0001305.

[36]Aworh MK, Kwaga JKP, Okolocha EC. Assessing knowledge, attitude, and practices of veterinarians towards antimicrobial use and stewardship as drivers of inappropriate use in Abuja, Nigeria. *One Health Outlook* 2021; **3**: 1-12.

[37]Ogwuche A, Ekiri AB, Endacott I, Maikai BV, Idoga ES, Alafiatayo R, et al. Antibiotic use practices of veterinarians and para-veterinarians and the implications for antibiotic stewardship in Nigeria. *J S Afr Vet Assoc* 2021; **92**(1): 1-14.

[38]Ström G, Boqvist S, Albihn A, Fernström LL, Andersson Djurfeldt A, Sokerya S, et al. Antimicrobials in small-scale urban pig farming in a lower middle-income country—Arbitrary use and high resistance levels. *Antimicrob Resist Infect Control* 2018; **7**: 1-11.

[39]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; 17; **6**(1): 75.

[40]Muteeb G, Rehman MT, Shahwan M, Aatif M. Origin of antibiotics and antibiotic resistance, and their impacts on drug development: A narrative review. *Pharmaceuticals* 2023; **16**(11): 1615.

[41]Dogbatse R, Folitse R, Nyarku RE, Burimuah V, Amemor E, Emikpe BO. Antibiotic use and knowledge of antibiotic resistance among pig farmers in Ejisu and Juaben municipalities of Ashanti region, Ghana. *Pan Afr Med J One Health* 2023; **12**(1): 12.

[42]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; **17**(10): 3579.

[43]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; **15**(6): 1284.

[44]Bor N, Seguino A, Sentamu DN, Chepyatich D, Akoko JM, Muinde P, et al. Prevalence of antibiotic residues in pork in Kenya and the potential of using gross pathological lesions as a risk-based approach to predict residues in meat. *Antibiotics* 2023; **12**(3): 492.

[45]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; **4**(1): 0004.

[46]Baptiste KE, Pokludová L. *Mass medications: Prophylaxis and metaphylaxis, cascade and off–label use, treatment guidelines and antimicrobial stewardship.* In: Antimicrobials in Livestock 1: Regulation, Science, Practice: A European Perspective. Cham, Switzerland: Springer Nature; **2020**. pp. 167-193.

[47]Jerab J, Jansen W, Blackwell J, van Hout J, Palzer A, Lister S, et al. Real-world data on antibiotic group treatment in European livestock: Drivers, conditions, and alternatives. *Antibiotics* 2022; **11**(8): 1046.

[48]United Nations. *High–Level Meeting on Antimicrobial Resistance*, September 21. OPGA/WHO/FAO/OIE Joint News Release. 2016. [Online] Available from: https://www.un.org/pga/71/2016/09/21/press-release-hl-meeting-on-antimicrobial-resistance/. [Accessed on 6 September 2025].

[49]Musa K, Okoliegbe I, Abdalaziz T, Aboushady AT, Stelling J, Gould IM. Laboratory surveillance, quality management, and its role in addressing antimicrobial resistance in Africa: A narrative review. *Antibiotics* 2023; **12**(8): 1313.

[50]Olagunju OJ, Egbo B, Olayinka O, Majolagbe OG, Osanyinlusi OO, Titilade A, et al. Poorly regulated antibiotic use in Nigeria: A critical public health concern and its impact on medical practice. *Cureus* 2025; **17**(6): e85212.

[51]Beshiru A, Igbinosa IH, Omeje FI, Ogofure AG, Eyong MM, Igbinosa EO. Multi-antibiotic resistant and putative virulence gene signatures in *Enterococcus* species isolated from pig farms environment. *Microb Pathog* 2017; **104**: 90-96.

[52]Ojo OE, Fabusoro E, Majasan AA, Dipeolu MA. Antimicrobials in animal production: Usage and practices among livestock farmers in Oyo and Kaduna States of Nigeria. *Trop Anim Health Prod* 2016; **48**: 189-197.

[53]Adebowale O, Abubakar RH, Fasanmi OG, Madoroba E, Fasina FO. Antimicrobial usage in pig production: Effects on *Escherichia coli*

virulence profiles and antimicrobial resistance. *Onderstepoort J Vet Res* 2019; **86**(1): 1-11.

[54]Mamfe LM, Akwuobu CA, Ngbede EO. Phenotypic detection, antimicrobial susceptibility and virulence profile of staphylococci in the pig production setting, Makurdi, Nigeria. *Access Microbiol* 2021; **3**(12): 000293.

[55]Love DC, Tharavichitkul P, Arjkumpa O, Imanishi M, Hinjoy S, Nelson K, et al. Antimicrobial use and multidrug-resistant *Salmonella* spp., *Escherichia coli*, and *Enterococcus faecalis* in swine from northern Thailand. *Thai J Vet Med* 2015; **45**(1): 43-53.

[56]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* 2020; **9**(10): 662.

[57]Pholwat S, Pongpan T, Chinli R, Rogawski McQuade ET, Thaipisuttikul I, Ratanakorn P, et al. Antimicrobial resistance in swine fecal specimens across different farm management systems. *Front Microbiol* 2020; **11**: 1238.

[58]Ventero MP, Marin C, Migura-Garcia L, Tort-Miro C, Giler N, Gomez I, et al. Identification of antimicrobial-resistant zoonotic bacteria in swine production: Implications from the One Health perspective. *Antibiotics* 2024; **13**(9): 883.

[59]Olayinka OA, Faleye TOC, Omotosho OO, Odukaye OA, Oluremi B, Ibitoye IH, et al. Fecal antibiotic resistome of pigs from a small-scale piggery in Ibadan, South-West Nigeria. *Vet Sci Res Rev* 2021; **7**(1): 52-57.

[60]McInnes RS, McCallum GE, Lamberte LE, van Schaik W. Horizontal transfer of antibiotic resistance genes in the human gut microbiome. *Curr Opin Microbiol* 2020; **53**: 35-43.

[61]Partridge SR, Kwong SM, Firth N, Jensen SO. Mobile genetic elements associated with antimicrobial resistance. *Clin Microbiol Rev* 2018; **31**(4): e00088-17.

[62]Li S, Ondon BS, Ho SH, Li F. Emerging soil contamination of antibiotics resistance bacteria (ARB) carrying genes (ARGs): New challenges for soil remediation and conservation. *Environ Res* 2023; **219**: 115132.

[63]Akpan SN, Odeniyi OA, Adebowale O, Alarape SA, Adeyemo OK. Antibiotic resistance profile of Gram-negative bacteria isolated from Lafenwa abattoir effluent and its receiving water (Ogun River) in Abeokuta, Ogun state, Nigeria. *Onderstepoort J Vet Res* 2020; **87**(1): 1-6.

[64]Zalewska M, Błażejewska A, Czapko A, Popowska M. Antibiotics and antibiotic resistance genes in animal manure—consequences of its application in agriculture. *Front Microbiol* 2021; **12**: 610656.

[65]National Agency for Food, Drug Administration and Control (NAFDAC). *List of banned veterinary drugs. 2024.* [Online] Available from: https://www.nafdac.gov.ng/veterinary-products/list-of-banned-veterinary-drugs/. [Accessed on 6 September 2025].

[66]World Health Organization. *Antibiotics most responsible for drug resistance are overused—WHO report. 2025.* [Online] Available from: https://www.who.int/news/item/29-04-2025-antibiotics-most-responsible-for-drug-resistance-are-overused---who-report. [Accessed on 14 October 2025].

[67]Puri B, Vaishya R, Vaish A. Antimicrobial resistance: Current challenges and future directions. *Med J Armed Forces India* 2025; **81**(3): 247-258.

[68]Gigante V, Alm RA, Melchiorri D, Rocke T, Arias CA, Czaplewski L, et al. Multi-year analysis of the global preclinical antibacterial pipeline: Trends and gaps. *Antimicrob Agents Chemother* 2024; **68**(8): 00535-00524.

[69]Matheou A, Abousetta A, Pascoe AP, Papakostopoulos D, Charalambous L, Panagi S, et al. Antibiotic use in livestock farming: A driver of multidrug resistance? *Microorganisms* 2025; **13**(4): 779.

[70]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* 2018; **8**(1): 2.

[71]Ezeh CC, Michael EO. Socio-economic analysis of smallholder pig production in Sabon Gari local government area, Kaduna State, Nigeria. In *44th Annual Conference—ABUJA 2019, Book of Proceedings,* Nigerian Society for Animal Production.

[72]Abreu R, Semedo-Lemsaddek T, Cunha E, Tavares L, Oliveira M. Antimicrobial drug resistance in poultry production: Current status and innovative strategies for bacterial control. *Microorganisms* 2023; **11**(4): 953.

[73]Oliveira M, Antunes W, Mota S, Madureira-Carvalho Á, Dinis-Oliveira RJ, da Silva DD. An overview of the recent advances in antimicrobial resistance. *Microorganisms* 2024; **12**(9): 1920.

[74]Xie WY, Shen Q, Zhao FJ. Antibiotics and antibiotic resistance from animal manures to soil: A review. *Eur J Soil Sci* 2018; **69**(1): 181-195.

[75]Ifedinezi OV, Nnaji ND, Anumudu CK, Ekwueme CT, Uhegwu CC, Ihenetu FC, Obioha P, Simon BO, Ezechukwu PS, Onyeaka H. Environmental antimicrobial resistance: Implications for food safety and public health. *Antibiotics* 2024; **13**(11): 1087.

[76]Shahid A, Ali MA, Muzammil S, Aslam B, Shahid M, Saqalein M, et al. Antibiotic residues in food chains; impact on the environment and human health: A review. *Appl Ecol Environ Res* 2021; **19**(5): 1-10.

[77]Ugoeze K, Alalor C, Ibezim C, Chinko B, Owonaro P, Anie C, et al. Environmental and human health impact of antibiotics waste mismanagement: A review. *Adv Environ Eng Res* 2024; **5**(1): 1-21.

[78]Schmithausen RM, Schulze-Geisthoevel SV, Heinemann C, Bierbaum G, Exner M, Petersen B, et al. Reservoirs and transmission pathways of resistant indicator bacteria in the biotope pig stable and along the food chain: A review from a one health perspective. *Sustainability* 2018; **10**(11): 3967.

[79]Al-Mustapha AI, Adetunji VO, Heikinheimo A. Risk perceptions of antibiotic usage and resistance: A cross-sectional survey of poultry farmers in Kwara State, Nigeria. *Antibiotics* 2020; **9**(7): 378.

[80]Ojo OE, Iledare AM, Amosun EA, Dipeolu MA. Antimicrobial use and detection of cefotaxime-resistant Enterobacteriaceae in the pig production chain, Ogun State, Nigeria. *REMVT* 2019; **72**(4): 147-154.

[81]Freeland G, Hettiarachchy N, Atungulu GG, Apple J, Mukherjee S. Strategies to combat antimicrobial resistance from farm to table. *Food Rev Int* 2023; **39**(1): 27-40.

[82]Monger XC, Gilbert AA, Saucier L, Vincent AT. Antibiotic resistance: From pig to meat. *Antibiotics* 2021; **10**(10): 1209.

[83]Sirichokchatchawan W, Apiwatsiri P, Pupa P, Saenkankam I, Khine NO, Lekagul A, et al. Reducing the risk of transmission of critical antimicrobial resistance determinants from contaminated pork products to humans in south-east Asia. *Front Microbiol* 2021; **12**: 689015.

[84]Raboisson D, Ferchiou A, Sans P, Lhermie G, Dervillé M. The economics of antimicrobial resistance in veterinary medicine: Optimizing societal benefits through mesoeconomic approaches from public and private perspectives. *One Health* 2020; **10**: 100145.

[85]Ahmed SK, Hussein S, Qurbani K, Ibrahim RH, Fareeq A, Mahmood KA, et al. Antimicrobial resistance: Impacts, challenges, and future prospects. *J Med Surg Public Health* 2024; **2**: 100081.

[86]Dione MM, Amia WC, Ejobi F, Ouma EA, Wieland B. Supply chain and delivery of antimicrobial drugs in smallholder livestock production systems in Uganda. *Front Vet Sci* 2021; **8**: 611076.

[87]Bitrus AA, Charibu DH, Akinsola OM, Oladele OO, Adanu AW, Unanam ES, et al. Awareness of antibiotic use and antibiotic resistance among stakeholders in the pig value chain: A preliminary report. *Vet Int Sci* 2025; **23**(3): 1-7.

[88]Kimera ZI, Frumence G, Mboera LE, Rweyemamu M, Mshana SE, Matee MI. Assessment of drivers of antimicrobial use and resistance in poultry and domestic pig farming in the Msimbazi river basin in Tanzania. *Antibiotics* 2020; **9**(12): 838.

[89]Bedekelabou AP, Talaki E, Dzogbema KF, Dolou M, Savadogo M, Seko MO, et al. Assessing farm biosecurity and farmers' knowledge and practices concerning antibiotics and antibiotic resistance in poultry and pig farms in Southern Togo. *Vet World* 2022; **15**(7): 1727.

[90]Luu QH, Nguyen TL, Pham TN, Vo NG, Padungtod P. Antimicrobial use in household, semi-industrialized, and industrialized pig and poultry farms in Viet Nam. *Prev Vet Med* 2021; **189**: 105292.

[91]Fang J, Gong G, Yuan J, Sun X. Antibiotic use in pig farming and its associated factors in L County in Yunnan, China. *Vet Med and Sci* 2021; **7**(2): 440-454.

[92]Ting S, Pereira A, Davis S, Vong da Silva PG, Alves A, Dos Santos C, et al. Knowledge and practices on antibiotic use and antibiotic resistance among smallholder pig farmers in Timor-Leste. *Front Vet Sci* 2022; **8**: 819643.

[93]Van Boeckel TP, Brower C, Gilbert M, Grenfell BT, Levin SA, Robinson TP, et al. Global trends in antimicrobial use in food animals. *PNAS* 2015; **112**(18): 5649-5654.

[94]Klein EY, Impalli I, Poleon S, Denoel P, Cipriano M, Van Boeckel TP, Pecetta S, Bloom DE, Nandi A. Global trends in antibiotic consumption during 2016-2023 and future projections through 2030. *PNAS* 2024; **121**(49): e2411919121.

[95]95.Sulis G, Sayood S, Gandra S. Antimicrobial resistance in low-and middle-income countries: Current status and future directions. *Expert Rev Anti–infective Ther* 2022; **20**(2):147-60.

[96]Shao Y, Wang Y, Yuan Y, Xie Y. A systematic review on antibiotics misuse in livestock and aquaculture and regulation implications in China. *Sci Tot Env* 2021; **798**: 149205.

[97]Van Boeckel TP, Pires J, Silvester R, Zhao C, Song J, Criscuolo NG, et al. Global trends in antimicrobial resistance in animals in low-and middle-income countries. *Science* 2019; **365**(6459): eaaw1944.

[98]Awoke OO, Edeh PA, Ekuma UO, Ede JU, Ituma MA, Odo II, et al. Characterization of multidrug-resistant extended spectrum β-lactamase producing *Escherichia coli* from commercial swine farms in Ohaukwu local government Area, Ebonyi State Nigeria. *GSC Biol Pharmaceu Sci* 2025; **30**(02): 306-319.

[99]Okpaga JU, Oke B. Characterization of extended spectrum beta-lactamase producing *Escherichia coli* isolates from swine in Ohaukwu local government area, Ebonyi State Nigeria. *Nigerian J Microb* 2024; **38**(1): 7045-7058.

[100]Thuan NK, Minh BT, Thong NV, Tuyen NH, Truong NL, Thien PM. Antibiotic resistance and adhesive antigen of *Escherichia coli* isolated from pigs in farm and slaughterhouse in Hau Giang Province, Vietnam. *J Anim Health Prod* 2024; **12**(s1): 15-22.

[101]Peng Z, Hu Z, Li Z, Zhang X, Jia C, Li T, et al. Antimicrobial resistance and population genomics of multidrug-resistant *Escherichia coli* in pig farms in mainland China. *Nature Comm* 2022; **13**(1): 1116.

[102]Da Silva RA, Arenas NE, Luiza VL, Bermudez JAZ, Clarke SE. Regulations on the use of antibiotics in livestock production in South America: A comparative literature analysis. *Antibiotics* 2023; **12**(8): 1303.

[103]Adegbeye MJ, Adetuyi BO, Igirigi AI, Adisa A, Palangi V, Aiyedun S, et al. Comprehensive insights into antibiotic residues in livestock products: Distribution, factors, challenges, opportunities, and implications for food safety and public health. *Food Control* 2024; **163**: 110545.

[104]Food and Agriculture Organization of the United Nation (FAO). *Reducing the need for antimicrobials by improving animal husbandry practices. 2024*. [Online] Available from: https://www.fao.org/antimicrobial-resistance/news-and-events/news/news-details/en/c/1675480/. [Accessed on 6 September 2025].

[105]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.

[106]Moyo P, Moyo E, Mangoya D, Mhango M, Mashe T, Imran M, Dzinamarira T. Prevention of antimicrobial resistance in sub-Saharan Africa: What has worked? What still needs to be done? *J Infect Public Health* 2023; **16**(4): 632-639.

[107]Golding SE, Ogden J, Higgins HM. Shared goals, different barriers: A qualitative study of UK veterinarians' and farmers' beliefs about antimicrobial resistance and stewardship. *Front Vet Sci* 2019; **6**: 132.

[108]Gozdzielewska L, King C, Flowers P, Mellor D, Dunlop P, Price L. Scoping review of approaches for improving antimicrobial stewardship in livestock farmers and veterinarians. *Prev Vet Med* 2020; **180**: 105025.

[109]Manyi-Loh C, Mamphweli S, Meyer E, Okoh A. Antibiotic use in agriculture and its consequential resistance in environmental sources: potential public health implications. *Molecules* 2018; **23**(4): 795.

[110]Mitchell SA, Sok DK. Precision livestock farming in the digital age: Sensors and microfluidics paving the way for sustainable agriculture. *Sage Sci Rev Educ Technol* 2023; **6**(1): 71-87

[111]Sanders P, Vanderhaeghen W, Fertner M, Fuchs K, Obritzhauser W, Agunos A, et al. Monitoring of farm-level antimicrobial use to guide stewardship: Overview of existing systems and analysis of key components and processes. *Front Vet Sci* 2020; **7**: 540.

[112]Mudenda S, Chabalenge B, Daka V, Mfune RL, Salachi KI, Mohamed S, et al. Global strategies to combat antimicrobial resistance: A one health perspective. *Pharmacol Pharm* 2023; **14**(8): 271-328.

[113]Ding L, Hu F. China's new national action plan to combat antimicrobial resistance (2022–25). *J Antimicrob Chem* 2023; **78**(2): 558-560.

[114]Swedish Veterinary Agency. *Antibiotic use for animals in Sweden. 2025.* [Online] Available from: https://www.sva.se/en/what-we-do/antibiotics/antibiotic-use-for-animals-in-sweden/. [Accessed on 16 October 2025].

[115]Danish Veterinary and Food Administration. *Facts about livestock–associated MRSA and about livestock–associated MRSA in Denmark in relation to Danish pigs and pork. 2025.* [Online] Available from: https://en.foedevarestyrelsen.dk/animals/animal-health-/monitoring-and-control-of-animal-diseases/mrsa? [Accessed on 16 October 2025].

[116]Amegayibor EF, Ohene Larbi R, Ayim-Akonor M, Ansa ED, Thekkur P, Owusu H, et al. Prevalence of antimicrobial and colistin resistance in enterobacterales in healthy pigs in Ghana before and after farmer education. *Trop Med Inf Dis* 2025; **10**(9): 266.

[117]Food and Agriculture Organization of the United Nation (FAO). *FAO and UK unite to tackle antimicrobial resistance in Viet Nam. 2025.* [Online] Available from: https://www.fao.org/ectad/asiapacific/news-and-events/news/news-detail/fao-and-uk-unite-to-tackle-antimicrobial-resistance-in-viet-nam/. [Accessed on 16 October 2025].

[118]Postma M, Backhans A, Collineau L, Loesken S, Sjölund M, Belloc C, et al. Evaluation of the relationship between the biosecurity status, production parameters, herd characteristics and antimicrobial usage in farrow-to-finish pig production in four EU countries. *Porcine Health Mgt* 2016; **2**(1): 9.

[119]Isomura R, Matsuda M, Sugiura K. An epidemiological analysis of the level of biosecurity and animal welfare on pig farms in Japan and their effect on the use of veterinary antimicrobials. *J Vet Med Sci* 2018; **80**(12): 1853-1860.

[120]Wang J, Shi Z, Hu X. Status, evaluation, and influencing factors of biosecurity levels in pig farms in China. *BMC Vet Res* 2023; **19**(1): 272.

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Edited by Liang TC, Qi Y

Supplementary Table 1. List of prohibited antimicrobials for livestock production in Nigeria (NAFDAC, 2024)

Antimicrobial	Class of drug	Health concern
Dimetridazole	Antiprotozoal/Antibacterial	Adverse effects on blood cell formation and persistence in the environment
Ipronidazole	Antiprotozoal/Antibacterial	Associated with genotoxicity
Furaltadone	Antibacterial	Potential carcinogen
Malachite Green	Antifungal/Antiprotozoal	AMR, Toxicity and persistence in the environment
Metronidazole	Antiprotozoal/Antibacterial	Potential to cause AMR, cancer and allergies
Olaquinox	Antibacterial	Allergic reactions and has potential to contribute to the emergence of AMR
Nitrofurantoin	Antibacterial	Pulmonary toxicity
Carbadox	Antiprotozoal	Carcinogenic effects and potential for residues in pork products
Ronidazole	Antiprotozoal/Antibacterial	Carcinogenic and genotoxic effects
Furazolidone	Antibacterial	Antimicrobial residues and emergence of AMR
Chloramphenicol	Antibacterial	Risk of aplastic anaemia
Nitrofural	Antibacterial	Potential carcinogens and allergic reactions