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RESEARCH ARTICLE

Antimicrobial usage, awareness, and animal health management practices among household dairy farmers in West Bengal, India

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ABSTRACT

Background and Aim: Antimicrobial resistance (AMR) is a critical global health threat, projected to cause up to 10 million deaths annually by 2050. Livestock production, where antimicrobials are widely used, plays a significant role in the emergence and spread of resistant pathogens. In India, small-scale dairy farming forms a key part of rural livelihoods, yet limited evidence exists on antimicrobial usage and animal health practices in this sector. This study assessed antimicrobial usage patterns, awareness, and associated animal health management practices among smallholder dairy farmers in West Medinipur district, West Bengal.

Materials and Methods: A community-based cross-sectional study was conducted between January and June 2024. Using expert-validated questionnaires and observational checklists, data were collected from 302 household dairy farmers and eight veterinarians across four blocks. Descriptive statistics, Chi-square tests, and logistic regression analyses were performed to identify factors associated with antimicrobial misuse and non-adherence to withdrawal periods.

Results: All farmers reported antimicrobial use for their cattle, yet only 18.2% had heard of AMR and 8.9% adhered to drug withdrawal periods. About 13.2% used antimicrobials without prescriptions and 15.2% relied on previous prescriptions. Storage of antimicrobials at home (odds ratio [OR] = 3.998; 95% confidence interval [CI] = 1.598–10.002), sharing drugs with peers (OR = 5.289; 95% CI = 2.148–13.020), and lack of veterinary consultation (OR = 0.148; 95% CI = 0.0365–0.597) were significant predictors of misuse. Farm-level practices such as absence of isolation units, herd overcrowding, and poor cleaning frequency were significantly associated with higher cattle morbidity ($p < 0.001$). While all farmers vaccinated and dewormed cattle, 78.1% did not quarantine new animals, and only 19.5% maintained treatment records. Veterinarians generally adhered to guidelines but reported inadequate facilities for safe drug disposal.

Conclusion: This study reveals widespread antimicrobial misuse and low AMR awareness among small-scale dairy farmers, compounded by inadequate biosecurity and waste disposal practices. Strengthening AMR mitigation requires targeted farmer education, regulation of over-the-counter antimicrobial sales, better veterinary infrastructure, and integration of One Health-based waste management systems. Interventions should prioritize prescription-based antimicrobial access, continuous farmer training, and community-level monitoring to safeguard both animal and human health.

Keywords: Antimicrobial resistance, antimicrobial use, drug withdrawal period, India, One Health, smallholder dairy farming.

INTRODUCTION

Antimicrobial resistance (AMR) has emerged as one of the most pressing global public health challenges. The World Health Organization lists AMR among the top ten health threats worldwide [1]. The 2022 Global

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AMR and Use Surveillance System report paints a worrisome picture: Across 76 countries, median resistance rates were 42% for third-generation cephalosporin-resistant *Escherichia coli* and 35% for methicillin-resistant *Staphylococcus aureus*. In 2020, one in five urinary tract infections caused by *E. coli* showed reduced susceptibility to widely used antibiotics such as ampicillin, co-trimoxazole, and fluoroquinolones, complicating the treatment of common infections [1]. India carries a particularly heavy burden, with an estimated 297,000 deaths due to AMR in 2019, while drug-resistant bacteria contributed to nearly 1 million deaths overall [2, 3]. By 2050, India may account for nearly 20% of all AMR-related deaths globally [3].

One of the principal drivers of this crisis is the widespread use of antibiotics in livestock farming. Globally, nearly 70% of antimicrobial agents are used in animals, compared to 30% in humans [4]. As the world's largest producer of milk and a major producer of meat, fish, and eggs, India has witnessed rising antimicrobial use (AMU) in animal agriculture to meet growing demand [5]. However, this practice poses significant risks to public health. Studies in India and abroad have detected antibiotic residues [6–8] and resistant bacteria, including *E. coli*, *Klebsiella*, and *S. aureus*, in food of animal origin such as milk and meat [9–11]. Notably, *S. aureus* strains isolated from raw milk exhibit high resistance to penicillin G and tetracycline [12]. The detection of resistant bacteria in food highlights the urgent need for strict monitoring and regulation of AMU in livestock. A "One Health" approach, integrating animal, human, and environmental health, is essential. Without urgent and coordinated efforts, the AMR crisis will continue to grow, threatening the effectiveness of life-saving treatments [1].

Within the global health agenda, AMR is explicitly addressed under Sustainable Development Goal (SDG) 3, which emphasizes strengthening national capacities to detect, prevent, and manage health risks, particularly in developing nations [13]. AMR also intersects with SDGs related to food security (SDGs 1, 2, and 8) and environmental protection (SDGs 6, 12). International cooperation (SDG 17) and the adoption of One Health strategies are critical for an effective response [14]. In 2015, the World Health Assembly endorsed the Global Action Plan on AMR in collaboration with the Food and Agriculture Organization, the UN Environment Program, and the World Organization for Animal Health [1]. By November 2023, 178 countries had aligned their national action plans with this framework [15]. In India, the Ministry of Health and Family Welfare launched the National Action Plan on AMR in 2017, with the updated 2023 strategy reaffirming the nation's commitment to tackle AMR [16].

India's agricultural context makes this issue particularly urgent. Nearly 70% of the population is engaged in agriculture and animal husbandry, where the livestock sector is vital for food security and rural livelihoods. Yet, the widespread use of antimicrobials in small-scale dairy farming, combined with poor adherence to drug withdrawal periods, raises concerns about antibiotic residues in food and the spread of resistant pathogens [17]. In 2018, the Food Safety and Standards Authority of India reported the presence of antibiotic residues in milk samples, reflecting serious risks arising from irrational AMU and non-compliance with withdrawal periods in livestock production [17, 18]. Despite the recognition of AMR as a major global health challenge, there is a striking paucity of region-specific data on AMU practices among smallholder dairy farmers in India, particularly in eastern states such as West Bengal. Most existing studies have focused on northern and southern India, leaving substantial geographic and contextual blind spots in understanding the behavioral, socio-economic, and infrastructural factors driving AMU. While national and international frameworks such as the Global Action Plan on AMR and India's National Action Plan provide strategic direction, their effective implementation at the household farm level remains largely undocumented. Moreover, previous investigations often emphasize antimicrobial residues or microbiological surveillance, but very few integrate farmer-level behavioral practices, veterinary insights, and farm-level management conditions into a comprehensive framework. The absence of such holistic data limits the ability of policymakers to design culturally and regionally relevant interventions. Therefore, an evidence gap persists in understanding how smallholder farmers' knowledge, attitudes, and practices interact with veterinary services, biosecurity measures, and waste disposal practices to influence AMU and AMR risks in rural eastern India.

This study aimed to bridge these gaps by systematically assessing antimicrobial usage patterns, awareness levels, and animal health management practices among household dairy farmers in West Medinipur district, West Bengal, India. Specifically, the study sought to: (i) quantify the extent of antimicrobial use and adherence to treatment protocols, including drug withdrawal periods; (ii) identify socio-demographic, behavioral, and farm-level factors associated with misuse of antimicrobials; (iii) document farmers' knowledge and perceptions of AMR and compare them with veterinary insights; and (iv) evaluate biosecurity, hygiene, and waste disposal

practices within the smallholder dairy farming context. By adopting a One Health perspective, the study aimed to generate region-specific, ground-level evidence that can inform tailored interventions, strengthen farmer–veterinarian partnerships, and guide policy measures for sustainable AMU practices. Ultimately, the findings intend to contribute to national AMR containment strategies and safeguard both animal and human health through integrated approaches.

MATERIALS AND METHODS

Ethical approval

The study was approved by the Institutional Ethics Committee of Kasturba Medical College and Kasturba Hospital (KMC-KH-IEC; IEC2: 667/2023). Administrative permission was obtained from the Midnapore Co-operative Milk Producers' Union Ltd. (MIMUL), affiliated with the West Bengal Cooperative Milk Producers Federation. Informed written consent was obtained from all participants after the study objectives and procedures were explained. Participation was voluntary, and confidentiality and privacy were maintained throughout the study.

Study period and location

This community-based cross-sectional study was carried out in the West Medinipur district, West Bengal, India, between January and June 2024. The district is characterized by a high density of small-scale dairy farms and is one of the state's leading cattle-producing regions, highlighting the central role of dairy farming in the local economy [19]. Four blocks, Kesiari, Narayangarh, Debra, and Gharbeta III, were selected for the study.

Study population and sampling technique

The study population included 302 household dairy farmers and eight practicing veterinarians. The sample size for farmers was initially estimated as 330 using Daniel's sample size formula, based on a 95% confidence level, a 75% assumed prevalence of antimicrobial misuse [20], and a 10% anticipated non-response rate.

A two-stage cluster sampling method was employed. In the first stage, four blocks were selected using simple random sampling. In the second stage, one milk cooperative society was randomly chosen from each block using a list provided by MIMUL. Within each society, participants were selected using probability proportional to size sampling.

Out of the 330 farmers targeted, 302 completed the survey, yielding a response rate of 91.5%. The shortfall was due to refusals and time constraints but did not significantly impact statistical power, as all four clusters were proportionately represented. All eight veterinarians working in the selected blocks during the study period were included.

Data collection instruments

Three expert-validated tools were used:

1. Farmer questionnaire – covered four domains: sociodemographic details, farm characteristics, antimicrobial usage and associated factors, and animal health management practices.
2. Veterinarian questionnaire – included demographic information, knowledge of antimicrobial usage and AMR, factors associated with AMU, and practices related to prescription and drug disposal.
3. Observational checklist – contained 20 items related to farm infrastructure and animal health practices.

The tools were developed through literature review and expert consultation, then validated by two independent reviewers (a veterinary faculty member and a government veterinary officer). The questionnaire for the farmer was translated into the local language and validated by a language teacher of a government school in West Bengal for clarity and accuracy.

Data collection procedure

Data were collected through face-to-face interviews conducted by the principal investigator, accompanied by district milk union supervisors for quality assurance. Interviews lasted 20–30 min and were held at participants' homes or farms. Farm observations were recorded simultaneously using the structured checklist.

Data management and statistical analysis

Data were entered in Microsoft Excel 2019 (Microsoft Office, Washington, USA) and analyzed using Jamovi version 2.3.28 (https://www.jamovi.org/download.html). Descriptive statistics summarized frequencies and percentages. Chi-square tests were performed to identify bivariate associations. Variables with $p < 0.2$ were included in logistic regression models. Statistical significance was set at $p < 0.05$.

RESULTS

Sociodemographic characteristics of the farmers

Of the 302 farmers, the majority, 264 (87.4%), were males. The mean age of the farmers was 52.3 years (standard deviation = 11.5), ranging from 18 to 76 years. More than half of the farmers, 180 (59.6%), had attended primary school, while 18 (6%) were illiterate. A majority of them, 241 (79.8%), were full-time farmers. Approximately 148 of them (49.0%) reared dairy animals for supplementary income, with their primary occupation being cultivation or daily wage labor; 112 (37.1%) reared dairy animals as their primary income source (Table 1). Most farmers (295; 97.7%) reared dairy cows, while 10 households (3.3%) kept buffaloes. Among them, three households reared both dairy cows and buffaloes. Over half of the farmers, 181 (59.9%), housed their cattle in confined spaces. In addition to dairy cattle, 191 farmers (63.2%) reared other livestock, such as poultry and goats (Table 1).

Farmers' knowledge regarding antimicrobials and AMR

All 302 farmers reported knowledge of antimicrobials. A total of 172 farmers (57.1%) believed that antimicrobials have side effects. However, only 80 of them (26.5%) were aware of the potential risks associated with excessive use of antimicrobials in dairy farming (Figure 1). Of the farmers, 230 (76.2%) learned about antimicrobials for cattle from veterinarians, 60 (19.9%) from para-veterinarians, 6 (2%) from family or friends, and 6 (2%) from an Artificial Insemination (AI) worker. Only 5 of them (1.7%) reported awareness of antimicrobial usage

Table 1: Distribution of farmers according to sociodemographic and farm characteristics (n = 302).

Variable	Category	Numbers (n = 302)	Percentage
	Socio-demographics		
Gender	Male	264	87.4
	Female	38	12.6
Age in years	18–27	6	2
	28–37	26	8.6
	38–47	71	23.5
	48–57	92	30.5
	58–67	75	24.8
	68–77	32	10.6
Education	Illiterate	18	6
	Primary School	180	59.6
	Secondary School	72	23.8
	Intermediate	32	10.6
Farmer type	Full-time farmer	241	79.8
	Part-time farmer	61	20.2
Years of experience	1–10	16	5.3
	11–20	89	29.4
	21–30	128	42.4
	31–40	50	16.6
	41–50	15	5
	>50	4	1.3
Primary reason for keeping dairy animals	Primary income	112	37.1
	Extra income	148	49
	Family tradition	15	5
	Home consumption	15	5
	As pet	10	3.3
	Home consumption and pets	2	0.6
	Farm characteristics		
Cattle raised	Open pasture	121	40.1
	Confined space	181	59.9
Types of dairy animals	Cows	295	97.7
	Buffaloes	10	4.6
Animals other than dairy animals on the farm	Goats	91	30.1
	Chickens	101	33.4
	Ducks	29	9.6
	Dogs	32	10.6
	None	111	36.7

guidelines in dairy farming. Of the 167 farmers who were aware of the drug withdrawal period, only 27 (8.9%) adhered to it (Table 2).

Among the 55 farmers (18.2%) who had heard of AMR, 50 (90.9%) agreed that inappropriate antibiotic use could lead to the emergence of resistant microorganisms (Figure 2). In addition, 43 (78.2%) considered that antibiotic resistance could emerge in cattle. Only 17 (30.9%) of them knew that resistant infections may spread between humans and animals, while 15 (27.3%) believed that sharing the same environment with cattle increases the risk of being infected with antimicrobial-resistant pathogens (Figure 2).

Antimicrobial usage practices of farmers

Of the 302 farmers, 40 (13.2%) reported administering antimicrobials without a prescription (Figure 3). A total of 46 (15.2%) farmers admitted using previous prescriptions to purchase antimicrobials. Among these 46 farmers, 25 cited the cost of veterinary consultation as the reason for this practice, while 21 indicated that they resorted to previous prescriptions when the same symptoms reappeared in their cattle. Among the farmers, 69.2% claimed to have always completed the full course of antimicrobials (Figure 3). Of the 93 (30.8%) farmers who admitted not completing the full course, 40 (43%) attributed it to the high cost of antimicrobials, 36 (38.7%) mentioned that they ceased medication once their animals appeared to be cured, and 17 (18.3%) cited the considerable distance from the veterinary clinic as a significant challenge, making it difficult to bring the animal for each required visit.

A total of 34 farmers (11.3%) reported increasing antimicrobial dosages when their animals failed to show improvement. Seventy-eight farmers (25.8%) stored antimicrobials at home, and 70 (23.2%) admitted sharing leftover antibiotics with other farmers. A total of 244 (80.8%) farmers did not check the expiry date of stored antimicrobials before administering them to cattle (Figure 3). All of them admitted using antibiotics

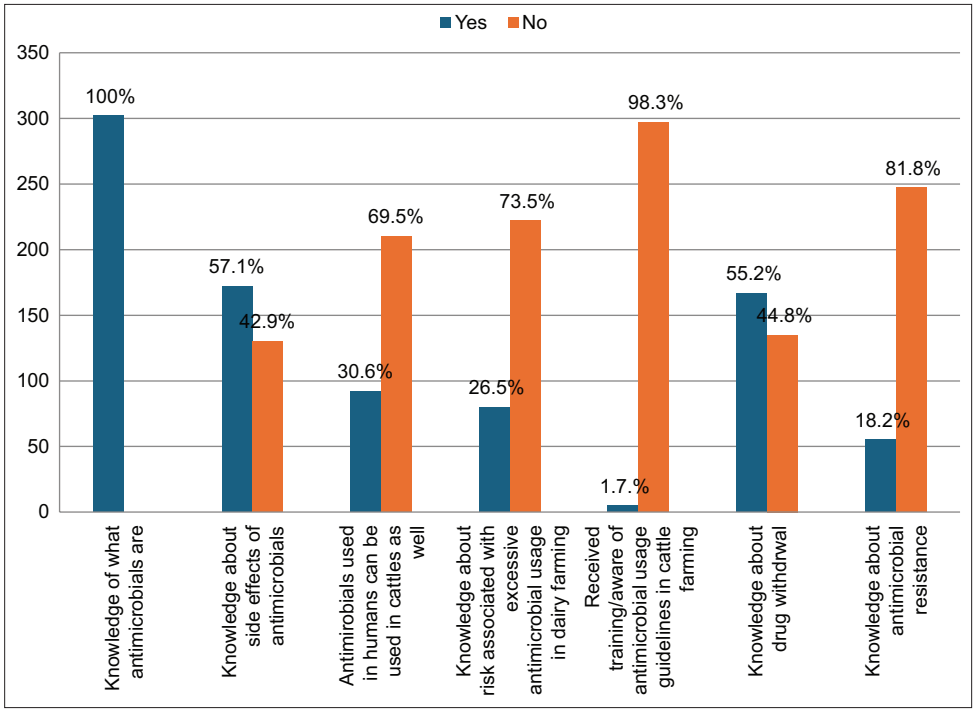

Figure 1: Distribution of farmers based on knowledge about antimicrobials (n = 302).

Table 2: A cross tab between knowledge and practice of the drug withdrawal period.

Knowledge about the drug withdrawal period	Numbers	Adherence to the drug withdrawal period	Numbers	Percentage
Yes	167	Yes	27	8.9
		No	140	46.4
No	135	Yes	2	0.7
		No	133	44

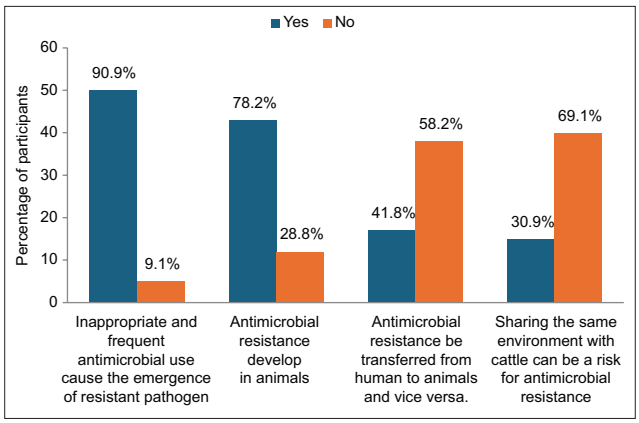

Figure 2: Distribution of farmers based on their knowledge about antimicrobial resistance (n = 55).

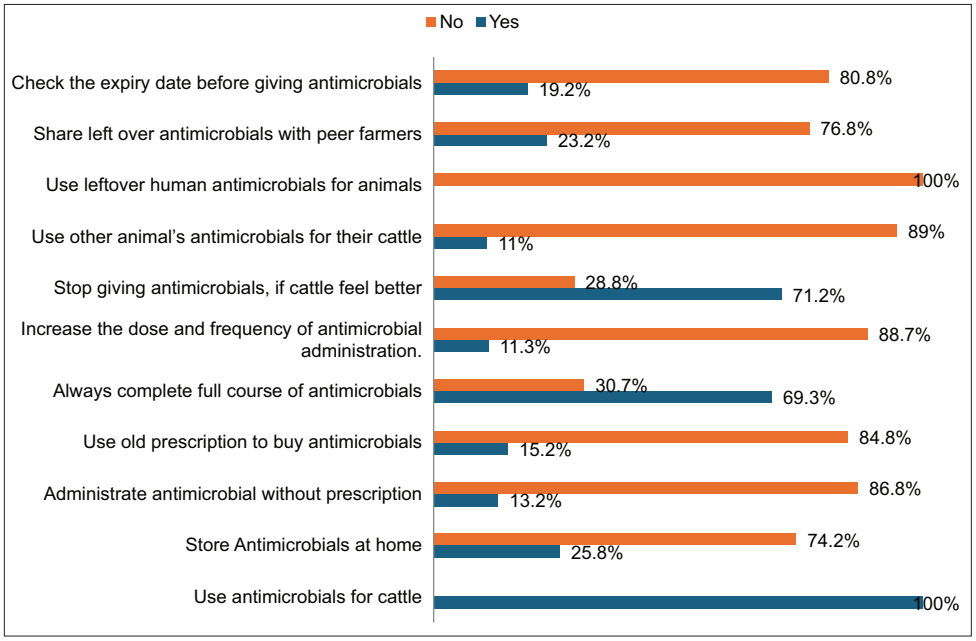

Figure 3: Distribution of farmers based on antimicrobial usage practices (n = 302).

and antifungals for treatment; however, 8% and 2.3% used antibiotics and antifungals for prevention, respectively. Majority of the farmers (92.4%) were administered anthelminthic for prevention. Among the 302 farmers included in the study, the majority (72.5%) threw unused or expired drugs in the surrounding areas; however, 16.9% and 10.6% of them mentioned disposing of the drugs in the pond and burning the drugs with household waste, respectively.

Source of antimicrobials for cattle

Among the 302 farmers, 201 (66.6%) reported purchasing antimicrobials from medical stores, including separate veterinary medical stores as well as public medical stores that keep veterinary drugs, followed by veterinarians (54.3%) and AI workers (27.9%). Of 302, 66.2% said that they followed the advice of a veterinarian or para-veterinarian to ensure proper antimicrobial dose, and 86 (28.5%) administered antimicrobials as per advice from AI workers. In addition, when questioned about the first step farmers take when their cattle become ill, 124 (41%) indicated that they consult a veterinarian and 79 (26.2%) consult an AI worker. Forty-five (14.9%) said that they wait to see if the disease resolves on its own and 38 (12.6 %) go for traditional medicine. However, 4% of respondents said that they consult a para-veterinarian and 1.3% get medication over the counter (Figure 4).

Only 59 farmers (19.5%) reported maintaining records of their cattle's antimicrobial usage. Of the 59 farmers who claimed to keep records, only 36 actually produced records such as prescriptions or medicine packaging. Amoxicillin, enrofloxacin, ceftriaxone, cephalosporine, fenbendazole, ivermectin, rafoxanide, and axefendol were the antimicrobials noted from the records.

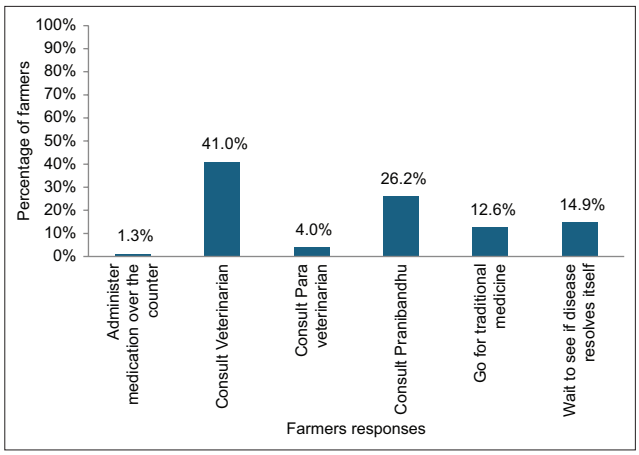

Figure 4: Distribution of farmers based on the first step taken when cattle fall sick (n = 302).

Association between antimicrobial usage practices and various factors

The use of antimicrobials without prescription was compared with the use of antimicrobials with prescription as a reference to associate with various factors. After performing the Chi-square test, variables that showed $p < 0.2$ were considered for the logistic regression analysis. Farmers who were aware of the risk of excessive AMU were more likely to use antimicrobials without prescription (odds ratio [OR] = 0.3002, 95% confidence interval [CI] = 0.1151, 0.783) (Table 3). Farmers who store antimicrobials at home were 11.46 times more likely to use antimicrobials without a prescription (OR = 3.998, 95% CI = 1.598, 10.002). Farmers who shared antimicrobials with their peers were more likely to use antimicrobials without a prescription (OR = 5.289, 95% CI = 2.148, 13.020). Farmers who consulted a veterinarian were less likely to use antimicrobials without prescription (OR = 0.148, 95% CI = 0.0365, 0.597) (Table 3).

Similarly, non-adherence to the drug withdrawal period was compared with adherence to the drug withdrawal period as a reference to associate with various factors (Table 4). After considering those variables that showed statistical significance in Chi-square ($p < 0.2$) were considered for logistic regression, it was seen that farmers who were unaware of the drug withdrawal period were 8.37 times more likely to not adhere to the drug withdrawal period (OR = 8.373, 95% CI = 1.8834, 37.22), and those who were unaware of AMR were 3.22 times more likely to not adhere to the drug withdrawal period (OR = 3.222; 95% CI = 1.255, 8.27) (Table 4).

Animal health management practices

Farm infrastructure and safety measures

On observing the farms, 97% of the farms were separate from the main house building, 20.2% of the herds were crowded, and 26.5% of the herds were smaller than the number of cattle on the farm. The majority, 75.2% of the farm shelters had sufficient ventilation and airflow (Table 5). Only 11.9% of farmers used health-monitoring tools and technology. The majority of farmers (64.6%) had water run off to household ponds, with only 19.5% having separate isolation areas for cattle in case of any disease. During the visit, 12 households had sick cattle kept in isolation. Only 20.3% of the farms had designated calving areas. Only 22.8% of farms had some first aid and emergency equipment available. Only 12% of the farm owners showed health records for vaccination, treatment, and breeding maintained (Table 5).

Preventive and safety measures followed by farmers

Among the farmers, 61.3% reported that their cattle had been affected by the disease. Foot-and-mouth disease was reported by 27.5% of the farmers, while 28.1% indicated that their cattle had suffered from mastitis. In addition, 14.2% of farmers reported parasitic infections in their cattle. For the preventive and safety measures followed by farmers in dairy farming, all of them acknowledged that they vaccinated and dewormed their cattle. However, only 27 (8.9%) cattle owners reported consistent testing for common illnesses. Furthermore, 236 (78.1%) said that they never quarantined newly bought cattle, and only 18 (6%) said that they always quarantined them (Figure 5).

Of the farmers, 140 (46.4%) reported that their cattle came in contact with animals from other farms, 233 (77.2%) said that they take no specific measures to prevent disease spread, and 69 (22.8%) isolated sick animals.

Table 3: Logistic regression analysis of farmer's practice of using antimicrobials without prescription with various factors.

Predictors	Categories	Use of antimicrobials without prescription (Yes)	p-value	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Awareness of the potential risks associated with excessive antimicrobial usage	Yes (ref)	21	**0.014**	1	1
	No	19		0.263 (0.133, 0.522)	0.3002 (0.1151, 0.783)
Knowledge about drug withdrawal	Yes (ref)	27	0.885	1	1
	No	13		0.553 (0.273, 1.118)	1.0692 (0.4308, 2.653)
Knowledge about antimicrobial resistance	Yes (ref)	16	0.288	1	1
	No	24		0.262 (0.128, 0.538)	0.5524 (0.1847, 1.652)
Storing antimicrobials at home	Yes	29	**0.003**	11.46 (5.358, 24.513)	3.998 (1.598, 10.002)
	No (ref)	11		1	1
Share leftover antimicrobials with a peer	Yes	27	**<0.001**	10.578 (5.057, 22.126)	5.289 (2.148, 13.020)
	No (ref)	13		1	1
Consultation	Vet/para vet	185	**0.007**	0.063 (0.0206, 0.193)	0.148 (0.0365, 0.597)
	AI workers	70	0.704	0.178 (0.576, 0.549)	0.754 (0.1762, 3.230)
	No consultation (ref)	7		1	1

OR = Odds ratio, CI: Confidence interval, Bold values indicate statistically significant p values (p < 0.05)

Table 4: Logistic regression analysis of farmer's non-adherence to drug withdrawal period with various factors.

Variables	Categories	Non-adherence to drug withdrawal	p-value	Unadjusted OR (95% CI)	Adjusted OR (95% CI)
Occupation	Full-time farmer	222	0.263	2.29 (1.01, 5.22)	1.680 (0.6775, 4.16)
	Part-time farmer (ref)	51		1	1
Knowledge about drug withdrawal	Yes (ref)	140	**0.005**	1	1
	No	133		12.82 (2.99, 54.96)	8.373 (1.8834, 37.22)
Knowledge of antimicrobial resistance	Yes (ref)	40	**0.015**	1	1
	No	233		6.24 (2.80, 13.92)	3.222 (1.255, 8.27)
Consultation	Veterinarian/Para veterinarian	183	**0.006**	8.37 (2.771, 25.30)	5.698 (1.637,19.83)
	AI workers	81	**0.025**	12.60 (3.305, 48.04)	5.820 (1.2421, 27.27)
	No consultation (ref)	9		1	1

OR = Odds ratio, CI: Confidence interval, Bold values indicate statistically significant p values (p < 0.05)

Approximately 154 (51%) farmers cleaned their farm daily, 120 (39.8%) weekly, and 18 (5.9%) monthly. A total of 120 (41.7%) farmers reported following safety measures when handling sick animals (Figure 5). Of the 126 farmers who acknowledged following some safety measures, 124 (98.4%) reported washing their hands with soap after handling sick animals. For pest control, 142 (47%) farmers used mosquito nets and 154 (51%) used pest control sprays. However, 100 (33.1%) did not follow any pest control measure.

Methods of disposing of dead animals were found to be specific to villages, and none of them were ideal practices. Moreover, 32.8% of farmers reported burying the dead animals, whereas 9.6% burned them. The majority of 251 (83.1%) and 199 (65.9%) farmers used manure directly as fertilizers and compost manure, respectively. In addition, 84 (27.8%) mopped the mud house using cow dung, 52 (17.2%) made cow dung cakes, which were then burned in a traditional stove for cooking, and 36 (12%) removed and disposed of manure from the farm.

Association between the frequency of animal illness and management practices

The frequency of animals falling sick was significantly associated with practices such as completing full antimicrobial courses ($p < 0.05$), having separate isolation areas for sick animals ($p < 0.001$), quarantining newly acquired cattle ($p < 0.001$), minimizing contact with animals from other farms ($p < 0.001$), ensuring proper

Table 5: Farm distribution based on observations (n = 302).

Variables	Category	Numbers (n = 302)	Percentage
Herd crowded	Yes	61	20.2
	No	241	79.8
Animal shelter separate from the household	Yes	293	97
	No	9	3
Current herd size is smaller in line with the number of cattle on the farm?	Yes	80	26.5
	No	222	73.5
Ventilation and sufficient airflow	Yes	227	75.2
	No	75	24.8
Is manure storage designed to prevent runoff into water sources?	Yes	107	35.4
	No	195	64.6
Tools and technology in place to aid in health monitoring, such as scales for weight measurement or temperature monitoring systems	Yes	36	11.9
	No	266	88.1
Separate isolation area for cattle in case of any disease symptoms	Yes	59	19.5
	No	243	80.5
Isolated cows due to illness during visit	Yes	12	4
	No	290	96
Antimicrobials stored at the farms	Yes	74	24.5
	No	228	75.5
Designated calving area with clean bedding and appropriate calving assistance	Yes	61	20.2
	No	241	79.8
First-aid supplies and emergency equipment availability	Yes	69	22.8
	No	233	77.2
Health records for each animal, including vaccinations, treatments, and breeding history	Yes	36	12
	No	266	88

ventilation and farm environment ($p < 0.001$), avoiding herd overcrowding ($p < 0.001$), maintaining clean and designated calving areas ($p < 0.001$), and regularly cleaning the farm ($p < 0.001$) (Table 6).

Knowledge of Veterinarians about Antimicrobials and AMR

All eight veterinarians agreed that antimicrobials should be prescribed in the right dosage and for the right duration for all animal species. Two of the eight veterinarians stated that antimicrobials should be discontinued once animals stop showing symptoms, and one veterinarian suggested that administering antimicrobials to healthy animals would prevent them from becoming ill. All the veterinarians (8) agreed that infections with resistant pathogens were difficult to manage and that a thorough examination and antimicrobial susceptibility testing (AST) should be performed before prescribing or administering antimicrobials to animals. In addition, they all agreed on the importance of adhering to appropriate drug withdrawal periods. Four of them said that resistant pathogens can spread among animals and humans, and five knew that AMR was associated with irrespective of antimicrobial usage, and a similar proportion was aware of facilities in the laboratory for antibiotic susceptibility. Of the eight veterinarians, four were aware of the existing action plan for AMR and four agreed that the use of medically important antimicrobials in animals should be banned (Figure 6).

Veterinarians' insights into farmers' antimicrobial usage

When veterinarians were asked about farmers' drug usage practices, five out of eight said farmers tend to use previous prescriptions to buy antimicrobials. In addition, seven of them reported that farmers stopped giving antimicrobials to cattle if the cattle felt better. In addition, three veterinarians acknowledged that farmers tend to increase the dose and frequency of antimicrobials if cattle do not show signs of recovery, and a similar proportion admitted that farmers share antimicrobials with their peer farmers (Figure 7).

When asked about factors that may influence farmers to use antimicrobials, most veterinarians said that farmers depended on the advice of the veterinarian and para-veterinarian. Other factors identified by veterinarians included peer influence, the cost of antimicrobials, previous experience with antimicrobial use, advice from AI workers, the ease of antimicrobial availability, and the cost of veterinarian consultation. Out of eight, five veterinarians who said farmers tend to use previous prescriptions to purchase antimicrobials indicated reasons

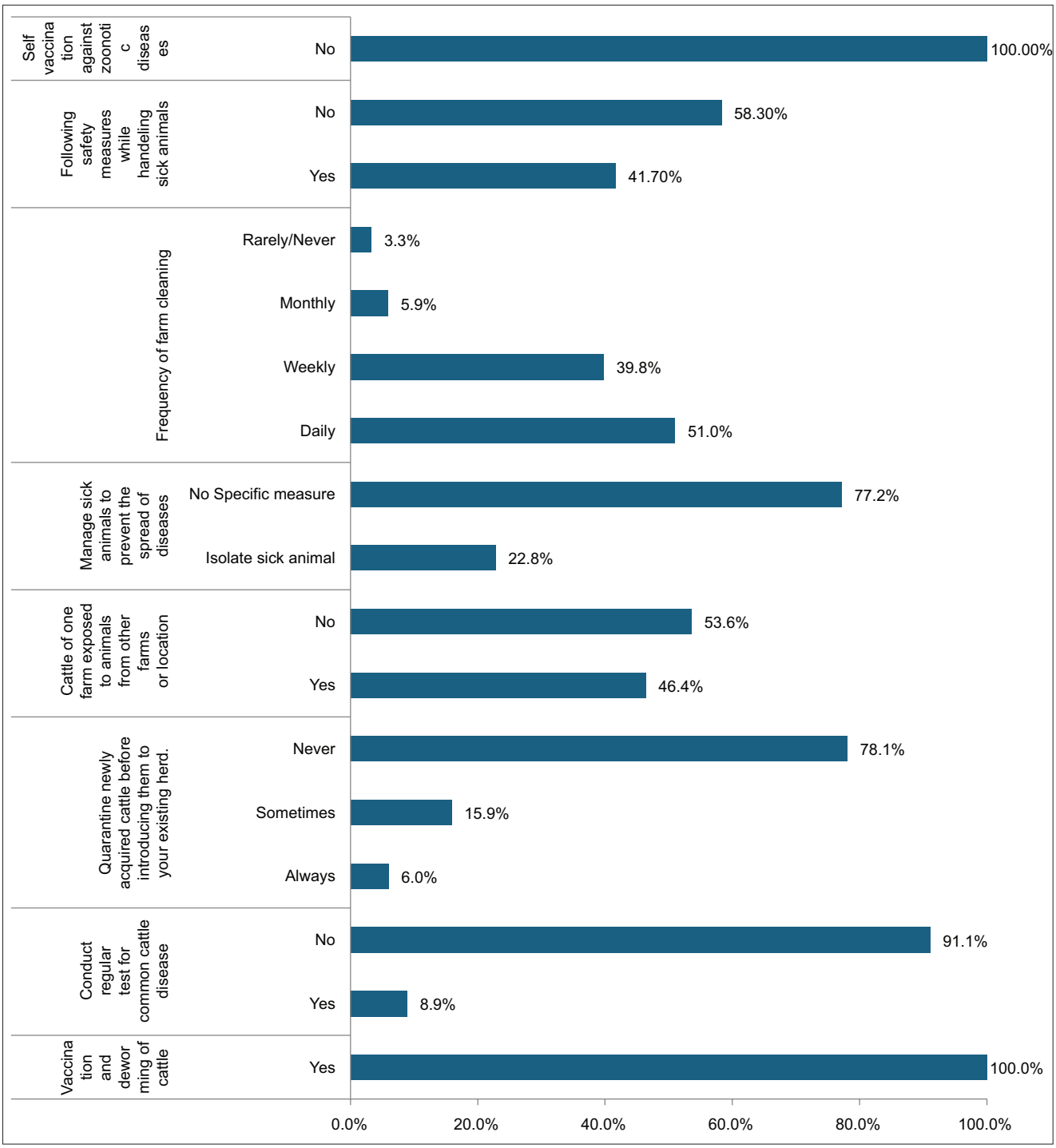

Figure 5: Distribution of farmers based on preventive and safety measures followed by them while handling livestock (n = 302).

for doing so, such as distance from veterinary clinics, peer influence, cost of consultation, and when animals get the same symptoms.

Veterinarians' drug usage practices

The commonly occurring diseases in the area were lumpy skin disease, parasitic infestation, mastitis, and FMD. Out of eight veterinarians, seven did not prescribe antibiotics for all infections. All eight veterinarians claimed to prescribe full antimicrobial courses. Six of them said that they changed antibiotics in case of therapeutic failure, and five acknowledged that they considered whether the infection was self-limiting before prescribing antimicrobials (Figure 8).

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Table 6: Chi-squared association between the frequency of animal illness and various animal health management practices (n = 302).

Independent variables	Categories	Outcome variable			χ^2 value	p-value
		Frequency of animals falling sick				
		Frequently (%)	Occasionally (%)	Rarely (%)		
Farms with other animal species and dairy products.	Yes	28 (14.7)	141 (73.8)	22 (11.5)	3.92	0.141
	No	10 (9)	81 (73)	20 (18)		
Cattle grazing	Open pasture	16 (13.2)	94 (77.7)	11 (9.1)	3.91	0.141
	Confined space	22 (12.2)	128 (70.7)	31 (17.1)		
Completed the antimicrobial course	Yes	19 (9)	163 (78)	27 (13)	8.91	**0.012**
	No	19 (20.4)	59 (63.4)	15 (16.2)		
Regularly conduct tests for common cattle diseases	Yes	4 (14.8)	20 (74.1)	3 (11.1)	0.285	0.867
	No	34 (12.4)	202 (73.5)	39 (14.1)		
Cattle given the booster dose	Yes	37 (12.7)	214 (73.5)	40 (13.8)	0.262	0.877
	No	1 (9.1)	8 (72.7)	2 (18.2)		
Separate isolation area in place in case of disease	Yes	1 (1.7)	35 (59.3)	23 (39)	42.1	**<0.001**
	No	37 (15.2)	187 (77)	19 (7.8)		
Ventilation and farm environment are appropriate	Yes	12 (5.3)	173 (76.2)	42 (18.5)	53.5	**<0.001**
	No	26 (34.7)	49 (65.3)	0 (0)		
Herd is crowded	Yes	21 (34.4)	40 (65.6)	0 (0)	40.3	**<0.001**
	No	17 (7.1)	182 (75.5)	42 (17.4)		
Clean and designated calving area	Yes	0 (0)	30 (49.2)	31 (50.8)	90.7	**<0.001**
	No	38 (15.8)	192 (79.7)	11 (4.5)		
Frequency of farm cleaning	Daily	4 (2.6)	110 (71.4)	40 (26)	107	**<0.001**
	weekly	21 (17.5)	97 (80.8)	2 (1.7)		
	Monthly	13 (72.2)	5 (27.8)	0 (0)		
	Rarely/Never	0 (0)	10 (100)	0 (0)		
Pest control measures followed in the farm	Yes	26 (12.9)	148 (73.3)	28 (13.8)	0.0462	0.977
	No	12 (12)	74 (74)	14 (14)		
Cattle come in contact with animals from other farms	Yes	23 (16.4)	112 (80)	5 (3.6)	24.6	**<0.001**
	No	15 (9.3)	110 (67.9)	37 (22.8)		
New quarantine cattle	Always	4 (22.2)	9 (50)	5 (27.8)	34.6	**<0.001**
	Sometimes	3 (6.3)	27 (56.3)	18 (37.4)		
	Never	31 (13.1)	186 (78.8)	19 (8.1)		

*Categories under the cleaning frequency have been merged, Bold values indicate statistically significant p values ($p < 0.05$)

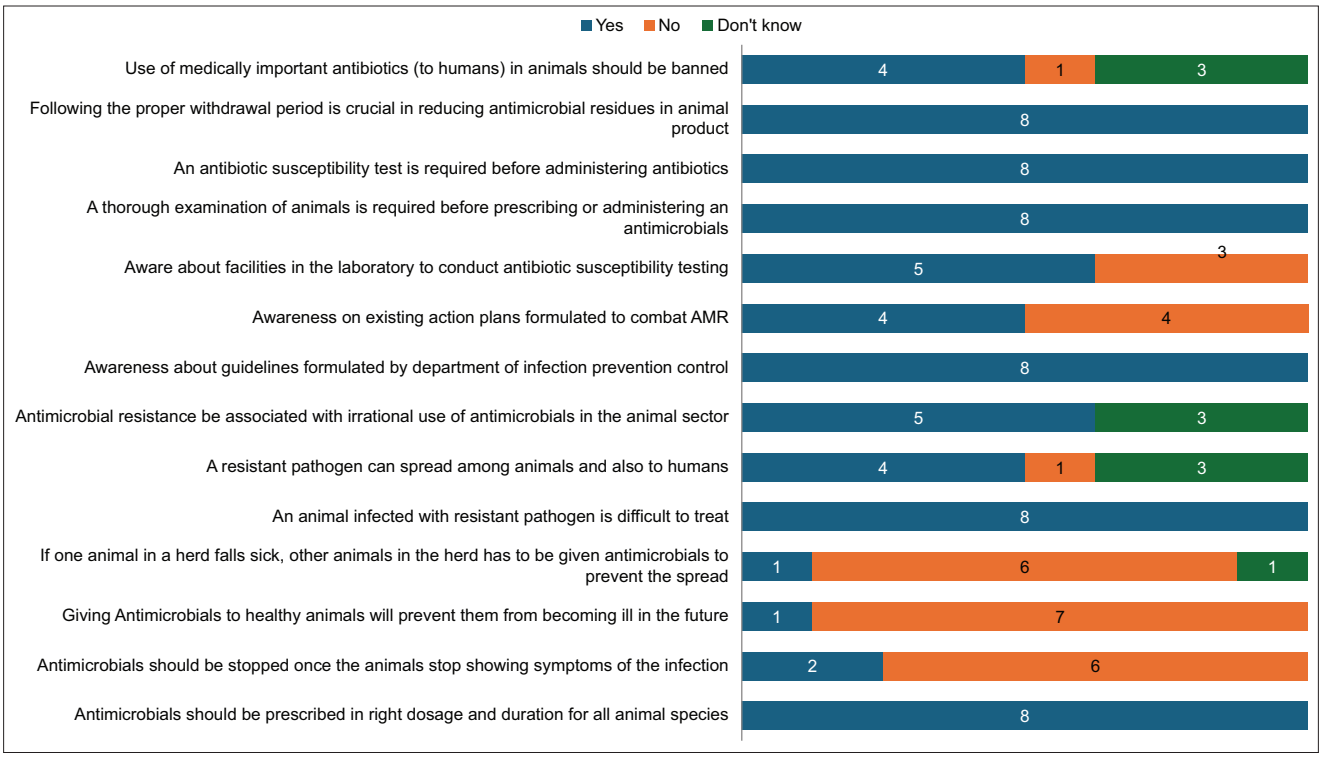

Figure 6: Distribution of veterinarians based on their knowledge of antimicrobials and antimicrobial resistance (n = 8).

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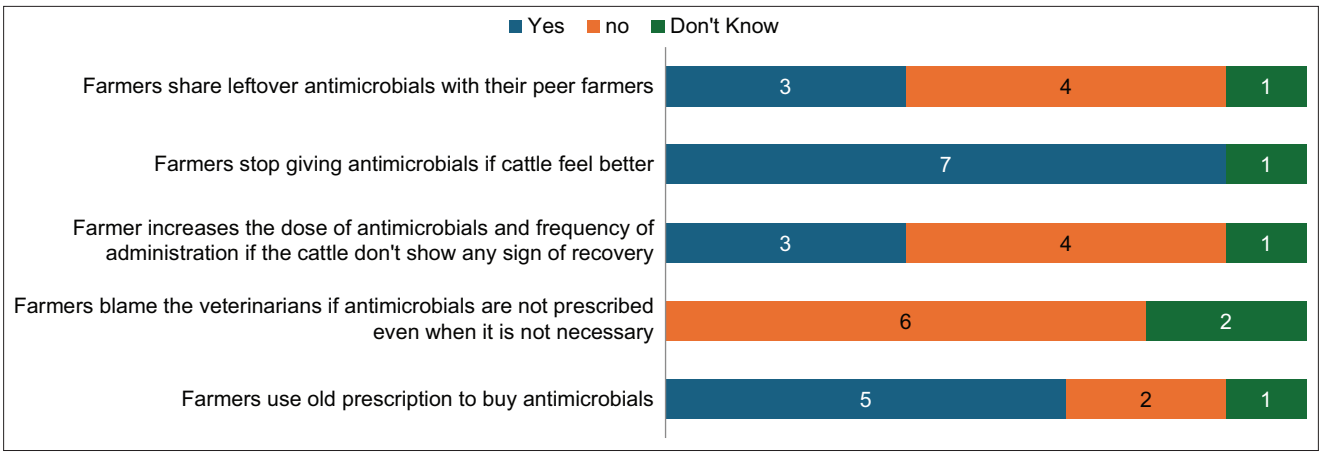

Figure 7: Veterinarian's perspective on farmers' antimicrobial usage practices (n = 8).

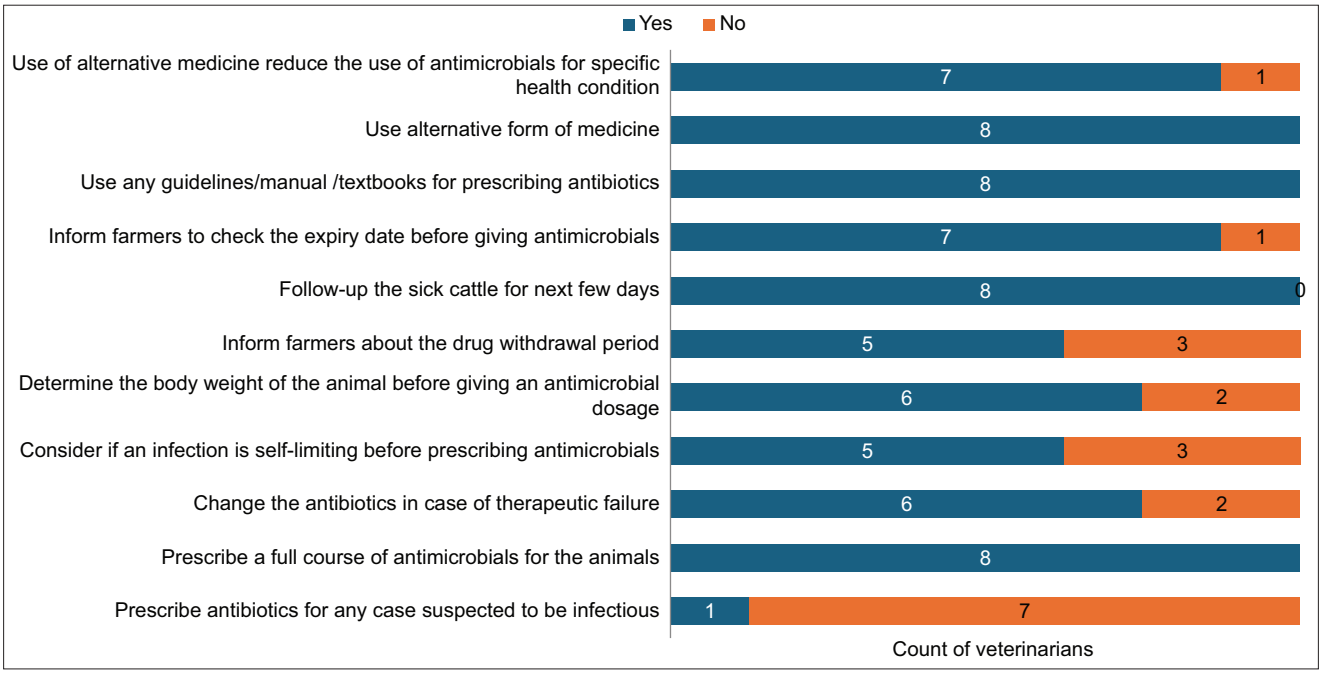

Figure 8: Distribution of Veterinarians based on their antimicrobial usage and prescription practices (n = 8).

All eight veterinarians claimed to prescribe antimicrobials as per guidelines and manuals. Out of eight, six considered weighing animals before prescribing the antimicrobial dose. Five of the veterinarians said that they inform farmers about the drug withdrawal period and seven inform farmers to check the expiry date before administering antimicrobials to animals (Figure 8). All eight said that they would follow up with the cattle for the next few days. In addition, two veterinarians mentioned following government guidelines, two preferred consulting with peers, and three relied on their pharmacological knowledge when prescribing antimicrobials for animals. None of the veterinarians reported any issues with expired drugs. Of the eight veterinarians, seven reported that they disposed of expired drugs in the general waste. However, one did not give a response, saying that they do not get expired drugs. No segregation of waste was observed through color-coded bins.

The most commonly used antibiotics, as indicated by veterinarians, were ceftriaxone, amoxicillin, and enrofloxacin. The majority of veterinarians indicated that the anthelmintics fenbendazole, albendazole, levamisole, oxyclozanide, and the antifungals ketoconazole and fluconazole were commonly used in cattle. Other antimicrobials used by veterinarians included sulbactam, antimycin, fluoroquinolones (antibiotics), ivermectin, rafoxanide, and axefendol (anthelmintics), as well as enilconazole and itraconazole (antifungals). All veterinarians reported that they use alternative medicines for treatment animals and that the use of alternative medicine reduces the use of antimicrobials. An average of 47 cases was treated each month within the system using alternative methods. The common alternative forms used were homeopathy and Ayurveda.

All eight veterinarians acknowledged that they prescribed antibiotics and antifungals for cattle treatment. In addition, one veterinarian mentioned that he prescribed antibiotics for preventive purposes. Of all the veterinarians, seven reported prescribing anthelmintics for prevention, four for treatment, and two for growth promotion.

DISCUSSION

AMR as a global threat

AMR presents a serious global threat to both animal and human health, with veterinarians and farmers playing critical roles in its emergence and mitigation. This quantitative study was designed to assess antimicrobial usage and its associated factors, as well as evaluate animal health management practices, within small-scale household dairy farms located in West Bengal, India. These farmers raise a variety of animals that reflect the region's agricultural diversity, with cows being the most common.

Farmers' knowledge and awareness

Despite reporting familiarity with antimicrobials, farmers demonstrated limited knowledge regarding the different classes and functions of these agents. However, they defined antimicrobials as "a medicine, something for infections or for fever or mastitis." Over 70% of farmers were unaware of the risks posed by excessive AMU; 30.6% believed that human antimicrobials could be used in cattle, and only 18% had a basic understanding of AMR – an issue influenced by literacy levels. These findings were similar to those of a study from Bangladesh in which 91% of farmers were aware of antibiotics, but 19.2% were aware of AMR [21]. Another study by Farhan *et al*. [22] reported that 40% of farmers were unaware of the consequences of antibiotic abuse. Similarly, Dhayal *et al.* [20] reported that 39.5% of participants were unfamiliar with antibiotics, and 48.5% were unaware of AMR. According to a previous study by Ozturk *et al*. [23], basic education, particularly up to the high school level, significantly improves farmers' understanding of antimicrobials and their implications. Most farmers (76.2%) cited veterinarians as their primary source of information on AMR and antimicrobials. These findings were concordant with another study in which awareness of AMR was mainly given by doctors (46.6%), followed by para-vets (16.8%) [20].

Sources of antimicrobials and healthcare providers

The majority of farmers (66.6%) said that they bought antimicrobials from medical stores, including separate veterinary medical stores and public medical stores that stock veterinary drugs. Several farmers reported a preference for purchasing antimicrobials from private medical stores and believed that medicines from government veterinary hospitals were ineffective. Others reported that they had to purchase the remaining dose from a medical store because they did not receive a full course of antimicrobials from the government veterinarian. Veterinarians explained that medicines were often provided for only the first few days due to shortages in supply, with the rest of the prescribed doses purchased by farmers. A total of 27.9% of farmers obtained antimicrobials for their cattle through AI workers. When cattle became sick, 41% of farmers indicated consulting a veterinarian, whereas 26.2% said that they consulted an AI worker. Typically, an AI worker performs tasks such as AI, deworming, vaccination, and first aid [24]. In our study, it was observed that, farmers often rely on AI workers when livestock become ill, particularly in areas with limited access to veterinary services. Another study by Kumar and Gupta [25] reported that 50% of small farmers visited veterinarians, 30.36% consulted para-vets, 12.50% obtained antibiotics from over-the-counter sales, and 7.14% received antibiotics from milk vendors on a regular basis.

Withdrawal period knowledge and practices

Although 55.2% of farmers reported being aware of withdrawal periods, only 8.9% adhered to them. Poor adherence has serious implications, including the presence of antibiotic residues in milk and meat, which contribute to bacterial drug resistance that affects humans. Resistant strains of *E. coli*, *Klebsiella*, and *S. aureus* have been reported in food products, which can be transferred to humans and cause illness. Interestingly, two farmers who denied awareness of withdrawal periods reported informally practicing them, possibly by habitually waiting a few days before using milk. This informal behavior likely reflects experiential practices rather than an understanding of official guidelines. Inconsistent responses may also result from limited technical knowledge, recall bias, or social desirability bias during the interview process.

Prescription use and treatment compliance

In this study, 13.2% of farmers reported using antimicrobials without a prescription, and 15.2% used antimicrobials from previous prescriptions for repeat treatments. Out of eight, five veterinarians indicated that farmers tend to use previous prescriptions to buy antimicrobials due to distance from clinics, peer influence, consultation costs, and recurring symptoms. Although all eight veterinarians reported prescribing complete antimicrobial courses, 30.7% of farmers admitted prematurely discontinued treatment, largely due to high costs. Farmers often stopped medication once animals appeared cured, citing the difficulty of frequent veterinary visits. These findings are in contrast to a previous study by Ramesh and Tripathi [26], where 78% of participants purchased antibiotics without a prescription and 80% failed to complete the full dosage. The present study also found that 11.3% of farmers increased antimicrobial dosage and frequency without professional guidance. Seven veterinarians reported that farmers discontinued antimicrobials once the cattle appeared to be better. Among the eight veterinarians, three acknowledged that farmers increased dose and frequency when animals did not recover, and a similar proportion admitted that farmers shared antimicrobials with peers. Another study reported that 68.1% of farmers adhered to dosage guidelines, but 61.5% terminated therapy once symptoms resolved [22]. These results highlight systemic obstacles such as economic, geographic, and infrastructure issues that compel farmers to look for alternatives that pave the way for antimicrobial misuse.

Discrepancies in treatment reporting

Regarding treatment adherence, 69.2% of farmers initially stated they "always complete" the full course of antimicrobials. However, 71.2% later admitted that they stopped the treatment once animals improved. Such discrepancies likely result from social desirability bias or misunderstanding of questions. Veterinarians also noted that farmers discontinued antimicrobials once the cattle had recovered. By contrast, another study reported that 92% of farmers completed a full course of antimicrobials [21]. In the present study, 23.2% of farmers admitted to sharing antimicrobials, a finding similar to those where 20.7% shared antibiotics with friends and peers [22]. Three veterinarians in this study also confirmed this practice.

Awareness of withdrawal periods and expiry dates

Five of the eight veterinarians reported routinely informing farmers about drug withdrawal periods. Although 55.2% of farmers reported awareness, only 19.2% adhered, citing economic pressures and inadequate instructions. A total of 80.8% ignored withdrawal practices, either due to lack of knowledge or economic reasons. These findings diverged from earlier studies, where 33.7% and 20% of respondents reported awareness of drug withdrawal [20, 26]. Ramesh and Tripathy [26] reported that only 10% of farmers adhered to drug withdrawal, while Rahman *et al.* [21] reported that although 88.1% knew about antibiotic residues, 99% ignored withdrawal times because prescribers never emphasized it. In the present study, 19.2% of farmers checked expiry dates before administering antimicrobials, and seven of eight veterinarians said that they advised this practice.

Disposal practices

The study revealed concerning disposal practices: 72.5% of farmers discarded unused or expired drugs in household surroundings, and veterinarians disposed of expired drugs with general waste due to the absence of color-coded bins. In addition, 16.9% disposed in ponds and 10.6% burned them with household waste. By contrast, Farhan *et al.* [22] found that 41.9% discarded leftover antibiotics in dustbins, while 2.2% flushed or threw them into water bodies. These practices highlight the environmental dimension of AMR, underscoring the need for One Health approaches that integrate waste management.

Disease prevalence and AMU

Lumpy skin disease was identified as the most prevalent condition, followed by parasitic infestations, mastitis, and FMD. In contrast, a previous study by Sharma *et al*. [27] across four Indian regions found mastitis as the main disease, alongside FMD, repeat breeding, and abortion. Over 90% of farmers in this study used antimicrobials (excluding anthelmintics) primarily for therapeutic purposes, while 65.2% used anthelmintics prophylactically. This finding aligns with a study where 98.21% of small farmers used antibiotics for medicinal purposes, and a few used them sub-therapeutically [25]. The present study reported 7.9% farmers using antibiotics for both therapeutic and prophylactic purposes. Only 19.5% of farmers maintained antimicrobial usage records, compared with 30.6% reported by Rahman *et al.* [21]. This lack of record-keeping hampers surveillance and reflects the informal nature of rural animal health management.

Role of advisors and influencing factors

The majority of farmers provided antimicrobials to cattle based on the advice of veterinarians (49.3%), para-veterinarians (20.2%), and AI workers (27.2%). In addition, 8.6% reported lack of alternative therapies, and 8.6% reported antimicrobial cost as influencing factors to use antimicrobials for their cattle. A similar response was obtained from majority of veterinarians who also reported that farmers depend on veterinarians and para-veterinarians' advice. Veterinarians identified further influences such as peer advice, high drug costs, past experiences, easy availability, and consultation fees.

Vaccination and deworming practices

The Department of Animal Husbandry and Dairying launched a livestock health and disease control program to improve animal health through preventive vaccination [28]. Farmers reported high compliance with initial vaccination for major bovine diseases: 98.3% for FMD, 94.7% for lumpy skin disease, 87.7% for brucellosis, and 83.8% for hemorrhagic septicemia. Smaller proportions reported vaccinating against rabies (9.9%) and anthrax (1.7%). However, adherence to booster schedules was poor. Only 26.5% followed boosters; 69.9% did so only when recommended by veterinarians, while 3.6% did not at all. A total of 44.3% lacked a specific vaccination schedule, relying on government vaccination camps. Regarding deworming, all participants reported deworming their cattle, though frequencies varied: 46.5% quarterly, 39.5% semi-annually, and 14% annually.

Commonly used antimicrobials

The most commonly used antibiotics, as reported by veterinarians, were ceftriaxone, amoxicillin, and enrofloxacin. Anthelmintics such as fenbendazole and antifungals, such as ketoconazole and fluconazole were also common. Records from 34 farmers confirmed the frequent use of amoxicillin, enrofloxacin, ceftriaxone, fenbendazole, and ivermectin. Similarly, enrofloxacin (89.47% of herds), ceftriaxone (50%), and amoxicillin (50%) were commonly reported by Vijay *et al.* [29]. The heavy use of these antimicrobials, many critical in human medicine, raises concerns that resistance could compromise both human and veterinary healthcare.

CONCLUSION

This study highlights critical gaps in AMU and AMR awareness among small-scale household dairy farmers in West Bengal, India. While most farmers reported familiarity with antimicrobials, their knowledge of drug classes, functions, and AMR implications was limited, with only 18% demonstrating a basic understanding. Misconceptions were common, such as the belief that human antimicrobials can be used in cattle (30.6%). Although veterinarians were identified as the primary source of information (76.2%) about antimicrobials, farmers often relied on para-veterinarians and AI workers, reflecting limited access to veterinary services.

A significant proportion of farmers reported poor adherence to treatment protocols. Only 8.9% followed withdrawal periods despite 55.2% reporting awareness, raising concerns about antibiotic residues in milk and meat. Nearly one-third of farmers discontinued treatments prematurely due to cost, and 23.2% admitted to sharing antimicrobials with peers. Inappropriate disposal practices were also prevalent, with 72.5% discarding expired drugs in household surroundings, exacerbating the environmental dimension of AMR. Lumpy skin disease emerged as the most prevalent cattle health issue, followed by parasitic infestation, mastitis, and FMD. Vaccination coverage against major bovine diseases was high (>80%), though adherence to booster schedules remained low. Ceftriaxone, amoxicillin, and enrofloxacin were the most frequently used antimicrobials, raising concerns due to their importance in human medicine.

These findings stress the urgent need for region-specific AMR mitigation strategies integrating veterinary guidance, farmer education, and regulatory measures. Training programs on AMU, waste disposal, and withdrawal periods, along with strengthening the role of veterinarians in rural areas, can enhance compliance. Improved access to affordable veterinary services and medicines may reduce misuse driven by economic constraints.

This study provides region-specific, ground-level insights into the behavioral, socio-economic, and infrastructural drivers of AMU among household dairy farmers, a rarely documented perspective from eastern India. The mixed data from both farmers and veterinarians enrich the findings with dual perspectives. However, being cross-sectional and self-reported, the study is subject to recall bias, social desirability bias, and limited generalizability beyond the study region. The small number of veterinarians interviewed also restricts broader inference.

Longitudinal studies incorporating microbiological testing of animal products for residues and resistant pathogens are needed to link farmer practices with measurable AMR risks. In addition, evaluating the

effectiveness of One Health-based training programs, community awareness campaigns, and stricter enforcement of prescription-only antimicrobial sales could guide policymaking.

The findings underscore systemic gaps in knowledge, practices, and access that drive inappropriate AMU in West Bengal's dairy sector. Addressing these issues requires a multi-pronged One Health approach, combining farmer education, veterinary empowerment, policy enforcement, and sustainable livestock health strategies to mitigate the growing threat of AMR to both animal and human health.

AUTHORS' CONTRIBUTIONS

RD, NV, SP, and AK: Study design and conceptualization. RD: Data collection and data entry. RD, NV, UG, BDS, and SB: Data analysis and visualization. RD, SP, SB, and UG: Drafted the manuscript. NV, BDS, and AK: Supervised and reviewed the manuscript. RD and NV: Project administrative work. All authors have read and approved the final version of the manuscript.

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COMPETING INTERESTS

The authors declare that they have no competing interests.

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REFERENCES

1. World Health Organization. (2023) Antimicrobial Resistance. World Health Organization, Geneva. Available from: https://www.who.int/news/room/fact/sheets/detail/antimicrobial-resistance. Retrieved on 11-06-2025.
2. AMR Insights. (2024) Innovate UK Global Expert Mission Report Antimicrobial Resistance in India. AMR Insights. Available from: https://www.amr/insights.eu/innovate/uk/global/expert/mission/report/antimicrobial/resistance-in-india. Retrieved on 11-06-2025.
3. Institute for Health Metrics and Evaluation. (2023) The Burden of Antimicrobial Resistance (AMR) in India. Available from: https://www.healthdata.org/sites/default/files/files/projects/gram/india_0.pdf. Retrieved on 14-06-2025.
4. Centers for Disease Prevention and Control. (2024) Antimicrobial Resistance. Available from: https://www.cdc.gov/antimicrobial-resistance/about/index.html. Retrieved on 11-06-2025.
5. PIB Delhi. (2023) India Ranks First in Milk Production in the World Contributing 24% of Global Milk Production. Available from: https://www.pib.gov.in/pressreleaseiframepage.aspx?prid=1897084#:~:text=according%20to%20production%20data%20of,in%20the%20year%202021%2d22. Retrieved on 11-06-2025.
6. Mohamed, M.A., Elmi, A.S., Dubad Aa, B., Hassan, Y.H.S., Osman, A.M. and Bitrus, A.A. (2020) Antibiotic residue in raw milk collected from dairy farms and markets in Benadir, Somalia. *PAMJ One Health*, 2: 19.
7. Treiber, F.M. and Beranek-Knauer, H. (2021) Antimicrobial residues in food from animal origin-a review of the literature focusing on products collected in stores and markets worldwide. *Antibiotics (Basel)*, 10(5): 534.
8. Jindal, P., Bedi, J., Singh, R., Aulakh, R. and Gill, J.P. (2021) Epidemiological assessment of antibiotic residues in dairy farm milk and farm waste and water in northern India. *Environ. Sci. Pollut. Res. Int*., 28(23): 29455–29466.
9. Godziszewska, J., Pogorzelska-Nowicka, E., Brodowska, M., Jagura-Burdzy, G. and Wierzbicka, A. (2018) Detection in raw cow's milk of coliform bacteria - reservoir of antibiotic resistance. *LWT*, 93: 634–640.
10. Jindal, P., Bedi, J., Singh, R., Aulakh, R. and Gill, J. (2021) Phenotypic and genotypic antimicrobial resistance patterns of *Escherichia coli* and *Klebsiella* isolated from dairy farm milk, farm slurry and water in Punjab, India. *Environ. Sci. Pollut. Res. Int.,* 28(22): 28556–28570.
11. Deepak, S.J., Kannan, P., Savariraj, W.R., Ghatak, S., Ayyasamy, E., Senthil Kumar, T.M.A., Ravindran, N.B., Sundaram, S., Kang, Q., Cull, C.A. and Amachawadi, R.G. (2023) Prevalence and characterization of *Staphylococcus aureus* isolated from retail raw milk samples in Chennai, India. *Foodborne Pathog. Dis.*, 20(12): 570–578.
12. Alorainy, M.S., Alhajuj, A.M. and Fathi, S.M. (2023) Biochemical identification, direct molecular detection, and antimicrobial agent resistance of *Staphylococcus aureus* isolated from raw camel milk in Al Madinah region, Saudi Arabia. *Int. J. Vet. Sci.,* 12(5): 740–745.

13. World Health Organization. (2021) Sustainable Development Goals (SDGs) AMR Indicator. Available from: https://www.who.int/data/gho/data/themes/topics/global/antimicrobial/resistance/surveillance-system-glass/sustainable-development-goals-amr-indicator. Retrieved on 10-06-2025.
14. World Health Organization. (2020) The Fight against Antimicrobial Resistance is Closely Linked to the Sustainable Development Goals. World Health Organization, Geneva. Available from: https://iris.who.int/bitstream/handle/10665/337519/who/euro/2020/1634/41385/56394/eng.pdf?sequence=1. Retrieved on 11-06-2025.
15. World Health Organization. (2016) Division AR. Global Action Plan on Antimicrobial Resistance. World Health Organization, Geneva. Available from: https://www.who.int/publications/i/item/9789241509763. Retrieved on 11-06-2025.
16. PIB Delhi. (2023) National Action Plan on Containment of Antimicrobial Resistance. Available from: https://www.pib.gov.in/pressreleasepage.aspx?prid=1896028#:~:text=national%20action%20plan%20on%20containment%20of%20antimicrobial%20resistance%20. Retrieved on 11-06-2025.
17. Mutua, F., Sharma, G., Grace, D., Bandyopadhyay, S., Shome, B. and Lindahl, J. (2020) A review of animal health and drug use practices in India, and their possible link to antimicrobial resistance. *Antimicrob. Resist. Infect. Control*, 9(1): 103.
18. Sharma, C., Rokana, N., Chandra, M., Singh, B.P., Gulhane, R.D., Gill, J.P.S., Ray, P., Puniya, A.K. and Panwar, H. (2018) Antimicrobial resistance: Its surveillance, impact, and alternative management strategies in dairy animals. *Front. Vet. Sci.,* 4: 237.
19. National Dairy Development Board. (2017) Dairying in West Bengal - a Statistical Profile; 2017. Available from: https://www.nddb.coop/sites/default/files/pdfs/nddb/wb_05-05-17.pdf. Retrieved on 14-06-2025.
20. Dhayal, V.S., Krishnan, A., Rehman, B.U. and Singh, V.P. (2023) Understanding knowledge and attitude of farmers towards antibiotic use and antimicrobial resistance in Jhunjhunu District, Rajasthan India. Antibiotics (Basel), 12(12): 1718.
21. Rahman, S., Ape, T., Islam, MD. and Chowdhury, S. (2021) Perception of dairy farmers regarding antibiotic use and antimicrobial resistance in Bangladesh. *Sarhad J. Agric*., 37(4): 1238–1243.
22. Farhan, M., Awan, N., Kanwal, A., Sharif, F., Hayyat, M.U., Shahzad, L. and Ghafoor, G.Z. (2024) Dairy farmers' levels of awareness of antibiotic use in livestock farming in Pakistan. *Humanit. Soc. Sci. Commun.,* 11(1): 165.
23. Ozturk, Y., Celik, S., Sahin, E., Acik, M.N. and Cetinkaya, B. (2019) Assessment of farmers' knowledge, attitudes and practices on antibiotics and antimicrobial resistance. *Animals (Basel),* 9(9): 653.
24. Ministry of Skill Development and Entrepreneurship. (2019) Participant Handbook: Artificial Insemination Technician. 1st ed. Agriculture Skill Council of India. Available from: https://www.nsdcindia.org/scmp/assets/image/1645802064/01._artificial_insemination_technician-phb_-english_2020_kaushal_mart.pdf. Retrieved on 14-06-2025.
25. Kumar, V. and Gupta, J. (2018) Prevailing practices in the use of antibiotics by dairy farmers in Eastern Haryana region of India. *Vet. World*, 11(3): 274–280.
26. Ramesh, N. and Tripathi, H. (2022) Antibiotic usage practice and knowledge on antimicrobial resistance among livestock and poultry farmers of Telangana state, India. *Indian J. Anim. Sci*., 92(2): 766–173.
27. Sharma, G., Mutua, F., Deka, R.P., Shome, R., Bandyopadhyay, S., Shome, B., Kumar, N.G., Grace, D., Dey, T.K., Venugopal, N., Sahay, S. and Lindahl, J. (2020) A qualitative study on antibiotic use and animal health management in smallholder dairy farms of four regions of India. *Infect. Ecol. Epidemiol.,* 10(1): 1792033.
28. Department of Animal Husbandry and Dairying Ministry of Fisheries. (2022) Operational Guidelines Livestock Health and Disease Control Scheme, Animal Husbandry and Dairying Government of India. Available from: https://dahd.nic.in/sites/default/filess/2853-lhdc-10-08-2022-f-e_.pdf. Retrieved on 14-06-2025.
29. Vijay, D., Bedi, J.S., Dhaka, P., Singh, R., Singh, J., Arora, A. and Gill, J.P.S. (2023) Monitoring of antimicrobial usage among adult bovines in dairy herds of Punjab, India: A quantitative analysis of pattern and frequency. *Front. Vet. Sci.,* 10: 1089307.

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