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Treatment strategies and antibiotic usage practices in mastitis management in Kenyan smallholder dairy farms

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Abstract

Background Mastitis is a common driver of antibiotic use in dairy farms and is exacerbated in low-income settings by the lack of diagnostics and treatment strategies. We assessed the decision-making process of animal health providers (AHPs) in managing mastitis in small-holder dairy farms in Kiambu County, Kenya. Data were collected from 114 AHPs and using item response theory, scales were developed to measure attitudes toward udder health, and multivariable linear regression was used to analyse demographic factors associated with these attitudes.

Results Overall, 90% of AHPs diagnose clinical mastitis based on clinical symptoms such as visible udder signs and milk changes, with little diagnostic testing support. Antibiotic treatment was initiated immediately after clinical examination by all, 80% and 50% of AHPs in severe, moderate, and mild mastitis cases, respectively. β-lactams (namely penicillins) and aminoglycosides which were administered mostly parenterally, were the frequently reported antibiotic classes used in treatment of mastitis irrespective of the severity. AHPs with a larger farmer client base and those who did not treat mild mastitis cases with antibiotics had significantly higher mean attitude scores. Treatment of mastitis is primarily based on clinical judgment, with limited microbiological diagnostic support, and parenteral antibiotics are used empirically as first-line therapy.

Conclusions We recommend development of mastitis management support tools such as treatment guidelines and advocate for adoption of routine on-farm rapid testing supported by bacterial culture to guide treatment decision making and antibiotic choice.

Keywords Mastitis, Treatment guidelines, Small holder, Dairy farming, Antibiotic use

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Introduction

Mastitis is a significant economic burden in global dairy production and responsible for the largest volume of antibiotics administered to dairy cows [1–4]. To optimise antibiotic use in dairy production systems, stewardship programs have been developed and adopted to reduce the incidence of mastitis and reduce unnecessary antibiotic use [5]. For example, the National Mastitis Council's *5-point mastitis control plan* and its successor, the *10-point plan*, were associated with reduced incidence of clinical mastitis in the USA by promoting improved milking hygiene practices and farm biosecurity [6, 7]. Concurrently, development of rapid diagnostic tests that provide on-farm treatment support [8, 9] along with the introduction of stricter regulations governing access and use of antibiotics [10, 11] have contributed to a more targeted antibiotic use and hence reducing overall antibiotic consumption. However, most of these efforts are predominantly practiced in high-income countries.

Dairy production is a significant source of income and employment in Kenya, contributing 4% and 12% to the national and agricultural Gross Domestic Product, respectively in 2019 (KNBS, 2019a). In addition, milk consumption improves household nutritional status, particularly for children under five years old [12]. The Kenyan dairy production system is dominated by small-holder dairy farms with farmers owning between 2 and 15 cows and producing 82% of the milk in the country [13]. Similar to other settings, mastitis is a major constraint reducing milk yield, compromising animal welfare, increasing animal health costs and reducing farm profits [14]. Several studies in Kenya have reported high prevalence rates of subclinical mastitis, defined as infections without visible clinical signs, ranging from 53% [15, 16] to 74% [17, 18]. In contrast, lower prevalence rates have been observed for clinical mastitis, characterised by inflammation with noticeable clinical signs, at 0.9% [18] and 6.8% [17]. The prevalence findings have been associated with poor husbandry practices, and the use of diagnostics and treatment guidelines is often lacking. As a result, non-targeted antibiotic treatment is a common practice in these resource-limited small-holder settings [19, 20].

The decision to administer antibiotics for mastitis treatment should ideally be based on bacteriological diagnostic results, the ability to achieve clinical cure, and minimizing negative animal health, welfare, and farm economic impacts [21]. A recent study in Denmark reported that veterinarians determine antibiotic use for mastitis based on clinical severity and herd history (like disease incidence), prescribing treatment more often in severe or moderate cases (92% and 79%, respectively), while only 25% would typically or always use antibiotics for mild cases [22]. Data on how mastitis is diagnosed and treatment protocols that include antibiotic selection, duration, and route of administration, are lacking in small-holder settings. This study aimed to elucidate the decision-making process by animal health providers (AHPs) for mastitis management in small-holder dairy systems in Kenya. Understanding this decision-making process is crucial to gain insights into AHPs' perceptions and attitudes towards mastitis management, and how these, in turn, influence antibiotic use.

Materials and methods

Study design and participants

A cross-sectional study targeting AHPs offering veterinary services to dairy farms in Kiambu County, Kenya, was conducted between December 2023 and January 2024. Kiambu County, a peri-urban area near Nairobi city, the capital of Kenya, is an important area for dairy farming in Kenya, broadly representative of the wider central and Rift Valley highlands. This area is characterized by small-scale family managed dairy farms (< 5 cows), mostly integrated with small-holder poultry, pig, and horticultural farming [23]. AHPs were identified initially by asking farmers for the contact information of their AHPs, as a comprehensive list of AHPs in Kenya is unavailable. Participants were recruited using a snowball sampling approach. Recruitment started with an initial group of AHPs identified by dairy farmers involved in a related study. These initial participants were then asked to recommend additional potential participants. The process continued iteratively until saturation was reached, meaning no new contacts were identified. According to Kenya Veterinary Board's (KVB) regulations, there are two categories of animal health professionals: (i) veterinarians holding a bachelor's degree in veterinary medicine, and (ii) veterinary paraprofessionals who have either a bachelor's, diploma, or certificate in animal health science. While only veterinarians are legally authorised to prescribe antibiotics in Kenya, and veterinary paraprofessionals are restricted to administering antibiotics with a veterinarian's prescription, previous studies indicate that paraprofessionals also engage in prescribing [24, 25]. In our study, we refer to all individuals who provide animal health services to farmers as AHPs, regardless of their education and training level [26]. This definition is based on the reality that farmers are unable to differentiate between these educational categories or aren't concerned with the qualification or training level of AHPs, and all are referred to as 'doctors'.

Survey instrument and data collection

We developed a questionnaire adapted from Wilms et al., [22] to collect data on: (i) demographics (age, sex, education level, years of veterinary practice), (ii) decision-making process relating to management of clinical mastitis,

(iii) antibiotic use practices (brands, frequency), and (iv) attitudes and perceptions towards udder health and mastitis management [27]. For the latter, answers were given as a four-point Likert scale; strongly agree, agree, disagree, and strongly disagree. The survey tool was tested with three external AHPs and adapted based on their feedback. Consenting AHPs completed the validated questionnaire using Open DataKit Collect software. The final questionnaire is accessible at [28], and completion took approximately 30 minutes.

Data analysis

Descriptive statistics were generated for all data including frequencies and percentages for categorical variables and means, medians, and ranges for quantitative variables. To determine if demographic characteristics of respondents were associated with the number of cases treated per month a Poisson generalized linear regression (GLM) analysis was performed using the 'glm' function in stats package [29] in R.

Next, a scoring system was developed to measure attitudes and perceptions of AHPs to udder health and mastitis management. First, descriptive statistics were computed, and internal consistency and reliability analysis estimated using Cronbach's alpha, with a value > 0.70

Table 1 Participant demographics

Item	*N* (%)
Number of respondents	114
Level of Animal Health Training	
Bachelor of Veterinary Medicine	4 (3.5)
Bachelor of Science in Animal Health	20 (17.5)
Diploma in Animal Health	42 (36.8)
Certificate in Animal Health	47 (41.2)
None	1 (0.9)
Age (Mean, range)	32.1, 21–61
Gender	
Male	67 (58.8)
Female	47 (41.2)
Years in practice (Mean, range)	6.9 (range: 1–40)
Employment type	
Self employed	79 (69.3)
Farmer association	12 (10.5)
Veterinary retail store	9 (7.9)
Vet practice/clinic	7 (6.1)
Government	7 (6.1)
Number of mastitis cases treated per month (Mean, range)	24.4 (1-120)
Use of antibiotics to treat mild clinical mastitis	
Yes	112 (98%)
No	2 (2%)
Use of antibiotics to treat severe clinical mastitis	
Yes	113 (99%)
No	1 (1%)

indicating good consistency of item responses. Next, we tested whether the two primary assumptions of Item response theory (IRT): unidimensionality and local independence were met. The unidimensionality of a scale based on the questions was evaluated using confirmatory factor analysis (CFA). We ran CFAs model using a Weighted Least Squares Mean and Variance Adjusted estimator suitable for ordinal data. Model fit was evaluated using the standardized Root-Mean-Square Error of Approximation (RMSEA), Comparative Fit Index (CFI), Tucker Lewis Index (TLI), and Standardized Root-Mean-Square Residual (SRMR). Sufficient evidence for unidimensionality and thus an adequate model fit was considered if CFI > 0.95, TLI > 0.95, RMSEA < 0.06 and a SRMR < 0.08 [30] (Supplemental Table S1). Four items with poor fit were removed from further analyses (Supplemental Table S2). We used the Yen's Q3 statistic to test local dependence with residual correlations > 0.2 indicating violation [31]. After evaluation of the IRT assumptions, a logistic Graded Response Model (GRM) which is an IRT-model for ordered polytomous response data, was used to fit the item response data via the *ltm* package [32]. The GRM estimates two parameters: the discrimination parameter for each item (α) and the difficulty (β) threshold for each response category within the item. Both discrimination and difficulty threshold parameters are represented graphically as item characteristic curves (ICCs) (Supplemental Figure S1) and item information functions (IIF) (Supplemental Figure S2). Attitude scores for each individual were derived using Expected A-Posteriori method [33] using the *factor.scores* function in *ltm*. After constructing a score of udder-health attitudes, we a used linear regression model in R stats package to model whether socio-economic demographics influence the perceptions of AHPs. Explanatory variables in the model included length of practice, employment status, highest level of animal health training, monthly number of mastitis cases treated, and whether AHPs used antibiotics to treat mild cases (Table 1). Analyses were performed using the *stats* package [29] with significance assessed using Wald χ2-tests in *car* package [34]. All analyses were conducted in R v4.4.0 with P values < 0.05 considered statistically significant.

Results

Demographic characteristics of study participants

A total of 114 AHPs participated in the study, of whom 58.8% were male with an average age of 32.1 years (range 21–61 years, Table 1). Most respondents (95%) were veterinary paraprofessionals and only four (3.5%) were veterinarians as defined by Kenyan law. One respondent lacked any formal animal health training and certification yet was still considered an AHP. The mean length of practice as AHP was 6.9 years (range 1–40 years), and most were self-employed/private (69.3%). On average, AHPs managed 24.4 cases of mastitis per month (range 1-120), with self-employed individuals and those with more years of veterinary practice handling significantly more cases per month (OR = 1.23, 95% CI = 1.13–1.34; P value < 0.001 and OR = 1.01, 95% CI = 1.00-1.02, P value < 0.001, respectively, GLM).

Treatment decisions

We evaluated the AHPs' decision-making process for initiating antibiotic treatment for mastitis. Clinical signs in the udder and milk, such as udder swelling and heat, along with clots and pus in milk, or the cow's general appearance, were the most frequently considered factors (93%, $n = 106$) by AHPs when initiating antibiotic treatment. The outcome of a diagnostic test was the second most important factor reported by 44.7% ($n = 51$) of AHPs, while history of previous mastitis cases in the farm or the cow was the third most important factor reported by 21% ($n = 24$) of AHPs. California Mastitis Test (CMT) was the most used diagnostic test by 94% ($n = 48$) of the 51 AHPs who considered diagnostics important for treatment decision making, while the remaining 6% used either microbiology or somatic cell counts. The high cost of testing and the reluctance of farmers to pay for testing were the main reported hindrances to diagnostic use.

Almost all (99.1%), 80%, and half of the respondents (50%) reported that they always started antibiotic treatment immediately when they suspected that the mastitis case was either severe (i.e. showing signs of systemic illness), moderate (displaying inflammatory signs of the infected quarter), or mild (with visible changes to the milk only), respectively (Fig. 1).

Antibiotic use patterns

We asked AHPs to list the different antibiotic brands they used to treat mastitis. In total, 30 unique brands were mentioned, representing 19 antibiotic compounds belonging to nine classes. Two-thirds (66.7%) of the unique brands were injectables, while the remaining one-third (33.3%) were intramammary formulations. A third of the brands ($n = 9$) contained more than one antibiotic, with three brands containing three antibiotics (Supplemental Table S5). Overall, penicillin (31.9% of mentions), streptomycin (30.1%), gentamycin (23.7%), and enrofloxacin (11.8%) were most frequently used (Fig. 2).

Supportive treatments

A third of AHPs reported that they always used non-steroidal anti-inflammatory drugs (NSAIDs) in combination with antibiotics in the management of mastitis and a further 40% reported to practice this sometimes. The reported NSAIDs included diclofenac (32.9%), dexamethasone (24.7%), phenylbutazone (21.9%), meloxicam (12.7%) and diphenhydramine (8.2%). Less than 1% of AHPs reported that they use NSAIDs alone. Other supportive treatments frequently used included, regular milking and massage of the udder (Supplemental Figure S3).

Analysis of attitudes on reported mastitis treatment behaviour and socio-demographics

Most AHPs acknowledged that good udder health and strong farmer engagement were essential in reducing the incidence of mastitis and the need for antibiotic treatment (Supplemental Table S3, Supplemental Figure S4). We created a score to measure AHPs' attitudes from a set of ten questions. The estimated item parameters of the ten questions retained in the final GRM model are displayed in Supplemental Table S4. The statement about the importance of farmer's trust in AHP's knowledge (Item 8) had the highest degree of discrimination with a slope estimate of 2.04. Conversely, the statement suggesting that advice from multiple AHPs decreases implementation (Item 10) had the weakest discrimination, with a slope estimate of 0.14. After establishing an

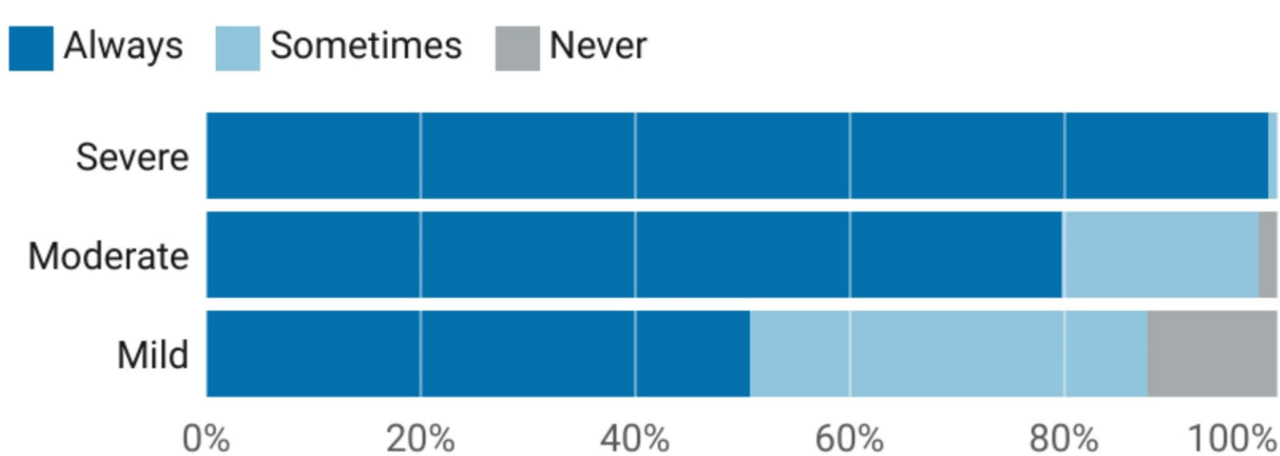

Fig. 1 Responses about treatment decisions based on perceived severity of mastitis cases

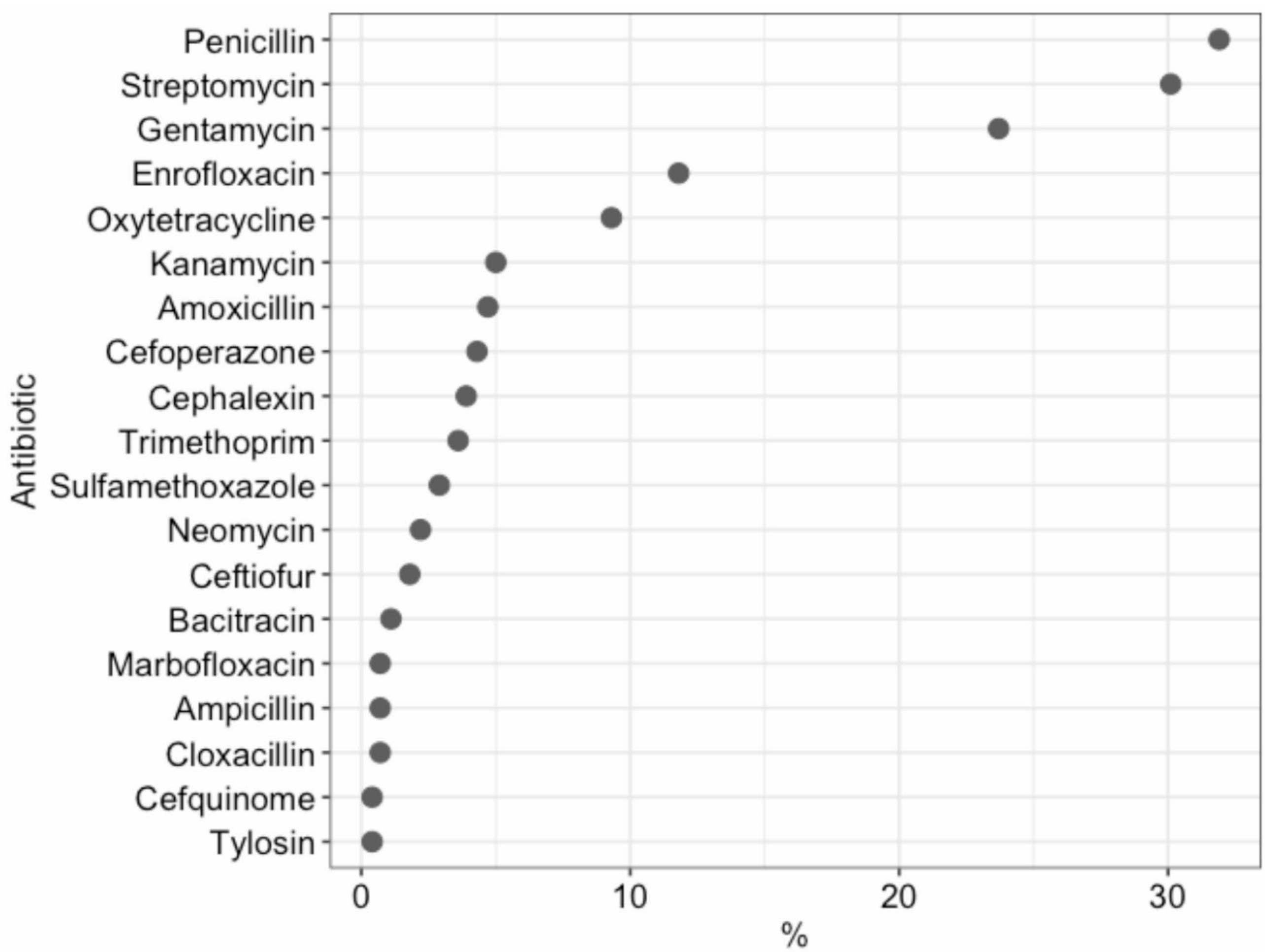

Fig. 2 Antibiotics reported as used by AHPs to treat mastitis

attitude score for each AHP, we analysed it in relation to the set of socio-demographic and behavioural variables (Table 1). Our analysis showed that AHPs who attended more mastitis cases were significantly more likely to have higher scores on attitudes towards good udder health (β: 0.01, 95% CI: 0.00-0.02, p-value: 0.01). Similarly, AHPs who did not use antibiotics to treat mild mastitis cases were significantly more likely to have higher scores on attitudes towards good udder health compared to those who used antibiotics (β: 0.75, 95% CI: 0.09–1.41, p-value: 0.02) (Fig. 3; Table 2).

Discussion

This study describes factors influencing decisions by AHPs to treat different presentations of mastitis with antibiotics, and types of antibiotics used in smallholder dairy systems in Kenya. We found that the decision to initiate antibiotic treatment was largely based on presentation of clinical factors, with little or no use of microbiological diagnostic testing. Antibiotics, belonging to various classes, were used empirically, mostly as systemic application, for all severities of mastitis without prior knowledge on the pathogen or antibiotic susceptibility.

Our findings that treatment decisions are mostly made based on clinical presentation are not unexpected and align with a recent study showing that 91% of Danish veterinarians relied on clinical examination before using antibiotics [22]. An interplay of multiple factors influences AHPs' treatment decision-making and the choice to use antibiotics. These include the severity of infection, farm- and cow-level history, causative agent, socioeconomic and behavioural factors such as the availability of diagnostic tests, economic considerations, and AHP knowledge and practices related to antibiotic use [21]. In resource limited dairy production regions, like our study site, quantifying the relative contribution of these factors to treatment decision-making is challenging. Our study does not attempt to disentangle them but provides some insights.

Mastitis diagnostics to inform treatment decisions has been widely adopted in a number of countries and shown to contribute to targeted use of antibiotics and

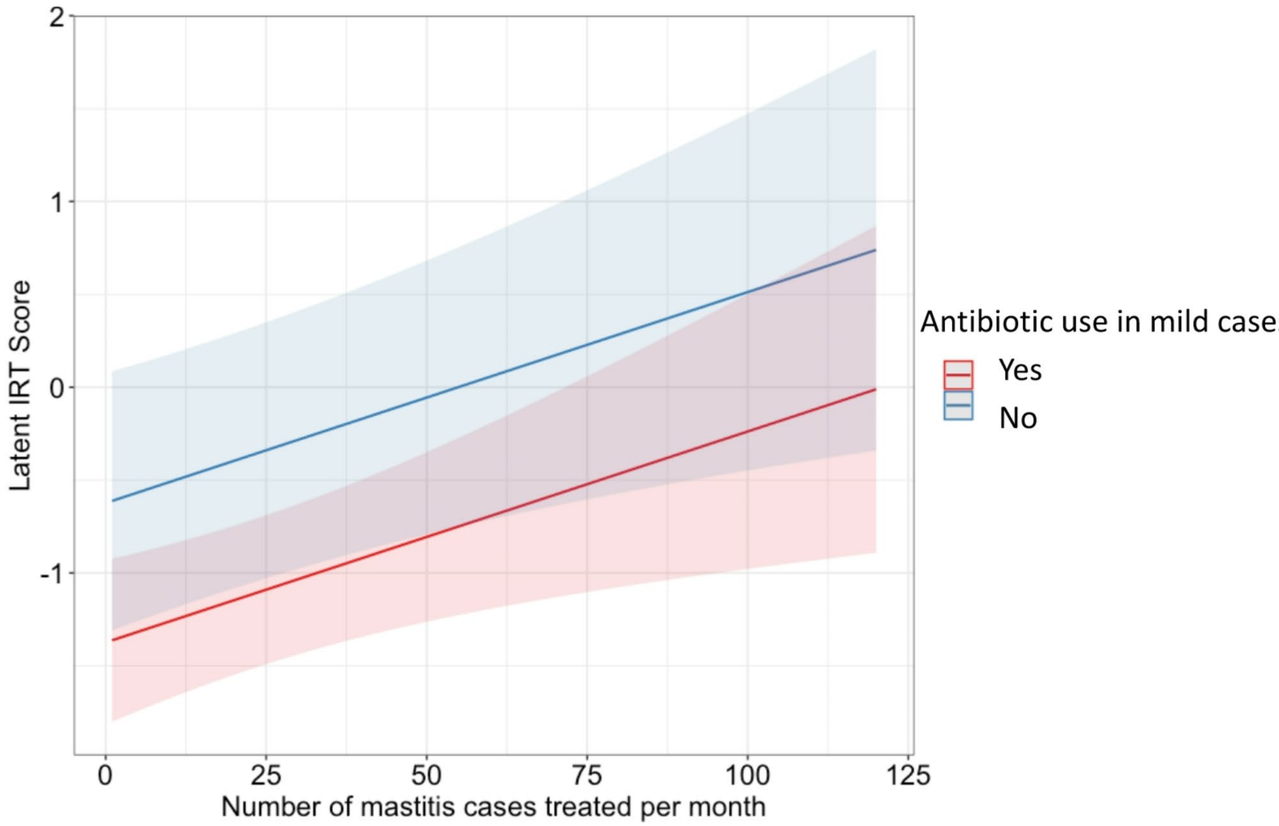

Fig. 3 Fit of the generalized linear model relating the effect of antibiotic use in mild mastitis cases on the relationship between AHPs attitude scores and the number of mastitis cases treated in a month, while keeping all other covariates constant. The shaded area indicates the 95% confidence interval

Table 2 Results of the generalized linear model illustrating the association between attitude score and various sociodemographic and behavioural variables

Predictors	Estimates	CI	*p* value
Length of practice (years)	0	-0.04–0.03	0.79
Employment status: no (reference: yes)	-0.32	-0.79–0.16	0.18
Highest level of qualification (reference: BVM)			
BSc Animal Health	-0.85	-2.16–0.46	0.2
Diploma Animal Health	-0.69	-1.93–0.55	0.27
Certificate Animal Health	-1.12	-2.34–0.09	0.07
No Animal Health training	-2.31	-4.88–0.26	0.08
Number of mastitis cases treated per month	0.01	0.00–0.02	0.01
Does not treat mild mastitis cases with antibiotics (reference yes)	0.8	0.09–1.51	0.02

reducing antibiotic use [8]. Similar to previous findings [15, 35], CMT was the most preferred test by AHPs due to its cost-effectiveness and ease of use but CMT is only indicative of inflammation and does not confirm the presence of a bacterial infection and if the antibiotic of choice would be effective. Affordability is a critical factor in smallholder settings where the combined cost of treatment including the cost of veterinary services and diagnostic testing, which are not always readily available to farmers, can be higher than the cost of antibiotics alone [36]. As such, farmers frequently purchase and administer antibiotics with or without AHP or diagnostic guidance [24]. Furthermore, Kenya lacks standardized guidelines for mastitis treatment and diagnosis, thus, AHPs rely on their animal health training, which can vary across institutions, and their own field experience. To that end, it is therefore important for Kenya's veterinary authorities to consider developing and adopting national standardized treatment guidelines to assist practitioners in making informed treatment decisions for specific clinical conditions and enforcing regulations on antibiotic access and use.

Management of mastitis is multifactorial, often needing a multi-pronged approach, with improving udder health central to the control strategy [37, 38]. In our study, AHPs recognised their role in advising farmers on best practices to improve udder health with proactive engagement with farmers; however, practices were largely curative than preventive. This is in part due to the fact that AHPs earn a significant portion of their income from dispensing antibiotics, thus disincentivizing preventive approaches [39]. This highlights the need for continued education of AHPs on antibiotic stewardship, better incentives for behaviour change, and stricter regulations promoting prudent use and limiting profits from antibiotic sales [40, 41]. These education programs that promote better herd health should be coupled with communication training to develop skills on enhancing farmer participation and shared decision-making [42]. Such skills have received less focus in continuing professional development in Kenya. Further, the finding that AHPs with a larger farmer client base and those who refrained from using antibiotics in mild mastitis cases were more receptive to udder health practices (i.e. higher attitude scores) underscore the importance of tailoring interventions programs to individual AHP needs.

In this study, β-lactams and aminoglycosides were the most commonly used antibiotics, which is also reflective of the commonly reported resistance among bacteria associated with mastitis in Kenyan dairy farms [15, 43]. Two thirds of all antibiotics reported in our study were available and used for systemic treatment, with only a third for local intramammary treatment. The preference for parenteral administration of antimicrobials in treating mastitis is common [44] because of the broad spectrum activity which is beneficial when you don't know which pathogen is the causative agent and the perceived risk of septicaemia, of which there is little evidence linking mastitis to septicaemia [45]. Moreover, it is possible that AHPs prefer systemic antibiotics for profitability reasons, as farmers have access to intramammary formulations and don't need AHP intervention for prescription or administration. Studies that estimate quantities of antibiotics at the farm level, for example, using garbage can audits [46–48], represent critical steps toward antibiotic stewardship, but just a handful exist in smallholder dairy settings [49]. NSAIDs are frequently used in the management of clinical mastitis [50–52], either alone or in combination with antibiotics, and our findings align with this, similar to a comparable Danish study [22].

Our study has several limitations. Our findings reflect the perspectives of veterinary paraprofessionals rather than veterinarians, mirroring the animal health dynamics in Kenya. Similar to other sub-Saharan African countries, paraprofessionals play a crucial role in providing accessible and affordable animal healthcare. Further studies in diverse epidemiological settings are needed to generalise these findings. In the absence of lists of AHPs, it was not possible to apply a random sampling approach. Studying behaviour and attitudes using questionnaire-based surveys is susceptible to a certain degree of social desirability bias, whereby respondents prefer to select the best answer over the true answer. While our attitude scale provides some insights into AHP perceptions of udder health, a context-specific scale for LMICs is needed, possibly co-created with veterinary stakeholders, while maintaining convergent and discriminant validity. Some mastitis cases treated with antibiotics may have been mild clinical cases misclassified as subclinical, reflecting common on-farm practices where farmers seek treatment upon noticing a drop in milk production. This aligns with the broader issue that AHPs may be treating more cases than would be expected based on clinical prevalence estimates. While our study does not explicitly differentiate between mild clinical and subclinical cases, these findings highlight the possibility that AHPs may also be administering antibiotics to cows with subclinical mastitis, a point worthy of further investigation.

Conclusion

Our findings indicate that AHPs primarily rely on clinical signs and herd history, with limited to no microbiological diagnostic support to guide antibiotic treatment of mastitis. Moreover, standardized mastitis treatment guidelines are lacking, as well as the incentives aimed at reducing irrational use, leading AHPs to make antibiotic treatment decisions (the decision to use and the choice) without evidence. This study highlights the need for mastitis management tools, similar to the National Mastitis Council *5-point mastitis control plan*. There are also opportunities for adoption of regulations that limit the ability for AHPs to profit from sales of antibiotics while increasing monitoring of prescriptions.

Abbreviations

AHPs	Animal health providers
KVB	Kenya Veterinary Board
IRT	Item response theory
CFA	Confirmatory factor analysis
RMSEA	Standardized Root-Mean-Square Error of Approximation
CFI	Comparative Fit Index
TLI	Tucker Lewis Index
SRMR	Standardized Root-Mean-Square Residual
GRM	Graded Response Model
ICCs	Item characteristic curves
IIFs	Item information functions
GLM	Generalised linear regression
NSAIDs	Non-steroidal anti-inflammatory drugs
CMT	California Mastitis Test

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12917-025-04662-7.

Supplementary Material 1

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Author contributions

Conceptualization– D.M.M, A.M; field investigation - E.L.I, S.N, H.K, A.A, S.M, A.C, statistical analysis - D.M.M; writing - original draft- D.M.M; writing - reviewing and editing - all. All authors read and approved the final manuscript.

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Data availability
The survey tool and data collected from the animal health prroviders survey have been made publicly available and can be accessed at (28).

Declarations

Ethics statement and consent to participate
The collection of data adhered to the legal requirements of the Government of Kenya. Ethical approval for human data collection was obtained from the ILRI Institutional Research Ethics Committee (ILRI-IREC2023-36). Written informed consent was obtained from animal health providers.

Consent to publish
Not applicable..

Competing interests
The authors declare no competing interests.

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