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INVESTIGATION OF FARMERS KNOWLEDGE, ATTITUDE AND PRACTICES ON THE USE OF ANTIMICROBIALS AMONG CATTLE FARMERS, WITH IN KOINADUGU DISTRICT SIERRA LEONE

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ABSTRACT

Antimicrobial resistance (AMR) is an increasing One Health threat, particularly in low-resource livestock systems where veterinary services, diagnostic capacity and antimicrobial-use surveillance are limited. This study assessed cattle farmers' knowledge, attitudes and practices regarding antimicrobial use and AMR in extensive production systems in Koinadugu District, Northern Sierra Leone. A cross-sectional survey of 187 cattle farmers was conducted using a structured questionnaire adapted from the World Health Organization KAP framework. Data were analyzed in R using descriptive statistics, composite KAP scores, chi-square and Fisher's exact tests, non-parametric tests, Spearman correlation and binary logistic regression.

The findings revealed marked deficiencies in foundational antimicrobial knowledge, including limited understanding of antibiotics, their specificity against bacterial infections and differentiation from other veterinary medicines. Although respondents generally expressed favorable attitudes towards veterinary guidance, responsible antimicrobial use and AMR control, these attitudes were not consistently translated into practice. Major stewardship deficiencies included inconsistent veterinary consultation, poor adherence to recommended dosage and treatment duration, premature treatment discontinuation, poor observance of withdrawal periods, absence of treatment records, inappropriate antimicrobial storage and disposal, low vaccination coverage, inconsistent biosecurity, lack of laboratory diagnosis before treatment and limited participation in extension programmes. Conversely, isolation of sick animals and avoidance of sharing or reusing leftover antibiotics were comparatively positive practices. The findings demonstrate a

substantial knowledge–attitude–practice gap, suggesting that inappropriate antimicrobial use is shaped not only by knowledge deficits but also by structural, economic and veterinary-service constraints.

The study concludes that strengthening AMR control in Northern Sierra Leone requires integrated One Health interventions combining farmer education, improved veterinary access, laboratory diagnostic support, vaccination, biosecurity, antimicrobial-use surveillance, treatment record systems and stronger regulation of veterinary medicines. These findings provide baseline evidence for targeted antimicrobial stewardship policies in Sierra Leone's cattle sector. Implementation should prioritize practical, appropriate extension strategies that convert positive intentions into sustained stewardship behavior.

Keywords: Antimicrobial resistance; antimicrobial use; cattle farmers; knowledge, attitudes and practices; antimicrobial stewardship; One Health; Koinadugu District; Sierra Leone.

1.0. INTRODUCTION

1.1. Background.

The utilization of antimicrobials is escalating worldwide at a frightening rate (Majumder 2021). About two-thirds of the worldwide antimicrobial consumption is in the animal industry (Cully, M 2014). Directly related to the higher consumption of antimicrobials is a corresponding rise in the prevalence of antimicrobial resistance (AMR), which adversely impacts the economy, human health, food security, and related social–economic factors (Organization for Animal Health (OIE) 2019.

According to WHO (2018), "Antimicrobial resistance (AMR) is the ability of a microorganism (like bacteria, viruses, and some parasites) to stop an antimicrobial (such as antibiotics, antivirals and anti-malarials) from working against it. As a result, standard treatments become ineffective, infections persist and may spread to others". According to CDC (2019), AMR is killing an estimated 1.2 million people annually and is related with 5 million deaths in 2019 single-handedly (Lancet, 2022). The state of affairs is even bad for sub-Saharan Africa with the main burden of 255,000 deaths and West Africa with the utmost resistance decease rate of 27.3 decease per 100,000 to AMR (Chekwuema Muanya, 2022). It is anticipated that 10 million yearly deaths might be recorded by 2050.

Across the world, human diets are gradually becoming animal-protein-based, escalating the demand for animal products and rising the use of antimicrobials in animals, principally livestock (Godfray et,al 2010 and Van Boeckel, et.al,.2015) When used prudently for preventing and treating ill health, antimicrobials lower production expenses and improve profits(Robinson, et,al 2016). However, mishandling of antimicrobials can lead to the growth of AMR (World Health Organization 2022).

The World Health Organization (WHO), Food and Agriculture Organization of the United Nations (FAO), and the World Organization for Animal Health (also known as Office International des

Epizooties, OIE) jointly have acknowledged the growing danger of AMR originating from the livestock manufacturing. In 2015, these organizations collaboratively developed the Global Action Plan on AMR with five strategic objectives. One of the primary objectives is to focus on the "optimized" use of antimicrobials in animal health practices. Explanation to these goals is gathering valuable data for operational and strategic decision-making that can be used going forward (World Health Organization 2016). The OIE strategy on AMR with the prudent use of antimicrobials and the FAO action plan on AMR equally highlight the significance of surveillance systems, monitoring, and recordkeeping linked to antimicrobial use in animals in fighting AMR (World Organization for Animal Health (OIE).and Food and Agriculture Organization 2016).

In response to concerns regarding optimal use of antimicrobials and AMR, the Sierra Leone Ministry of Health and Sanitation (MOHS), Ministry of Agriculture and Forestry (MAF), and the Environmental Protection Agency (EPA) published the national strategic plan for combating AMR in 2018. The goals of this national plan have been adapted from the Global Action Plan on AMR to suit the country context. They include improving over sight, surveillance, and education for optimizing antimicrobial use in the country (Government of Sierra Leone. 2017). Currently, in Sierra Leone, the Livestock and Veterinary Services Division at the Ministry of Agriculture and Forestry relies on the existing Integrated Animal Disease Surveillance and Reporting (IADSR) system to collect data on antimicrobial use. Data Were collected on antimicrobial use weekly from the community level and submitted to the national level utilizing the IADSR (Government of Sierra Leone. 2017). According to Leno, A.et.al., (2021), reported extremely poor district reporting rates, complete discordance in data between district and sub-district level treatment forms, and workforce shortage from 2016–2019. According to Bangura et.al.(2022), reports showed that 25% of the livestock had an infectious disease, and a quarter of the sick animals had received an antimicrobial drug. Most animals received antimicrobials belonging to World Organization for Animal Health's "veterinary critically important". These indicate a significant improvement in the animal health surveillance system and highlight the need for enhanced antimicrobial stewardship to prevent misuse of antimicrobials that are significant in animal and human health. However, this report did not indicate the use or misuse of these antimicrobials

2.1. Statement of Problem.

According to the Sierra Leone National Strategic Plan for Combating Antimicrobial resistance (2018-2020), it was revealed, among others, the following:

i. Inadequate public awareness on Antimicrobial resistance (AMR).

ii. Just prepared national plan for the detection and reporting of priority Antimicrobial resistance (AMR) pathogens.

iii. Insufficient diagnostic laboratories for antimicrobial resistance (AMR).

iv. The national health laboratory strategic plan (2016-2020) does not address antimicrobial resistance (AMR).

v. Inadequate qualified and experienced Lab Technicians on Antimicrobial resistance (AMR).

vi. Lack of monitoring on the use of antimicrobial agents in human and animal

vii. Few published scientific studies on antimicrobial resistance (AMR) in Animals.

Moreover, Sierra Leone is an Agrarian country with most of her farmers engaged in Livestock Production (Cattle, Small ruminants, Swine and Poultry) with Shortage of Veterinary Personnel and majority of livestock farmers raise their animals in traditional setting with poor access to veterinary services(personnel's), high cost of drugs and treatment cost. These limitations have compelled majority of farmers with inadequate knowledge of animal diseases to embark on the indiscriminate use of drugs to treat their animals. Resulting to an alarming situation where there are total disregards to adherence, treatment regime, poor diagnosis and dosage of drug to be administered. Likewise, poor surveillance system on antimicrobial resistance (AMR) by the livestock Division, Ministry of Agriculture and food security.

2.2. Aim

This research aims to examine the knowledge, attitudes, and practices surrounding antimicrobial use, as well as to identify the patterns of antimicrobial resistance found in farm and trade cattle raised under extensive management systems in Koinadugu District of Sierra Leone.

2.3. Objectives.

1. Assess the level of knowledge of cattle farmers regarding the use of antimicrobials in cattle production in Koinadugu District.
2. Evaluate the attitudes of cattle farmers towards antimicrobial use, antimicrobial resistance, and prudent antimicrobial practices in cattle production.
3. Determine the antimicrobial use practices among cattle farmers under extensive cattle management systems in Koinadugu District.

2.4. Research Questions.

1. What is the level of knowledge regarding antimicrobial use among cattle farmers in Falaba District, Sierra Leone?
2. What attitudes do these stakeholders have towards antimicrobial use and antimicrobial resistance in Koinadugu Districts, Sierra Leone?
3. What antimicrobial use practices are commonly employed in cattle production systems in Falaba District, Sierra Leone?

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study Population

The target population consisted of cattle farmers who own herds and herdsmen who provide animal health services in the absence of fully qualified veterinarians. Together, these two groups make most of the day-to-day decisions about when and how antimicrobials are used in the cattle sector.

3.2. Sample Size

Step 1: Calculate the initial sample size

For a cross-sectional AMR/KAP survey, Cochran's formula is:

$n0 = Z^2 p\ (1-p)/d^2$

Where n0 is the initial sample size, Z=1.96 for a 95% confidence level, p=0.50 when the expected proportion is unknown, 1−p=0.50, and d=0.05 is the 5% margin of error.

Substituting: $n0 = (1.96)^2(0.50)\ (0.50)/\ (0.05)2$

$n0 = 3.8416 \times 0.25/0.0025$

$n0=0.9604/0.0025 =384.16$

Thus: n0≈384

Step 2: Apply the finite population correction

The corrected formula is: n=n0+N/n0+N- 1

Assuming: N=364

Then: n= 384.16 x 364/384.16+364−1

n= 139,834.24/747.16

n=187.16

Therefore: n≈187 cattle farmers. A total of 187 respondents were enrolled in the study from Koinadugu District.

3.3. Sampling Procedure

A purposive sampling approach was used to select communities where extensive cattle production is the primary farming activity. Within each selected community, respondents were approached via Mama Afro U-turn Koinadugu cooperative, Kabala (local livestock associations) and the Ministry of Agriculture and Food Security, which helped identify cattle farmers. This approach is appropriate when the target population is geographically concentrated and formal sampling frames are unavailable.

Participation was voluntary. Anyone who agreed to take part was interviewed using the questionnaire, regardless of how long they had been farming or how big their farm was.

3.4. Data Collection Instrument.

Data were collected using a structured questionnaire adapted from the World Health Organization KAP questionnaire on antimicrobial resistance (World Health Organization, 2019), with modifications to suit the local context. The questionnaire was organised into the following sections:

Section A — Sociodemographic background (gender, age, education, occupation, years of farming, farm size).

Section B — Farm and animal health information (animals raised, recent disease outbreaks, general health practices).

Section C — Knowledge of antimicrobial and AMR (14 items including yes/no questions and multi-response items on the nature of AMR, contributing practices and preventive measures).

Section D — Attitudes towards antimicrobial use (10 items measured on five-point Likert scales of agreement and concern).

Section E — Practices regarding antimicrobial use (14 items on sources, reasons, frequency, prescription, quality assurance, mode of administration, duration, record keeping, treated diseases and disposal).

Section F — Information sources and learning preferences (six items on preferred sources of news, entertainment and farming information).

The questionnaire was administered face to face. For respondents who did not speak English, the interview was conducted in the local language by trained enumerators who translated the questions on the spot.

3.5. Data Management.

Responses were captured electronically using the KoBoToolbox platform, which exported the dataset as a structured file. The raw export contained 211 columns, including identifier fields, GPS coordinates, multi-select parent fields and free-text 'specify' columns.

The data were then cleaned through a structured pipeline. The cleaning steps included removing identifier and GPS columns to protect respondent privacy, dropping duplicate columns generated by KoBoToolbox, removing columns with more than 95 per cent missing values, renaming variables to short and consistent names (for example, K1_Describe AMR for the first knowledge question), recoding numeric missing codes (999, -9, -99) to system-missing, standardizing spellings of nationality, and recoding multi-select binary variables so that an unselected option was treated as a clear zero rather than as missing data. After cleaning, 163 variables remained for analysis.

3.6. Data Analysis.

All analyses were carried out using R software (version 4.5.3). The analysis followed a structured plan organized around the three study objectives.

3.6.1. Descriptive analysis.

Frequencies and percentages were calculated for all categorical variables, including the demographic profile, individual KAP items and multi-response items. Means and standard deviations were calculated for the Likert items and for the composite KAP scores. Distributions were summarized using Tables

3.6.2. Composite scores.

Three composite scores were constructed to summarize overall knowledge, attitude and practice.

The Knowledge Score was calculated by summing the number of correct responses across the K9 items (nature of AMR, five items), the K12 items relating to practices that contribute to AMR (four correct items) and the K13 items relating to practices that prevent AMR (four correct items). This produced a possible range of 0 to 13.

The Attitude Score combined six Likert items, with the negatively worded items (A5, A6 and A7) reverse-coded so that a higher score reflected a more cautious attitude towards antimicrobial use.

The Practice Score combined four binary indicators of prudent practice: always obtaining a prescription, sourcing antimicrobial from a veterinarian, checking the expiry date and not keeping excess antimicrobial for future use.

3.6.6. Significance threshold.

All inferential tests were carried out at a significance level of 0.05. Where applicable, p-values were reported to four decimal places and significance was indicated using the conventional notation (*** for $p < 0.001$, ** for $p < 0.01$, * for $p < 0.05$, ns for not significant).

3.7. Ethical Considerations

Ethical clearance for the study was obtained from the Njala University Ethical Consideration before data collection began. Permission was also sought from Mama Afro Koinadugu U Turn Livestock farmers Cooperative and Ministry of Agriculture and Food Security in the study area.

All respondents were informed about the purpose of the study, how their information would be used and their right to withdraw at any time without giving a reason. Verbal informed consent was obtained from each respondent before the interview began. No identifying information has been included in the dataset used for analysis: names, contact details and GPS coordinates were removed during the data cleaning stage to protect privacy.

3.8. Limitations of the Methodology

Three methodological limitations should be acknowledged. First, the cross-sectional design captures the situation at one point in time and does not allow conclusions about cause and effect. Second, purposive sampling was used to identify suitable communities, which may limit how far the findings can be generalized to all cattle producers in Sierra Leone. Third, all responses were self-reported,

which means they may be affected by social desirability bias, although this risk was reduced by the candid nature of many of the responses received and by interviewing in the respondent's preferred language.

RESULTS

3.0 Introduction

This chapter presents the study's findings on the detection and phenotypic characterization of antimicrobial-resistant pathogens in cattle managed under free-range production systems in Koinadugu Districts, Northern Sierra Leone. The results are systematically presented and analyzed in line with the study objectives, providing empirical evidence on cattle management practices, patterns and determinants of antimicrobial use, bacterial isolation and identification, antimicrobial susceptibility profiles, phenotypic resistance patterns, multidrug resistance, and associated risk factors. To provide a more comprehensive understanding of the epidemiology of antimicrobial resistance within the study area, findings are disaggregated by district and chiefdom, enabling meaningful assessment of similarities, differences, and distinctive local patterns. Descriptive and inferential statistical techniques are employed to summarize the data, test relevant associations, and generate evidence-based interpretations of the observed patterns.

3.1. Demographic Characteristics of Livestock Farmers Regarding Antimicrobial Resistance (AMR) in Koinadugu Districts, Northern Sierra Leone

3.1.1 Demographic Characteristics of Livestock Farmers

The demographic characteristics of livestock farmers provide important context for interpreting antimicrobial resistance (AMR) patterns among cattle under free-range management systems. Socio-demographic factors such as sex, age, education level, occupation, farming experience, and herd size influence farmers' knowledge, attitudes, and practices regarding antibiotic use, disease management, and the adoption of antimicrobial stewardship measures. Table 4.1 presents the demographic characteristics of cattle farmers sampled from the Koinadugu District in Northern Sierra Leone.

3.1.2 Sex Distribution of Livestock Farmers

The sex distribution of livestock farmers revealed a clear predominance of male participation in cattle production activities across Koinadugu Districts. This finding reflects the prevailing socio-cultural structure of livestock ownership and management in Northern Sierra Leone, where cattle rearing is traditionally regarded as a male-dominated responsibility. Men are often responsible for herd ownership, grazing management, disease decision-making, and procurement of veterinary medicines, while women frequently participate in supportive livestock-related activities such as milk processing, animal feeding, and household-level utilization of livestock products.

In Koinadugu District, male farmers constituted most respondents, accounting for 152 out of 187 participants (81.28%), while females represented 35 respondents (18.72%). Male dominance was observed across all surveyed chiefdoms. The highest male representation was recorded in Sengbeh chiefdom, where 34 respondents (94.44%) were males compared with 2 females (5.56%). Similarly, Kabongo chiefdom recorded 33 males (94.29%) and 2 females (5.71%), while Wara Bafoedia chiefdom had 33 males (84.62%) and 6 females (15.38%). Although female participation was generally lower, Wara Yangala chiefdom demonstrated comparatively higher female involvement, with 10 female respondents (28.57%), suggesting greater participation of women in cattle-related activities within this community.

The predominance of male farmers has significant implications for antimicrobial resistance (AMR) management. Because men are often the primary decision-makers on antibiotic purchase, selection, and administration, AMR interventions must actively target male livestock owners and herders. However, women's participation should not be overlooked, as their roles in milk handling, meat preparation, and animal care directly expose them to potential antibiotic residues and resistant bacteria. Accordingly, gender-sensitive antimicrobial stewardship programmes that involve both men and women are essential for effective AMR control.

The observed female participation, particularly in Wara Yangala chiefdom in Koinadugu and Debelia Sinkunia chiefdom in Falaba, provides an opportunity to expand community-based AMR awareness programmes beyond traditional livestock decision-makers. Integrating women into veterinary extension activities, training programmes, and food safety initiatives may enhance responsible antibiotic use practices and contribute to reducing the transmission of antimicrobial-resistant Enterobacteriaceae pathogens within the One Health framework.

3.1.3 Age Distribution of Livestock Farmers

The age distribution of respondents indicates that cattle production in Koinadugu District is predominantly undertaken by mature, experienced livestock farmers. Age is an important demographic characteristic because it influences farming experience, decision-making capacity, adoption of improved livestock management practices, and compliance with antimicrobial stewardship recommendations. The predominance of older farmers suggests that cattle production in Northern Sierra Leone remains a long-established livelihood sustained by indigenous knowledge and traditional husbandry practices.

In Koinadugu District, the largest proportion of respondents belonged to the above 50 years age category, with 82 respondents (43.85%), followed by those aged 41–50 years, 72respondents (38.50%), and 31–40 years, with 27 respondents (14.44%). The 18–30 years age group constituted the smallest proportion, averaging only 6 respondents (3.21%). The results indicate that cattle farming in

Koinadugu is largely managed by older household heads with substantial practical experience in livestock husbandry.

The predominance of older farmers has important implications for antimicrobial resistance (AMR) control. Older livestock keepers possess extensive indigenous knowledge and practical experience in disease recognition, animal husbandry, and herd management. However, they may also rely heavily on traditional treatment practices and experiential knowledge rather than evidence-based veterinary recommendations. Where veterinary extension services are inadequate, such practices may encourage empirical antibiotic use, inappropriate drug selection, or repeated use of familiar antimicrobials, thereby increasing selection pressure for resistant Enterobacteriaceae pathogens. Conversely, the limited participation of younger farmers may constrain the adoption of modern livestock technologies and antimicrobial stewardship practices. These findings underscore the need for targeted veterinary extension programmes that combine the valuable experience of older farmers with contemporary evidence-based approaches to prudent antibiotic use, thereby ensuring sustainable cattle production and effective AMR mitigation in Northern Sierra Leone.

3.1.4 Educational Status of Livestock Farmers

The educational profile of livestock farmers revealed generally low levels of formal education in both Koinadugu and Falaba Districts. This finding is an important demographic determinant in understanding antibiotic-use behaviors and potential risks associated with antimicrobial resistance (AMR) among cattle managed under free-range production systems. Educational attainment influences farmers' ability to access, interpret, and apply technical information related to veterinary medicines, disease prevention, antimicrobial stewardship, and food safety practices.

In Koinadugu District, most livestock farmers had no formal education, accounting for 157 respondents (83.96%). Farmers with some level of formal education represented a relatively small proportion of the study population, including 11 respondents (5.88%) with primary education, 16 respondents (8.56%) with secondary education, 1 respondent (0.53%) with tertiary education, and 2 respondents (1.07%) with other forms of education. The findings demonstrate that cattle production in Koinadugu is largely undertaken by farmers with limited exposure to formal educational systems.

The predominance of farmers without formal education has important implications for antimicrobial stewardship and AMR mitigation efforts. Limited literacy may restrict farmers' ability to correctly interpret antibiotic labels, understand dosage calculations based on animal weight, recognize differences between antimicrobial agents, comply with treatment duration requirements, and appreciate the consequences of inappropriate antibiotic use. Additionally, farmers with low educational attainment may depend more heavily on traditional knowledge, peer advice, livestock

traders, or informal medicine vendors when making decisions about antibiotic treatment, thereby increasing the risk of inappropriate antimicrobial use.

To effectively address AMR risks within cattle production systems, training programs should be designed using participatory approaches that accommodate low literacy levels. These should include the use of local languages, practical demonstrations, pictorial training materials, farmer field schools, and regular veterinary extension visits. Strengthening farmers' understanding of antibiotic use, disease prevention, vaccination, biosecurity, and the public health consequences of antimicrobial resistance will be essential for reducing inappropriate antibiotic practices and limiting the emergence and spread of resistant Enterobacteriaceae pathogens in Northern Sierra Leone.

Table 3.1 Demographic Characteristics of Livestock Farmers Regarding AMR use in Koinadugu and Falaba Districts in Northern Sierra Leone

District /Chiefdom	**Sex**		**Age**				**Level of Education**					**Main Occupation**			**Experience**					**Farm Size**		
	(%)		**(x̄)**				**(%)**					**(%)**			**(%)**					**(%)**		
Koinadugu	**M**	**F**	**1**	**2**	**3**	**4**	**N**	**1°**	**2°**	**3°**	**Oth**	**Fa**	**T**	**Oth**	**6**	**7**	**8**	**9**	**10**	**S**	**M**	**L**
Wara Yangala	25	12	0	1	14	22	29	1	6	0	1	37	0	0	0	0	7	0	30	20	11	6
Wara Bafoedia	32	6	2	10	12	14	34	2	1	1	0	38	0	0	0	0	3	0	35	22	10	6
Kabongo	30	8	0	4	19	15	33	1	4	0	0	33	5	0	0	0	2	1	35	27	8	3
Bonkibo Kayaka	31	6	4	4	13	16	32	2	3	0	0	31	6	0	0	0	1	2	34	15	12	10
Sengbeh	34	3	0	8	14	15	29	5	2	0	1	31	6	0	0	1	1	1	34	32	5	0

M = Male, F = Female, 1 = Age bracket Between 18 to 30 years, 2 = Age bracket Between 31 to 40, 3 Age Bracket Between 41 to 50, 4 = Age Bracket Above 50 years, 6 = 1-2 years of experience, 7 = 2-5 years of experience, 8 = 5 to 10 years of experience, 9 = 10 to 15 years of experience, 10 = above 15 years of experience N = No Formal Education, 1° = Primary Education, 2° = Secondary Education, 3° = Tertiary Education, Oth – Other Forms of Education, Fa = Farming, T = Trading, S = Small, M = Medium, L = Large

3.1.5 Main Occupation of Respondents

Livestock farming was identified as the predominant occupation among cattle farmers in Koinadugu District, reflecting the central role of cattle production in sustaining rural livelihoods in Northern Sierra Leone. The occupational profile of respondents demonstrates a high level of dependence on livestock production for household income, food security, and socio-economic stability.

In Koinadugu District, most respondents identified farming as their main occupation, accounting for 170 farmers (90.91%). Trading was reported by only 17 respondents (9.09%), while 0 respondents (0%) indicated involvement in other occupations. This result suggests that cattle production represents the primary economic activity among surveyed communities, with limited diversification into alternative livelihood sources.

The overwhelming dominance of farming as the principal occupation has significant implications for antimicrobial resistance (AMR) and livestock health management. Since cattle production is the main economic activity, disease outbreaks and treatment failures associated with antimicrobial-resistant pathogens may have substantial consequences for household income, animal productivity, and community food security. Reduced effectiveness of commonly used antibiotics due to AMR may increase production costs through repeated treatments, increased mortality, reduced growth rates, and additional veterinary expenses.

Additionally, the strong dependence on cattle farming underscores the need to improve access to veterinary services, diagnostic facilities, and farmer education programmes. Because farmers rely heavily on livestock production, they are a critical stakeholder group for antimicrobial stewardship interventions. Strengthening their capacity through training in responsible antibiotic use, disease prevention, vaccination, biosecurity, and early disease detection will significantly reduce inappropriate antimicrobial use and limit the emergence and transmission of antimicrobial-resistant Enterobacteriaceae in cattle production systems.

Overall, the occupational characteristics of farmers in Koinadugu District emphasise that AMR is not only a veterinary health concern but also a major socio-economic and food security issue requiring integrated One Health interventions.

3.1.6 Livestock Farming Experience

Experience in cattle production varied across Koinadugu District, with most farmers demonstrating several years of involvement in livestock management. Farming experience is an important factor in understanding antimicrobial use behaviours because experienced farmers often develop practical knowledge of disease recognition, animal handling, and treatment decision-making. However, prolonged reliance on traditional practices without continuous veterinary education may also influence antibiotic-use behaviours and contribute to antimicrobial resistance (AMR).

In Koinadugu District, farmers with over 5years of cattle production experience constituted the largest group, accounting for 168 respondents (89.83%). This was followed by farmers with 10–15 years (17 respondents; 9.09%), and farmers with 2–5 and 10-15 years of experience (1 respondent each; 0.13%). The least represented group comprised farmers with only 1–2 years of experience, accounting

for 0 respondents. This distribution indicates that cattle production in Koinadugu is largely managed by farmers with moderate levels of practical experience.

Although extensive farming experience may enhance farmers' ability to recognize common livestock diseases and respond to animal health challenges, it does not necessarily guarantee appropriate antibiotic-use practices. Experienced farmers may develop strong confidence in traditional treatment approaches, including self-diagnosis, empirical antibiotic selection, and reliance on previously successful treatments. Without regular exposure to veterinary extension services and antimicrobial stewardship training, such practices may promote inappropriate antibiotic use, increasing selective pressure for resistant Enterobacteriaceae pathogens.

Accordingly, the findings highlight the importance of integrating experienced livestock farmers into AMR control programmes as key community stakeholders. Targeted training that combines farmers' indigenous knowledge with modern veterinary principles will be essential for improving responsible antibiotic use and reducing AMR risks in cattle production systems in Northern Sierra Leone.

3.1.7 Farm Size Distribution

The distribution of farm sizes indicates that cattle production in both Koinadugu and Falaba Districts is predominantly characterized by smallholder farming systems. Farm size is an important determinant of livestock management practices, access to veterinary services, disease prevention capacity, and the likelihood of appropriate antimicrobial use. Small-scale farmers often face constraints related to financial resources, infrastructure, veterinary support, and access to diagnostic facilities, which may influence antibiotic-use behaviours and contribute to antimicrobial resistance (AMR) development.

In Koinadugu District, small-scale farms represented most cattle holdings, accounting for 116(62.03%) respondents, Medium-sized farms constituted 46 respondents (24.59%), while large-scale farms represented the smallest category, with 25 respondents (13.36%). This distribution demonstrates that cattle production in Koinadugu is largely based on household-level and subsistence-oriented livestock systems rather than commercial production. The dominance of small farms may reflect the traditional extensive cattle production system commonly practised in the district, where animals are managed under free-range conditions with limited inputs.

Financial limitations and inadequate veterinary support may encourage farmers to rely on empirical treatment approaches, including self-prescribing antibiotics, using drugs obtained from informal sources, or repeating previously successful treatments without laboratory confirmation. Such practices create selective pressure that promotes the emergence and persistence of antimicrobial-resistant bacteria.

Accordingly, strengthening veterinary extension services, improving access to affordable diagnostic facilities, promoting farmer education on responsible antibiotic use, and supporting preventive health measures are essential interventions for reducing AMR risks among smallholder cattle farmers in Koinadugu District. Addressing the challenges associated with small-scale production will be critical for achieving effective antimicrobial stewardship within Sierra Leone's livestock sector.

3.2 Livestock Farmers' Knowledge, Attitudes and Practices (KAP) in use of Antibiotics in Cattle in Koinadugu Districts in Northern Sierra Leone

3.2.1 Livestock Farmers' Knowledge on the Use of Antibiotics in Cattle in Koinadugu District, Northern Sierra Leone

Table 3.2 presents the findings on the knowledge of livestock farmers regarding the prudent use of antibiotics in cattle production in Koinadugu District, Northern Sierra Leone. The responses were measured using a five-point Likert scale, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. The analysis reveals considerable variation in farmers' understanding of the fundamental concepts of antibiotics, while indicating overwhelmingly positive responses concerning recommended antibiotic stewardship practices. Overall, the findings suggest that although farmers exhibit excellent knowledge of practical antibiotic management, important deficiencies remain in their foundational scientific understanding of antibiotics and bacterial diseases.

3.2.2 Understanding of Antibiotics

The first dimension examined respondents' basic understanding of antibiotics. The results indicate relatively low conceptual knowledge among the farmers.

Regarding the statement "What do you know antibiotics are?", 90 respondents (48.13%) strongly disagreed, 40 (21.40%) disagreed, 50 (26.73%) remained neutral, while only 7 respondents (3.74%) strongly agreed that they possessed adequate knowledge of antibiotics. Notably, no respondent selected the "Agree" category. Collectively, nearly 70% of respondents expressed disagreement, indicating that the majority lacked a clear understanding of what antibiotics are.

Similarly, when respondents were asked whether antibiotics are effective only against bacterial infections, 100 respondents (53.48%) strongly disagreed, 25 (13.37%) disagreed, 57 (30.48%) were neutral, while only 5 respondents (2.67%) strongly agreed. These findings indicate widespread misconceptions regarding the specific therapeutic role of antibiotics. The absence of responses in the "Agree" category further suggests that only a very small proportion of farmers correctly understood that antibiotics are ineffective against viral, fungal, and most parasitic infections.

Knowledge was even lower concerning the ability to distinguish antibiotics from other veterinary medicines. Approximately 140 respondents (74.87%) strongly disagreed, 40 respondents (21.39%) remained neutral, while only 7 respondents (3.74%) strongly agreed. Again, no respondents selected

either "Disagree" or "Agree." This finding represents one of the weakest knowledge domains observed in the study and suggests that many livestock farmers may confuse antibiotics with dewormers, anti-inflammatory drugs, vitamins, vaccines, or other veterinary pharmaceuticals.

These results collectively indicate that although antibiotics are commonly used in cattle production, many farmers possess only limited scientific understanding of their pharmacological properties and appropriate indications.

3.2.3 Disease Recognition

The second domain assessed farmers' ability to recognize bacterial diseases and determine when antibiotic therapy is appropriate. For the statement "Identify common signs of bacterial diseases requiring veterinary attention," 100 respondents (53.48%) strongly disagreed, 10 (5.35%) disagreed, 69 (36.89%) were neutral, while only 8 respondents (4.28%) strongly agreed. The overwhelming proportion of disagreement indicates inadequate knowledge regarding clinical recognition of bacterial infections.

Likewise, concerning whether not all sick animals require antibiotic treatment, 110 respondents (58.82%) strongly disagreed, 10 (5.35%) disagreed, 60 (32.09%) remained neutral, while only 7 respondents (3.74%) strongly agreed. The results suggest that many cattle farmers have difficulty differentiating bacterial diseases from viral, nutritional, parasitic, or metabolic disorders. Consequently, there is a substantial risk of unnecessary antibiotic use whenever animals become ill, thereby increasing the likelihood of antimicrobial resistance development.

3.2.4 Veterinary Prescription and Diagnosis

An exceptionally positive finding emerged regarding veterinary consultation.

All 187 respondents (100%) strongly agreed that they seek diagnosis and prescriptions from qualified veterinarians before administering antibiotics. Likewise, 100% strongly agreed that they avoid self-prescribing or using antibiotics without professional guidance.

This unanimous response indicates complete acceptance of veterinary oversight in antibiotic use. Such behavior is highly desirable because veterinary diagnosis improves treatment accuracy, reduces inappropriate antimicrobial use, and supports antimicrobial stewardship.

The findings also suggest that veterinary professionals remain the primary source of guidance regarding antibiotic use among cattle farmers in Koinadugu District.

3.2.5 Correct Antibiotic Selection

Knowledge regarding antibiotic selection was equally impressive. All 187respondents (100%) strongly agreed that they use the appropriate antibiotic for the specific disease and animal species; and understand that different bacteria respond differently to different antibiotics. These findings demonstrate complete awareness of pathogen-specific antibiotic therapy, which is one of the

cornerstones of responsible antimicrobial use. Appropriate antibiotic selection reduces treatment failures and minimizes the selective pressure responsible for antimicrobial resistance.

Table 4.2 Livestock Farmers Knowledge on the use of Antibiotics in Cattle in Koinadugu Districts in Northern Sierra Leone

Knowledge Parameters	Likert Scale (f and %), n = 187				
Understanding of Antibiotics	**1**	**2**	**3**	**4**	**5**
What do you know antibiotics are?	90 (48.13)	40 (21.4)	50 (26.73		7 (3.74)
Do you know antibiotics are effective only against bacterial infections?	100 (53.48)	25 (13.37)	57 (30.48)		5 (2.67)
Can you recognize the differences between antibiotics and other drugs?	140 (74.87)		40 (21.39)		07 (3.74)
Disease Recognition					
Identify common signs of bacterial diseases requiring veterinary attention	100 (53.48)	10 (5.35)	69 (36.89)		8 (4.28)
Understand that not all sick animals require antibiotic treatment	110 (58.82)	10 (5.35)	60 (32.09)		7 (3.74)
Veterinary Prescription and Diagnosis					
Seek diagnosis and prescriptions from qualified veterinarians	187 (100)				
Avoid self-prescribing or using antibiotics	187 (100)				
Correct Antibiotic Selection					
Use the appropriate antibiotic for the specific disease and animal species	187 (100)				
Understand that different bacteria respond to different antibiotics	187 (100)				
Correct Dosage					
Know how to calculate the correct dose based on the animal's body weight	187 (100)				
Use appropriate measuring devices to avoid under- or overdosing	187 (100)				
Route of Administration					
Understand the correct method of administration (oral, intramuscular, etc.)	187 (100)				
Follow label instructions or	187 (100)				

veterinary guidance					
Treatment Duration					
Complete the full course of treatment even if the animal appears to recover	187 (100)				
Avoid stopping treatment prematurely	187 (100)				
Withdrawal Periods					
Understand and observe withdrawal periods before milk, meat consumed	187 (100)				
Appreciate the public health implications of antibiotic residues in food.	187 (100)				
Antimicrobial Resistance (AMR)					
Understand how misuse and overuse of antibiotics contribute to .AMR.	187 (100)				
Recognize the consequences of AMR for animal and human health	187 (100)				
Avoiding Prophylactic and Growth-Promoting Use					
Know that antibiotics should not be routinely used for growth promotion	187 (100)				
Disease Prevention and Biosecurity					
Implement vaccination, proper nutrition, sanitation, quarantine, and biosecurity measures to reduce disease occurrence and antibiotic use.	100 (100)				
Understand that prevention is more effective and economical than routine antibiotic treatment.					
Reading Drug Labels					
Interpret information on drug labels, including active ingredients, indications, dosage, administration, contraindications, storage requirements, expiry dates, and withdrawal periods.	187 (100)				

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

3.2.6 Correct Dosage

Proper dosage administration is essential for maximizing therapeutic effectiveness while minimizing antimicrobial resistance. The findings indicate that all respondents (100%) strongly agreed that they know how to calculate antibiotic doses according to animal body weight and use appropriate measuring devices to prevent under- or overdosing. This unanimous response suggests widespread adherence to recommended dosage practices. Appropriate dosing reduces treatment failure, limits bacterial survival following sub-therapeutic exposure, and improves treatment outcomes.

3.2.7 Route of Administration

Knowledge regarding the correct route of antibiotic administration was universally high.

Every respondent (100%) strongly agreed that they understand the correct methods of administering antibiotics (oral, intramuscular, subcutaneous, etc.); and follow product label instructions or veterinary guidance during administration. Correct administration enhances drug absorption, therapeutic efficacy, and animal welfare while reducing medication errors.

3.2.8 Treatment Duration

The study also demonstrates excellent knowledge regarding treatment duration. All respondents (100%) strongly agreed that they complete the full course of antibiotic treatment even when animals appear clinically recovered and avoid stopping treatment prematurely. This finding is particularly encouraging because incomplete antibiotic therapy is widely recognized as one of the major drivers of antimicrobial resistance. Adherence to prescribed treatment duration ensures complete bacterial elimination and reduces opportunities for resistant bacteria to emerge.

3.2.9 Withdrawal Periods

Knowledge concerning withdrawal periods was universally satisfactory. Every respondent (100%) strongly agreed that they understand and observe withdrawal periods before meat or milk is consumed; and appreciate the public health implications associated with antibiotic residues in food products. Observance of withdrawal periods protects consumers from exposure to antimicrobial residues, contributes to food safety, and facilitates compliance with national and international food quality standards.

3.2.10 Knowledge of Antimicrobial Resistance (AMR)

Knowledge regarding antimicrobial resistance was exceptionally high. All respondents (100%) strongly agreed that they understand misuse and overuse of antibiotics contribute to antimicrobial resistance; and antimicrobial resistance threatens both animal and human health.

This finding demonstrates widespread awareness of the One Health implications of antimicrobial misuse and reflects increasing dissemination of AMR education among livestock farmers.

3.2.11 Avoiding Prophylactic and Growth-Promoting Antibiotic Use

The results further indicate unanimous agreement regarding the non-therapeutic use of antibiotics. All respondents (100%) strongly agreed that antibiotics should not routinely be used for growth promotion. This finding aligns with global recommendations from the World Health Organization (WHO), World Organization for Animal Health (WOAH), and the Food and Agriculture Organization (FAO) advocating the restriction of antibiotics for therapeutic purposes only.

3.2.12 Disease Prevention and Biosecurity

Knowledge concerning disease prevention strategies was equally outstanding. All respondents (100%) strongly agreed that implementing vaccination programmes, proper nutrition, sanitation, quarantine measures, and biosecurity practices reduces disease occurrence and consequently minimizes antibiotic use. Although the second statement, "Understand that prevention is more effective and economical than routine antibiotic treatment," contains no recorded responses in the dataset, the unanimous agreement on biosecurity practices strongly suggests that respondents appreciate preventive herd health management as a sustainable alternative to excessive antimicrobial use.

3.2.13 Reading Drug Labels

The findings also demonstrate complete knowledge regarding interpretation of veterinary drug labels. All respondents (100%) strongly agreed that they understand information relating to active ingredients, indications, dosage, administration routes, contraindications, storage requirements, expiry dates, and withdrawal periods. Proper interpretation of drug labels is essential for ensuring correct drug use, minimizing medication errors, and enhancing treatment success.

3.2.14 Overall Interpretation of the Findings

Overall, the findings reveal two distinct patterns of knowledge among cattle farmers in Koinadugu District. The first concerns basic scientific knowledge, where respondents demonstrated limited understanding of the fundamental characteristics of antibiotics, their specificity against bacterial infections, differentiation from other veterinary drugs, and recognition of bacterial diseases. Between 58% and 75% of respondents strongly disagreed with statements assessing these foundational concepts, indicating important knowledge deficiencies that could contribute to inappropriate antibiotic use.

Conversely, the second pattern reveals exceptionally high reported knowledge (100% strong agreement) across virtually all practical dimensions of antibiotic stewardship, including veterinary consultation, appropriate antibiotic selection, dosage determination, administration, treatment duration, withdrawal periods, antimicrobial resistance, biosecurity, and interpretation of drug labels. Such uniformly positive responses suggest that farmers may rely heavily on veterinary professionals

for guidance and have internalized recommended practices through extension services and routine interactions rather than through a comprehensive understanding of antimicrobial pharmacology.

From a methodological perspective, this marked contrast between poor conceptual knowledge and perfect practical knowledge warrants careful interpretation. It may reflect social desirability bias, where respondents reported practices perceived as desirable, or indicate that knowledge acquired through practical experience exceeds formal scientific understanding. Future studies should therefore complement self-reported questionnaires with direct observational assessments of antibiotic use practices to validate these findings.

3.2.15 Implications for Antimicrobial Stewardship and Policy

The findings have significant implications for antimicrobial stewardship programmes in Sierra Leone. While veterinary extension services appear to have successfully promoted adherence to recommended antibiotic-use practices, substantial efforts are still required to improve farmers' foundational understanding of antibiotics and bacterial diseases. Educational interventions should focus on distinguishing antibiotics from other veterinary medicines, emphasizing that antibiotics are effective only against bacterial infections, improving recognition of diseases requiring antimicrobial therapy, and strengthening farmers' scientific literacy regarding antimicrobial pharmacology.

Additionally, the apparent reliance on veterinary professionals underscores the need to expand access to qualified veterinary services in rural communities and institutionalize continuous farmer education through regular training programmes. Such interventions would strengthen antimicrobial stewardship, reduce inappropriate antibiotic use, limit the emergence of antimicrobial resistance, improve food safety through compliance with withdrawal periods, and contribute to the implementation of Sierra Leone's National Action Plan on Antimicrobial Resistance within the broader One Health framework.

Overall, the results suggest that while practical compliance with prudent antibiotic-use practices is commendably high among cattle farmers in Koinadugu District, strengthening foundational knowledge remains essential for ensuring informed decision-making and sustaining responsible antimicrobial use in livestock production systems.

3.3. Livestock Farmers' Attitudes Towards the Use of Antibiotics in Cattle in Koinadugu District, Northern Sierra Leone

Table 3.3 presents the attitudes of livestock farmers towards the prudent use of antibiotics in cattle production in Koinadugu District, Northern Sierra Leone. Attitudes were measured using a five-point Likert scale. The analysis demonstrates that cattle farmers generally exhibited positive attitudes towards prudent antibiotic use, although varying degrees of uncertainty and disagreement were observed across some attitude indicators. Overall, the results suggest that respondents recognize the importance of veterinary supervision, disease prevention, responsible antibiotic use, and antimicrobial

resistance (AMR) control. However, certain findings indicate the need for continued awareness creation and behavioural change interventions to strengthen antimicrobial stewardship among livestock farmers.

3.3.1 Attitudes Towards Veterinary Prescription

Respondents were asked whether they believed antibiotics should be used only when prescribed or recommended by a veterinarian. The results show that 123 respondents (65.78%) agreed, while 64 respondents (34.22%) strongly agreed. No respondent expressed disagreement or neutrality. This unanimous positive response demonstrates a strong appreciation for veterinary oversight in antibiotic administration. It suggests that farmers recognise the importance of professional diagnosis and prescription in promoting rational antimicrobial use, reducing inappropriate medication, and minimising the development of antimicrobial resistance.

Table 3.3 Livestock Farmers' Attitudes on the Use of Antibiotics in Cattle in Koinadugu District in Northern Sierra Leone

	Likert Scale (*f* and %); n = 187				
Attitudes Parameters	**1**	**2**	**3**	**4**	**5**
Do you believe antibiotics should only be used when prescribed or recommended by a veterinarian?			123 (65.78)	64 (34.22)	
Do you believe disease can be prevented through good hygiene and vaccination is better than relying on antibiotics?			12 (6.42)	103 (55.08)	72 (38.50)
Do you believe that misuse of antibiotics can contribute to antimicrobial resistance?	18 (9.63)	22 (11.76)	90 (48.13)	57 (30.48)	
Are you willing to pay for veterinary advice before treating sick animals?	25 (13.37)	28	74 (39.57)	60 (32.08)	
Do you believe it is important to complete the full course of antibiotic	30 (16,04)	11 (5.88)	127 (67.91)	19 (10.16)	

treatment, even if the animal appears healthy?					
I believe observing withdrawal periods is essential to protect consumers from antibiotic residues.			187 (100.00)		
I believe that using antibiotics as growth promoters should be avoided.		24 (12.83)	163 (87.17)		
I feel responsible for helping prevent antimicrobial resistance through responsible antibiotic use.		38 (20.32)	149 (79.68)		
I am willing to adopt alternative disease prevention measures to reduce antibiotic use.	14 (7.7)	23 (12.30)	98 (52.41)	52 (27.81)	
I believe keeping treatment records improves antibiotic use on my farm.			180 (96.23)	7 (3.74)	
I am confident that following veterinary instructions leads to better animal health outcomes.		32 (17.11)	155 (82.89)		
Do you believe that unnecessary antibiotic use wastes money and may harm livestock production?		10 (5.35)	170 (90.91)	7 (3.74)	
Are you willing to participate in training programs on prudent antibiotic use?					187 (100)
I believe every livestock farmer has a responsibility to use antibiotics responsibly.			99 (52.94)	70 (37.43)	18 (9.63)

Do you support government regulations that promote responsible antibiotic use in livestock production?		15 (8.02)	48 (25.67)	77	47

1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, 5 = Strongly Agree

3.3.2 Attitudes Towards Disease Prevention

When respondents were asked whether disease prevention through good hygiene and vaccination is preferable to relying on antibiotics, 12 respondents (6.42%) disagreed, 103 respondents (55.08%) were neutral, and 72 respondents (38.50%) agreed. The predominance of neutral responses indicates that although many farmers appreciate preventive animal health measures, a considerable proportion remain uncertain about the relative benefits of preventive management versus antibiotic treatment. This uncertainty may reflect limited knowledge of preventive veterinary medicine and highlights the need for greater emphasis on biosecurity, vaccination, and improved husbandry practices in livestock extension programmes.

3.3.4 Attitudes Towards Antimicrobial Resistance

Regarding whether misuse of antibiotics contributes to antimicrobial resistance, 18 respondents (9.63%) strongly disagreed, 22 (11.76%) disagreed, 90 (48.13%) remained neutral, while 57 respondents (30.48%) agreed. Although approximately one-third of respondents acknowledged the relationship between antibiotic misuse and antimicrobial resistance, nearly half remained undecided, while about one-fifth disagreed. The results indicate that awareness of AMR remains insufficient among many cattle farmers despite growing global concern regarding antimicrobial resistance. This represents a significant knowledge-attitude gap that requires targeted educational interventions.

3.3.5 Willingness to Pay for Veterinary Advice

Farmers' willingness to seek professional veterinary advice before treating sick animals produced mixed responses. Approximately 25 respondents (13.37%) strongly disagreed, 28 respondents (14.97%) disagreed, 74 respondents (39.57%) remained neutral, while 60 respondents (32.08%) agreed.

The results suggest that although nearly one-third of respondents expressed willingness to pay for veterinary services, a substantial proportion remained uncertain or unwilling. Financial constraints, limited access to veterinary professionals, and reliance on traditional livestock management practices may influence these attitudes. Improving affordability and accessibility of veterinary services could therefore encourage greater utilization of professional animal healthcare.

3.3.6 Attitudes Towards Completing Antibiotic Treatment

Respondents were asked whether it is important to complete the full course of antibiotic treatment even when animals appear healthy. The results indicate that 30 respondents (16.04%) strongly disagreed, 11 (5.88%) disagreed, 127 (67.91%) remained neutral, while 19 respondents (10.16%) agreed. The predominance of neutral responses suggests uncertainty regarding treatment adherence. Since premature discontinuation of antibiotic therapy contributes significantly to antimicrobial resistance development, the results indicate that many farmers may not fully appreciate the importance of completing prescribed treatment regimens.

3.3.7 Attitudes Towards Withdrawal Periods

An overwhelmingly positive attitude was observed regarding withdrawal periods. All 187 respondents (100%) agreed that observing withdrawal periods is essential for protecting consumers from antibiotic residues in meat and milk. This finding demonstrates strong awareness of food safety concerns and indicates that livestock farmers recognize the importance of protecting public health through responsible antibiotic use.

3.3.8 Attitudes Towards Growth Promotion

Regarding the use of antibiotics as growth promoters, 24 respondents (12.83%) were neutral, while 163 respondents (87.17%) agreed that antibiotics should not be routinely used for growth promotion. The high level of agreement reflects increasing acceptance of international recommendations advocating the restriction of antibiotics for therapeutic purposes only. This represents a favourable attitude towards antimicrobial stewardship within livestock production.

3.3.9 Personal Responsibility for Preventing Antimicrobial Resistance

The study further assessed respondents' sense of responsibility in combating antimicrobial resistance. Approximately 38 respondents (20.32%) were neutral, while 149 respondents (79.68%) agreed that they have a personal responsibility to prevent antimicrobial resistance through responsible antibiotic use. This result suggests that most cattle farmers acknowledge their individual role in safeguarding antibiotic effectiveness and protecting both animal and human health.

3.3.10 Willingness to Adopt Alternative Disease Prevention Measures

When asked about willingness to adopt alternative disease prevention measures to reduce antibiotic use, 14 respondents (7.49%) strongly disagreed, 23 (12.30%) disagreed, 98 (52.41%) remained neutral, while 52 respondents (27.81%) agreed. Although approximately one-quarter expressed positive attitudes, the majority remained uncertain. This result indicates that adoption of preventive management practices such as improved nutrition, vaccination, sanitation, and biosecurity may still be limited, emphasizing the need for intensified extension education.

3.3.11 Attitudes Towards Treatment Record Keeping

Respondents demonstrated highly positive attitudes towards maintaining treatment records.

Approximately 180 respondents (96.23%) agreed, while 7 respondents (3.74%) strongly agreed that maintaining treatment records improves antibiotic use on their farms. Proper record-keeping facilitates monitoring of drug administration, evaluation of treatment outcomes, compliance with withdrawal periods, and improved herd health management. This finding represents one of the strongest positive attitudes identified in the study.

3.3.12 Confidence in Veterinary Instructions

Similarly, 32 respondents (17.11%) were neutral, while 155 respondents (82.89%) agreed that following veterinary instructions leads to better animal health outcomes. This result indicates high confidence in veterinary expertise and suggests that fa2rmers generally value professional guidance during disease management.

3.3.13 Economic Attitudes Towards Antibiotic Use

The findings indicate widespread recognition of the economic consequences of inappropriate antibiotic use. Approximately 10 respondents (5.35%) were neutral, 170 respondents (90.91%) agreed, while 7 respondents (3.74%) strongly agreed that unnecessary antibiotic use wastes money and may adversely affect livestock production. This demonstrates that farmers appreciate both the economic and animal health implications associated with irrational antibiotic use.

3.3.14 Willingness to Participate in Training Programmes

An exceptionally encouraging finding emerged regarding farmers' willingness to improve their knowledge. All 187 respondents (100%) strongly agreed that they are willing to participate in training programmes on prudent antibiotic use. This finding suggests considerable opportunities for strengthening antimicrobial stewardship through farmer education, veterinary extension services, and continuous capacity-building initiatives.

3.3.15 Collective Responsibility

When respondents were asked whether every livestock farmer has a responsibility to use antibiotics responsibly, 99 respondents (52.94%) agreed, 70 (37.43%) strongly agreed, and 18 respondents (9.63%) were neutral. Overall, more than 90% expressed positive attitudes towards collective responsibility, demonstrating strong recognition that prudent antibiotic use requires collaboration among all livestock producers.

3.3.16 Support for Government Regulations

Support for government regulations promoting responsible antibiotic use was generally favourable. Approximately 15 respondents (8.02%) were neutral, 48 respondents (25.67%) agreed, 77

respondents (41.18%) strongly agreed, while 47 respondents (25.13%) selected the highest level of agreement (based on the reported frequencies).

Overall, approximately 66.3% of respondents expressed positive support for government regulation, indicating broad acceptance of policies designed to strengthen antimicrobial stewardship in livestock production. This support provides a favorable policy environment for implementing national antimicrobial resistance control programmes.

Overall, the attitude assessment indicates that cattle farmers in Koinadugu District generally hold favourable attitudes towards prudent antibiotic use, although the strength of these attitudes varies across different aspects of antimicrobial stewardship. The strongest positive attitudes were observed regarding veterinary prescribing, adherence to withdrawal periods, avoidance of antibiotic growth promoters, treatment record-keeping, participation in training programmes, and confidence in veterinary guidance. The results suggest that farmers appreciate the importance of professional veterinary involvement, food safety, and responsible antimicrobial use.

Conversely, relatively high proportions of neutral responses were recorded for disease prevention through hygiene and vaccination (55.08%), understanding of antimicrobial resistance (48.13%), willingness to pay for veterinary services (39.57%), completion of antibiotic treatment (67.91%), and adoption of alternative disease prevention measures (52.41%). These neutral responses suggest uncertainty rather than outright disagreement and indicate areas where farmers may lack confidence or adequate information.

The findings therefore reveal that while farmers demonstrate positive behavioural intentions towards responsible antibiotic use, additional educational interventions are required to strengthen attitudes towards preventive animal healthcare, treatment adherence, and the broader implications of antimicrobial resistance.

3.3.17 Implications for Antimicrobial Stewardship and Policy:

The results have important implications for livestock health management and antimicrobial stewardship in Sierra Leone. The generally positive attitudes observed among respondents provide a solid foundation for implementing interventions aimed at promoting prudent antibiotic use. However, the substantial proportion of neutral responses across several key indicators highlights the need for sustained behavioral change communication and targeted educational programmes.

Veterinary extension services should focus on improving farmers' understanding of antimicrobial resistance, reinforcing the importance of completing prescribed antibiotic treatments, promoting preventive livestock management through vaccination and biosecurity, and demonstrating the economic benefits of investing in professional veterinary services. Additionally, farmers' overwhelming willingness to participate in training programmes presents an excellent opportunity for

government agencies, veterinary authorities, universities, and development partners to expand antimicrobial stewardship education.

Strengthening these educational initiatives within Sierra Leone's National Action Plan on Antimicrobial Resistance and the One Health framework will contribute to improved livestock productivity, enhanced food safety, reduced antimicrobial resistance, and sustainable livestock production systems. Collectively, the results indicate that while cattle farmers in Koinadugu District exhibit predominantly positive attitudes towards responsible antibiotic use, continued education and policy support are necessary to transform favorable attitudes into consistently appropriate antibiotic-use behaviors.

3.4.0 Best Practices Adopted by Livestock Farmers in the Use of Antibiotics in Cattle in Koinadugu District, Northern Sierra Leone

Table 3.4 presents the findings on the best practices adopted by livestock farmers regarding the prudent use of antibiotics in cattle production in Koinadugu District, Northern Sierra Leone. The practices were assessed using a five-point Likert scale. The findings reveal varying levels of compliance with internationally recommended antimicrobial stewardship practices. While respondents demonstrated commendable adherence to some practices, substantial deficiencies were observed in others, suggesting inconsistencies between farmers' knowledge, attitudes, and actual practices. These findings underscore the need for strengthened veterinary extension services, continuous farmer education, and improved regulatory oversight to promote rational antibiotic use and mitigate antimicrobial resistance (AMR).

3.4.1 Consultation with Veterinarians Before Antibiotic Administration

The first indicator examined whether farmers consult veterinarians before administering antibiotics to livestock. The results show that 19 respondents (10.16%) never, 27 (14.44%) rarely, 96 (51.34%) sometimes, and 45 respondents (24.06%) often consult veterinarians before administering antibiotics. Notably, none of the respondents selected "Always."

This distribution suggests that veterinary consultation is inconsistent among cattle farmers. Although approximately one-quarter frequently seek professional advice, more than half consult veterinarians only occasionally, while approximately one-quarter rarely or never do so. This finding raises concern because inadequate veterinary supervision increases the likelihood of inappropriate antibiotic selection, incorrect diagnosis, and irrational antimicrobial use.

3.4.2 Use of Antibiotics Only Under Professional Recommendation

When respondents were asked whether they use antibiotics only when prescribed or recommended by qualified animal health professionals, 55 respondents (29.41%) reported "Never," 30 (16.04%) "Rarely," 62 (33.16%) "Sometimes," and 40 respondents (21.39%) "Often." Again, no respondents

selected "Always." The results suggest that although some farmers rely on veterinary recommendations, many continue to administer antibiotics independently. Nearly half reported rarely or never following professional prescriptions, indicating a substantial risk of inappropriate antimicrobial use and self-medication practices.

3.4.3 Compliance with Recommended Dosage and Treatment Duration

Adherence to prescribed dosage and treatment duration is fundamental to successful antimicrobial therapy. The findings indicate that 138 respondents (73.80%) never, while 49 respondents (26.20%) rarely, follow the recommended dosage and treatment duration. No respondents selected the categories Sometimes, Often, or Always. This represents one of the most alarming findings of the study. Failure to administer correct dosages and complete treatment regimens substantially increases treatment failure, encourages bacterial survival, and accelerates the emergence of antimicrobial resistance.

3.4.4 Completion of the Full Course of Treatment

All 187 respondents (100%) indicated "Never" completing the full course of antibiotic treatment once animals appear clinically recovered. This finding is particularly concerning because premature discontinuation of antimicrobial therapy is among the leading contributors to antimicrobial resistance worldwide. It suggests that treatment is frequently discontinued based on visible clinical improvement rather than veterinary recommendations. This practice significantly undermines treatment effectiveness and promotes the survival of resistant bacterial populations. 4.3.38 Observance of Withdrawal Periods

The study further assessed compliance with withdrawal periods before marketing or consuming animal products. Approximately 144 respondents (77.00%) never, 32 respondents (17.11%) rarely, while only 11 respondents (5.88%) sometimes observed recommended withdrawal periods. No respondent reported observing withdrawal periods often or always. These findings present serious public health concerns because failure to observe withdrawal periods allows antibiotic residues to remain in meat and milk destined for human consumption. Such residues contribute to antimicrobial resistance, allergic reactions, and food safety risks.

3.4.5. Reading Antibiotic Labels

All 187 respondents (100%) reported never reading or following instructions on antibiotic labels before use. This finding indicates extremely poor compliance with one of the most basic principles of responsible medicine use. Failure to read product labels increases the likelihood of incorrect dosage, inappropriate administration routes, improper storage, and non-compliance with withdrawal periods.

3.4.6. Record Keeping

Similarly, all respondents (100%) reported never keeping records of antibiotic treatments administered to livestock. Poor record keeping compromises treatment monitoring, disease surveillance, antimicrobial stewardship, traceability, and regulatory compliance. Without treatment records, farmers cannot effectively evaluate treatment outcomes or monitor recurring disease patterns.

3.4.7 Storage of Antibiotics

The results indicate that 100% of respondents never store antibiotics according to manufacturers' recommendations. Improper storage conditions may reduce antibiotic potency, compromise drug quality, and increase therapeutic failure. This finding highlights another critical area requiring farmer education.

3.4.8 Checking Expiry Dates

When asked whether they check expiry dates before using antibiotics, 99 respondents (52.94%) rarely did so, while 88 respondents (47.06%) sometimes checked expiry dates. No respondents reported checking expiry dates frequently or consistently. This suggests that expired veterinary medicines may still be used within livestock production, thereby reducing treatment effectiveness and increasing the likelihood of resistance development.

3.4.9 Safe Disposal of Expired Antibiotics

All respondents (100%) reported never disposing of expired or unused antibiotics safely.

Improper disposal allows antimicrobial compounds to contaminate soil and water environments, thereby contributing to environmental antimicrobial resistance. This finding reflects poor environmental stewardship practices.

3.4.10 Isolation of Sick Animals

Disease containment practices were comparatively encouraging. Approximately 48 respondents (25.67%) often, while 139 respondents (74.33%) always, isolate sick animals to prevent disease transmission. This represents one of the strongest positive findings in the study and demonstrates widespread appreciation of biosecurity measures.

3.4.11 Vaccination Practices

Regarding vaccination, 180 respondents (96.26%) never vaccinate livestock according to recommended schedules, while only 7 respondents (3.74%) sometimes vaccinate. The absence of routine vaccination suggests heavy reliance on therapeutic interventions rather than preventive animal health management. Limited vaccination coverage may increase disease incidence and consequently increase antibiotic consumption.

3.4.12 Farm Hygiene and Biosecurity

Maintenance of farm hygiene also demonstrated mixed results. Approximately 19 respondents (10.16%) never, 86 (45.99%) rarely, 42 (22.46%) sometimes, while 40 respondents (21.39%) often maintain good farm hygiene and biosecurity. No respondents selected Always. The results indicate that biosecurity implementation remains inconsistent and may contribute to increased disease transmission within herds.

3.4.13 Avoidance of Antibiotics for Growth Promotion

Concerning routine antibiotic use for growth promotion, 56 respondents (29.95%) rarely, 41 respondents (21.92%) sometimes, while 90 respondents (48.13%) often avoid this practice.

Although nearly half frequently avoid non-therapeutic antibiotic use, many farmers continue to demonstrate inconsistent compliance with international antimicrobial stewardship recommendations.

3.4.14 Laboratory Diagnosis Before Antibiotic Selection

All respondents (100%) reported never seeking laboratory diagnosis before selecting antibiotics during disease outbreaks. This finding suggests complete reliance on empirical treatment without bacteriological confirmation. Such practices frequently result in inappropriate antibiotic selection and contribute to antimicrobial resistance.

3.4.15. Correct Route of Administration

Knowledge regarding administration routes translated into relatively good practice. Approximately 10 respondents (5.35%) rarely, 90 respondents (48.13%) sometimes, while 87 respondents (46.52%) often administer antibiotics using the correct route. Although encouraging, The results indicate that correct administration practices remain inconsistent among some farmers.

3. 4.16 Avoiding Sharing Antibiotics

All respondents (100%) reported often avoiding sharing or borrowing antibiotics from other farmers. This represents good antimicrobial stewardship because sharing medicines encourages inappropriate treatment and increases disease transmission risks.

3.4.17 Avoiding Leftover Antibiotics

Similarly, all respondents selected Always (100%) for avoiding the use of leftover antibiotics unless advised by veterinarians. This finding demonstrates excellent adherence to recommended treatment practices and reduces inappropriate antimicrobial exposure.

3.4.18 Monitoring Treatment Outcomes

Conversely, all respondents (100%) reported never monitoring treated animals or reporting treatment failures to veterinarians. This finding limits opportunities for early detection of antimicrobial resistance and compromises disease surveillance systems.

3.4.17 Participation in Training

Finally, all respondents (100%) indicated rarely participating in training or extension program on responsible antibiotic use. This finding suggests inadequate access to continuous professional education and may partly explain the poor compliance observed across several antibiotic-use practices.

Overall, the findings reveal a mixed pattern of antibiotic-use practices among cattle farmers in Koinadugu District. Positive practices were observed in the isolation of sick animals, avoidance of antibiotic sharing, avoidance of leftover antibiotics, and correct administration routes. The results indicate that some aspects of biosecurity and antimicrobial stewardship have been successfully adopted. However, several critical deficiencies were identified, including failure to consult veterinarians consistently, poor adherence to prescribed dosages and treatment duration, premature discontinuation of treatment, failure to observe withdrawal periods, inadequate record keeping, improper storage and disposal of antibiotics, poor vaccination coverage, limited biosecurity implementation, absence of laboratory diagnosis, and limited participation in extension programmes.

A notable observation is the apparent inconsistency between the respondents' knowledge, attitudes, and reported practices. While earlier analyses indicated generally favourable knowledge and attitudes towards prudent antibiotic use, the present findings suggest that these positive perceptions are not consistently translated into actual farm-level practices. This discrepancy reflects the well-documented Knowledge–Attitude–Practice (KAP) gap, where awareness and favourable attitudes do not necessarily result in behavioural change due to constraints such as limited veterinary access, financial barriers, inadequate extension services, traditional husbandry practices, and weak regulatory enforcement.

3.4.18 Implications for Policy and Practice

The findings have important implications for antimicrobial stewardship and livestock health policy in Sierra Leone. The widespread deficiencies observed in antibiotic-use practices highlight the urgent need to strengthen veterinary extension services, improve access to affordable veterinary care, and intensify farmer education on prudent antimicrobial use. Regular training programmes should emphasize correct dosage calculation, completion of treatment regimens, observance of withdrawal periods, appropriate record keeping, safe disposal of veterinary medicines, vaccination, and biosecurity measures.

Additionally, government regulatory agencies should strengthen surveillance of veterinary antimicrobial use, promote routine laboratory diagnosis through improved veterinary diagnostic infrastructure, and encourage farm-level monitoring systems. Integrating these interventions into Sierra Leone's National Action Plan on Antimicrobial Resistance under the One Health framework

would contribute significantly to reducing inappropriate antibiotic use, safeguarding animal productivity, ensuring food safety, and slowing the emergence and spread of antimicrobial-resistant pathogens.

Overall, the results indicate that although some prudent antibiotic-use practices have been adopted by cattle farmers in Koinadugu District, substantial improvements are required to achieve comprehensive compliance with internationally accepted antimicrobial stewardship principles and sustainable livestock production practices.

Table 3.4 Livestock Farmers Best Practices Adopted in the use of Antibiotics in Cattle in Koinadugu District in Northern Sierra Leone

	Likert scale (f and %). n =187				
Best Practice Parameters	**1**	**2**	**3**	**4**	**5**
I consult a veterinarian before administering antibiotics to my livestock.	19 (10.16)	27 (14.44)	96 (51.34)	45 (24.06)	
I use antibiotics only when they are prescribed or recommended by a qualified animal health professional.	55 (29.41)	30 (16.04)	62 (33.16)	40 (21.39)	
I follow the recommended dosage and treatment duration when administering antibiotics.	138 (73.80)	49 (26.20)			
I complete the full course of antibiotic treatment even when animals appear to have recovered.	187 (100,00)				
I observe the recommended withdrawal period before selling or consuming meat, milk, or eggs from treated animals.	144 (77.00)	32 (17.11)	11 (5.88)		
I read and follow the instructions on antibiotic labels before use.	187 (100.00)				
I keep records of all antibiotic treatments administered to my	187 (100.00)				

livestock.					
I store antibiotics according to the manufacturer's recommendations.	187 (100.00)				
I check the expiry date before using any antibiotic.		99 (52.94)	88 (47.06)		
I dispose of expired or unused antibiotics safely.	187 (100.00)				
I isolate sick animals to prevent the spread of infectious diseases.			48 (25.67)	139 (74.33)	
I vaccinate my livestock according to recommended schedules to reduce disease occurrence.	180 (96.26)		7 (3.74)		
I maintain good farm hygiene and biosecurity to minimize the need for antibiotics.	19 (10.16)	86 (45.99)	42 (22.46)	40 (21.39)	
I avoid using antibiotics for growth promotion or routine disease prevention unless specifically recommended by a veterinarian and permitted by national regulations.	56 (29.95)	41 (21.92)	90 (48.13)		
I seek laboratory testing or veterinary diagnosis when disease outbreaks occur before selecting an antibiotic.	187 (100.00)				
I use the correct route of administration (e.g., oral or injectable) as instructed.		10 (5.35)	90 (48.13)	87 (46.52)	
I avoid sharing or borrowing antibiotics from other farmers.				187 (100.00)	
I avoid using leftover antibiotics from previous treatments unless advised by a veterinarian.					187 (10.00)

I monitor treated animals and report treatment failures to a veterinarian.	187 (100.00)				
I regularly participate in training or extension programs on responsible antibiotic use.		187 (100.00)			

1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, 5 = Always

DISCUSSION

4.1 Overview of the Findings

The present study provides important evidence on the socio-demographic, knowledge, attitudinal and behavioral determinants of antimicrobial use among cattle farmers operating predominantly under extensive production systems in Northern Sierra Leone. The findings are particularly relevant because antimicrobial resistance (AMR) in livestock is not determined solely by microbiological factors; it is also shaped by farmer knowledge, access to veterinary services, medicine availability, disease-management practices, economic constraints, preventive animal-health systems and the regulatory environment. The demographic variables examined in this study—sex, age, educational attainment, occupation, farming experience and farm size—therefore provide an essential epidemiological context for interpreting antimicrobial-use behaviors and potential AMR selection pressure.

Farmers demonstrated weak foundational understanding of antibiotics and bacterial diseases, while simultaneously reporting exceptionally high knowledge of several practical stewardship principles. Their actual reported practices, however, demonstrated substantial deficiencies, including inconsistent veterinary consultation, poor adherence to recommended dosages and treatment duration, premature treatment discontinuation, poor compliance with withdrawal periods, absence of treatment records, inappropriate antibiotic storage and disposal, inadequate vaccination, weak biosecurity and complete absence of laboratory diagnosis before antimicrobial selection.

This pattern is consistent with emerging evidence from livestock systems elsewhere in sub-Saharan Africa. A 2025 systematic review concluded that interventions to improve antimicrobial stewardship in African livestock remain limited and that financial constraints, implementation barriers, self-reported practices and sustainability challenges continue to undermine AMR-control efforts. More recent 2026 studies in Zambia, Tanzania and Uganda continue to document important deficiencies in antimicrobial knowledge and stewardship among livestock keepers, demonstrating that the challenges identified in Sierra Leone remain highly contemporary.

4.2 Sex distribution and implications for antimicrobial stewardship

Cattle farming in Koinadugu District was strongly male dominated, with 152 of the 187 respondents (81.28%) being male and only 18.72% female. Male dominance was evident across all sampled chiefdoms. This distribution reflects the socio-cultural organization of cattle production in many African pastoral and agro-pastoral systems, where men frequently control herd ownership, grazing decisions, livestock sales and animal-health expenditure.

The result has important implications for antimicrobial stewardship because the individuals controlling animal-health decisions are also likely to determine when antimicrobials are purchased, what product is selected and whether professional veterinary services are sought. Caudell et al. examined livestock systems in five African countries and showed that antimicrobial-related KAP varied according to livelihood and socio-demographic characteristics, including gender, source of animal-health information and disease experience. Importantly, people living and working directly on farms commonly made treatment decisions themselves, frequently with limited professional veterinary input.

However, AMR interventions should not consequently be directed exclusively at men. Women may participate substantially in milking, food preparation, animal feeding and caring for sick animals and may therefore experience exposure to antimicrobial residues or resistant organisms even when they do not control medicine purchasing. A gender-responsive approach should consequently recognize both decision-making authority and exposure pathways.

4.3 Age, farming experience and traditional treatment knowledge

The study population was dominated by mature and experienced farmers, with older age categories constituting a substantial proportion of respondents. The study further reported extensive livestock-management experience in Koinadugu District.

Experience can function in two opposing ways. On the positive side, long-term cattle keepers often develop extensive knowledge of animal behavior, locally important diseases, seasonal disease patterns and herd management. This experiential knowledge can improve early disease recognition and enable rapid responses to illness. Conversely, repeated reliance on historically successful treatment practices can reinforce empirical antimicrobial selection, particularly when access to diagnostic services and continuing veterinary education is limited.

The distinction is important because experience should not automatically be interpreted as equivalent to antimicrobial competence. Tufa et al. (2023) demonstrated that livestock producers' KAP outcomes in Ethiopia varied in complex ways with education, livestock disease experience and animal ownership. Higher disease exposure increased familiarity with medicines but did not necessarily result in more prudent antimicrobial behavior. Similarly, the 2024 Addis Ababa dairy-farmer study

found significant relationships between farming experience, knowledge and risk perception, demonstrating that experience affects antimicrobial decision-making but does not guarantee stewardship-compliant practice.

For Northern Sierra Leone, this suggests that interventions should not replace farmers' indigenous knowledge but should integrate it with contemporary veterinary principles, antimicrobial stewardship and disease diagnostics.

4.4 Educational attainment and antimicrobial literacy

One of the most important demographic findings was the very low level of formal education among cattle farmers. The study reports that the overwhelming majority of respondents in Koinadugu had no formal education.

Low formal educational attainment is relevant to AMR because modern veterinary pharmaceutical use requires farmers to interpret drug names, concentrations, indications, withdrawal periods, storage instructions and expiry dates. Limited literacy may therefore constrain safe antimicrobial use even when farmers possess substantial livestock experience.

Empirical studies provide strong support for this interpretation. Among dairy farmers in Addis Ababa, Kallu et al. found significant associations between educational attainment and antimicrobial knowledge and practices; respondents with greater educational exposure generally demonstrated stronger understanding of AMU and AMR. Similarly, a study of livestock producers in northeastern Ethiopia found that 55.9% were unaware of rational antimicrobial use and AMR prevention, while education influenced relevant KAP dimensions. Another Ethiopian study reported that participants with higher education demonstrated better knowledge, attitudes and practices towards antibiotic use and resistance.

More recent 2026 evidence from Zambia is particularly relevant. Among smallholder dairy farmers, considerable deficiencies remained in overall KAP despite relatively high awareness of antibiotics and resistance, demonstrating that simply having heard of AMR does not guarantee detailed understanding or responsible practice.

The implication for Sierra Leone is that farmer education should not depend primarily on text-heavy manuals. Pictorial dosing instructions, colour-coded withdrawal information, practical demonstrations, community radio and locally spoken languages are likely to be more appropriate.

4.5 Dominance of smallholder cattle systems

Smallholder farming dominated the study population. Small farms accounted for 78.61% of holdings in Koinadugu District.

This finding has important structural implications. Smallholder production itself does not cause AMR. However, small farms in low-resource settings may experience reduced access to veterinarians,

diagnostic laboratories, quality-assured medicines, vaccination and biosecurity infrastructure. These constraints can make self-treatment or empirical antimicrobial use economically attractive.

Gemeda et al. (2020), studying extensive smallholder livestock systems in Ethiopia, found widespread antimicrobial use alongside poor regulatory enforcement, easy access to veterinary medicines and limited supervision by qualified veterinarians. Tetracyclines, aminoglycosides and trimethoprim-sulfonamides were among the commonly used antibiotic classes.

Similarly, Caudell et al. demonstrated across five African livestock systems that antimicrobial decisions were often made at household or farm level and medicines were commonly acquired from agro-veterinary shops with limited professional supervision.

The Sierra Leone findings therefore fit a broader regional epidemiological pattern in which structural limitations of smallholder animal-health systems may encourage antimicrobial self-management.

4.6 Poor fundamental understanding of antibiotics

The findings concerning basic antibiotic knowledge are particularly important. Nearly 70% of respondents expressed disagreement when asked whether they understood what antibiotics are. Furthermore, 53.48% strongly disagreed that antibiotics are effective specifically against bacterial infections, while 74.87% strongly disagreed that they could differentiate antibiotics from other veterinary medicines.

These findings suggest a significant deficiency in antimicrobial literacy.

Farmers who cannot distinguish antibiotics from anthelmintics, antiprotozoals, vaccines, analgesics or vitamins may have difficulty deciding when antibacterial treatment is justified. The problem is especially important in cattle systems where trypanosomiasis, helminthiasis and tick-borne diseases occur alongside bacterial infections.

The findings closely resemble Tufa *et al.* (2023), who reported that only 7% of Ethiopian livestock producers demonstrated adequate understanding of antibiotics or antimicrobials and that approximately 94% had poor overall knowledge concerning AMU, residues and AMR.

Obolensky *et al.* (2025) provided similarly relevant evidence from rural Kenya. Their study demonstrated confusion between antibiotics and anthelmintics, inconsistent dosing and reliance on previous experience or agro-veterinary outlets where formal veterinary guidance was limited.

The consistency between these findings suggests that poor differentiation of veterinary drug classes is a continuing stewardship problem across African smallholder livestock systems.

4.7 Disease recognition and unnecessary antimicrobial exposure

More than half of respondents strongly disagreed that they could recognise signs of bacterial disease requiring veterinary attention, while 58.82% strongly disagreed that not every sick animal requires antibiotic treatment.

This is epidemiologically important because most clinical signs are not pathogen-specific. Fever, diarrhoea, anorexia, weakness and reduced production may be associated with bacterial, viral, parasitic, nutritional or metabolic disorders.

Poor disease differentiation increases the probability that antibiotics will be administered against conditions for which they provide no therapeutic benefit.

This concern is reinforced by the finding that all respondents reportedly never sought laboratory diagnosis before antibiotic selection during disease outbreaks.

Sierra Leone's own surveillance evidence supports the importance of this problem. *Bangura et al.* (2022) reported that approximately one-quarter of sick livestock received antimicrobial treatment and documented use of several important antimicrobial classes, including tetracyclines, macrolides, beta-lactams, aminoglycosides and quinolones. A follow-up operational study in 2023 found that the proportion of sick animals receiving antibiotics remained approximately 25% and that strengthening laboratory infrastructure for confirmation of animal diseases had not yet been fully implemented.

Thus, inadequate diagnostic access is not simply an individual farmer problem; it reflects a wider systems constraint.

4.8 The major knowledge–practice contradiction

Perhaps the most scientifically important finding is the discrepancy between farmers' reported knowledge and actual behavior.

All respondents reportedly strongly agreed that they understood correct dosage, administration, treatment duration, withdrawal periods, AMR, preventive measures and drug-label interpretation. Yet actual reported practices revealed almost the reverse picture.

For example, 73.80% never followed recommended dosage and treatment duration, all respondents reportedly stopped treatment when animals appeared clinically recovered, and 77% never observed withdrawal periods. This represents a substantial KAP gap. Recent evidence strongly supports the interpretation that knowledge does not automatically translate into behavior. *Tufa et al.* (2023) found poor knowledge among 94% and unfavorable attitudes among 97% of livestock producers, yet approximately 80% obtained relatively favorable behavioral scores. Their regression analysis also produced the counter-intuitive finding that better knowledge did not necessarily predict better behavior.

Likewise, a 2026 Ethiopian One Health mixed-methods study reported a consistent gap between knowledge, attitudes and actual AMR-related practices. The investigators concluded that service access, antimicrobial availability, diagnostic capacity, regulatory enforcement and household constraints influence behavior in addition to factual understanding.

This provides a strong empirical basis for arguing that the Sierra Leone findings reflect not merely ignorance, but structurally constrained behavior.

4.9 Veterinary consultation and professional oversight

Only 24.06% of respondents often consulted veterinarians before antibiotic administration, while 51.34% did so only sometimes and approximately one-quarter rarely or never sought professional advice. Furthermore, 29.41% never and 16.04% rarely restricted antimicrobial use to professional recommendation.

The findings are consistent with research elsewhere in Africa. Caudell et al. found that reliance on formal animal-health professionals was uncommon in several African livestock systems, while farmers frequently used personal experience, family, neighbours and agro-veterinary retailers to make treatment decisions.

Kallu et al. reported that approximately two-thirds of dairy farmers surveyed in Addis Ababa obtained antibiotics from private pharmacies without prior veterinarian or animal-health professional approval. Obolensky et al. (2025) similarly found considerable reliance on agro-veterinary outlets and prior treatment experience among livestock keepers in rural Kenya.

The most recent 2026 Tanzanian study examining cattle keepers, animal-health practitioners and veterinary drug retailers continues to identify stewardship challenges spanning multiple actors in the veterinary medicine supply chain.

The implication is that stewardship interventions cannot focus exclusively on farmers. Veterinary retailers, para-veterinarians and community animal-health workers must also be incorporated into AMR programmes.

4.10 Financial barriers to veterinary consultation

Only 32.08% of respondents agreed that they were willing to pay for veterinary advice, while 39.57% were neutral and approximately 28% disagreed or strongly disagreed.

This finding provides evidence that antimicrobial behavior may be economically mediated.

For a subsistence-oriented cattle farmer, professional consultation, transport and diagnostics may represent additional expenditure beyond the cost of the medicine itself. Farmers may therefore consider self-treatment economically preferable.

Tufa et al. reported substantial gaps between farmers' expressed belief in professional consultation and their actual ability to obtain animal-health services. The 2025 systematic review of livestock AMR interventions in sub-Saharan Africa similarly identified finance as an important barrier to adoption and sustainability of stewardship interventions.

Consequently, recommendations to “consult a veterinarian” should be paired with investments in accessible and affordable animal-health services.

4.11 Poor dosage and treatment-duration practices

The reported treatment-adherence pattern is one of the most concerning findings. Approximately 73.80% never followed recommended dosage and treatment duration, while the remaining 26.20% rarely complied. No respondent reported frequent adherence.

From a pharmacological perspective, inappropriate dosing can result in failure to achieve effective drug exposure. However, the relationship between duration and AMR should be interpreted carefully. It is scientifically inaccurate to imply that longer antibiotic treatment is invariably preferable. Both unnecessarily prolonged treatment and inappropriate premature cessation may increase antimicrobial exposure or compromise treatment outcomes depending on the infection and drug involved.

The key stewardship principle is therefore adherence to an appropriately prescribed dose and duration. Recent Kenyan evidence similarly reported inconsistency in livestock antibiotic dosing and treatment decisions based partly on previous experience. The 2026 Zambian study likewise identifies incorrect antimicrobial dosages and durations among important misuse behaviors relevant to AMR development.

4.12 Withdrawal-period non-compliance

Approximately 77.0% of respondents never observed withdrawal periods, 17.11% rarely complied and only 5.88% sometimes observed the recommended interval.

This represents an important food-safety problem because withdrawal periods are designed to ensure veterinary drug residues fall below regulatory limits before animal products enter the food chain.

Caudell et al. reported limited observance of withdrawal periods across African livestock systems, with animal products sometimes consumed or marketed while animals were still receiving antimicrobial treatment. Tufa et al. also found extremely poor awareness of withdrawal periods and drug residues among Ethiopian livestock keepers; only 17% were aware of withdrawal periods and only 5% knew about veterinary drug residues.

These comparisons demonstrate that withdrawal-period non-compliance remains a widespread challenge across low-resource livestock systems.

The concern is particularly relevant in Sierra Leone because national surveillance indicates substantial livestock use of critically important veterinary antimicrobials. In 2021, 77% of treated animals received agents classified as veterinary critically important, while 60% received antimicrobials considered highly important for human medicine.

5.13 Drug-label interpretation versus actual label use

A particularly striking contradiction occurs between reported knowledge and practice regarding veterinary drug labels. All respondents claimed knowledge of how to interpret active ingredients,

indications, dosage, storage requirements and withdrawal periods. Yet all respondents subsequently reported never reading or following antibiotic labels before use.

This discrepancy strongly suggests that self-reported knowledge should not be interpreted as objective technical competency.

It may reflect social-desirability bias, misunderstanding of Likert-scale questions or the difference between hearing information verbally and independently interpreting written pharmaceutical instructions.

5.14 Absence of treatment records

All respondents reported never maintaining records of antibiotic treatments. Remarkably, 96.23% nevertheless agreed that record keeping improves antimicrobial use.

This provides another strong demonstration of the knowledge–practice gap.

Treatment records are necessary for documenting medicines administered, dosage, dates, withdrawal periods and treatment outcomes. Without them, repeated treatment, treatment failure and antimicrobial consumption cannot easily be assessed.

The problem also affects surveillance. Sierra Leone's national animal-health surveillance has improved substantially, with district reporting increasing to approximately 88%, but farm-level antimicrobial records remain essential for complete antimicrobial-use estimates.

4.15 Antibiotic storage and expiry-date practices

All respondents reportedly failed to store antibiotics according to manufacturers' recommendations. Approximately 52.94% rarely checked expiry dates and 47.06% only sometimes did so.

This has potential implications for drug effectiveness. Temperature, humidity and sunlight can affect the stability of some veterinary pharmaceutical products. Use of damaged or expired products may result in reduced efficacy.

An important analytical distinction follows: treatment failure cannot automatically be interpreted as antimicrobial resistance. Failure may result from resistance, but may also arise from incorrect diagnosis, inappropriate drug selection, inadequate dosing, poor adherence or compromised medicine quality.

This distinction is particularly important for laboratory-based AMR studies and should be emphasized during thesis defence.

4.16 Unsafe disposal and environmental AMR

Every respondent reported never disposing of unused or expired antibiotics safely.

This introduces an important environmental component. Antimicrobial residues entering soil, water or waste streams may expose environmental microorganisms to selective pressure. In free-ranging

livestock systems, environmental exposure pathways are potentially extensive because cattle interact with communal grazing areas, water sources and agricultural land.

The 2025 sub-Saharan African systematic review reinforces the need for One Health-oriented livestock AMR interventions rather than focusing exclusively on clinical treatment.

However, the thesis should avoid stating that improper disposal directly caused resistant bacteria unless environmental samples were analyzed. The evidence establishes a plausible AMR risk pathway, not direct causation.

4.17 Vaccination and preventive herd-health management

Vaccination was one of the weakest preventive-health practices: 96.26% of farmers never vaccinated cattle according to recommended schedules. Farm hygiene was also inconsistent, with 45.99% rarely implementing adequate hygiene and biosecurity.

Conversely, isolation of sick animals was one of the strongest practices, with 74.33% always separating affected animals.

This suggests that farmers may be more likely to implement preventive measures requiring limited financial investment, such as separation of sick animals, than interventions requiring vaccines, professional services or additional inputs.

The finding is important for stewardship because preventing infectious disease reduces demand for antimicrobial therapy. The solution to livestock AMR is therefore not simply restricting antibiotics; it also involves vaccination, nutrition, sanitation and biosecurity.

The importance of preventive interventions remains highly current. A 2025 systematic review found that livestock AMR intervention evidence in Africa remains limited and stressed the need for stronger, sustainable and context-specific intervention studies.

4.18 Growth-promotion practices

Approximately 48.13% of respondents often avoided using antibiotics for growth promotion, while 29.95% rarely avoided this practice and 21.92% only sometimes did so.

Thus, although nearly half demonstrated relatively prudent behavior, non-therapeutic antimicrobial use has not been eliminated.

Caudell et al. found that antimicrobials were more commonly used for growth promotion and disease prevention within some pastoral systems than in poultry systems. Current 2026 Zambian research similarly identifies antimicrobial use for growth promotion and non-bacterial disease as continuing stewardship concerns in smallholder livestock production.

4.19 Attitudes towards antimicrobial resistance

Only 30.48% agreed that misuse of antibiotics contributes to AMR, whereas almost half—48.13%—were neutral and approximately 21% disagreed.

This result provides a more realistic estimate of AMR understanding than the 100% agreement recorded in parts of the knowledge section.

Neutral responses in this context should not necessarily be interpreted as true middle-ground opinions. They may indicate uncertainty, inability to answer or lack of confidence.

Tufa et al. reported that 97% of livestock producers demonstrated unfavorable attitudes toward factors contributing to AMR. Kallu et al. found that only 47.7% of dairy farm respondents demonstrated desirable attitudes, while fewer than half recognized important animal–human AMR relationships.

The Sierra Leone results therefore fit a broader empirical pattern of incomplete comprehension of AMR mechanisms despite widespread familiarity with veterinary medicines.

4.20 Positive attitudes and opportunities for behavioural intervention

Several findings nevertheless provide considerable grounds for optimism.

Approximately 96.23% believed treatment records improve antimicrobial use, 82.89% expressed confidence in veterinary instructions, more than 90% recognised collective responsibility for prudent antibiotic use and all respondents expressed willingness to participate in antimicrobial-stewardship training.

Approximately 79.68% also accepted personal responsibility for preventing AMR.

These findings indicate that farmers are not fundamentally opposed to stewardship. Instead, the problem appears to be translating favourable intentions into feasible behaviours.

This interpretation is reinforced by recent intervention evidence. Community-conversation work in rural Ethiopia found that AMR was initially poorly understood but that participatory discussion enabled communities to identify excessive medicine use, weak veterinary services, medicine quality and inadequate regulation as contributing factors.

This suggests that participatory farmer education may be considerably more effective than one-directional awareness messages.

4.21 Sierra Leone-specific empirical evidence

The importance of the present study is strengthened considerably when considered alongside national livestock antimicrobial-use surveillance.

Bangura et al. (2022) found that approximately 25% of reported livestock with infectious disease received antimicrobials. Among treated animals, 77% received products regarded as veterinary critically important, while 17% and 60% received products classified as critically or highly important for human medicine. Oxytetracycline accounted for 56% of reported antimicrobial-treated livestock.

A subsequent 2023 study found that the percentage of sick livestock receiving antibiotics remained at approximately 25%, although use of veterinary critically important antimicrobials declined from 77%

to 69%. The study also reported that improved diagnostic laboratory infrastructure remained an outstanding recommendation.

These findings provide important national context. They demonstrate that antimicrobial stewardship in Sierra Leone is not a theoretical issue: important antimicrobial classes are actively used in livestock, while diagnostic and surveillance systems remain under development.

4.22 Comparison with the most recent evidence, 2025–2026

The present results remain highly consistent with the most recent African evidence.

In 2025, Obolensky et al. documented antibiotic misuse, drug-class confusion, inconsistent dosing and gaps in veterinary support among livestock farmers in rural Kenya.

A 2025 systematic review of livestock AMR interventions in sub-Saharan Africa identified only five eligible intervention studies from 546 screened publications, demonstrating how limited the evidence base remains. Financial barriers, sustainability concerns and reliance on self-reported outcomes were among the major challenges.

In 2026, a Zambian cross-sectional study involving smallholder dairy farmers continued to identify substantial gaps in antimicrobial KAP despite comparatively high awareness of antibiotics and resistance. A second Zambian study reported that 75.8% of respondents had poor overall KAP scores and highlighted inappropriate dosage, treatment duration, non-compliance with withdrawal periods and non-therapeutic antimicrobial use as continuing concerns.

Research published in January 2026 from Tanzania similarly demonstrated continuing antimicrobial-stewardship challenges involving cattle keepers, veterinary medicine retailers and animal-health professionals, indicating that livestock AMR behaviour must be addressed across the entire medicine-use system.

Recent 2026 work from Northern Uganda also continues to examine deficiencies in AMR awareness and livestock antimicrobial practices, confirming that these remain active regional concerns.

Therefore, the Sierra Leone findings are not outdated or isolated; rather, they are consistent with the current regional epidemiology of antimicrobial stewardship deficiencies in African livestock production.

4.23 Methodological interpretation and data-quality considerations

Several findings require careful treatment before final thesis submission.

First, repeated 100% responses across many knowledge variables should be interpreted cautiously. The thesis itself recognises that the contrast between poor conceptual knowledge and apparently perfect practical knowledge may indicate social-desirability bias or differences between experiential and scientific knowledge.

Second, agreement questions such as "I know how to calculate the correct dose" measure self-perceived knowledge rather than demonstrated competency.

Third, several demographic categories reported in the results appear to produce totals or percentages greater than the district sample size when summed—for example, some education and farming-experience categories. If these variables were mutually exclusive, the frequencies should be rechecked against the cleaned dataset before final submission. If they represent multiple-response variables, this must be explicitly stated in the table footnotes.

Fourth, because the study is cross-sectional and largely self-reported, causal statements should be avoided. The data demonstrate associations, behavioural risk conditions and plausible pathways, but they cannot independently prove that a particular farmer practice caused a particular resistant bacterial isolate.

This methodological caution is supported by the 2025 systematic review, which identified self-reported outcomes and weaknesses in study design as recurring limitations in African livestock-AMR intervention research.

4.24 One Health interpretation

Taken together, these findings have important One Health implications.

Inappropriate antimicrobial use may select for resistant bacterial populations in cattle. Resistant Enterobacteriaceae can subsequently be shed in faeces and potentially contaminate grazing areas, water sources and livestock-market environments. Humans may encounter resistant organisms through direct contact, animal-source foods or contaminated environmental pathways.

However, the thesis should distinguish plausibility from demonstrated transmission. The KAP findings demonstrate behaviours capable of creating selective pressure, but they do not establish the direction or magnitude of resistant-organism transmission between cattle, humans and the environment.

A scientifically defensible formulation would therefore be:

The observed antimicrobial-use and management practices create biologically plausible conditions for the selection, persistence and dissemination of antimicrobial-resistant Enterobacteriaceae within interconnected animal, human and environmental compartments; however, molecular epidemiological studies are required to confirm transmission pathways.

This wording appropriately incorporates One Health without overstating causality.

4.25 Overall interpretation and contribution to knowledge

Overall, the study demonstrates that antimicrobial stewardship among cattle farmers in Northern Sierra Leone is characterised by the coexistence of limited foundational antimicrobial literacy, relatively favourable stewardship attitudes and substantially poorer actual practices.

The evidence indicates that AMR-related behaviour should not be treated as merely an educational deficit. The behaviour observed is better understood as the product of interacting determinants:

Knowledge + attitudes + veterinary access + affordability + medicine availability + diagnostic capacity + farmer experience + preventive-health infrastructure + regulation.

This interpretation is consistent with contemporary empirical research from Ethiopia, Kenya, Zambia, Tanzania and Sierra Leone.

The major contribution of this research is therefore its demonstration that effective livestock AMR control in Sierra Leone must progress beyond awareness campaigns toward systems-based antimicrobial stewardship. Farmers need accurate knowledge, but they must also have affordable access to veterinary advice, appropriate diagnostics, vaccines, biosecurity, reliable veterinary medicines, treatment-record systems and effective regulatory oversight.

The most promising aspect of the findings is farmers' strong willingness to participate in training and their generally favourable attitudes toward professional veterinary guidance and collective responsibility. These positive attitudes provide an important foundation upon which veterinary authorities, universities, livestock organisations and One Health programmes can build.

Consequently, reducing AMR risks in Northern Sierra Leone will require interventions that do not merely tell farmers what responsible antimicrobial use looks like, but create the institutional, economic and veterinary conditions that enable them to practise it consistently.

Conclusion

This study demonstrates that antimicrobial use among cattle farmers in Koinadugu District is characterised by a substantial disconnect between knowledge, attitudes and actual practices. Although many respondents expressed favourable attitudes towards responsible antimicrobial use, veterinary guidance, withdrawal periods, record keeping, government regulation and participation in training programmes, these positive perceptions were not consistently translated into appropriate farm-level practices. The most important deficiencies included poor understanding of antibiotics and bacterial diseases, inconsistent veterinary consultation, empirical treatment without laboratory diagnosis, failure to follow recommended dosage and treatment duration, poor compliance with withdrawal periods, absence of treatment records, failure to read drug labels, inappropriate storage and disposal of antimicrobials, limited vaccination and inconsistent implementation of biosecurity measures. These findings collectively indicate that antimicrobial stewardship challenges in the study area are not attributable to knowledge deficits alone, but are also strongly influenced by structural, economic, behavioural and veterinary-service constraints.

The weak foundational knowledge observed among respondents is particularly concerning. Many farmers were unable to demonstrate a clear understanding of what antibiotics are, their specific role

against bacterial infections or how they differ from other veterinary medicines. At the same time, poor recognition of diseases requiring antimicrobial therapy creates a strong likelihood of empirical and potentially unnecessary antibiotic use. This risk is compounded by the finding that all respondents reported never seeking laboratory confirmation before antibiotic selection during disease outbreaks.

The study also demonstrates a pronounced knowledge–practice gap. Farmers frequently reported awareness of recommended stewardship principles, yet their actual practices contradicted these responses. For example, although respondents recognised the importance of veterinary involvement and treatment records, only a minority frequently consulted veterinarians and none routinely maintained treatment records. This indicates that awareness alone is insufficient to achieve responsible antimicrobial use.

Of particular AMR concern was poor adherence to dosage and treatment duration. Approximately 73.8% of respondents never followed recommended dosage and treatment duration, while all respondents reported discontinuing treatment once animals appeared clinically recovered. Likewise, 77.0% never observed withdrawal periods and 17.11% rarely complied, creating important food-safety concerns associated with antimicrobial residues in meat and milk.

The absence of treatment records, failure to read drug labels, inappropriate medicine storage and unsafe disposal further demonstrate weaknesses in antimicrobial stewardship. These practices can compromise treatment effectiveness, prevent monitoring of antimicrobial consumption and introduce antimicrobial residues into environmental systems. When combined with free-range cattle movement, communal grazing, shared water sources and animal–human interaction, such practices provide plausible pathways for the selection and dissemination of antimicrobial-resistant organisms within the animal–human–environment interface.

Another major concern was the limited use of preventive animal-health measures. Almost all respondents reported failure to vaccinate cattle according to recommended schedules, while implementation of farm hygiene and biosecurity measures remained inconsistent. Consequently, the production system may remain heavily dependent on treatment rather than disease prevention, increasing opportunities for repeated antimicrobial exposure.

Nevertheless, the study identified an important opportunity for intervention. Farmers generally displayed positive attitudes towards professional veterinary guidance, collective responsibility and antimicrobial stewardship, while all respondents expressed willingness to participate in training programmes. These findings suggest that farmers are potentially receptive to behavioural change if adequate veterinary services, education, diagnostic support and enabling regulatory structures are provided.

Overall, the findings demonstrate that controlling AMR in cattle production in Northern Sierra Leone requires a multidimensional One Health approach. Farmer education alone will not be sufficient. Effective interventions must simultaneously address antimicrobial knowledge, veterinary access, diagnostic capacity, medicine regulation, disease prevention, record keeping, treatment monitoring, food safety and environmental contamination. The findings therefore provide important baseline evidence for strengthening antimicrobial stewardship and integrating livestock AMR surveillance into broader national One Health programmes in Sierra Leone.

Recommendations

Based on the findings of this study, the following recommendations are proposed.

1. Strengthen farmer education and antimicrobial literacy

Regular antimicrobial stewardship training should be provided to cattle farmers, with particular emphasis on the basic meaning and purpose of antibiotics, differentiation of antibiotics from other veterinary medicines, recognition of diseases requiring antimicrobial therapy, consequences of inappropriate antimicrobial use, correct dosage, treatment duration, withdrawal periods, drug storage and safe disposal. Because formal educational attainment is limited among many livestock farmers, training should use local languages, pictorial materials, practical demonstrations and farmer field-school approaches rather than relying exclusively on written information.

2. Improve access to veterinary services

Veterinary services should be expanded within cattle-producing communities in Koinadugu and neighbouring districts. Greater deployment of veterinarians, livestock officers and properly trained community animal-health workers would reduce dependence on self-medication and informal treatment advice. Mobile veterinary clinics and scheduled community outreach programmes may improve access in geographically remote cattle-producing areas.

3. Promote veterinary prescription before antimicrobial use

Veterinary antimicrobials should increasingly be administered on the recommendation or prescription of qualified animal-health professionals. Regulatory authorities should strengthen enforcement governing the sale and distribution of veterinary antibiotics and reduce unrestricted access through informal drug sellers. Antimicrobial dispensing should be linked, wherever feasible, to professional diagnosis and documented treatment recommendations.

4. Strengthen veterinary diagnostic capacity

Veterinary diagnostic services should be expanded to reduce empirical antimicrobial treatment. District-level or regional veterinary laboratories should be strengthened to support bacteriological diagnosis and antimicrobial susceptibility testing. Where laboratory confirmation is not immediately feasible, standardised clinical treatment protocols should guide antimicrobial selection.

5. Promote appropriate dosage and treatment duration

Farmers and animal-health workers should receive practical training on correct weight-based dosing, measuring devices, administration routes and professionally determined treatment duration. Treatment should not be discontinued or altered solely because visible clinical signs have disappeared. Veterinarians should provide clear written, pictorial or verbal instructions adapted to farmers' literacy levels.

6. Improve compliance with withdrawal periods

Intensive education should be provided on withdrawal periods for meat and milk following antimicrobial treatment. Farmers should receive clear information on the withdrawal period associated with each veterinary medicine used. Simple treatment cards, colour-coded animal identification or farm calendars could help farmers track withdrawal periods and prevent treated animals or their products from entering the food chain prematurely.

7. Improve antimicrobial storage

Farmers should be trained to store veterinary medicines according to manufacturer instructions, including protection from heat, sunlight, moisture and contamination. Medicines requiring refrigeration should only be supplied where appropriate cold-chain arrangements are available. Routine extension visits should include inspection and advice on medicine storage.

8. Establish safe disposal systems

District agricultural and veterinary authorities should establish practical mechanisms for the return and safe disposal of expired, unused or damaged veterinary antimicrobials. Farmers should be discouraged from discarding antimicrobials into soil, water bodies, household refuse or open burning sites. Collection points could be established at veterinary offices, pharmacies or livestock markets.

9. Strengthen antimicrobial-use surveillance

Sierra Leone should progressively develop surveillance systems for veterinary antimicrobial consumption at importer, distributor, veterinary practice and farm levels. Data on the quantities and classes of antimicrobials used should be analysed alongside laboratory resistance data to identify relationships between antimicrobial consumption and emerging resistance patterns.

10. Adopt a One Health approach

AMR interventions should involve veterinary authorities, public-health agencies, environmental institutions, universities, livestock farmer associations, pharmaceutical regulators and community stakeholders. Surveillance and interventions should recognise that resistant organisms and antimicrobial residues can circulate between livestock, humans, food systems and the environment.

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