Antimicrobials use by Smallholder Dairy Farmers in Peri-Urban Area of Nakuru Kenya: Knowledge, Attitudes and Practices

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Abstract

In dairy intensification, mastitis infections become prevalent and induce frequent Antimicrobial Use (AMU), sometimes inappropriately. This poses public health risks because of growing Antimicrobial Resistance (AMR). Stewardship programs informed by Knowledge, Attitude and Practices (KAPs) about AMU and AMR are necessary to halt or reverse their worrying trends. Data was obtained in cross sectional survey conducted in four peri-urban wards of Nakuru city in Kenya. Randomly selected sample farmers (n=124) with free-grazing, semi-zero-grazing and zero-grazing dairy management, representing increasing dairy intensification levels provided data on KAPs. Chi-square test statistics was fitted to establish associations between KAPs and dairy intensification levels. Results revealed that six in ten farmers (58.8 percent) had intensified dairy production; at least six in ten marketed their milk through informal outlets and were using antimicrobial drugs. Compliance with the withdrawal period was high and increased with ($p<0.05$) increasing intensification level. During the antibiotic withdrawal period, at least seven in ten farmers did not sell milk, fewer than four in ten consumed their milk at home and fewer than three in ten fed their milk to calves. Though independent of dairy intensification level ($p>0.05$), using antimicrobials for mastitis treatment increased while sourcing information on antimicrobial use from extension and veterinary officers decreased, with increasing intensification level. Farmers with some training on prudent antimicrobial use and with positive attitudes that milk from antimicrobial treated cows is unsafe, antimicrobial resistant pathogens and residues can be passed from milk to humans, mastitis can be treated without antimicrobial drugs, and that antimicrobial residues can end up accumulating in the soils increased ($p>0.05$) with increasing dairy intensification level. These results show that farmers knowledgeable and with positive attitudes and practices increased with increasing intensification of dairy management. The implication is that intensification of dairy management motivates farmers to improve their knowledge, positive attitudes and practices towards prudent use of antimicrobials in livestock. However, room exist for further targeted training and sensitization of farmers on the prudent and responsible antimicrobial use to foster stewardship.

Keywords: Antimicrobial Resistance, Antimicrobial Use, Kenya, Knowledge Attitude and Practices, Mastitis,

1.0 Introduction

Growing consumption demand for animal protein is driving intensification of livestock production systems in which antimicrobial use (AMU) is projected to increase by 67 percent between the year 2010 and 2030 (Gemeda *et al.,* 2020). In intensive dairy production, mastitis disease is prevalent and induces overdosing, under dosing or inappropriate use of veterinary antimicrobial drugs for treatment (Dankar *et al.,* 2023). Consequential to this is occurrence of antimicrobial residue in food of animal origin and subsequent development of antimicrobial resistance (AMR), with impacts on food safety and public health (Sulis *et al.,* 2022). These present public health risks because of a high probability of future treatment failures in both animals and humans. This public health concern is growing in countries where growth in consumption demand for animal protein is more rapid, yet consumption of antimicrobial veterinary drugs (AMD) is weakly regulated.

The growing public health concerns on AMU and AMR justifies antimicrobial stewardship programs. Effective antimicrobial stewardship programs are evidence-informed with the Knowledge, Attitudes and Practice (KAPs) regarding AMU of the farmers. This is a critical step in developing antimicrobial stewardship programs (Hassan, 2022). The 2021–2025 action plan of the Food and Agriculture Organization of the United Nations (FAO) has proposed antimicrobial stewardship program actions. These include boosting stakeholder engagement and awareness, enhancing research and surveillance, encouraging good practices, and strengthening governance and sustainable resource allocation (FAO, 2021). However, instance of inappropriate AMU frequently arises, which poses public health risks. This is a likely situation among the peri-urban smallholder dairy farmers in Kenya. The are intensifying their dairy production systems and so are more likely to engage in high AMU in treating mastitis infections, a prevalent intensification disease (Geta & Kibret, 2021). However, there is a dearth of information on KAPs regarding AMU and AMR among peri-urban smallholder dairy farmers, particularly in Kenya, a country with well-developed dairy industry in Africa (JKUAT, 2020), (Okello *et al.,* 2021).This knowledge gap is a barrier to evidence informed antimicrobial stewardship program actions that can reverse the trends in antimicrobial resistance development (Hassan *et al.,* 2021). The goal of responsible antimicrobial stewardship is to prevent the emergence and spread of antimicrobial resistance, maintain the effectiveness of veterinary drugs, and promote a One-Health concept (Sweeney *et al.,* 2024). Antimicrobial stewardship program actions are being implemented in industrial livestock systems because data is available from effective monitoring of AMU and AMR trends in livestock production (Gemeda *et al.,* 2020). In order to track the susceptibility of the principal mastitis pathogens to antimicrobial medications used to treat the disease in North America, mastitis pathogen antimicrobial susceptibility surveillance program was established and continues to implemented a in 2002 (Sweeney *et al.,* 2024). This is yet to be achieved in peri-urban smallholder dairy systems in Kenya because data on KAPs regarding AMU and AMR remain scarce. This knowledge gap hinders good understanding of the association between dairy intensification and KAPs about AMU and AMR. Therefore, this study assessed Knowledge, Attitudes and Practices related to antimicrobial use in different dairy production systems representing increasing intensification levels (free-, semi-zero and zero-grazing) among smallholder dairy farmers in Nakuru peri-urban areas of Kenya.

2.0 Materials and Method

2.1 Study Area

The study was conducted in peri-urban area of Nakuru city, specifically smallholder farms in Njoro, Lare, Lanet and Kabatini Wards. The area is located within Longitudes 35.41 º East or 35 º 24' 36" East and 36.6 ºEast or 36 º36' 0" East and Latitude 0.23 º North or 0 º 13' 48" North and 1.16 º South or 1º 9`36" South (Figure1). Dairy production under mixed farming dominates in these Wards, deeply rooted in White Settler farming heritage (Bebe et al., 2003). Dairy production is a major productive economic activity, with developed supportive infrastructure. The supportive infrastructure includes education, training and research institutions and facilities, milk processing, feed manufacture and veterinary investigation laboratories. These institutions are under public, farmer or private operation ownership (County Government of Nakuru Integrated Development Plan, 2018).

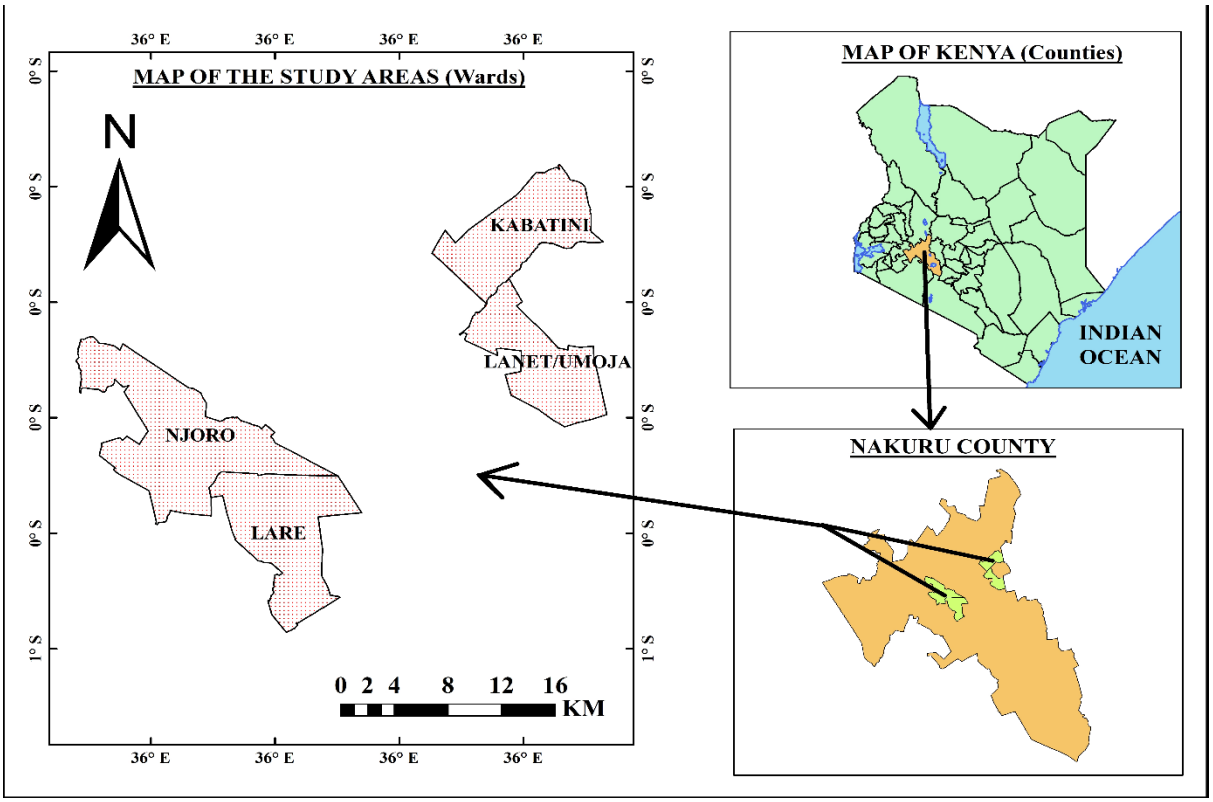

Figure 9:Map of the study area.

Source: Self

2.2Data collection

A structured questionnaire was developed in Kobo tool kit with four sections. The first section captured demographical information, the second section captured farmers' knowledge, the third section captured farmers' attitudes, and the last section captured practices by farmers about antimicrobial use, antimicrobial drugs and antimicrobial resistance. The interest on farmers' knowledgebase was to establish the purpose of using antimicrobial, whether antimicrobials are used for mastitis treatment and the recommended withdrawal periods are observed, and how

farmers source information on antimicrobial residues and antimicrobial resistance. The interest on farmers' attitudes was assessed with nine questions for the degree of agreement or disagreement to reveal positive and negative attitudes that farmers have about antimicrobial use on animals and humans. The interest on practices that farmers deploy in using antimicrobials was to gain insight into how farmers prudently used the antimicrobials. The questionnaire was pretested among 10 dairy farmers outside the four wards targeted for the study. Pre-testing was done to enhance the clarity and accuracy of the questions so that the intended information could be obtained. The adjusted questionnaire was administered to a random sample of 124 farmers who provided information on their KAPs regarding antimicrobial use, antimicrobial drugs and antimicrobial resistance.

2.3 Data analysis

Data in the Kobo tool kit was exported to Excel version 2016 for cleaning then processed for further descriptive and inferential statistics using SAS version 9.3 software. The descriptive and inferential statistics were generated by applying cross tabulation and Chi square test statistics for association between KAPs and dairy intensification level. Rejection of the null hypothesis of independence between KAPs and dairy intensification levels was set to $p< 0.05$. In analysing the sampling distribution, Pearson's Chi square was used when the expected frequencies in each cell were greater than five; otherwise Fisher's exact test probability was used when the expected frequencies were less than five.

3 Results

3.1 Demographic characteristics of sample farmers

Demographic characteristics of the sample farmers (n=124) is presented in Table 1. The demographic statistics reveal that more than 70 percent of the sample farmers came from two neighbouring wards (Njoro and Lare). Among the farmers, male (56.5 percent; 70/124) dominated over female (43.5 percent; 54/124), and seven in ten (70.2 percent) had attained at least secondary level education. Observed frequencies show that six in ten (58.8 percent) of the farmers had intensified dairy production management by adopting semi-zero-grazing or complete zero dairy management grazing. Though being in peri-urban area of the city is expected to present proximity advantage to formal market channels to these farmers, it is found that at least six in ten (63.7 percent) were marketing milk through informal market outlets.

Table 8: ***Demographic statistics of the sample farmers***

Categories	Frequency	Percent
Wards		
Njoro	50	40.3
Lare	40	32.3
Lanet	17	13.7
Kabatini	17	13.7
Sex		
Male	70	56.5
Female	54	43.5
Education Level		
Adult Education	4	3.2
Primary	33	26.6
Secondary	59	47.6
Post-secondary	28	22.6
Production System		
Free Grazing	51	41.1
Semi Grazing	33	26.6
Zero Grazing	40	32.2
Milk market outlets		
Informal only	79	63.7
Both formal and informal	36	29.0
Formal only	9	7.3

3.2 Farmers' knowledge about antimicrobial use

Summary statistics of farmers' knowledge about antimicrobial use is presented in Table 2. Use of milk before end of withdrawal period was associated with dairy intensification levels ($p<0.05$) as those selling milk decreased while those feeding milk to calves increased with increasing intensification levels. Before withdrawal period ended, farmer selling the milk decreased (15.7, 12.1, 0.0 percent) while those feeding milk to calves increased (9.8, 21.2 and 25.0 percent) in free, semi- and zero-grazing farmers, respectively. In overall, compliance with the recommended withdrawal period was high, with at least seven in ten farmers not selling such milk during the withdrawal period while less than four in ten consumed such milk at home. Regardless of dairy intensification levels, up to four in ten (21.1 to 37.3 percent) farmers did not use antimicrobials. Though reasons for using antimicrobials were independent of ($p>0.05$) of dairy intensification levels, use of antimicrobials for treatment (33.3 to 40.0 percent) and for treating mastitis (19.6 to 40.0 percent) had a pattern of increasing with increasing intensification levels from free to zero-grazing. When frequently using antimicrobials, the reason was treatment (30 to 40 percent) or production (22 to 42 percent) and not disease prevention (4 to 6 percent). Among the sample farmers, sourcing of information about antimicrobial use was independent ($p>0.05$) of their dairy intensification levels. However, those sourcing information from the extension and veterinary officers had a pattern of decreasing with increasing intensification levels from free- and semi-zero grazing (66.7 -68.6 percent) to zero-grazing (47.5 percent).

Table 9: ***Association between farmers' antimicrobial use knowledge and dairy intensification levels***

Question	Free grazing (n=51)	Semi grazing (n=33)	Zero grazing (n=40)	Chi-square test
Purpose of using antimicrobial (Percent)				*p=0.5110**
Do not use	37.3	21.2	32.5	
Treatment	33.3	30.3	40.0	
Prevention	3.9	6.1	5.0	
Production	25.5	42.4	22.5	
Using antimicrobials for mastitis treatment (Percent)				*p*=0.1939
Do not use	43.1	39.4	25.0	
Use sometimes	37.3	27.3	35.0	
Use frequently	19.6	33.3	40.0	
Using milk from antimicrobial treated cows before end of withdrawal period (percent)				*p*= 0.0405*
Home consumption	3.9	0.0	2.5	
do not sale out	70.6	66.7	72.5	
Sell out	15.7	12.1	0.0	
Give to calves	9.8	21.2	25.0	
Sourcing information on antimicrobial residues in food and antimicrobial resistance (Percent)				*p*= 0.0655*
No	21.6	30.3	25.0	
Extension/ veterinary officers	68.6	66.7	47.5	
Fellow farmers, relatives	2.0	0.0	5	
Field days	0.0	3.0	7.5	
Media (radio, newspapers, TV)	7.8	0.0	15	

***p* value from Fisher's exact test**

3.3 Farmers' attitudes towards antimicrobial use in dairy farming

The study identified the specific recommendations for antimicrobial use in animals and humans that farmers have positive and negative attitudes towards. Agreement with statement of recommendations for antimicrobial use indicated positive attitude. The observed frequency statistics for which the association with dairy intensification levels was significant ($p<0.05$) are presented in Table 3.

Overall, farmers with positive attitude towards AMU recommendations increased with increasing dairy intensification levels. Farmers with the attitude that milk from antimicrobial treated cows is unsafe to human health increased from those practicing free-grazing (56.9 percent) through semi-zero-grazing (78.8 percent) to zero-grazing (82.5 percent). Also, farmers with the attitude that antimicrobial resistant pathogens and residue from milk can be passed to humans through the food chain increased from those practicing free-grazing (60.8 percent) through semi-zero-grazing (69.7 percent) to zero-grazing (70.0 percent). Further, it was found that more of farmers practicing zero-

grazing (70.0 percent) than those practicing free-grazing (62.8 percent) had the attitude that mastitis can be treated without antimicrobial drugs. Similarly, more of farmers practicing zero-grazing (70.0 percent) than those practicing free-grazing (66.7 percent) had the attitude that antimicrobial residues can end up accumulating in the soils.

Table 10: Significant associations between farmers' attitudes towards antimicrobial use and dairy intensification levels

Production systems	Degree of agreement or disagreement (Percent)			Chi-square test
	Agree	Neutral	disagree	
Mastitis can be treated without using antimicrobial drugs				*P*=0.0010
Free (n=51)	62.8	23.5	13.7	
Semi (n=33)	24.2	39.4	36.4	
Zero (n=40)	70.0	12.5	17.5	
Milk from antimicrobial treated cows is harmful to human health				P=0.0283*
Free (n=51)	56.9	35.3	7.8	
Semi (n=33)	78.8	21.2	0.0	
Zero (n=40)	82.5	17.5	0.0	
Antimicrobial residues can end up accumulating in the soils				P=0.0004
Free (n=51)	66.7	25.5	7.8	
Semi (n=33)	51.5	12.1	36.4	
Zero (n=40)	70.0	36.4	2.5	
Antimicrobial resistant pathogens and residue from milk can be passed to humans through the food chain				*P*=0.0089*
Free (n=51)	60.8	37.3	2.0	
Semi (n=33)	69.7	12.1	18.2	
Zero (n=40)	70.0	27.5	2.5	

p value from Fisher's exact test

The observed frequency statistics for farmer attitudes towards antimicrobial use recommendations which showed no association with dairy intensification levels ($p>0.05$) are presented in Table 4. Farmer attitudes that were independent of their dairy intensification levels were whether any antimicrobial drug can be used to treat a lactating cow, withdrawal period should be observed to avoid antimicrobial drug residues in milk, relationship exists between antimicrobial use and antimicrobial resistance, and whether antimicrobial drug residues and drug resistance occurs when AMU is not prudent. Though independent of the dairy intensification levels also, farmers with the attitude that sale and distribution of antimicrobial drugs be restricted to licensed persons had a pattern of increasing with increasing intensification levels. The proportion of farmers increased

from free-grazing (58.8 percent) through semi-zero-grazing (63.6 percent) to zero-grazing (67.5 percent).

Table 11: Insignificant associations between farmers' attitudes towards antimicrobial use and dairy intensification levels

Production systems	Degree of agreement or disagreement (Percent)			Chi-square test
	Agree	neutral	disagree	
Any antimicrobial drug can be used to treat a lactating cow				*P=0.3076**
Free (n=51)	70.6	25.5	3.9	
Semi (n=33)	54.6	30.3	15.2	
Zero (n=40)	72.5	20.0	7.5	
Withdrawal periods should be observed to avoid antimicrobial drug residues in milk				*P=0.8945**
Free (n=51)	70.6	21.6	7.8	
Semi (n=33)	69.7	21.1	9.1	
Zero (n=40)	62.5	30.0	7.5	
Relationship exists between antimicrobial use and antimicrobial resistance				*P=0.0524*
Free (n=51)	66.7	27.5	5.9	
Semi (n=33)	39.4	45.6	15.2	
Zero (n=40)	67.5	30.0	2.5	
Sale and distribution of antimicrobial drugs be restricted to licensed persons				*P=0.6918**
Free (n=51)	58.8	33.3	7.8	
Semi (n=33)	63.6	27.3	9.1	
Zero (n=40)	67.5	20.0	12.5	
Antimicrobial drug residues and drug resistance occurs when not prudently used				*P=0.7747**
Free (n=51)	72.6	19.6	7.8	
Semi (n=33)	60.6	24.2	15.2	
Zero (n=40)	65.0	22.5	12.5	

***p value from Fisher's exact test**

3.4 Farmer practices in administration and prescription of antimicrobial drugs

Table 5 presents the observed association between farmers' practices (in the administration and prescription of antimicrobial drugs) and dairy intensification levels. Regardless of their dairy intensification levels, at least seven in ten farmers had professional prescription by veterinarians or pharmacy, observed withdrawal period and had been trained in antimicrobial use including residual effects and development of antimicrobial resistance. Farmers who self-prescribed and administered antimicrobial drugs declined ($p<0.05$) with increasing intensification of dairy management from free- to zero-grazing. Farmers who had most intensified their dairy management (zero-grazing) were the majority with some training on prudent antimicrobial use (87.5 percent) and in observing the withdrawal period (97.5 percent). There were several of farmers' practices in administration and prescription of antimicrobial drugs that were independent ($p>0.05$) of the dairy

intensification levels. These include where farmers were buying the antimicrobial drugs, how often they called a veterinarian whenever an animal is sick, and common disease condition(s) of lactating cows for which they administered antimicrobial drugs. Other practices were administering a follow up dose, stopping treatment when an animal recovers, checking for the expiry date before use, and using human drugs on animals. Though was independent of dairy intensification levels, use of human drugs on animals was prevalent (over 60.0 percent).

Table 12: Association between farmers' practices (in the administration and prescription of antimicrobial drugs) and dairy intensification levels

Question	Free grazing (n=51)	Semi grazing (n=33)	Zero grazing (n=40)	Chi-square test
From where do you usually buy the antimicrobial drugs? (Percent)				P= 0.1230*
Extension/veterinary officer	80.4	81.8	85.0	
Pharmacy	5.9	18.1	12.5	
Fellow farmers	13.7	0.0	2.5	
Who often prescribes antimicrobial drugs for you? (Percent)				P= 0.0124*
Extension/veterinary officer	63.6	97.0	85.0	
Pharmacy	5.8	0.0	5.0	
Self	25.5	3.0	10.0	
Who administers antimicrobial drugs to your animals? (Percent)				P = 0.0040*
Extension/veterinary officer	66.7	97.0	67.5	
Fellow farmers	11.8	0.0	5.0	
Self	21.6	3.0	27.5	
How often do you call a veterinarian whenever an animal is sick? (Percent)				P= 0.0524*
Frequently	27.5	42.4	45.0	
Sometimes	51.0	48.5	52.5	
Do not	21.6	9.1	2.5	
What is the common disease condition(s) of lactating cows for which you administer antimicrobial drugs? (Percent)				P= 0.4051*
Mastitis	11.8	24.2	35.0	
Respiratory diseases	17.7	12.1	10.0	
Diarrhoea	27.5	21.2	20.0	
Udder injuries	7.8	12.1	10.0	
Others	35.3	30.3	25.0	
Do you observe the withdrawal period after treating the animals with antimicrobials (Percent)				P= 0.0316*

Yes	86.3	78.8	97.5	
No	13.7	21.2	2.5	
Do you give subsequent doses after the administration of the first dose of the treatment. (Percent)				P= 0.4861
Yes	72.6	72.7	82.5	
No	27.5	27.3	17.5	
Do you stop giving treatment when an animal recovers? (Percent)				P= 0.5867
Yes	72.6	66.7	77.5	
No	27.5	33.3	22.5	
Have you had training on antimicrobial usage, AMR, and residue. (Percent)				p= 0.0221
Yes	68.6	60.6	87.5	
No	31.4	39.4	12.5	
Do you check for the expiry date before AMU (Percent)				P= 0.0737
Yes	82.4	66.7	87.5	
No	17.7	33.3	12.5	
Do you use human drugs on animals. (Percent)				P= 0.5034
Yes	66.7	54.6	65.0	
No	33.3	45.5	35.0	

***p value from Fisher's exact test**

4.0 Discussion

The distribution of farmers with free-, semi-zero and zero-grazing dairy management observed in this study support that intensification of dairy management is increasing in the peri-urban areas of Nakuru city. Though more than half of the sample farmers (58.8 percent) had intensified their dairy management, a larger majority marketed milk in the informal market outlets. Participation in the informal milk market outlets is likely a weak link in implementing antimicrobial stewardship programs, boosting stakeholder engagement and awareness, enhancing research and surveillance, encouraging good practices, and strengthening governance and sustainable resource allocation (FAO, 2021).

This study reported that seven of ten farmers at least had secondary education. Training farmers to enhance disease detection accuracy is vital for antimicrobial stewardships program. However, achieving lasting progress will necessitate a comprehensive approach(Habing & Pereira, 2024). A higher level of education among dairy farmers and farm workers can play a significant role in promoting AMU stewardship practices. Better-educated individuals are more likely to understand the importance of prudent antimicrobial use, follow recommended guidelines, implement bio security measures, and adopt best management practices. Education can also enhance their ability to interpret diagnostic test results, maintain accurate treatment records, and make informed decisions about antimicrobial therapy. Consequently, increased education levels can encourage more responsible and sustainable AMU stewardship actions as dairy farming intensifies.

Regardless of the level of dairy intensification management, the study revealed that at least seven out of ten farmers were utilizing antimicrobial drugs, with up to eight out of ten employing these drugs specifically for the treatment of mastitis. This finding is not surprising, as mastitis is a highly prevalent infection in intensified dairy management among smallholder farmers (Abdi *et al.*, 2021). The observed therapeutic use of antimicrobials is consistent with the observations of many researchers. Gemeda *et al.* (2020), Farrell *et al.* (2021), Geta & Kibret (2021), and Hassan (2022) have all reported that antimicrobials are predominantly used for therapeutic purposes in livestock production systems. However, other researchers have reported contrasting observations, suggesting that the primary use of antimicrobials is for disease prevention rather than treatment. Nyokabi *et al.* (2021), Omwenga *et al.* (2021), Mogotu *et al.* (2022), and Kisoo *et al.* (2023) are among the researchers who have highlighted the preventive use of antimicrobials as a common practice in various livestock production settings. This discrepancy in findings may be attributed to regional differences, variations in production systems, or the specific contexts in which the studies were conducted. It is crucial to investigate the underlying factors contributing to the contrasting observations and tailor interventions accordingly to promote judicious antimicrobial use practices. The high prevalence of mastitis and the associated therapeutic use of antimicrobials observed in the present study underscore the need for effective disease management strategies and alternative approaches to minimize the reliance on antimicrobial treatments. Improved hygiene practices, vaccination programs, and the adoption of preventive measures could contribute to reducing the incidence of mastitis and, consequently, the need for antimicrobial therapy. Ongoing research, education, and collaboration among stakeholders, including farmers, veterinarians, and policymakers, are essential to address the challenges of antimicrobial resistance and promote sustainable livestock production practices.

The present study revealed a high level of compliance with the withdrawal period among farmers, which refers to the mandated time after administering antimicrobials to dairy animals before their milk can be introduced into the food chain. Notably, this compliance increased significantly ($p<0.05$) as the level of dairy intensification increases. Specifically, during the antimicrobial withdrawal period, at least seven out of ten farmers refrained from selling the milk, fewer than four out of ten consumed the milk at home, and fewer than three out of ten fed the milk to calves. These findings align with the recommendations of Uyama *et al.* (2022), who emphasized the importance of adhering to withdrawal periods to prevent antimicrobial residues from entering the food supply and safeguard public health. Their study highlighted the potential risks associated with the consumption of milk containing antimicrobials residues, including the development of antimicrobial resistance and adverse health effects. Similarly, Asaah Ndambi *et al.* (2022) reported a positive correlation between farmer knowledge of withdrawal periods and compliance with these guidelines in their study conducted in Cameroon. They stressed the need for continuous education and awareness campaigns to promote responsible antimicrobial stewardship practices among dairy farmers. The observed trend of increased compliance with withdrawal periods as dairy operations intensified could be attributed to factors such as improved access to veterinary services, better record-keeping, and enhanced awareness of food safety and public health concerns, as suggested by Kashongwe *et al.* (2020) in their study on antimicrobial use practices in intensive dairy farming systems. However, it is concerning that a significant proportion of farmers still engaged in practices such as consuming or feeding milk to calves during the withdrawal period. These practices can contribute to the spread of antimicrobial resistance and pose potential health risks, as highlighted by Uyama *et al.* (2022) and Asaah Ndambi *et al.* (2022). Continued efforts are needed to address these practices through targeted education and extension programs, as

recommended by organizations such as the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO). These initiatives should emphasize the importance of strict adherence to withdrawal periods and promote alternative management strategies to minimize the need for antimicrobial treatment, ensuring food safety and public health throughout the dairy production chain (WHO, 2015; FAO, 2021).

The study revealed that although independent of the level of dairy intensification ($p>0.05$), there was an increasing trend in the use of antimicrobials for treating mastitis, while the practice of sourcing information on antimicrobial use from extension and veterinary officers decreased as dairy operations became more intensive. This finding contrasts with previous research that has emphasized the importance of veterinary guidance and extension services in promoting judicious antimicrobial use, particularly in intensive livestock production systems. For instance, Redding *et al.* (2014) highlighted the positive impact of veterinary-client relationships and education programs on reducing unnecessary antimicrobial use among dairy farmers in the United States. Similarly, a study by Higham *et al.* (2020) found that farmers who received training and support from extension services were more likely to adopt best practices for responsible antimicrobial stewardship, such as improved record-keeping and adherence to treatment protocols. The observed trend in the present study raises concerns about the potential for increased antimicrobial use and the risk of antimicrobial resistance as dairy operations intensifies, especially if farmers rely less on professional advice and guidance from veterinary and extension services. It is crucial to address this issue by strengthening the collaboration between farmers, veterinarians, and extension services, as recommended by the World Organisation for Animal Health (OIE) and the Food and Agriculture Organization of the United Nations (FAO) in their guidelines for prudent and responsible use of antimicrobials in agriculture (OIE, 2018; FAO, 2021). Ongoing education and awareness campaigns, coupled with accessible and affordable veterinary services, can play a vital role in promoting sustainable antimicrobial use practices, even as dairy production systems become more intensive.

The present study found that farmers who received training on prudent antimicrobial use and held positive attitudes regarding the risks associated with antimicrobial overuse were more likely to adopt responsible practices as dairy production intensified. Specifically, those who believed milk from antimicrobial-treated cows is unsafe for consumption, that antimicrobial-resistant pathogens and drug residues can transmit from milk to humans, that mastitis can be managed without antibiotics, and that antimicrobial residues accumulate in soil demonstrated an increased tendency ($p>0.05$) toward judicious use as their dairy operations became more intensive. These findings align with previous research highlighting the importance of farmer education and awareness. Higham *et al.* (2020) emphasized that understanding antimicrobial resistance risks and residue entry into the food chain positively shapes attitudes toward antimicrobial stewardship. Similarly, Redding *et al.* (2014) found U.S. dairy farmers receiving prudent use training were more likely to implement best practices like selective dry cow therapy to reduce unnecessary antimicrobial administration. Moreover, Saini *et al.* (2012) observed farmers recognizing antimicrobial residue risks in milk and the environment were more receptive to alternatives such as improved hygiene and preventive measures to minimize treatment needs. These findings underscore the pivotal role of education in promoting responsible antimicrobial stewardship, especially as dairy production intensification.

In the present study, it was observed that the majority of farmers obtained antimicrobial drugs through veterinarians, who not only prescribed but also administered the drugs themselves. This practice is considered beneficial and should be encouraged, promoted, and strengthened to mitigate concerns related to antimicrobial resistance (AMR) and contribute to the sustainable use of antimicrobials (Dankar *et al.,* 2022). This approach aligns with the Global Action Plan on AMR, which outlines strategies for combating the emergence and spread of AMR. The implementation of such strategies is a response to the threats posed by the emergence and spread of AMR to multiple Sustainable Development Goals, including those related to health, food security, environmental well-being, and socioeconomic factors (WHO *et al.,* 2019; FAO, 2021). By promoting the involvement of veterinary professionals in the procurement and administration of antimicrobial drugs, the study's findings support responsible antimicrobial stewardship practices. However, our findings deviate from those reported by Gemeda *et al*. (2020) in their study conducted in Ethiopia. The researchers observed that antimicrobial drugs were primarily accessed from private suppliers in the context of their study. It is important to note that their study sample focused on a pastoralist production system, which differs from the smallholder peri-urban dairy systems examined in our research. The contrasting findings could be attributed to the differences in production systems, as accessibility to veterinary services is often limited in pastoralist production settings. In our study, we did not observe a predominant reliance on private suppliers for antimicrobial drug procurement. This discrepancy with the findings of Gemeda *et al.* (2020) could potentially be explained by the variations in the production systems under investigation. Smallholder peri-urban dairy operations may have more readily available access to veterinary services and guidance compared to pastoralist systems, which could influence the sources from which antimicrobial drugs are obtained.

The observed practice of farmers obtaining antimicrobial drugs through veterinarians, who also prescribed and administered the drugs, can be attributed to the education and guidance received from veterinary extension officers on prudent antimicrobial use and the relationship between antimicrobial use (AMU) and antimicrobial resistance (AMR). This educational intervention by veterinary officials likely played a crucial role in shaping the responsible antimicrobial procurement and administration practices among the farmers in this study. However, this finding stands in contrast with a study conducted in Ethiopia by Geta & Kibret (2021), where farmers reportedly administered antimicrobial drugs to sick animals before seeking veterinary assistance. Furthermore, the same authors stated that farmers claimed they would continue to use antibiotics on animals even if they were aware of the potential negative impact on public health (Geta & Kibret, 2021). This unfortunate practice can be attributed to lack of education on prudent use of antimicrobials and the relationship between AMU and AMR by the veterinary officials from the private sector.

5.0 Conclusion

It can be concluded that farmers knowledgeable and with positive attitudes and practices increased with increasing intensification of dairy management. This indicates that intensification of dairy management somewhat motivates farmers to improve their knowledge, positive attitudes and practices towards prudent use of antimicrobials in livestock. However, room exists for further targeted training and sensitization of farmers on the prudent and responsible antimicrobial use to foster stewardship.

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