Research Article

The Relationship Between Farmers' Knowledge and Practices Regarding Antibiotic Use and *Escherichia coli* Resistance in Broiler Chicken Farms in Tabanan Regency, Bali, Indonesia

I Gede Bagus Dharma Adnyana[1], I Nengah Kerta Besung[2], Kadek Karang Agustina[3*]

[1]Veterinary Medicine, Faculty of Veterinary Medicine, Udayana University, PB. Sudirman St. Campus Denpasar, Bali, Indonesia, 80234; [2]Department of Microbiology, Faculty of Veterinary Medicine, Udayana University, PB. Sudirman St. Campus Denpasar, Bali, Indonesia, 80234; [3]Department of Veterinary Public Health, Faculty of Veterinary Medicine, Udayana University, PB. Sudirman St. Campus Denpasar, Bali, Indonesia, 80234.

Abstract | The growing reliance on antibiotics in broiler farming has sparked significant concern about antimicrobial resistance (AMR). Despite its global implications, discussions on AMR often remain confined to elite circles, with limited outreach to grassroots stakeholders, including farmers. This study investigates the relationship between farmers' knowledge, antibiotic use practices, and *Escherichia coli* resistance in broiler farms. A cross-sectional design was employed, with multi-stage random sampling of 20 farms in Tabanan Regency, Bali. Data on farmers' knowledge and practices were collected using structured questionnaires, while antibiotic resistance was assessed through sensitivity testing of *E. coli* isolates. The Kirby-Bauer diffusion method was used to evaluate resistance to ciprofloxacin, ampicillin, tetracycline, and sulfamethoxazole-trimethoprim. Findings indicated that farmers' knowledge levels were categorized as good (15%), moderate (70%), and poor (15%), while practices were rated as good (65%) and moderate (35%). *E. coli* isolates demonstrated complete resistance to ampicillin (100%), followed by sulfamethoxazole-trimethoprim (80%), tetracycline (65%), and ciprofloxacin (45%). Statistical analysis revealed a significant correlation between farmers' knowledge and antibiotic use practices ($p < 0.05$), but notably, no significant link was found between farmers' practices and observed resistance patterns in *E. coli*. This unexpected finding suggests that antibiotic resistance in broiler farms may be driven by broader factors (e.g., environmental contamination, historical antibiotic use, or microbial adaptation) underscoring the need for systemic interventions. The study revealed that despite varying levels of farmer knowledge, a significant gap persists between understanding antibiotic use and implementing AMR-prevention practices. To bridge this gap, enhanced education initiatives must evolve from basic awareness to targeted, practical training programs. Such efforts require collaboration between farmers, policymakers, and researchers to effectively reduce AMR risks and safeguard both public and animal health.

Keywords | Antimicrobial, AMR, broiler, *E. coli*, farmer, resistance

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***Correspondence** | Kadek Karang Agustina, Department of Veterinary Public Health, Faculty of Veterinary Medicine, Udayana University, PB. Sudirman St. Campus Denpasar, Bali, Indonesia, 80234; **Email:** k.agustina@unud.ac.id
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INTRODUCTION

Antimicrobial resistance (AMR) has emerged as one of the most urgent global health challenges of the 21st century. The World Health Organization (WHO) has declared AMR a serious threat to public health, food security, and sustainable development. WHO estimates that by 2030, AMR could push up to 24 million people into extreme poverty if effective measures are not taken to address this issue (WHO, 2023). Currently, at least 700,000 people die annually due to infections caused by drug-resistant bacteria, and this number is predicted to rise significantly if preventive and control measures are not urgently implemented (Aguilar *et al*., 2023). AMR is not confined to human health alone but is recognized as a One Health issue, encompassing animal health and environmental sustainability. The complex interactions between humans, animals, and the environment create ideal conditions for the spread and evolution of antimicrobial resistance (Velazquez-Meza *et al*., 2022). Consequently, AMR not only threatens the effectiveness of bacterial infection treatments in humans but also increases healthcare costs and the risk of mortality from untreatable infections (Salam *et al*., 2023).

The livestock sector, particularly poultry farming, plays a significant role in driving the development of AMR. The use of antibiotics in livestock, especially in the broiler industry, remains a common practice despite efforts to reduce its prevalence (Hedman *et al*., 2020). On the one hand, the broiler industry holds a strategic position in supporting global food security. Broiler chickens provide an affordable source of animal protein and significantly contribute to meeting nutritional needs, particularly in developing countries (Attia *et al*., 2022). Furthermore, the growing broiler business has spurred economic growth and created employment opportunities for millions worldwide (Grzinic *et al*., 2023). On the other hand, the increase in broiler production is directly correlated with high antibiotic consumption, used for therapeutic purposes, disease prevention, and as growth promoters. If unregulated, these practices can accelerate the development of AMR, posing serious threats to human, animal, and environmental health (Mehdi *et al*., 2018).

The excessive use of antibiotics in broiler farming creates selective pressure, which drives the emergence of resistant bacteria. These bacteria can subsequently spread to humans through the consumption of poultry products, direct contact with animals, or contaminated environments (Okaiyeto *et al*., 2024). *Escherichia coli* has long been recognized as a key indicator bacterium for monitoring the development of AMR (Elankumuran *et al*., 2023). Naturally present in the digestive tracts of humans and animals, including broilers, *E. coli* is often used as a model for evaluating antibiotic resistance patterns due to its ability to accumulate and transfer resistance genes through horizontal mechanisms such as plasmids, transposons, and integrons (Hedman *et al*., 2020). As a commensal bacterium, *E. coli* is frequently exposed to antibiotics used in farming, making it a significant reservoir for resistance genes. Moreover, *E. coli* can also act as an opportunistic pathogen, causing urinary tract infections, sepsis, and gastrointestinal infections in humans, further exacerbating the clinical impact of antibiotic resistance (Manyi-Loh *et al*., 2018).

Broiler farming in Bali, Indonesia has unique characteristics, with the majority of operations being small-scale and run by local farmers. These farming systems are typically simple, often utilizing open-house systems that allow direct interaction between poultry and their surrounding environment (Junaidi *et al*., 2023). While this approach reduces production costs, it is often accompanied by limited farmer knowledge regarding proper animal health management and responsible antibiotic use. As a result, reliance on antibiotics in broiler farming in Bali is exceptionally high, particularly for disease prevention and growth promotion. The easy availability and affordability of antibiotics further exacerbate the situation. Antibiotics are often obtained without prescriptions or veterinary oversight, leading to a high potential for misuse (Coyne *et al*., 2020). Bali's broiler industry, dominated by small-scale farms (70-80% with < 5,000 birds), faces unique AMR challenges due to intensive production practices and humid tropical conditions that increase disease pressure. Government reports indicate antibiotic use is widespread, with 60-70% of farms routinely employing antibiotics for disease prevention (particularly tetracyclines and sulfonamides), often without veterinary supervision. This practice mirrors trends across Indonesia, where poultry accounts for nearly 50% of veterinary antibiotic consumption. Tabanan Regency is recognized as one of the largest broiler farming centers in the Province of Bali. This region has a high concentration of poultry farms. It plays a vital role in meeting the demand for animal protein, particularly chicken meat, for the people of Bali, especially in Denpasar City, which serves as the primary consumption hub. It makes Tabanan Regency an ideal study site to examine how farmer behavior intersects with resistance patterns in a high-antibiotic-use environment (Siahaan *et al*., 2022). Therefore, this study aims to investigate the relationship between farmers' knowledge, antibiotic use practices, and *E. coli* resistance in broiler farms in Tabanan, one of Bali's primary broiler farming centers. By addressing these issues, this research seeks to contribute to the development of targeted strategies to mitigate AMR and promote sustainable farming practices in the region.

MATERIALS AND METHODS

Ethical clearance

This study received ethical approval from the Research Ethics Committee of Udayana University, with approval letter number B/9/UN14.2.9/PT.01.04/2025. Prior to data collection, all participating farmers provided written informed consent after receiving comprehensive explanations about the study objectives, procedures, potential risks/benefits, and their rights as participants. The consent form explicitly stated that anonymized data would be used for research purposes and potential publication, while ensuring confidentiality of personal and farm identifiers. Participants were informed of their voluntary participation rights, including the option to withdraw at any stage without consequences.

Study design and sampling

This study employed an observational analytic design with a cross-sectional sampling approach by a two-stage random sampling approach: First, Tabanan Regency was purposively selected as the study area, and second, two broiler farms were randomly chosen from each of its 10 sub-districts, yielding a representative sample of 20 farms. The random selection at both administrative levels ensured geographical diversity while minimizing selection bias in assessing antibiotic use practices and AMR patterns. Data on farmers' knowledge and practices regarding antibiotic use were collected through face-to-face interviews using a structured questionnaire. Additionally, one fecal sample was randomly collected from each farm. Samples were obtained using cloacal swabs from broilers exhibiting diarrhea and immediately placed in Amies transport media to ensure sample integrity during transportation.

Isolation and identification of *E. coli*

Samples were cultured on Eosin Methylene Blue (EMB) Agar to isolate *E. coli*. Gram staining was performed to confirm bacterial morphology, and suspected *E. coli* colonies were further identified through biochemical tests, including Indole, Methyl Red, Voges-Proskauer, and Citrate (IMViC) assays. *E. coli* isolates were confirmed by positive Indole and Methyl Red tests and negative Voges-Proskauer and Citrate tests (Geletu *et al*., 2022).

Antibiotic susceptibility testing

The Kirby-Bauer disk diffusion method was used to assess the antibiotic sensitivity of *E. coli* isolates. Bacterial suspensions were evenly inoculated onto Mueller Hinton Agar plates, and four antibiotic disks (OXOID) were applied: ciprofloxacin (5 µg), ampicillin (10 µg), tetracycline (30 µg), and sulfamethoxazole-trimethoprim (25 µg). Plates were incubated at 37°C for 16–18 hours, after which the inhibition zones around the disks were measured. Results were interpreted according to the Clinical and Laboratory Standards Institute (CLSI) guidelines, categorizing isolates as sensitive, intermediate, or resistant based on the diameter of the inhibition zones (Lewis *et al*., 2025).

Data collection and analysis

Farmers' knowledge and practices regarding antibiotic use were assessed using a validated and reliable questionnaire, consisting of 20 closed-ended questions each. Questionnaire validity was established via expert validation and pilot testing, and reliability was verified with Cronbach's alpha ($\alpha > 0.7$), ensuring the tool measured constructs consistently. The questionnaire covered topics such as types of antibiotics used, their functions, administration methods, dosages, and the impacts of antibiotic use. Responses were scored and tabulated to categorize knowledge and practices into three levels: good (76–100% correct answers), moderate (50–75% correct answers), and poor (<50% correct answers). Data were analyzed using regression and correlation tests to evaluate the relationships between farmers' knowledge, antibiotic use practices, and the occurrence of *E. coli* resistance. Statistical significance was set at $p < 0.05$.

RESULTS AND DISCUSSION

Table 1 shows the demographic analysis of the research subjects revealed that the majority of broiler farmers in Tabanan Regency were over 55 years old (40%), followed by those aged 25–35 years (30%). This indicates that broiler farming in the region is primarily managed by older individuals, which may reflect a generational gap and a lack of younger farmers entering the industry. In terms of farming experience, 40% of farmers had 1–5 years of experience, while 25% had more than 20 years of experience. This wide range of experience levels suggests varying degrees of familiarity with modern farming practices and antibiotic use.

The predominance of older farmers (40% aged >55 years) may reflect age-related biases in knowledge and practice assessments. Older farmers often rely on traditional experience rather than updated AMR mitigation strategies, potentially leading to: (1) greater adherence to routine antibiotic use due to established habits, and (2) lower adoption of digital tools for farm management (Doidge *et al*., 2021). Conversely, the presence of younger farmers (30% aged 25–35) might reflect emerging awareness of AMR risks, as they are typically more exposed to modern training programs. However, the limited proportion of mid-career farmers (not mentioned in data) could indicate a generational transition gap, where neither traditional knowledge nor contemporary practices are fully optimized. This demographic divide underscores the need for age-tailored educational interventions to bridge experience-based and science-based approaches (Ferraz, 2024).

Table 1: Characteristics of the research subjects.

Parameter	Category	N	%
Age (Year)	<25	2	10
	25-35	6	30
	36-45	3	15
	46-55	1	5
	>55	8	40
Total		20	100
Farming experience (Year)	1-5	8	40
	6-10	5	25
	11-15	1	5
	16-20	1	5
	>20	5	25
Total		20	100
Educational background	Elementary school	4	20
	Junior high school	4	20
	Senior high school	8	40
	Bachelor	3	15
	Postgraduate	1	5
Total		20	100

Educational background data showed that 40% of farmers had completed senior high school, while 20% had only elementary or junior high school education. Only 15% held a diploma or bachelor's degree, and a mere 5% had postgraduate qualifications (Table 1). The relatively low educational attainment among farmers may contribute to limited understanding of proper antibiotic use and antimicrobial resistance (AMR), as education has been shown to positively influence knowledge and practices in agricultural settings (Chah *et al*., 2022). These findings highlight the need for targeted educational programs to improve farmers understanding of AMR and its implications.

The study found that only 15% of farmers had a good level of knowledge about antibiotic use, while 70% demonstrated moderate knowledge, and 15% had insufficient understanding. In contrast, 65% of farmers were categorized as having good antibiotic use practices, with the remaining 35% falling into the moderate category (Table 2). This discrepancy between knowledge and practices suggests that farmers may rely on traditional methods, peer advice, or veterinary recommendations rather than formal knowledge when administering antibiotics. The relatively high percentage of farmers with moderate practices despite limited knowledge could be attributed to the influence of local farming networks or external guidance. However, the lack of insufficient practices indicates that most farmers adhere to some level of responsible antibiotic use, which is encouraging. Nevertheless, the presence of insufficient knowledge highlights the need for targeted educational interventions to improve understanding of AMR and its implications (Ozturk *et al*., 2019).

Table 2: Knowledge and practices of broiler farmers regarding antibiotic use.

Variable	Good	Moderate	Insufficient
Knowledge	15%	70%	15%
Practice	65%	35%	0%

The farmers knowledge of AMR is limited, with only 15% demonstrating sufficient understanding. However, a majority (65%) adhere to proper antibiotic use practices in poultry farming. This disparity is likely attributable to Tabanan's broiler farming system, which operates exclusively under corporate partnerships (contract farming arrangements between farmers and companies). In practice, farmers follow strict protocols enforced by technical support staff, primarily veterinarians, appointed by the partnering companies. Consequently, while farmers may lack theoretical knowledge, their compliance with sound practices is facilitated by a structured, externally guided system (Junaidi *et al*., 2023).

Table 3: Correlation-regression between research variables.

Variable	Correlation coefficient (r)	P value
Age-Knowledge	0.625	0.003**
Educational background-Knowledge	0.494	0.027*
Farming experience-Knowledge	0.740	0.000**
Age-Practice	0.202	0.392
Educational background-Practice	0.336	0.148
Farming experience-Practice	0.264	0.261
Knowledge-Practice	0.574	0.008**
Practice-*E. coli* resistance	0.279	0.078

Note: ** Highly significant (P<0.01); * Significant (P<0.05)

Statistical analysis (Table 3) revealed significant correlations between several variables. Age showed a strong positive correlation with knowledge ($r = 0.625$, $p = 0.003$), indicating that older farmers tend to have better knowledge about antibiotic use, possibly due to accumulated experience. Similarly, educational background ($r = 0.494$, $p = 0.027$) and farming experience ($r = 0.740$, $p = 0.000$) were significantly correlated with knowledge, underscoring the importance of education and experience in shaping farmers' understanding of antibiotic use. Interestingly, while knowledge was significantly correlated with practices ($r = 0.574$, $p = 0.008$), no significant correlations were found between age, educational background, or farming experience and practices. This suggests that knowledge is a key driver of appropriate antibiotic use practices, but other factors, such as access to veterinary services, community norms, or economic constraints, may also play a role. These findings align with previous studies emphasizing the importance of knowledge in influencing health-related behaviors (Shahi and Jeamsripong, 2024).

The apparent paradox of moderate antibiotic use practices (65% good) despite limited farmer knowledge (15% good) likely stems from Bali's prevalent partnership farming system, where corporate-affiliated veterinarians provide standardized treatment protocols, ensuring proper practices regardless of individual understanding. While this system explains the moderate practice-knowledge correlation (r= 0.574, p= 0.008), it raises concerns about long-term AMR mitigation, as dependence on external guidance may hinder autonomous decision-making. Notably, older farmers demonstrated better knowledge, likely from experience, yet showed no direct practice correlation, suggesting that institutional support, not just age or education, drives compliance. The remaining 35% with only moderate practices may reflect non-partnered smallholders lacking veterinary oversight, highlighting the need to complement structural support with farmer education to internalize AMR understanding, particularly for younger entrants who showed lower knowledge levels but greater openness to training (Gualtieri and Finn, 2022).

Table 4: Resistance of *E. coli* to several commonly used antibiotics in broiler farms in Bali.

Antibiotic type	Sensitive	Intermediate	Resistant
Ciprofloxacin	20%	35%	45%
Ampicillin	0%	0%	100%
Sulfamethoxazole-trimethoprim	15%	5%	80%
Tetracycline	30%	5%	65%

The antibiotic susceptibility testing of *E. coli* isolates revealed alarming levels of resistance, with all isolates (100%) exhibiting resistance to ampicillin, followed by sulfamethoxazole-trimethoprim (80%), tetracycline (65%), and ciprofloxacin (45%) (Table 4). These findings align with global trends of escalating AMR in livestock farming, which is largely driven by the overuse and misuse of antibiotics in both therapeutic and non-therapeutic contexts (Aguilar *et al.*, 2023). The universal resistance to ampicillin, a first-line antibiotic, is particularly troubling, as it reflects the extensive and often indiscriminate use of this drug in poultry farming for disease prevention and growth promotion (Abreu *et al.*, 2023). The pattern mirrors finding in Medan (Audiya *et al.*, 2023), Bandung (Prasaja *et al.*, 2024), and Bantul (Wulandari *et al.*, 2025) suggest a nationwide AMR crisis in Indonesia poultry farming. This consistent pattern of complete resistance suggests a nationwide crisis in poultry farming, likely driven by the uncontrolled use of ampicillin for both treatment and prophylaxis. Similar trends have been documented across other ASEAN countries, indicating a regional AMR epidemic that demands urgent attention (Malik *et al.*, 2023).

Similarly, the high resistance to sulfamethoxazole-trimethoprim, a combination antibiotic widely used in both veterinary and human medicine, underscores the dual risks posed to animal and public health (Martínez-Álvarez *et al.*, 2022). The moderate resistance to ciprofloxacin, a fluoroquinolone classified as critically important for human medicine by the WHO, is especially concerning. Fluoroquinolones are often reserved for treating severe bacterial infections in humans, and the emergence of resistance in livestock populations raises the specter of cross-species transmission through the food chain or environmental contamination, potentially rendering these life-saving drugs ineffective (Shang *et al.*, 2023).

Although the farmers practices were not directly linked to *E. coli* resistance, the widespread antimicrobial resistance (AMR) observed in this study can be attributed to several factors. First, the frequent use of antibiotics for prophylactic purposes and as growth promoters in broiler farming creates selective pressure that favors the survival and proliferation of resistant bacterial strains. This practice is often exacerbated by the lack of stringent regulatory frameworks and the easy availability of antibiotics without veterinary prescriptions, which encourages misuse and overuse. Second, the open-house farming systems commonly used in Tabanan Regency, characterized by direct interaction between poultry and their environment, may facilitate the spread of resistant bacteria through contaminated water, soil, or equipment. Third, the limited knowledge and training among farmers regarding proper antibiotic use and AMR further compound the problem, as inappropriate dosing, duration, and frequency of antibiotic administration can accelerate the development of resistance (Manyi-Loh *et al.*, 2018). Other critical factors driving AMR include suboptimal farm management, high animal density, and poor sanitation, which increase stress and compromise poultry immunity, elevating susceptibility to infections. Limited disease management and barn hygiene further create reservoirs for resistant bacteria to persist and spread within flocks. However, the most significant mechanism amplifying resistance is horizontal gene transfer (e.g., conjugation), which enables rapid dissemination of resistance genes across bacterial populations, transcending species and environmental boundaries (Hedman *et al.*, 2020).

These findings underscore the urgent need for a multifaceted approach to combat AMR in broiler farming (Abou-

Jaoudeh *et al*., 2024). Stricter regulations on antibiotic use, including bans on non-therapeutic applications and the enforcement of veterinary oversight, are critical first steps. Additionally, improving farm management practices, such as enhancing biosecurity measures, implementing vaccination programs, and adopting alternatives to antibiotics like probiotics, prebiotics, and phytogenic feed additives, can reduce reliance on antibiotics while maintaining animal health and productivity (Manyi-Loh *et al*., 2018). Equally important is the need for targeted educational interventions to raise awareness among farmers about the risks of AMR and the importance of responsible antibiotic use (Azim *et al*., 2023).

Study limitation

This study has several limitations that should be considered when interpreting the results. First, the relatively small sample size (20 farms) may affect the statistical power and generalizability of the findings, though efforts were made to ensure representative sampling. Second, while the study was conducted in a single regency, this location was deliberately selected as it hosts the highest broiler farm population in Bali, thereby capturing a significant proportion of regional poultry production. Third, the predominance of corporate partnership farms in our sample may limit generalizability to independent smallholders, who likely face different AMR drivers (e.g., less veterinary oversight). Fourth, we recognize that the cross-sectional design cannot definitively establish causation; however, the observed associations between knowledge, practices, and antibiotic resistance patterns support the plausibility of our hypothesis that enhanced knowledge could improve farming practices. Thus, despite these constraints, the findings provide a logical foundation for targeted educational interventions, while underscoring the need for future longitudinal or experimental studies to validate causal relationships.

CONCLUSION

This study highlights the complex interplay between demographic factors, knowledge, practices, and antibiotic resistance in broiler farming in Tabanan Regency. While older, more educated, and experienced farmers tend to have better knowledge about antibiotic use, knowledge alone is not sufficient to ensure appropriate practices. The high levels of antibiotic resistance observed in *E. coli* isolates demand immediate policy action, including implementing mandatory veterinary prescriptions for all antibiotic purchases, and establishing farmer training certification programs on AMR mitigation. Given that 60% of farmers had only elementary/high school education (Table 1), targeted programs must adapt content to low-literacy audiences, using visual aids or local language. These measures should be coupled with routine farm-level resistance surveillance and incentives for adopting antibiotic-free farming alternatives (e.g., probiotics, improved vaccines). Sustained collaboration between farmers, veterinarians, and policymakers will be critical to operationalize these strategies while maintaining poultry productivity and protecting both animal and public health. While these findings provide critical insights, the study's limited sample size and sampling approach may affect generalizability, potentially underrepresenting smaller independent farms outside partnership systems.

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NOVELTY STATEMENT

This study's novelty lies in its identification of a critical double disconnect in AMR management at the grassroots level. First, a disconnect between farmers' "moderately good" knowledge levels and their still suboptimal antibiotic use practices. Second, and more significantly, a disconnect between these on-farm practices and the observed antibiotic resistance patterns in E. coli isolates. This research empirically demonstrates that even on farms with relatively good practices, high levels of antibiotic resistance persist. This generates a crucial new insight: improving individual knowledge and practices, while important, is insufficient to combat AMR without parallel systemic interventions that target the entire farming ecosystem (e.g., environmental contamination, historical drug use, and regulation of antibiotic access). Consequently, our findings necessitate a recalibration of national AMR mitigation strategies to address these broader, structural drivers.

AUTHOR'S CONTRIBUTION

All authors contributed equally to this research and manuscript. Each author played a significant role in the study design, data collection, analysis, interpretation of results, and the writing of the manuscript. All authors have reviewed and approved the final version of the manuscript.

Generative AI or AI-assisted Technology Statement

The author(s) declare that no Genrative AI was used in the creation of this manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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