

Promoting Antimicrobial Stewardship in Small Ruminants: A Behavioral Assessment and Footbath Intervention at a Community Farm in Purbalingga, Central Java

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Abstract

Infectious diseases such as lameness remain persistent health challenges for small ruminants within community farming systems. Although antimicrobials are commonly used for treatment, their widespread application raises concerns about increasing drug use and the emergence of antimicrobial resistance. This study evaluated farmer practices related to antimicrobial use at Ngudi Dadi, a community farm in Central Java, Indonesia, and implemented a multifaceted intervention that included farmer training and the construction of a biosecurity-oriented footbath. Behavioral data were collected through a structured survey administered to 21 farmers, covering five key domains: antimicrobial administration, disposal of veterinary medicines, frequency of antimicrobial use, medication storage, and treatment of sick animals. Behavioral scores varied across domains, with consistently higher scores observed for treatment-related practices, while significant gaps were identified in the administration and disposal of antimicrobials. Notably, no significant correlation was found between years of farming experience and behavioral practice scores (Spearman's $\rho = 0.0488$, $p = 0.8335$), indicating that these gaps were consistent regardless of experience level. Following the survey, a training session was conducted, and a footbath was installed using lemongrass essential oil as a natural disinfectant. The footbath is now routinely used for incoming livestock at Ngudi Dadi Farm as a preventive biosecurity measure, contributing to reduced antimicrobial dependency. This study represents the first initiative in Indonesia to integrate behavioral assessment, farmer education, and footbath installation into a comprehensive antimicrobial stewardship strategy. Scaling this model to other community farming settings and developing standardized operating procedures may strengthen its impact and long-term sustainability.

1. INTRODUCTION

Small ruminants such as goats and sheep are vital livestock in Indonesia, playing a crucial role in rural livelihoods and national food security (Sujarwanta et al., 2024). However, their productivity is frequently compromised by clinical

conditions such as lameness, which significantly affect both animal welfare and farm profitability. Lameness remains a persistent health and welfare issue for small ruminants, particularly in communal farming settings, where outbreaks

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are linked to reduced productivity and increased treatment costs. Economic losses attributed to lameness are estimated to account for 20–25% of total livestock production costs (Nalon & Stevenson, 2019). The pathophysiology of lameness typically involves structural damage to the foot, including inflammation of joints, ligaments, or tendons, as well as injury to bones and hooves. These conditions can cause substantial pain and impair the animal's ability to bear weight. In severe or untreated cases, lameness may ultimately result in mortality (Prosser et al., 2020).

Bacterial infections are the most common cause of lameness in livestock. Pathogens such as *Dichelobacter nodosus* and *Fusobacterium necrophorum* typically invade the foot, leading to tissue damage and clinical manifestations such as foot rot. In addition, systemic infections caused by bacteria like *Escherichia coli* or *Salmonella spp.* may result in joint or bone inflammation, which can occasionally progress to paralysis or death (Robcis et al., 2023a,b; Zanolari et al., 2021). Notably, approximately 80% of antimicrobial use in livestock production is directed toward the treatment of lameness (Prosser et al., 2020). As a result, reducing the incidence of lameness has become a critical objective in efforts to mitigate antimicrobial resistance (AMR) in livestock.

Antimicrobial therapy remains a cornerstone in the treatment of infectious diseases in both humans and animals. However, the irrational use of antimicrobials in the farming sector has significantly contributed to the global rise of antimicrobial resistance (AMR), now recognized as one of the top ten threats to public health. According to the World Health Organization (WHO), AMR is responsible for approximately 700,000 deaths annually – a number projected to reach 10 million per year by 2050 if effective interventions are not implemented. The consequences are particularly evident in zoonotic bacteria (Borelli et al., 2023; Manyi-Loh et al., 2018). The European Food Safety Authority (EFSA) has reported that approximately 70% of *Salmonella* infections in humans within the European Union are caused by strains resistant to one or more antimicrobials (Rahman & Hollis, 2023).

The widespread and often inappropriate use of antimicrobials in both humans and animals has played a significant role in accelerating the rise of antimicrobial resistance (AMR) (Martins & Rabinowitz, 2020; McEwen & Collignon, 2018; Morrison & Zembower, 2020). Data from the Centers for Disease Control and Prevention (CDC) show that approximately 30% of global antimicrobial consumption in 2020 occurred in livestock. Of this amount, an estimated 80% was used not for treating illness, but for prophylactic and growth-promoting purposes (Kadri, 2020). These practices reflect a troubling pattern of misuse that continues to undermine global efforts to combat AMR.

Given the substantial risks posed by AMR to human, animal, and environmental health, governments and health agencies must implement targeted regulations to limit the irrational use of antimicrobials in livestock, including for managing lameness. Restrictions on antimicrobial use have prompted the adoption of alternative strategies

for controlling infectious disease outbreaks in veterinary settings, one of which is the footbath protocol.

The footbath serves as a preventive measure to reduce microbial infections in livestock. This procedure involves soaking the animals' feet in disinfectant solutions for approximately 20–30 minutes. A large water chamber is typically used to allow proper soaking, with a recommended capacity to accommodate 5–10 animals per session. This setup enables the animals to stand comfortably in the disinfectant solution for the required duration. Commonly used disinfectants include chlorine, iodine, formaldehyde, and zinc sulfate at concentrations effective for eliminating pathogens while remaining safe for the animals. When performed regularly, footbaths can help prevent bacterial infections, enhance overall herd health, and reduce mortality rates (Krömker et al., 2018; Solano et al., 2017).

Farmers and livestock practitioners commonly adopt footbaths as part of integrated management programs to control lameness. However, their effectiveness depends on several factors, including the type and concentration of disinfectant, frequency of application, and adherence to recommended protocols (Browne et al., 2022; Robcis et al., 2023a,b; Solano et al., 2017).

The implementation of footbaths offers significant economic benefits. By reducing infection rates and associated mortality, farmers can lower treatment costs, enhance animal growth and productivity, and minimize losses from unproductive or deceased animals. In addition, improved livestock health practices contribute to better public perception, which may lead to premium pricing and increased consumer preference for ethically managed farms (Solano et al., 2017).

To address the challenges associated with irrational antimicrobial use in livestock and to help limit the spread of AMR, this study evaluated farmers' practices related to antimicrobial use and introduced a preventive footbath strategy aimed at reducing lameness-associated mortality. Ngudi Dadi Farm was selected as the program site due to its persistent challenges in managing foot-related infections and the limited adoption of preventive practices. These conditions made it an appropriate setting for assessing the impact of a biosecurity intervention. The study was conducted at Ngudi Dadi Farm, a community-based sheep and goat farming center located in Kedarpan Village, Kejobong Subdistrict, Purbalingga, Central Java. Data were collected through a structured questionnaire evaluating farmers' behavior regarding antimicrobial use, followed by a training session and the construction of a biosecurity-oriented footbath system.

2. METHOD

2.1 Study Design

This community-based outreach study was conducted at Ngudi Dadi Farm, a sheep and goat farming center located in Kedarpan Village, Kejobong Subdistrict, Purbalingga Regency, Central Java, Indonesia. The study took place

from May to December 2024 and consisted of three core activities: (1) a structured questionnaire survey to evaluate farmers' behavior regarding antimicrobial use; (2) a training session focused on the rational use of veterinary antimicrobials and the role of footbaths in biosecurity; and (3) the construction and implementation of footbath facilities to support on-farm biosecurity measures.

2.2 Study instrument and data collection

A structured questionnaire was developed to assess farmers' behaviors related to the rational use of veterinary antimicrobials. A total of 21 active farmer members of Ngudi Dadi Farm participated in the survey (Table 1). All participants were directly involved in the care and treatment of livestock and provided informed consent prior to participation. The questionnaire consisted of five sections, each using ordinal response options: *Always*, *Often*, *Sometimes*, *Rarely*, and *Never*. For the purposes of this study, "antimicrobials" refers to antibiotics, antifungals, antiparasitic agents, and antivirals.

Data were collected through face-to-face interviews using an interviewer-administered format to ensure clarity and accuracy of responses. Interviewers followed a standardized script, beginning each question with the prompt: "In the past 12 months, how often do you...?" This approach minimized variation in question delivery and reduced the risk of participant misunderstanding (Figure 1).



Figure 1 . Face-to-face interviews conducted with local farmers during a field survey at Ngudi Dadi Farm, Purbalingga, on June 8, 2024

2.3 Questionnaire structure

The questionnaire comprised five sections, each designed to assess a specific aspect of farmers' antimicrobial use practices (Table 1):

1. Section One evaluated behaviors related to the treatment of sick animals. This included whether farmers self-administered treatments, contacted a veterinarian, left animals untreated, used independently purchased medications, administered prescribed drugs, or employed alternative therapies.
2. Section Two examined the use of antimicrobials and vaccines, focusing on the frequency of antibiotic, antiparasitic, antifungal, and vaccine use for disease prevention.
3. Section Three assessed antimicrobial administration practices. Items included whether antimicrobials were administered according to label instructions, under veterinary supervision, independently, or with consideration of withdrawal periods before slaughter.
4. Section Four addressed medication storage practices. Topics included appropriate storage conditions (e.g., cool and dry environments), safety measures (e.g., locked cabinets and out-of-reach storage), adherence to manufacturer instructions, and whether different

Table 1 . A questionnaire for assessing farmer's behavior toward rational antimicrobial use

No.	Treatment of sick animals
1.	I administer treatment to sick animals by my self
2.	I contact a veterinarian upon discovering a sick animal
3.	I don't leave sick animals untreated
4.	I don't use medication purchased by myself from pharmacy
5.	I administer medication prescribed by a veterinarian
6.	I use alternative therapies for sick animals
7.	I clean the animal cage when animals get sick
No.	Frequency of antimicrobial use
1.	I use antibiotics for animals
2.	I use antiparasitic medications for animals
3.	I use antifungal medications for animals
4.	I use vaccines for disease preventions
No.	Antimicrobial administration practices
1.	I administer antimicrobials in accordance with label instructions
2.	I administer antimicrobials as directed by a veterinarian
3.	I administer antimicrobials independently to animals
4.	I Observe withdrawal periods before slaughtering animals
No.	Medication Storage Practices
1.	I store veterinary medicines in a cool and dry environment
2.	I store veterinary medicines in a locked cabinet
3.	I follow storage guidelines as stated on the drug label
4.	I store veterinary medicines out of reach of children
5.	I don't store different types of medications mixed together
No.	Disposal Practices for Veterinary Medicines
1.	I Dispose of expired veterinary medicines in accordance with recommended guidelines
2.	I Return unused medicines to a pharmacy or veterinary clinic
3.	I discard veterinary medicines in regular household waste
4.	I Bury unused and expired veterinary medicines
5.	I incinerate unused and expired veterinary medicines

medication types were stored together.

5. Section Five focused on disposal practices for unused or expired veterinary medicines. It assessed behaviors such as returning unused drugs to a pharmacy or veterinary clinic, discarding them in household waste, burying, or incinerating them.

2.4 Training session and footbath planning

After the completion of the survey, the research team conducted a training session at Ngudi Dadi Farm to educate farmers on the rational use of veterinary antimicrobials and to introduce footbath facilities as a preventive measure for reducing the incidence of infectious diseases in animals. The training aimed to raise farmers' awareness of antimicrobial resistance and to promote alternative strategies for maintaining animal health without over-reliance on antimicrobials. The session included lectures and visual materials covering the following topics: (1) lameness in small ruminants as a case study of an infectious disease resulting in significant economic losses; (2) principles of rational antimicrobial administration in livestock; (3) risks associated with irrational antimicrobial use; and (4) the role of biosecurity infrastructure – particularly footbaths – in disease prevention.

2.5 Footbath construction

Following the training session, a discussion was held to plan the implementation of a footbath system at the farm. Key topics included: (1) the design and dimensions of the footbath; (2) appropriate placement to ensure ease of access and user compliance; (3) the construction timeline and expected completion; and (4) budget planning and the division of responsibilities among farmer members. Construction was carried out collaboratively with farmers at Ngudi Dadi Farm, who contributed labor and jointly funded the purchase of materials. The research team provided technical guidance throughout the process to ensure the footbath system was designed in accordance with established biosecurity principles.

2.6 Statistical analysis

A descriptive analysis was conducted for all variables included in the study. Frequencies and percentages were calculated for farmer characteristics such as age group, gender, and years of farming experience to describe the study population. Farmers' responses to the questionnaire were categorized into behavioral practice scores, which were calculated as percentages of the total possible score for each behavioral domain: treatment of sick animals, antimicrobial use, administration practices, medication storage, and disposal practices. To examine potential associations between farmer characteristics and behavioral practice scores, Spearman's rank correlation test was applied. Specifically, the correlation between the total behavioral practice score and years of farming experience – as a continuous variable – was tested. A p -value ≤ 0.05 was considered statistically significant. All statistical analyses were performed using R Studio for macOS (version 2024.12.1).

3. RESULT AND DISCUSSION

A total of 21 farmers from Ngudi Dadi Farm participated in the study, all of whom were actively involved in livestock care. The majority of participants were male (76.19%), while only 23.81% were female. In terms of age distribution, most respondents belonged to the early elderly group (60–69 years old, 38.10%), followed by those in the late middle-age group (50–59 years old, 23.81%). Younger participants were less represented, with only 14.29% each in the 30–39 and 40–49 age groups. Two participants (9.52%) were aged 70 years or older (Table 2).

Regarding farming experience, nearly half of the farmers (47.62%) were classified as moderately experienced, with 6–15 years of experience. In contrast, 28.57% were beginners with up to 5 years of experience. A smaller proportion had more extensive experience, with 19.05% having farmed for 16–30 years, and only 4.76% classified as highly experienced (more than 30 years) (Table 1). This demographic profile provides insight into the composition of the Ngudi Dadi farming community, which is predominantly made up of older male farmers with moderate to long-term experience in animal husbandry.

Table 2 . Demographic characteristics of participants

Characteristics	Total	Percentage(%)
Age (years old)		
Young adults (30-39)	3	14.29
Early middle age (40-49)	3	14.29
Late middle age (50-59)	5	23.81
Early elderly (60-69)	8	38.10
Elderly (≥ 70)	2	9.52
Gender		
Male	16	76.19
Female	5	23.81
Years of farming experience (years)		
Beginner (0-5)	6	28.57
Moderately experienced (6-15)	10	47.62
Experienced (16-30)	4	19.05
Highly experienced (>30)	1	4.76

A survey was conducted to assess participants' behavior regarding the rational use of veterinary antimicrobials. The overall reported behavior was presented as percentages of behavioral practice scores. These scores varied considerably across the five domains assessed in the questionnaire: treatment of sick animals, frequency of antimicrobial use, administration practices, medication storage, and disposal practices (Figure 2).

Farmers demonstrated the highest median behavioral practice score in the Treatment of Sick Animals category, indicating consistent practices in seeking veterinary assistance or administering prescribed medications when animals were ill. The tight clustering of scores within this domain suggests a relatively uniform understanding and application of basic treatment procedures among participants. The Medication Storage Practices domain also

showed a relatively high median score, reflecting general adherence to recommended storage conditions – such as storing medicines in cool, dry environments and keeping them out of children’s reach. However, moderate variability in this domain indicates that some farmers still engage in improper practices, including storing different medications together without considering their classification or intended use (Pereira et al., 2017).

In contrast, the Frequency of Antimicrobial Use domain yielded a lower median score, pointing to potential concerns about overuse or misuse of antibiotics, antifungals, and antiparasitic agents. Similarly, the Disposal Practices for Veterinary Medicines domain had a low median with moderate variability, reflecting inconsistent and often inappropriate disposal methods. Reports of expired or unused antimicrobials being discarded in household waste raise concerns about possible environmental and public health risks.

Notably, the Antimicrobial Administration Practices domain exhibited the widest range of responses, with scores ranging from 20% to 100%. This variation suggests significant inconsistency in administration practices, including non-compliance with dosage instructions, lack of veterinary oversight, and failure to observe drug withdrawal periods before slaughter (McKernan et al., 2021).

Collectively, these findings highlight critical gaps in antimicrobial stewardship among farmers at Ngudi Dadi Farm, particularly in the domains of administration and disposal practices, and underscore the need for targeted interventions to address these deficiencies.

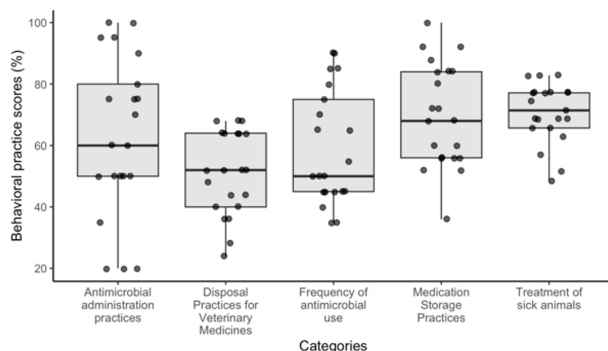


Figure 2 . Behavioral practice scores (%) across five domains of antimicrobial use among farmers at Ngudi Dadi Farm

Each data point on **Figure 2** represents an individual farmer’s score within a specific practice category. The boxplots show the median, interquartile range, and variability of reported behaviors related to antimicrobial administration, disposal practices, frequency of use, medication storage, and treatment of sick animals. Highest consistency was observed in treatment practices, while antimicrobial administration practices showed greatest variability. The frequency of antimicrobial use showed lowest median scores.

Revisiting the demographic profile of farmers is essential when interpreting behavioral data, as age, gender, and years of farming experience have been shown in

previous studies to influence knowledge, attitudes, and practices related to antimicrobial use (McKernan et al., 2021; Omolo et al., 2024; Pham-Duc et al., 2019). In this study, the relationship between years of farming experience and behavioral practice scores was examined using Spearman’s rank correlation test.



Figure 3 . Correlation between years of farming experience and behavioral practice scores ($p = 0.8335$). Each data point shows an individual farmer’s data.

As illustrated in **Figure 3**, no significant correlation was found between years of farming experience and behavioral practice scores (Spearman’s $\rho = 0.0488$, $p = 0.8335$). Although the regression line indicates a slight upward trend, the association was weak and statistically insignificant. These results suggest that years of experience alone do not predict better antimicrobial stewardship behaviors. This finding challenges the assumption that more experienced farmers are inherently more knowledgeable or compliant with best practices in antimicrobial use. On the contrary, in the absence of continuing education, veterinary oversight, or access to updated training resources, prolonged experience may reinforce outdated or suboptimal practices rather than promote evidence-based approaches (McKernan et al., 2021; Pereira et al., 2017).



Figure 4 . Training session conducted at Ngudi Dadi Farm

A training session on rational antimicrobial use and biosecurity was conducted on August 27, 2024, at Ngudi

Dadi Farm. Facilitated by the research team, the session focused on educating farmers about the prudent use of veterinary antimicrobials and the importance of preventive infrastructure – particularly the footbath system – in minimizing disease transmission and reducing reliance on antimicrobial treatments (Figure 4).

Following the training, the farmers collectively agreed to initiate the construction of a footbath facility as part of their communal farm's biosecurity improvements. The construction was completed in December 2024, and the footbath is now fully operational. It is routinely used for each new batch of animals entering the community farming area (Figure 5).



Figure 5 . Footbath facility for small ruminants at Ngudi Dadi Farm

The Infectious agents that cause diseases such as lameness typically enter through the interdigital skin of the foot or hoof. Footbaths help prevent these infections by cleaning and disinfecting the feet. Moreover, as a low-cost and locally adapted biosecurity measure, footbaths are designed to interrupt the transmission of pathogens between animal groups, thereby supporting overall herd health (Cook, 2017). Notably, during the implementation phase, the farmers reached a consensus to use lemongrass (*Cymbopogon nardus*) essential oil as a natural alternative to synthetic disinfectants. This decision aimed to reduce dependence on chemical agents and minimize potential environmental contamination.

The use of plant-based disinfectants reflects the community's commitment to sustainable farming practices

and aligns with broader efforts in antimicrobial stewardship. The participatory approach adopted in this study – from planning to material selection and construction – played a crucial role in fostering long-term adoption and promoting positive behavioral change among farmers at Ngudi Dadi Farm.

Several limitations may have influenced the findings of this study. The survey focused solely on assessing farmers' practices regarding rational antimicrobial use and did not evaluate their knowledge or attitudes. As a result, the study captured only the observed behaviors of farmers at Ngudi Dadi Farm without revealing the underlying motivations or levels of understanding that inform those practices.

Additionally, the effectiveness of the footbath implementation in reducing the incidence of infectious diseases – and thereby reducing antimicrobial use – was not measured and remains beyond the scope of this study. Future research is recommended to evaluate the impact of footbath use on animal health outcomes, particularly in lowering cases of lameness. Further investigation is also needed to assess the antimicrobial efficacy of *Cymbopogon nardus* essential oil when used in footbath solutions. Moreover, consideration should be given to extending footbath strategies beyond communal farms to smallholder operations, which may contribute more significantly to unregulated antimicrobial use due to limited oversight.

This study represents the first initiative in Indonesia to integrate behavioral assessment, farmer training, and footbath implementation into a combined antimicrobial stewardship strategy. Future efforts should prioritize expanding this model to other regions and developing standardized operating procedures to encourage broader adoption and ensure long-term sustainability.

4. CONCLUSION

This study identified critical gaps in antimicrobial stewardship among farmers at Ngudi Dadi Farm, particularly in the areas of antimicrobial administration and disposal practices. Targeted interventions – Including farmer training, routine monitoring, and the implementation of sustainable biosecurity measures such as footbaths – are essential for promoting rational antimicrobial use and mitigating the risk of antimicrobial resistance. Notably, unlike findings from previous studies, no correlation was observed between years of farming experience and adherence to good antimicrobial practices, underscoring the need for continuous education regardless of experience level. The study concluded with the successful construction of a footbath facility at Ngudi Dadi Farm, representing a practical and community-driven step toward improved farm biosecurity.

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CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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