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Cattle production systems characteristics and their influence on antimicrobial use, alternatives, and resistance in Nigeria

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Abstract

Background

Nigerian cattle production ranks 6th in Africa and 16th globally, constituting an important livelihood for many of its population. However, several health challenges affect the productivity of cattle herds, influencing antimicrobial use (AMU) and antimicrobial resistance (AMR). In this study, we attempt to characterise the cattle production system and its influence on health management practices. We also examined factors influencing farmers' use of antimicrobials and antimicrobial alternatives (vaccines, ethnoveterinary remedies, etc.) A mixed-methods approach, comprising semi-structured questionnaires (n = 736) and stakeholder focus group discussions, was employed.

Results

The majority of cattle production (78%) is extensive, with a median of 50 cattle per herd. Diseases of major burden are mastitis, gastrointestinal and respiratory diseases. Animal health was predominantly self-managed by farmers rather than using government or private veterinary services. Less than 5% of farmers regularly vaccinate their herds. Farmers reported difficulties accessing effective vaccines and largely relied on government veterinarians for immunisation services. Para-veterinarians are regularly consulted for treatment due to a reported unavailability of licensed veterinarians. More farmers used antibiotics (51%) than ethnoveterinary remedies (27%) within the last three months. Farmers stated they used herbs for diseases with limited effective antimicrobial options, such as foot-and-mouth disease (FMD) and contagious bovine pleuropneumonia (CBPP). 53% of farmers never used ethnoveterinary remedies primarily due to low awareness and difficulty in procuring herbs. Farmers also indicated that they were beginning to lose ethnoveterinary knowledge previously passed down from older generations due to an increasing dependence on antimicrobials. Farmers have poor knowledge and attitudes regarding the impact of AMU in cattle and the risk of AMR.

Conclusions

Future research should focus on identifying and preserving ethnoveterinary knowledge through culturally appropriate means. Efforts should be made to assess the efficacy of available herbs. Access to governmental veterinary services, agricultural extension agents, and vaccines should be improved for farmers. Finally, available legislation surrounding AMU should be implemented more rigorously, and antibiotic sales by unlicensed drugstores must be strictly regulated.

Highlights

- The most common diseases affecting cattle are FMD, CBPP, and mastitis.

- Antibiotics (51%) are more frequently used than ethnoveterinary remedies (27%) in health management.

- Farmers' use of vaccines is affected by a lack of access to effective vaccines.

- 53% of farmers reported non-use of ethnoveterinary remedies primarily due to difficulty in procuring herbs

- Antibiotics are freely accessible and used without prescription by farmers.

1. Background

Cattle production plays a crucial role in maintaining global economic balance and sustaining the livelihoods of millions of families worldwide. Nigeria is a major cattle producer in Africa, with an estimated cattle population of 18 to 22 million, including about 1.5 million dairy cows and 13.3 million beef cattle (1). Nigeria's cattle production systems range from pastoral herding of locally bred cattle on natural pastures to an intensive confinement system with formulated feed for crossbred cattle (2). The pastoral system (run by pastoralists from the Fulani tribe) accounts for approximately 90% of Nigeria's cattle production (3). Cattle production in Nigeria is constrained by a wide range of health challenges. Endemic diseases of significant economic burden include African animal trypanosomiasis (AAT), bovine tuberculosis, contagious bovine pleuropneumonia (CBPP), and foot-and-mouth disease (FMD) (1). Cows also suffer from mastitis, a leading health problem that causes substantial reduction in milk production, increased culling rates, and loss of replacement stock for farmers (4–6). Mastitis persists in two forms: clinical and subclinical. Clinical mastitis manifests as physical changes in the udder and milk and is thus the more obvious form. On the contrary, subclinical mastitis is not physically detectable. However, it is associated with higher milk production losses and is more prevalent, being confirmed in 89.50% of dairy cattle in one Nigerian local government area (6).

Generally, disease outbreaks in Nigerian cattle are further exacerbated by the predominant production characteristics in the country. The pastoral system consists of long-distance cattle transhumance and free-range grazing, factors which facilitate disease transmission between herds (3, 7–9). There is also limited access to vaccinations and veterinary services, reducing farmers' capability to institute preventive measures and/or mitigate disease outbreaks with effective strategies before substantial morbidity and mortality occurs (8, 9).

Disease challenges are usually managed by Nigerian cattle farmers through the administration of self-prescribed antimicrobials, particularly antibiotics. In this regard, antimicrobial overuse is common, triggered by factors such as high frequency of disease outbreaks, poor governmental regulatory control guiding nonprescribed antimicrobial use (AMU), and farmers being unfamiliar with correct dosage prescriptions. Alhaji *et al.* (2023) reported that over 75% of beef cattle farmers in Northern Nigeria did not follow any sort of antimicrobial dosage instructions prior to use, and 84% of semi-intensive farms did not observe withdrawal periods (10). In high-income countries with stricter regulations, high AMU is still prominent, fuelled predominantly by recurrent disease outbreaks. For instance, mastitis disease is estimated to account for 60–70% of AMU in dairy cattle (11–13). In low-to-middle income countries (LMICs), including Nigeria, levels of AMU are further increased through the use of antibiotics as growth promoters and prophylactics. For instance, 24% of cattle pastoralists in North-Central Nigeria reported

using antimicrobials to prevent mastitis in lactating cows (14, 15). The overuse and misuse of antimicrobials have fuelled the development of antimicrobial resistance (AMR), a major global health threat across the human, animal, and environmental sectors (15). AMR reduces the efficacy of existing antimicrobials against prevalent infectious diseases, rendering humans and animals susceptible to microbial infections and largely increasing mortality rates. This significantly undermines current bioscientific progress in terms of microbial therapy (16). In Nigeria, it was found that 11.9% of milk isolates from mastitic cows contained methicillin-resistant *Staphylococcus aureus* (MRSA), a resistant bacterium also prevalent in humans, albeit with possible strain differences (17).

While antimicrobial misuse can be partly constrained in LMICs like Nigeria through improved regulations, the threat of AMR also necessitates unique solutions against the complex problem of AMR. One of such potential solutions is the discovery and use of antimicrobial alternatives (ATAs) in health management for cattle production. ATAs include a variety of tools and strategies that allow for the prevention or treatment of diseases without using antibiotics. These include relatively popular strategies such as vaccination and biosecurity, but relatively novel strategies, including bacteriocin, nanopeptides, and phage therapy (18). Studies in China and Ireland have observed that bacteriocin administration provided some level of efficacy towards the prevention and treatment of bovine mastitis (19, 20). Currently, there are very few studies being conducted in Nigeria to assess the effectiveness of these novel ATAs in the health management of cattle. However, Nigerian farmers have traditionally been known to employ ethnoveterinary remedies such as medicinal plants in ruminant health management (21). This practice of using medicinal plants is also prevalent among other countries worldwide (3, 21). A Chinese review of herbal medicinal products noted that, in addition to possessing antibacterial activity, some herbs also improve growth performance and meat quality through their antioxidant properties (22). A recent review on Nigerian ethnoveterinary practices documented several plants presently being used to manage cattle diseases, including AAT and FMD. The majority of these plants, however, remain poorly documented, with insufficient information regarding their use and factors influencing farmers' choice of them. However, a review on ethnoveterinary remedies in Nigeria identified that there was possible distrust on farmers' parts regarding ATAs, due to the ease and proven effectiveness of conventional antimicrobials (21).

Generally, there are clear evidence gaps regarding the use and acceptability of ATAs in Nigeria, as well as factors influencing farmers' choices between antibiotics and available ATAs. This study presents an explanatory sequential mixed-methods approach aimed at exploring the cattle production characteristics in Nigeria, while understanding how these may shape health management decisions and the use of antimicrobials and ATAs.

2. Materials and methods

2.1. Study area and sample size:

This study was conducted in two predominantly cattle-farming states in North-Central Nigeria: Kwara and Niger (Fig. 1). Kwara is located between latitude 8° 05’ N and 10° 05’ and longitude 2° 50’ E to 6° 05’ E, while Niger lies approximately between 8° 00' N and 11° 30' N latitude and 3° 30' E to 7° 40' E longitude.

The target populations were cattle farmers, herders, and farm workers within the study area. The sample size was determined to be 321 per state using OpenEpi, based on a 50% proportion, a 6% margin of error at 95% confidence interval, with a 20% attrition rate, and a design effect of 1 (for cluster surveys). Ultimately, a total of 736 respondents were recruited in both states for the questionnaire survey. A multistage random sampling was implemented, with the first stage involving a selection of three Agricultural Development Zones (ADPs) from each state. Thereafter, the following pastoral communities and organised farm settings from ADPs were randomly selected: Amoyo, Lajiki, Amberi/Ijagbo, Ajase-Ipo, Kaiama, Ilesha Baruba, Okuta, Kageji, Fufu, Afon, Oke Oyi, and Tafatafa (in Kwara State), Bida, Agaie, Bosso, Edati, Gbako, Gurara, Katcha, Lapai, Lavum, Agwara, Mokwa, and Suleija from Niger State. Finally, 30–31 cattle herders were randomly selected from each community.

2.2. Questionnaire administration, quantitative data management, and analysis

A semi-structured questionnaire was developed and consisted of five sections: (a) farmers’ socio-demographics, (b) farm characteristics, (c) livestock management practices, (d) animal health management practices, and (e) knowledge, attitude, and practices (KAP) of AMU and AMR (Additional File 1). The questionnaire was developed in English and conducted by researchers who were bilingual or trilingual as English/Yoruba, English/Fulani, English/Fulani/Yoruba speakers. The questionnaire was piloted in one pastoral community (n = 10 participants), after which necessary changes were made before full deployment in the field.

Data was collected between January 2025 and May 2025 through face-to-face interviews, and responses were recorded on paper or electronic forms, depending on available Internet connection. Responses were checked daily for completeness and subsequently input into KoboToolbox (v.2.024.36) with validation checks to minimize entry errors.

Data analysis began with an initial data cleaning on Microsoft Excel, during which missing values and logical inconsistencies were identified. The cleaned data were then imported into R (v. 4.5.1) and summarised through descriptive statistics. Findings were summarised with frequencies, proportions, averages, and ranges. For the KAP section, a total of 4 knowledge questions, 10 attitude questions, and 12 practice questions were asked. Knowledge questions were scored 1 and 0 for ‘Yes’ and ‘No,’ respectively. Attitude questions were scored on a 3-point Likert scale to assess the level of agreement (0 = Disagree/ I don’t know, 1 = Neutral, 2 = Agree). A similar pattern was used for attitude questions (0 = Not likely, 1 = Likely, 2 = Most likely). Negative questions were scored in reverse. This led to a total maximum section of 4, 20 and 24 for K, A and P respectively. To enable relative comparison within the

study group, we obtained a data driven cutoff using the mean, consistent with other KAP studies (23, 24). The above-mean section included scores above the population mean (≥ 1.22 for knowledge, ≥ 9.25 for attitudes, and ≥ 9.34 for practices). As questions were all scored with whole numbers, this translated to ≥ 2 for knowledge, ≥ 10 for attitudes, and ≥ 10 for practices. Based on this categorical grouping, KAP results were further subjected to inferential analysis. First, Pearson's chi-square test was conducted to determine associations between the demographics of farmers and KAP scores. Afterwards, KAP categories with significant associations at the $p < 0.05$ level were included in a multivariate logistic regression model to examine the independent effects of each association.

2.3. Focus group discussion (FGD), qualitative data management, and analysis

After the analysis of the survey data, FGD was conducted in October 2025 to provide further insights and as a means of methodological triangulation. This involved the recruitment of 23 stakeholders, including farmers, veterinarians, para-veterinarians, and butchers/meat vendors. Stakeholders were purposely selected to ensure demographic diversity in terms of gender, age, herd size, and state of origin. Participants were split into three round tables; for each table, a trained moderator was assigned to lead the discussion with the aid of an interview guide. A co-moderator/note taker was taking notes and, when possible, recording the conversation for each table. Before discussions, consent was obtained from all participants, and confidentiality assurances were communicated. The questions asked focused on disease prevalence and farmers use of antimicrobials and ATAs (Additional File 2). ATAs here are defined as any substance other than antimicrobials used for the prevention and treatment of diseases (vaccines, ethnoveterinary remedies, other materials). Alternative therapeutic agents are agents employed only for treatment only (e.g., ethnoveterinary herbal remedies).

Audio recordings were transcribed manually and with the use of the TurboScribe software. Supplementary notes from the co-moderator captured nonverbal cues and group dynamics. Thereafter, analysis was conducted based on Braun and Clarke's guide to reflexive thematic analysis (25). Analysis was deductive, with a semantic coding approach. First, transcripts were read multiple times to allow for data familiarisation. Initial codes were generated by two independent researchers. Afterwards, researchers came together to search for potential themes. Final themes were decided on after multiple rounds of discussions and reflections. A systems map was created using Lucidchart to illustrate the interactions between these themes and how they influenced farmers' health management decisions.

3. Results

3.1. Demographic Characteristics

The demographic characteristics of 736 respondents are summarised in Table 1, and the geographic distribution in Fig. 2. More than half of the respondents (56.8%) were aged between 31 and 50 years. Most respondents (97.7%) were male. Most (70.1%) had no formal education, and 88.0% were farm

owners. More than 90% of farmers had herds of less than 75 animals, with a median of 49 animals per herd.

Table 1
Demographic characteristics of respondents.

Demographics	Number (%) (n = 736)
Age (Years)	
< 20	9 (1.22)
21–30	113 (15.35)
31–40	216 (29.35)
41–50	202 (27.45)
51–60	140 (19.02)
> 60 years	56 (7.61)
Gender	
Male	719 (97.69)
Female	17 (2.31)
State	
Kwara State	338 (45.92)
Niger State	398 (54.08)
Level of Education	
No formal education	516 (70.10)
Primary School	95 (12.91)
Secondary School	67 (9.10)
Tertiary Education	58 (7.89)
Role on Farm	
Owner	411 (55.84)
Owner and manager	237 (32.20)
Manager	39 (5.30)
Worker	49 (6.66)
Number of years in cattle farming	
≤ 10	177 (24.05)
11–20	194 (26.36)
21–30	195 (26.49)

Demographics	Number (%) (n = 736)
31–40	108 (14.67)
> 40	62 (8.42)
Herd size of animals	
≤ 25	150 (20.38)
26–50	249 (33.83)
51–75	178 (24.18)
75–100	91 (12.36)
> 100	68 (9.24)

3.2. Farm Characteristics and Husbandry Practices

Almost all farmers (99.1%) kept indigenous cattle in their herds, while relatively few (11.6%) kept foreign crossbreds. Herds were typically composed of more females than males, with cows above reproductive age (> 2 years) comprising the largest herd segment (Additional File 3). Herds (67%) were mostly kept in an open-housing system without protective netting, and most (78%) were reared in an extensive grazing system (Table 2). More farmers (57.1%) sourced replacement animals solely from their herds rather than purchasing new stock. Less than a quarter of participants reported having farm records such as feeding, reproduction, or vaccination records.

Table 2
Husbandry practices of farms

Husbandry practices	**n (%)**
Housing systems	
Open housing system without netting	493 (66.98)
Open housing system with netting	211 (28.67)
Closed housing system	32 (4.35)
Feeding practices	
Extensive system	574 (77.99)
Semi-intensive system	131 (17.80)
Intensive system (total mixed ration)	31 (4.21)
Purchase replacement animals?	
Yes	316 (42.93)
No	420 (57.07)
Use of community grazing lands	
Yes	331 (44.97)
No	405 (55.03)
Record keeping	
Feeding	95 (12.91)
Reproduction	157 (21.33)
Veterinary Health Products	11 (15.08)
Vaccination programs	159 (21.60)

3.3. Prevalent Diseases and Health Management Practices

Gastrointestinal diseases, respiratory diseases, and mastitis were identified as the most prevalent diseases affecting cattle over the last year by 41, 36, and 23% of farmers, respectively (Additional File 4). Gastrointestinal diseases experienced were helminth infections such as fasciolosis, while respiratory diseases included FMD and CBPP. Farmers lost a lot of money to diseases, due to loss in animal value and treatment costs. A farmer said of mastitis: *"(The cow was initially at a) ₦900,000 purchase price but we sold at ₦600,000 because of mastitis." – R08, Cattle farmer.* Treating mastitis cost farmers an average of ₦4,807 per case, while CBPP was reported to cost an average of ₦3,033. Fasciolosis cost farmers ₦13,500 per case.

Only 49.5 and 0.9% of farmers had vaccinated their animals against CBPP and FMD, respectively (Table 3). 50.8% of farmers reported that they took no action to prevent mastitis in their herd. 44.7% of farmers stated they believe mastitis occurred due to poor management, while 39.5% were not certain of the cause. To detect diseases, most farmers (> 75%) relied on personal experience and physical observation, with much less dependence (< 25%) on veterinary or para-veterinary services (Fig. 3).

Table 3
Health management practices reported by study participants.

Health management	**n (%)**
Frequency of herd vaccination	
Never	218 (29.62)
Sometimes	484 (65.76)
Always	34 (4.62)
Vaccination against specific diseases	
Contagious Bovine Pleuropneumonia (CBPP)	365 (49.59)
Anthrax	347 (47.15)
Foot-and-mouth disease (FMD)	7 (0.95)
Methods used to protect animals from mastitis	
Nothing	374 (50.82)
Proper management	314 (42.80)
Conventional treatment (antibiotics)	25 (3.40)
Local alternative treatment	22 (2.99)
Methods used to currently detect mastitis (multiple responses)	
Observation	710 (96.48)
Laboratory tests	41 (5.58)
Actions taken when mastitis is suspected	
Consult a veterinarian or para-veterinarian	310 (42.12)
Use self-prescribed antibiotics	164 (22.28)
Local alternative treatment	100 (13.57)
Isolate affected animal	29 (3.94)
Cull affected animal	3 (0.41)
Nothing	139 (8.89)
What farmers do with milk from animals under treatment with antibiotics (n = 646)	
Use it (consumption, sales, calves)	440 (72.76)
Discard it	179 (27.71)
Do you know any alternative therapeutic agents?	

Health management	n (%)
Yes	205 (27.85)
No	531 (72.15)
Do you use alternative therapeutic agents?	
Yes	203 (27.58)
No	388 (52.72)
I can't remember	145 (19.70)
Use of animal health service providers over the last three months	
Yes	376 (51.08)
No	360 (28.92)
Antibiotic self-prescription over the last three months	
Yes	377 (51.22)
No	280 (38.05)
I can't remember	79 (10.73)

51.1% of farmers had consulted different animal service providers at least once within the last three months. Figure 4 summarises the health provider, service rendered, and the frequency of consultations. Health providers were mostly consulted for treatment services rather than vaccination or other preventive services. For vaccination and preventive treatment, farmers relied largely on government veterinarians. For treatment, farmers relied mostly on para-veterinarians and drugstore vendors.

Most farmers (51.2%) had self-prescribed antibiotics to their herds over the last three months. The most frequently prescribed antibiotics were oxytetracycline (35.6%), tylosin (32.9%), and penicillin (21.2%) (Fig. 5). Farmers often purchased these drugs from livestock markets and unlicensed para-veterinarians, but also from veterinary doctors and licensed veterinary stores (Additional File 5). The cost of antibiotics ranged from ₦15,000 to ₦45,000. The majority of farmers (72.8%) continued to consume and sell milk from cows undergoing antibiotic treatment.

20.7% of farmers had used herbal plants for therapeutic treatment within the past three months. Herbs used included *dongoyaro* (Hausa name for neem plant or *Azadirachta indica*), bitterleaf (*Vernonia amygdalina), àgánwò/kahi/modachi* (Yoruba, Fulani, Hausa names for mahogany hardwood), *Gapde* (Hausa name for African birch), *Bagaruwa* (Hausa name for thorny acacia), *Kadanya* (Hausa name for shea butter tree), and *ígí ìpín* (Yoruba name for sandpaper tree). Table 4 presents some of the herbs identified and the diseases farmers utilised them against. Two farmers described their use of mahogany hardwood in treating mastitis here:

“We use modachi (the Hausa name). We dry the stem and seeds, then pound them till it becomes powder and add ginger. We put it in the (nostrils) of lactating cows.” - R15, cattle farmer.

“The tree is called àgánwò in Yoruba and it’s very bitter. We will grind it and mix it with salt and give it orally. It prevents mastitis.” - R18, cattle farmer.

Table 4
Herbs used by farmers and corresponding diseases treated.

Herbs	Scientific name	Therapeutic uses
Àgánwò or African mahogany	*Khaya senegalensis*	Mastitis, CBPP, trypanosomiasis, and tuberculosis
Kadanya or shea butter tree	*Vitellaria paradoxa*	CBPP, trypanosomiasis, and tuberculosis
Gapde or African birch	*Anogeissus leiocarpa*	FMD
Bagaruwa or thorny acacia	*Vachellia nilotica*	FMD
Ígí ìpín or sandpaper tree	*Ficus exasperata*	Mastitis

Agents such as ash, shea butter, chicken faeces, and heat were also used for treatment. Generally, ATAs were used in ways that differed among farmers. Two farmers said these when speaking of using ash to treat mastitis:

“Sometimes, we use ash. We soak it in water overnight and we allow (the sick cows) to drink it (…) When you soak the ash overnight, it will settle, and then you separate the water and give (the cows) that water.” – R18, Cattle farmer

“We also use ash, but hot ash. We will move it close to the udder and spread water on it so the fumes that come up can waft towards the udder.” – R20, Cattle farmer.

A minority of farmers (1.4%) refused to divulge the names of the herbs, stating that it was confidential information and could not be revealed. Others stated that they learnt of them from preceding generations but they had forgotten: “*My father taught me [about the herbs] but I forgot.” - Questionnaire respondent* .

52.7% of farmers stated that they did not use alternative therapeutics such as herbs and aforementioned agents. The most popular reasons given for this included their not being easily available (51.8%) and their being difficult to administer (26.8%). (Fig. 6).

3.4. Knowledge, Perceptions, and Practices (KAP) of Farmers towards antibiotics and AMR

Generally, farmers demonstrated unsatisfactory KAP regarding ABU and AMR (Table 5). Among the most significant findings on knowledge, only 28% of farmers had heard of the terms ‘antibiotics’ and ‘AMR’, and even fewer (21%) were aware that mastitis could be caused by antimicrobial-resistant pathogens.

Table 5
KAP scores of farmers.

KPP	Total obtainable score	Mean score of respondents	Satisfactory[1] n (%)	Unsatisfactory n (%)
Knowledge	4	1.22	290 (39.40)	466 (60.60)
Attitude	20	9.25	242 (32.88)	494 (67.12)
Practice	24	9.34	329 (44.70)	407 (55.30)

[1]Satisfactory score ≥ mean score of respondents, and unsatisfactory score < mean score of respondents.

Regarding attitudes, 55.6% believed that antibiotics were not effective for treating diseased animals (Fig. 7). 46.7% of farmers agreed that antibiotic overuse could lead to AMR, and 33.0% agreed AMR could become a problem in their herds. A significant portion (39.5%) believed that antibiotic use (ABU) in animals improved their own personal health. Only 26.6% of farmers agreed that the use of antibiotics in animals should be reduced. Regarding practices, participants stated that they were most likely to use antibiotics after noticing disease symptoms in their herd (62.1%), an increase in morbidity (52.5%), and a mortality rate (52.3%) (Fig. 8). Farmers were also most likely to use antibiotics after a recommendation from a veterinarian (46.1%). Factors that influenced farmers the least included antibiotics availability (28.7%) and cost (25.7%).

Gender was the only sociodemographic variable not significantly associated with KAP of participants (Additional File 6**).** In the multivariate model, farmers with primary (OR: 3.37, 95% CI: 2.01–5.74, $p < 0.001$) and tertiary (OR: 1.95, 95% CI: 1.04–3.69, $p = 0.038$) levels of education were more likely to have higher knowledge than farmers with no formal education (Table 6). Farmers with 30–40 years of experience in ruminant farming had better attitudes towards antibiotic use than farmers with less than ten years of experience (OR: 6.19, 95% CI: 2.96–13.40, $p < 0.001$). Farmers with secondary levels of education had better practices than farmers without formal education (OR: 1.97, 95% CI 1.08–3.63, $p = 0.027$).

Table 6
Multivariate Analysis for KAP in participants.

Variables	Category	Knowledge		Attitudes		Practices	
		OR (95% CI)	p-value	OR (95% CI)	p-value	OR (95% CI)	p-value
Age (years)	< 20	r		r		r	
	21–30	1.63 (0.37–8.63)	0.530		0.132	1.29 (0.29–5.86)	0.735
	31–40	1.14 (0.26–6.06)	0.866		0.136	0.79 (0.18–3.61)	0.752
	41–50	1.21 (0.27–6.59)	0.812	0.74 (0.15–4.36)	0.170	0.90 (0.20–4.21)	0.886
	51–60	1.15 (0.24–6.51)	0.864	0.94 (0.18–5.71)	0.155	0.72 (0.15–3.50)	0.671
	> 60	0.53 (0.09–3.47)	0.486	1.49 (0.24–10.80)	0.217	0.73 (0.13–4.08)	0.716
State	Kwara	r		r		r	
	Niger	1.00 (0.68–1.47)	0.991	0.17 (0.11–0.25)	0.248	1.02 (0.70–1.48)	0.928
Level of Education	No formal education	r		r		r	
	Primary School	**3.37 (2.01–5.74)**	**< 0.001**	0.98 (0.59–1.64)	0.949	1.43 (0.86–2.38)	0.166
	Secondary School	1.11 (0.595–2.05)	0.738	0.10 (0.54–1.83)	0.995	**1.97 (1.08–3.63)**	**0.027**
	Tertiary Education	**1.95 (1.04–3.69)**	**0.038**	0.83 (0.44–1.55)	0.554	1.04 (0.55–1.95)	0.903
Role on Farm	Owner	r		r		r	
	Owner and manager	0.86 (0.60–1.24)	0.424	1.07 (0.75–1.54)	0.697	1.03 (0.73–1.46)	0.874
	Manager	0.82 (0.38–	0.597	0.77 (0.36–	0.505	0.58 (0.27–	0.158

		1.71)		1.63)		1.22)	
	Worker	0.73 (0.36–1.44)	0.371	0.72 (0.36–1.40)	0.341	0.75 (0.38–1.46)	0.402
Number of years in ruminant farming	≤ 10	r		r		r	
	11–20	1.20 (0.74–1.94)	0.456	1.04 (0.65–1.66)	0.868	0.71 (0.44–1.13)	0.152
	21–30	1.05 (0.60–1.84)	0.866	0.69 (0.40–1.19)	0.181	0.90 (0.53–1.55)	0.706
	31–40	1.00 (0.35–2.01)	0.996	**6.19 (2.96–13.40)**	**< 0.001**	0.55 (0.28–1.08)	0.085
	> 40	2.12 (0.81–5.66)	0.130	1.19 (0.74–5.02)	0.185	1.65 (0.65–4.24)	0.296
Herd size of animals	≤ 25	r					
	26–50	0.81 (0.38–1.71)	0.339	0.96 (0.61–1.49)	0.844	1.06 (0.69–1.64)	0.793
	51–75	1.27 (0.77–2.08)	0.351	1.12 (0.68–1.86)	0.650	1.20 (0.73–1.96)	0.472
	75–100	1.02 (0.56–1.88)	0.943	1.17 (0.63–2.18)	0.617	1.16 (0.64–2.11)	0.623
	> 100	0.59 (0.29–1.16)	0.130	1.42 (0.74–2.75)	0.290	1.76 (0.94–3.31)	0.079

3.5. Factors affecting farmers' use of antimicrobials and ATAs:

Themes uncovered from the FGDs relate to trust, effectiveness, availability and awareness. Figure 9 represents these factors and how they affect farmers' use of ATAs and antibiotics.

Farmers were willing to purchase imported, more costly antimicrobials from verified stores rather than locally made antimicrobials from drugstore vendors, as long as it guaranteed a successful treatment. One farmer said:

"The [drugstore] sellers buy one bottle of antibiotics and [dilute] it to [make] ten [bottles]. The [antibiotics] are [also] poorly stored. If you don't buy [imported] antibiotics, you won't get [good] results." - R09, cattle

farmer.

Farmers also purchased different antimicrobials and mixed them to create what was considered a more effective dose, as stated here:

"We buy drugs [when we have diseases]: oxytetracycline, tylosin, [antiparasitic] dewormers. But if it does not work, we give a mixture [of all the drugs] and we administer it again. We can mix diminazene aceturate and long-acting oxytetracycline. The best [treatment] is [the] mixture of drugs." – R23, Cattle farmer.

Traditionally, Fulani pastoralists utilized herbal remedies for treating various conditions. However, most farmers interviewed (Fulanis and non-Fulanis) heavily relied on antibiotics as opposed to herbs in the present day. Some farmers stated that this was as a result of the popularity of antibiotics:

"The bottled drugs (antibiotics) have made us forget [the knowledge we had about herbs previously]." - R01, cattle farmer.

Antibiotics were noted by some farmers to now be declining in efficacy, prompting more farmers to adopt herbs. A farmer stated:

"[Antibiotics for mastitis] don't work anymore and that's why we use [herbal] methods of treatment." – R15, Cattle farmer.

For viral diseases with no antimicrobial treatment options (FMD and CBPP), farmers were driven to use herbal remedies. One farmer said:

"During one CBPP outbreak, for me it killed almost 40 cows. There is no conventional treatment for it. Then one Fulani (herdsman) came and recommended a [herb]. The [herb] cured and prevented [CBPP] […] No [cow] died again. Now, I don't bother with conventional drugs. Once it is [a case of] CBPP, I just use herbs." – R16, Cattle farmer.

Many farmers were not always aware of the right herbs to use for specific diseases or where to obtain them. This usually caused them to stick to antimicrobials, as in this account:

"For me, I prefer herbal [methods]. But sometimes, it is difficult to get the herbs. So I use conventional drugs first, and then, when I get the herbs, I use them. The conventional [drugs] are easy to get." – R18, Cattle farmer

Another factor affecting farmers' use of herbs was a lack of awareness of formulating the proper dosage. One farmer said:

"Sometimes we have dosage issues [with the herbs]. So when you use it, for example, bitterleaf, when you use it in excess, it can cause bloating." - R18, Cattle farmer.

Vaccines were sometimes avoided because of cold chain inadequacies that rendered them inactive. One farmer said:

“We have to be careful of vaccines [for FMD] because you will discover that most [of the available vaccines] are just inactive, maybe due to their preservation.” - R11, Cattle farmer.

Regarding animal healthcare providers, farmers identified veterinarians, unlicensed para-veterinarians, and Fulani herdsmen. Veterinarians were not always accessible, leading some farmers to rely on para-veterinarians:

“I [used to] consult a veterinarian, but he is no longer [in the community], so I take pictures [whenever I have diseases] and send them to a para-veterinarian [for treatment advice].” - R01, Cattle farmer.

While some farmers stated that they found veterinarians’ treatments unreliable, other farmers trusted them and their prescribed antimicrobials, as this quote states:

“I consult doctors because I believe doctors should know much about animals. Despite the fact that our Fulani herders have concoctions […], I consult doctors because I believe in their expertise and training.” – R07, Cattle farmer.

Para-veterinarians were considered untrustworthy due to their regular use of fake, dangerous, and expired drug mixtures, which were sometimes disastrous to the health of the animals. One farmer stated:

“*We don’t take risks for cattle. If we are not sure of what [disease] we are dealing with, we call our vets. We don’t call those [para-veterinarians] because they’ll kill your animals.” – R12, Cattle farmer.*

Fulani herdsmen were trusted, particularly by both non-Fulani and younger Fulani farmers who did not know how to obtain herbs themselves. One farmer said:

“The Fulani herdsman we [consulted] before regularly used herbs (for our animals) and it works [...] I don’t know the name of the herbs he uses.” - R02, Cattle farmer.

However, Fulani herdsmen did not usually share their knowledge, limiting farmers’ awareness of these herbs. One farmer said:

“Our Fulani herder doesn’t disclose his concoction to us. He is very secretive.” - R12, Cattle farmer.

4. Discussion

Our study provides new insights into cattle production characteristics in North-Central Nigeria, as well as their influence on farmers’ use of antibiotics and ATAs. Most farmers were male, had no formal education, and owned herds of about 50 animals. Consistent with our findings, other studies report male predominance in cattle rearing (26, 27). Cattle is chiefly produced by Fulani pastoralists in Northern

Nigeria. In this region, gender and societal expectations constrain women's participation in cattle rearing. Low levels of formal education have likewise been reported in other studies (27–28). The children of pastoralists are often recruited as rearers when they are quite young, and the frequent movement during grazing makes it difficult for them to also enrol into formal education (27, 28). Similar to our findings on herd size, Olafedan *et al.* (29) reported an average cattle herd of 28 among cattle farmers in South-Western Nigeria. Smaller herd sizes allow farmers to easily move around with their animals while grazing (29). Cattle farmers often walk long distances with their herds, sometimes migrating to southern states during dry seasons when pasture is scarce in the north (29, 30). Such migratory journeys often expose cattle to diseases more prevalent in Southern Nigeria, including trypanosomiasis (30).

Farmers mostly kept local breeds of cattle rather than foreign crossbreds, consistent with findings from other studies (29, 31, 32). This may reflect the tolerant nature of local breeds to weather conditions and endemic diseases in Nigeria, as well as the lack of access to artificial insemination (AI) technology necessary to breed foreign cattle, (27, 31–33). In our study, cows of reproductive age were the largest herd segment in most farms. This is likely due to farmers sourcing replacement stock primarily from their herds, thus requiring as many cows as possible for generational continuity. In addition, keeping more female cows maximises the milk production capacity of the herd (29). Record-keeping was recorded as generally low, similar to other studies (27). This is not surprising, as a low level of formal education evidently translates to fewer written records. The lack of consistent records would make it difficult for farmers to maintain consistent vaccination schedules or implement more modern techniques such as AI (31).

Several diseases were commonly experienced within herds, especially CCPP, FMD, and mastitis. These diseases led to devastating economic consequences due to mortality, loss of animal value, and treatment costs. Similarly, previous studies record high losses due to FMD and CBPP every year (34, 35). Our findings demonstrate low vaccination rates for these two diseases among farmers, despite their being locally produced by the National Veterinary Research Institute (36, 37). Farmers largely depended on government veterinarians for vaccination, contrary to their regular practices of consulting para-veterinarians and drugstore vendors for treatment. This implies that vaccines are majorly accessible through government officials, and there are possible supply chain gaps that prevent para-veterinarians and drugstore vendors obtaining them. Similarly, a study by Sopeju *et al.* (8) reports that the majority of veterinary drugstores across Nigeria do not retail vaccines due to the difficulties in maintaining a cold chain in a climate with unstable electricity, as well as the long-distance travel required to procure them. Therefore, farmers' reports of a lack of access to veterinarians (including government veterinarians) will likely translate to a lack of effective vaccines. However, the vaccination rates for CBPP were much higher than for FMD. This might be due to the CBPP control strategy launched by the Nigerian government in 2022 under the World Organisation for Animal Health (WOAH). Among other goals, this scheme aims to vaccinate 90% of Nigerian cattle annually till 2027 (36). Yet, less than 50% of farmers reported receiving the vaccines for their herds, suggesting a prevalent access gap. As remarked by farmers, FMD and CBPP did not have effective conventional remedies. Thus, herds infected with them will suffer from severe

mortality. There is an urgent need to increase the vaccination supply for these diseases to improve animal health outcomes.

Regarding mastitis, farmers did not institute preventive measures against this disease despite the high morbidity. This finding contrasts with observations in Ireland, where over 95% of dairy farmers reported implementing preventive measures against mastitis, including post-milking teat disinfection, spraying and dipping (38). In our study, a significant portion of farmers were not clear of the cause of mastitis. This likely led to farmers not being aware of what preventive strategies to institute. Conversely, Irish farmers' adoption of mastitis preventive measures was highly influenced by a national mastitis control programme in 2011 called CellCheck, where recommendations were delivered directly to farmers by local advisors (38, 39). Currently, no such programmes exist for mastitis in Nigeria, and there has been no record of similar mastitis preventive programmes in the past.

To diagnose diseases, farmers relied on physical observation and experience. Veterinary services were said to be scarce, prompting their self-reliance. Similarly, Suleiman *et al.* report that poor access to veterinary facilities and high cost drove farmers to manage diseases themselves (30). Though other studies have observed that cattle pastoralists generally have good knowledge of clinical manifestations of endemic diseases, an overwhelming reliance on physical signs for diagnosis will likely lead to cases of misdiagnosis and underreporting of diseases (30). For instance, more than 95% of farmers detected mastitis primarily through physical observation, implying that almost all cases of subclinical mastitis are not accounted for by farmers. This is particularly concerning, as a previous Northern Nigerian study reported that subclinical mastitis was nine times more prevalent than clinical mastitis within a community (6). Thus, there might be several diseases affecting the health and productivity of cattle in Nigeria unobserved by farmers, but manifesting through lower milk losses and less feed conversion efficiency. This indicates that the output yield in this sector has yet to be maximised to its full potential.

ABU by farmers was high, particularly oxytetracycline, tylosin and procaine penicillin. Similarly, Alhaji *et al.* (10) reported that penicillins and tetracyclines were one of the most commonly used classes of antibiotics on beef farms in Northern Nigeria. Tetracyclines and penicillins have been classified as Highly Important Antimicrobials (HIAs) by the World Health Organisation (WHO) due to their relevance in treating bacterial infections in humans and animals (40, 41). Tylosin belongs to the antibiotic class of macrolides and has also been classified as a CIA (40). Several recommendations guide the veterinary use of these antibiotics as prescribed by WOAH, including non-use for prophylactic and growth-promoting purposes, and the necessity of antimicrobial susceptibility testing prior to their use for therapeutic purposes (42). Most farmers surveyed did not follow these recommendations, bearing grave implications for AMR. While our study did not query farmers on dosages administered, the general dependence on self-medication suggests that these antibiotics are often under- or over-dosed. Another study in Northern Nigeria observed that 67% of farmers did not abide by any particular prescription recommendations, but rather used drugs arbitrarily (43). Farmers also combined antibiotics with antiparasitics and administered these in a single shot in order to improve drug effectiveness. These practices were said to be encouraged by para-veterinarians. Some farmers noted that “antibiotics do not

work anymore", implying that these practices most likely contribute to a high level of resistance development within the animal herds and might translate to resistance transfer to humans through pathways of contamination and food consumption. This risk is highest for cattle farmers themselves, as they often stay in close contact with their herds (10, 43).

A contributing factor to the high self-prescription of antimicrobials was farmers' ready access to antibiotics, as they could purchase them easily from drugstore markets, licensed veterinary stores, or even import foreign brands. This is despite the existence of regulations in Nigeria banning the sale of antimicrobials without prescriptions as well as the use of veterinary antimicrobials by unlicensed personnel (44). Our finding suggests weak enforcement of antimicrobial stewardship regulations. Due to the lack of veterinarians, farmers resorted to self-medication or sought advice from para-veterinarians. Para-veterinarians are unlicensed professionals who often engage in dangerous practices that contribute to antimicrobial misuse or endanger the health of the animal. While some farmers stated they distrusted them, para-veterinarians were still the most highly sought for treatment advice as per our findings, indicating that most farmers had no other viable options. Farmers' KAP towards AMR further reveals how misuse may be shaped by farmers' current knowledge and perceptions. Only 28% of farmers had heard of AMR before, while 40% believed that antibiotic use in animals improved the farmers' health. Similarly, a previous study observed that 52% of nomadic pastoralists across Nigeria were not aware of AMR or antimicrobial residues (45). Holistically, the easy access of farmers to self-prescribed antimicrobials, reliance on unlicensed para-veterinarians, and low awareness of AMR all contribute to the risky and dangerous practices adopted by farmers.

High costs of antibiotics did not affect farmers' purchase and utilisation of the drugs. Rather, farmers expressed willingness to buy the most effective drugs if they guaranteed effective treatment. Farmers were likewise willing to consult veterinarians, though paying a higher price for consultation when compared with self-medication. Our finding contrasts with another study in Nigeria, where small-scale poultry farmers were unwilling to consult veterinarians to save costs (46). As observed in our study, the losses cattle farmers faced due to reduced animal value are considerably greater than the costs of treatment. Thus, they are likely more willing to pay for veterinary services when compared to other animal farmers. However, this is hindered by the availability of veterinary and diagnostic services.

Farmers relied on a wide array of ATAs for treating diseases, including herbal plants, ash, and chicken faeces. Several studies in Nigeria have documented the use of ethnoveterinary remedies for the management of animal diseases (21, 47). Traditionally, Nigerian pastoralists have employed herbs and other materials in the management of their cattle herd (47). Some of the plants identified in this study, such as bitterleaf and African mahogany plants, have also been documented to possess antimicrobial properties and are promising therapeutic options for prevalent bovine diseases (48–50). Our finding also highlights the use of chicken faeces and ash for mastitis, which have both been documented to have antiviral activity against poultry viruses under laboratory conditions. (51, 52). While there have been no current studies testing the efficacy of these materials against cattle diseases, farmers' use of them suggests that there may be a level of effectiveness demonstrated. Through reports obtained from

farmers, however, ATAs were primarily used to relieve physical symptoms, such as the hardness of the udder observed in mastitis. It is unclear, however, whether these treatments led to a significant reduction in microbial load, especially as methods of use varied among farmers and most farmers likely stopped treatment as soon as physical symptoms abated. Future studies are indicated to determine the efficacy of ATAs identified in this study against cattle diseases, as well as the most effective methods of use.

More than half of farmers surveyed did not use alternative therapeutic agents. This was mostly attributed to a difficulty in obtaining the right herbs or preparing the right dosages. Due to this, some farmers consulted Fulani herdsmen for health management advice. However, they were usually secretive with knowledge about the herbs. Similarly, another study noted that Fulani pastoralists prefer to retain their knowledge within the family, passing it down to succeeding generations verbally (21). From our findings, farmers of the present generation are forgetting the knowledge passed on to them due to a greater dependence on antimicrobials, consistent with other studies (47). This indicates that knowledge about ethnoveterinary remedies for cattle production is at risk of becoming eroded. Without intentional efforts to preserve and record this knowledge, it might be permanently lost. Less than 10% of farmers believed that alternative therapeutics were not as effective as antimicrobials. Thus, the major hindrance to farmers' adopting herbs appears to be a lack of information regarding herbs and their use, rather than negative perceptions about effectiveness. Therefore, efforts to preserve and share knowledge will likely translate to greater use of herbs and less reliance on antimicrobials.

Limitations: Reports on herd prevalence collated in this study were based on farmers' reports. As farmers relied on physical observations for disease diagnosis, some diseases may be under- or overreported. This method was used to get a full picture of farmers' attitudes and beliefs that influenced their health management practices.

5. Conclusions and Recommendations

There was a high reliance on antimicrobials over ATAs (vaccines, herbs, household materials). Factors that contributed to this discrepancy included a lack of access to effective vaccines, low awareness about effective herbal options and how to procure them, and unrestricted access to nonprescribed antimicrobials. In addition, reduced access to veterinary services caused farmers to depend on self-medication and unlicensed para-veterinarians, increasing the potential of AMR development. Based on these findings, we recommend the following: (1) increasing the number of official governmental veterinarians assigned to cattle-dense regions in Nigeria, (2) strengthening the implementation of regulations that restrict the purchase and distribution of nonprescribed antimicrobials by unlicensed personnel (3) improve vaccine delivery channels through the use of agricultural extension agents targeting cattle pastoralists, (4) undertake participatory research with Fulani communities to identify culturally sensitive methods of preserving ethnoveterinary knowledge (5) conduct more studies identifying herbs utilised by pastoralists in Nigeria, assessing their efficacy, and determining effective dosage formulations, (6) researching methods to improve the ease of access of herbs to farmers.

Declarations

Ethics approval and consent to participate

Ethical approval for the study was obtained from the University of Ilorin Ethical Review Committee (UERC) (UERC Approval Number: (UERC/ASN/2024/2915).

Ethical approval was also obtained from Royal Holloway University of London (Application ID 4210). This research was conducted in accordance with the declaration of Helsinki (53). Informed consent was obtained from the participants before enrolment in the study. Farmers were made aware that they could refuse to answer any question or opt out anytime during the data collection process.

Consent for publication

Participants were made fully aware that their responses would be published and consent in this regard was obtained prior to their enrolment in the study.

Availability of data and materials

The data that support the findings of this study are obtainable from the corresponding author upon reasonable request.

Competing interests

The authors declare no competing interests.

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Authors' contributions

I.A.A., M.E., and A.A. secured the funding

I.A.A., M.E.,N.B.A., V.O.A. supervised the project and the writing

T.O.I., , J.J.A., R.O.O., M.I.A., I.A.A., O.A.A. wrote the first publication draft

T.O.I., J.J.A., R.O.O., M.I.A., I.A.A., O.A.A., M.E., I.A.A., N.B.A., collected the data for the project.

J.J.A., R.O.O. analysed the data and compiled all tables and figures.

All authors reviewed the manuscript

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References

1. FMARD. Nigeria livestock roadmap for productivity, improvement and resilience. 2021. https://faolex.fao.org/docs/pdf/nig228496.pdf. Accessed 30 Jan 2026.
2. Cecilia N, Victor O, Kemisola A, Adeola O. Technical efficiency of beef cattle production technologies in Nigeria: a stochastic frontier analysis. Afr J Agric Res. 2016;11(51):5152–61.
3. Cole J, Adetona MA, Basiru A, Jimoh WA, Abdulsalami S, Ade-Yusuf RO, et al. Climate change, land use, and the decline in traditional Fulani cattle practices: drivers of antimicrobial resistance in Kwara, Nigeria. Challenges. 2024;15(4):41.
4. Gussmann MK, Steeneveld W, Kirkeby CT, Hogeveen H, Nielen M, Farre M, et al. Economic and epidemiological impact of different intervention strategies for clinical contagious mastitis. J Dairy Sci. 2019;102(2):1483–93
5. Abebe R, Markos A, Abera M, Mekbib B. Incidence rate, risk factors, and bacterial causes of clinical mastitis on dairy farms in Hawassa City, southern Ethiopia. Sci Rep. 2023;13:10945.
6. Zailani JH, Sanusi M, Shehu ML. Prevalence of mastitis of dairy cows in Kanam Local Government Area of Plateau State, Nigeria. Niger J Anim Prod. 2022;49:461–8.
7. Hussaini J, Tjørnehøj K, Zamani M, Lazarus DD, Mshelbwala PP, Ularamu HG, et al. Complex circulation of foot-and-mouth disease virus in cattle in Nigeria. Front Vet Sci. 2020;7:466.
8. Sopeju AE, Onoja G, Abiodun VT, Peters AR. Foot-and-mouth disease (FMD) vaccine market survey at agro-veterinary stores in rural and peri-urban areas of Nigeria. Gates Open Res. 2025;9:40.
9. Mwacalimba K, Kimeli P, Tiernan R, Mijten E, Miroshnychenko T, Poulsen Nautrup B. Diseases of economic importance in feedlot cattle in sub-Saharan Africa: a review with a focus on existing and potential options for control. Animals. 2025;15(1):97.
10. Alhaji NB, Haruna AE, Isola TO, Odetokun IA, Lawal-Adebowale OA, Olaniran AO, et al. Antimicrobial usage and associated residues and resistance emergence in smallholder beef-cattle production systems in Nigeria: a One Health challenge. Vet Res Commun. 2023;47(1):233–45.
11. Ashraf A, Imran M. Causes, types, etiological agents, prevalence, diagnosis, treatment, prevention, effects on human health and future aspects of bovine mastitis. Anim Health Res Rev. 2020;21(1):36–49.
12. Cobirka M, Tancin V, Slama P. Epidemiology and classification of mastitis. Animals. 2020;10(12):2212.
13. Jamali H, Barkema HW, Jacques M, Lavallée-Bourget EM, Malouin F, Saini V, et al. Invited review: incidence, risk factors, and effects of clinical mastitis recurrence in dairy cows. J Dairy Sci. 2018;101(6):4729–46.

14. Alhaji NB, Aliyu MB, Ghali-Mohammed I, Odetokun IA. Survey on antimicrobial usage in local dairy cows in North-central Nigeria: drivers for misuse and public health threats. PLoS One. 2019;14(12):e0224949.
15. Van Boeckel TP, Brower C, Gilbert M, Grenfell BT, Levin SA, Robinson TP, et al. Global trends in antimicrobial use in food animals. Proc Natl Acad Sci U S A. 2015;112(18):5649–54.
16. Friedman ND, Temkin E, Carmeli Y. The negative impact of antibiotic resistance. Clin Microbiol Infect. 2016;22(5):416–22.
17. Anueyiagu KN, Benson NP, Daniel J, Nze C, Esilonu JT. Prevalence of methicillin-resistant Staphylococcus aureus in bovine subclinical mastitis in Jos South Local Government Area of Plateau State, Nigeria. Eur J Vet Med. 2022;2(6):7–11.
18. Kour S, Sharma N, Balaji N, Kumar P, Soodan JS, Santos MV, et al. Advances in diagnostic approaches and therapeutic management in bovine mastitis. Vet Sci. 2023;10(7):449. doi:10.3390/vetsci10070449.
19. Twomey DP, Wheelock AI, Flynn J, Meaney WJ, Hill C, Ross RP. Protection against Staphylococcus aureus mastitis in dairy cows using a bismuth-based teat seal containing the bacteriocin, lacticin 3147. J Dairy Sci. 2000;83(9):1981–88. doi:10.3168/jds.S0022-0302(00)75075-2.
20. Cao LT, Wu JQ, Xie F, Hu SH, Mo Y. Efficacy of nisin in treatment of clinical mastitis in lactating dairy cows. J Dairy Sci. 2007;90(8):3980–85. doi:10.3168/jds.2007-0153.
21. Ayoola MO, Ogunlakin AD, Oguntunji AO. Status of ethno-veterinary medicine in the management of dairy animals in Nigeria. J Anim Health Prod. 2025;13(1):88–105.
22. Abdallah A, Zhang P, Zhong Q, Sun Z. Application of traditional Chinese herbal medicine by-products as dietary feed supplements and antibiotic replacements in animal production. Curr Drug Metab. 2019;20(1):54–64. doi:10.2174/1389200219666180523102920.
23. Getu A, Solomon T, Fikre N, Eyasu E, Fufa Y, Tazebachew M, et al. Knowledge, attitudes, and practices regarding antimicrobial resistance and associated factors among healthcare workers in Addis Ababa, Ethiopia: a cross-sectional study. Can J Infect Dis Med Microbiol. 2025;2025:5354292. doi:10.1155/cjid/5354292.
24. Wangmo K, Dorji T, Pokhrel N, Dorji T, Dorji J, Tenzin T. Knowledge, attitude, and practice on antibiotic use and antibiotic resistance among the veterinarians and para-veterinarians in Bhutan. PLoS One. 2021;16(5):e0251327. doi:10.1371/journal.pone.0251327.
25. Braun V, Clarke V. Thematic analysis: a practical guide. London: Sage Publications; 2021.
26. Agboola AF, Ojo OA, Famakinwa M, Williams SO. Gender involvement of sedentary Fulani in dairy farming practices in Osun State, Nigeria. Contemp Agric. 2020;69(3–4):73–80. doi:10.2478/contagri-2020-0010.
27. Umar YA, Abu IA, Sani MH, Idi S, Owoade EO. Gender analysis of cattle farmers' participation in cattle production in Bauchi and Yobe States, Nigeria. Asian J Agric Ext Econ Sociol. 2023;41(9):637–46. doi:10.9734/ajaees/2023/v41i92085.

28. Olaniran SO. Community and cultural influence on child schooling: a case study of the Fulani people of Nigeria. J Soc Policy Issues. 2024;4(2):54–59. doi:10.58835/jspi.v4i2.244.
29. Olafadehan OA, Adewumi MK. Livestock management and production system of agropastoralists in the derived savanna of South-west Nigeria. Trop Subtrop Agroecosystems. 2010;12:685–91.
30. Suleiman A, Jackson EL, Rushton J. Challenges of pastoral cattle production in a sub-humid zone of Nigeria. Trop Anim Health Prod. 2015;47:1177–85. doi:10.1007/s11250-015-0845-0.
31. Rasak B, Asamu F, Arisukwu O, Iwelumor O, Oyekola I, Oyeyipo E, et al. Prospects and constraints of cattle farming business in Kwara State, Nigeria. In: Proc Int Conf Sci Eng Bus Sustain Dev Goals (SEB-SDG). 2023;1:1–9. doi:10.1109/SEB-SDG57117.2023.10124580.
32. Roessler R. Selection decisions and trait preferences for local and imported cattle and sheep breeds in peri-/urban livestock production systems in Ouagadougou, Burkina Faso. Animals. 2019;9(5):207. doi:10.3390/ani9050207.
33. Yusuf OJ, Adesina OM, Apata DF, Ayanda IF, Ishola H, Ajibade LA. Cattle farmers' attitude towards artificial insemination technology in Kwara State, Nigeria. Tanz J Agric Sci. 2024;23:301–12. doi:10.5897/tjas2024.0445.
34. Bolajoko MB. Biosecurity and economic impact of major diseases of livestock among rural farmers in Plateau State, Nigeria: a pilot study. J Vet Biomed Sci. 2023;5:74–86. doi:10.5897/jvbs2023.0123.
35. Alhaji NB, Babalobi OO. Economic impacts assessment of pleuropneumonia burden and control in pastoral cattle herds of North-central Nigeria. Bull Anim Health Prod Afr. 2017;65:235–48.
36. Danladi J. CBPP control strategy in Nigeria (an overview). WOAH SGE country presentation 2024. 2024;1–16.
37. Makoshi M, Oladimeji Y, Rekwot G, Hussaini A. Assessment of factors influencing level of adoption of NVRI vaccine among cattle farmers in North-Central Nigeria. Niger Agric J. 2023;54(2):36–41.
38. Uí Chearbhaill A, Boloña PS, Ryan EG, McAloon CI, Burrell A, Upton J. Survey of farm, parlour and milking management, parlour technologies, SCC control strategies and farmer demographics on Irish dairy farms. Ir Vet J. 2024;77:8. doi:10.1186/s13620-024-00267-y.
39. More SJ, McAloon C, Silva Boloña P, O'Grady L, O'Sullivan F, McGrath M, et al. Mastitis control and intramammary antimicrobial stewardship in Ireland: challenges and opportunities. Front Vet Sci. 2022;9:748353. doi:10.3389/fvets.2022.748353.
40. World Health Organization. WHO list of medically important antimicrobials: a risk management tool for mitigating antimicrobial resistance due to non-human use [Internet]. Geneva: World Health Organization; 2024. Available from: https://cdn.who.int/media/docs/default-source/gcp/who-mia-list-2024-lv.pdf. Accessed 30 Jan 2026.
41. Akinyemi KO, Fakorede CO, Amisu KO, Wareth G, El-Diasty MM, Al-Gaabary MH, et al. Human and animal brucellosis in Nigeria: a systemic review and meta-analysis in the last twenty-one years (2001–2021). Vet Sci. 2022;9(8):384. doi:10.3390/vetsci9080384.
42. World Organisation for Animal Health (WOAH). WOAH list of antimicrobial agents of veterinary importance (January 2025) [Internet]. Paris: WOAH; 2025. Available from:

https://www.woah.org/app/uploads/2021/06/202501-en-woah-trd-list.pdf. Accessed 30 Jan 2026.

43. Alhaji NB, Isola TO. Antimicrobial usage by pastoralists in food animals in North-central Nigeria: the associated socio-cultural drivers for antimicrobials misuse and public health implications. One Health. 2018;6:41–47. doi:10.1016/j.onehlt.2018.11.001.
44. Nigeria Centre for Disease Control (NCDC); Federal Ministries of Agriculture, Environment and Health. Antimicrobial use and resistance in Nigeria: situation analysis and recommendations. NCDC AMR Report 2017. 2017;1–158. Available from: https://ncdc.gov.ng/themes/common/docs/protocols/56_1510840387.pdf. Accessed 30 Jan 2026.
45. Olasoju MI, Abdullahi UM, Afolabi KM, Shittu AM, Oyedeji O. Knowledge and practice of cattle handlers on antibiotic residues in meat and milk in Kwara State, Northcentral Nigeria. PLoS One. 2021;16(9):e0257249. doi:10.1371/journal.pone.0257249.
46. Al-Mustapha AI, Adetunji VO, Heikinheimo A. Risk perceptions of antibiotic usage and resistance: a cross-sectional survey of poultry farmers in Kwara State, Nigeria. Antibiotics. 2020;9(7):378. doi:10.3390/antibiotics9070378.
47. Nodza GI, Chah JM, Ugwu DS, Anosa GN, Okoye JO, Ume SI, et al. Ethno-veterinary practice for the treatment of cattle diseases in the eastern highlands of Nigeria. Ethnobot Res Appl. 2022;24:1–16.
48. Kaseke TB, Chikwambi Z, Gomo C, Mashingaidze AB, Murungweni C. Antibacterial activity of medicinal plants on the management of mastitis in dairy cows: a systematic review. Vet Med Sci. 2023;9(6):2800–19. doi:10.1002/vms3.1268.
49. Kuevi DNO, Foli F, Tsegah E, Salia S, Glover W, Adinortey MB, et al. *Vernonia amygdalina* leaf extract shows in vitro antischistosomal activity against both juvenile and adult Schistosoma mansoni at 100 µg/mL. J Trop Med. 2024;2024:8074291. doi:10.1155/2024/8074291.
50. Adeyemi OO, Oladiji AT. Evaluation of the anthelmintic activity of *Khaya senegalensis* extract against gastrointestinal nematodes of sheep: in vitro and in vivo studies. Vet Parasitol. 2006;137(1–2):157–62. doi:10.1016/j.vetpar.2006.01.024.
51. Thammakarn C, Ishida Y, Suguro A, Takeda Y, Okamoto S, Cho J, et al. Inhibition of infectious bursal disease virus transmission using bioceramic derived from chicken feces. Virus Res. 2015;204:6–12. doi:10.1016/j.virusres.2015.04.010.
52. Ruenphet S, Punyadarsaniya D, Jantafong T, Takehara K. Stability and virucidal efficacies using powder and liquid forms of fresh charcoal ash and slaked lime against Newcastle disease virus and avian influenza virus. Vet World. 2019;12(1):1–6. doi:10.14202/vetworld.2019.1-6.
53. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. JAMA. 2013;310(20):2191–4. doi:10.1001/jama.2013.281053.

Figures

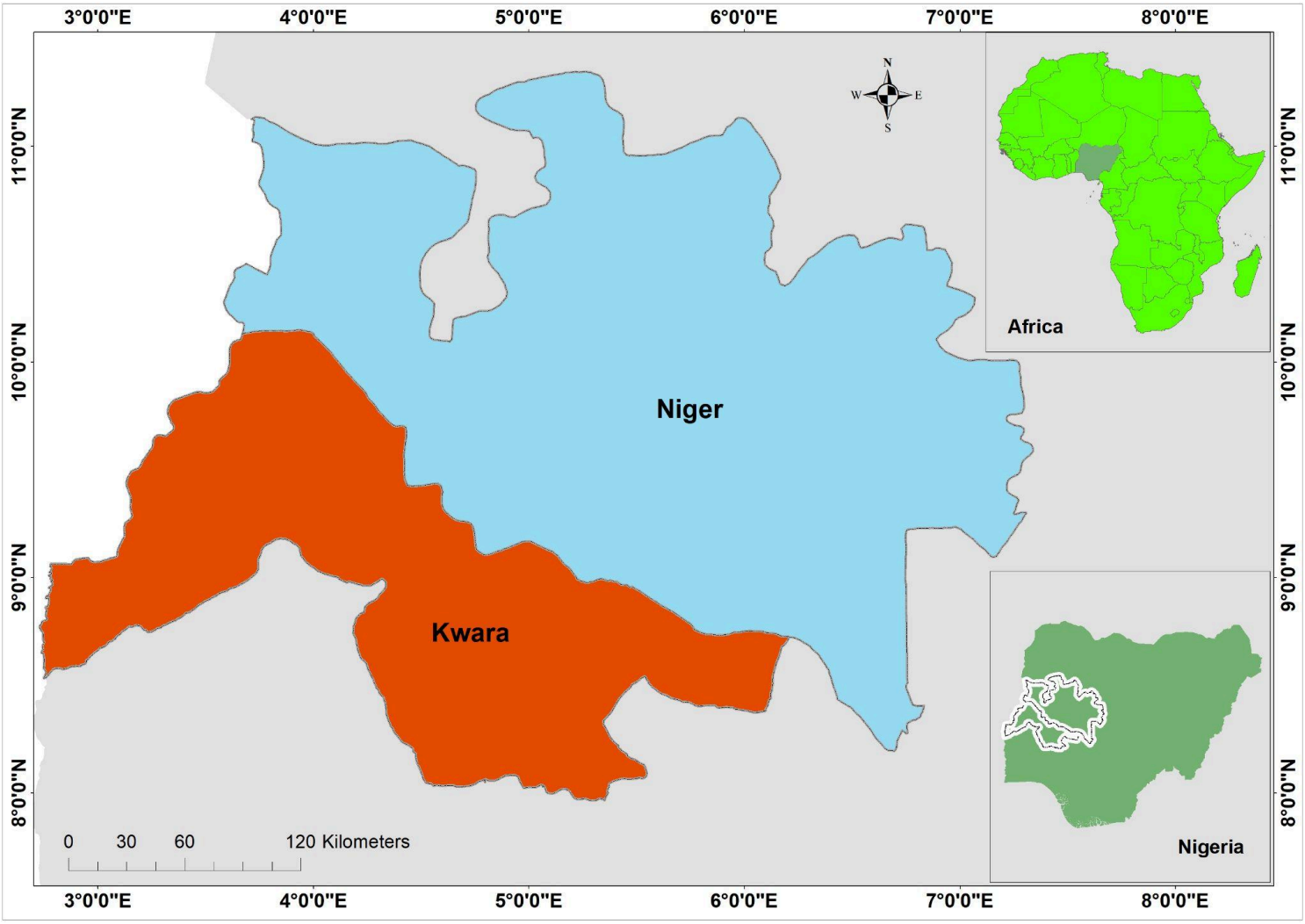


Figure 1

Map of Nigeria showing the study areas

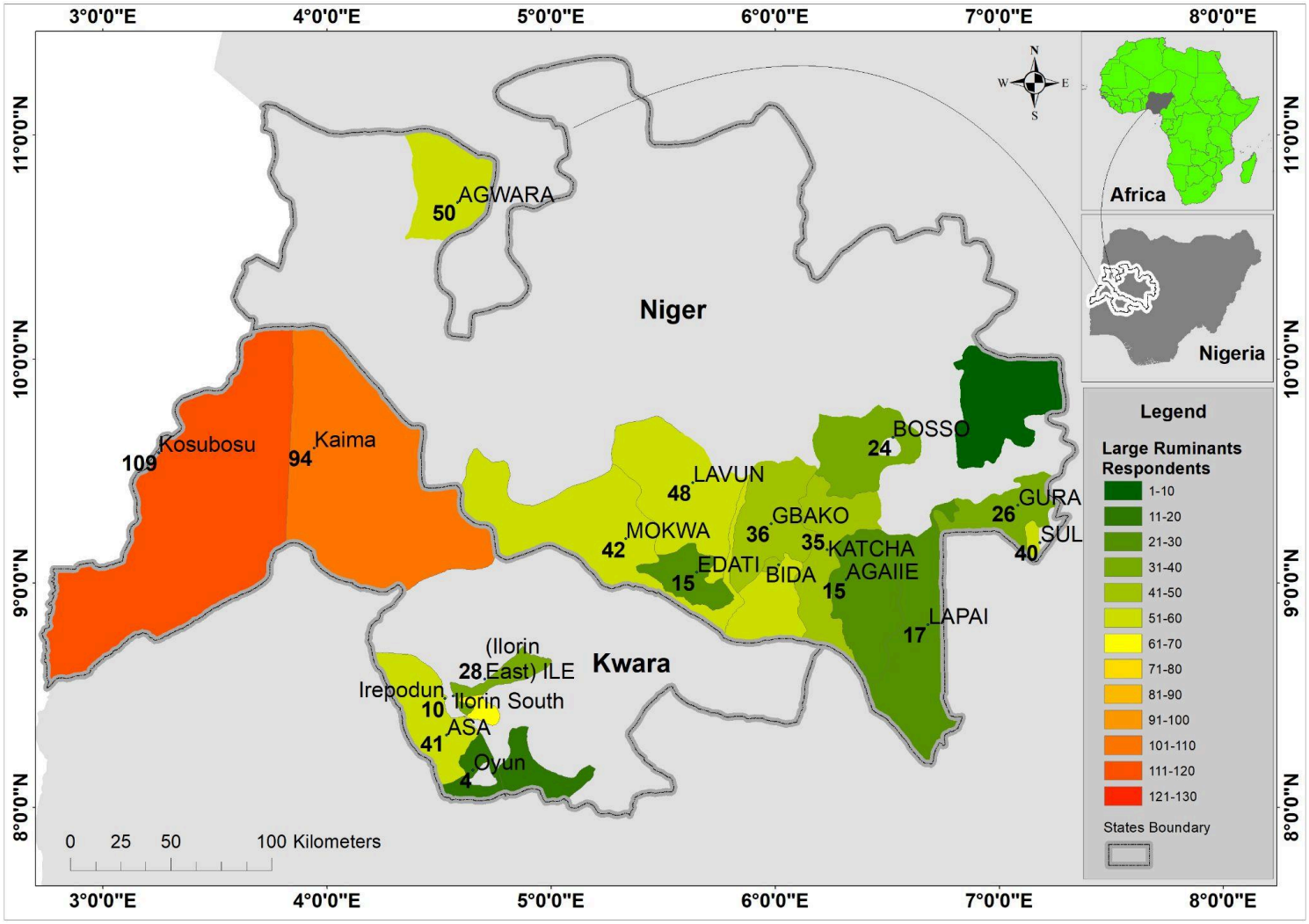


Figure 2

Geographical distribution of respondents.

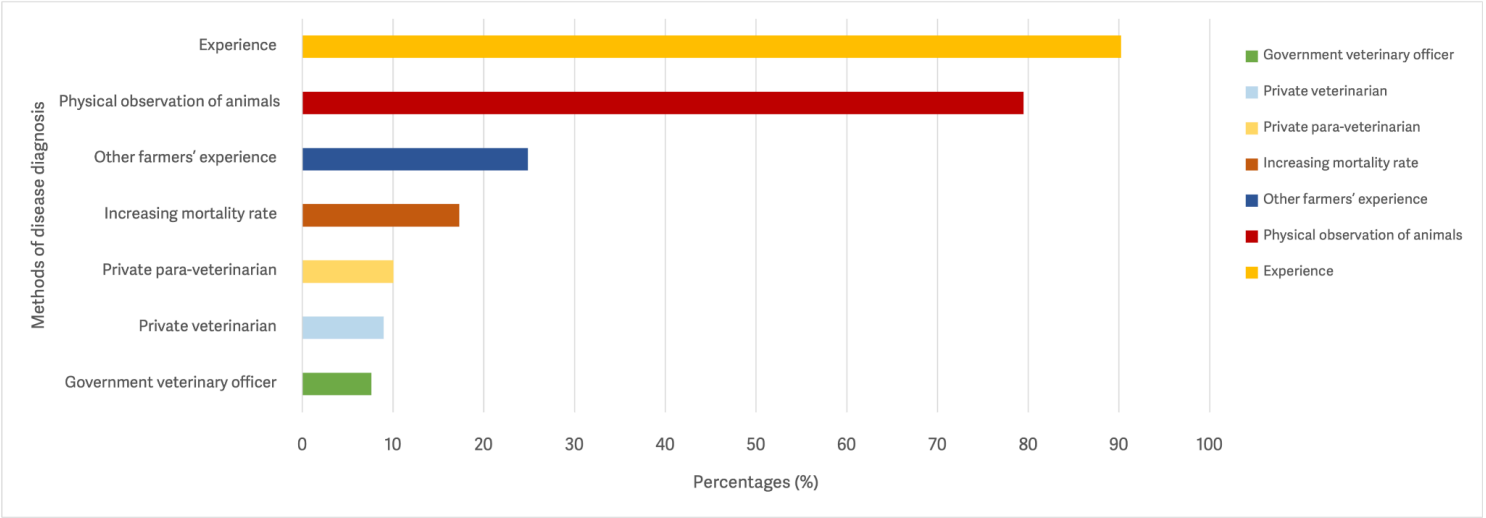


Figure 3

Methods for disease diagnosis used by farmers.

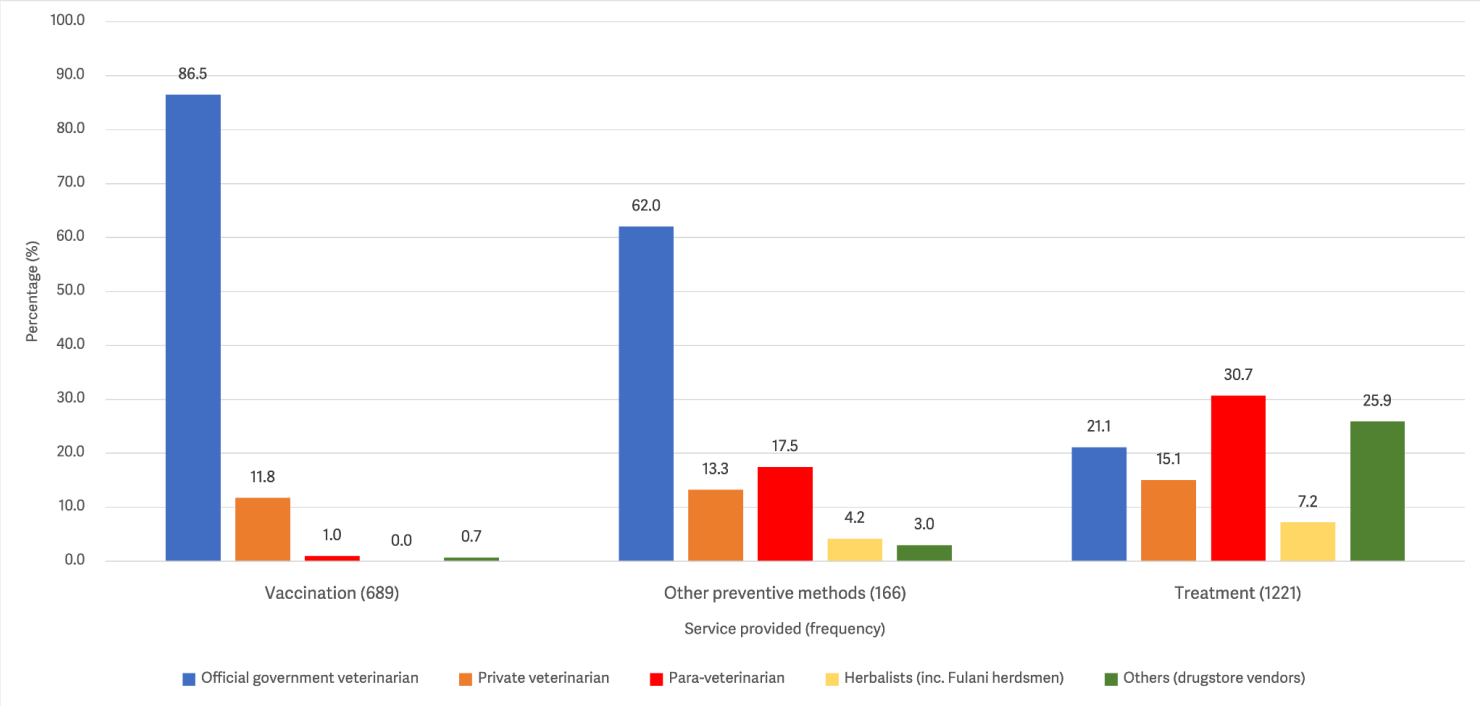


Figure 4

Animal health service providers used over the last three months according to services provided. Frequency here represents the number of times farmers consulted health providers for their services.

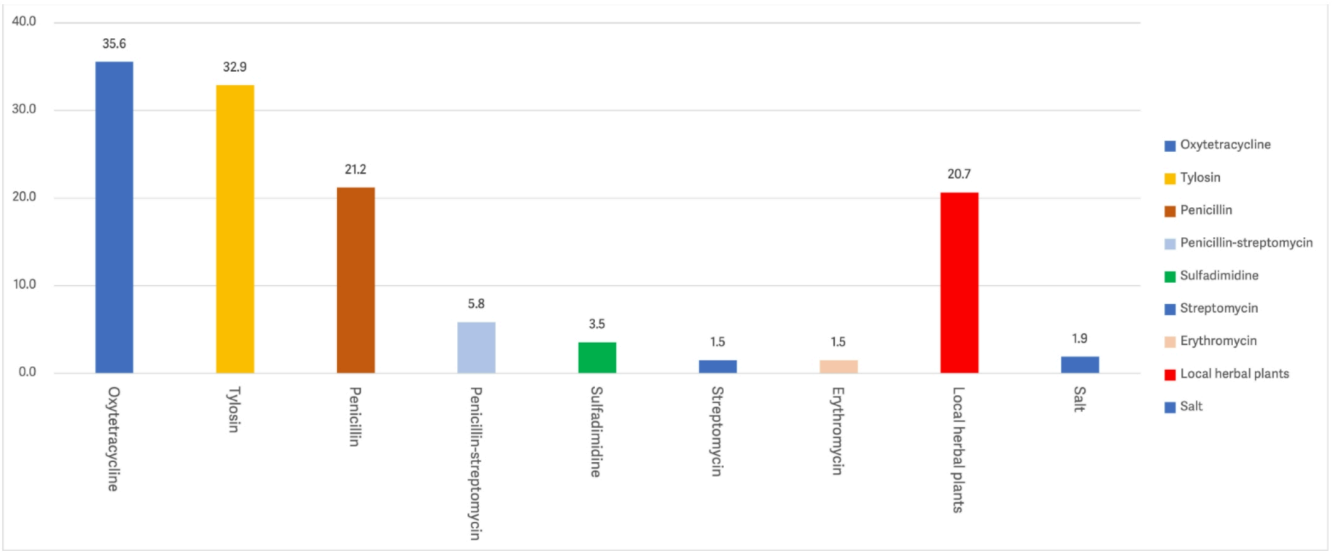


Figure 5

Antibiotics and alternatives used by farmers over the last three months.

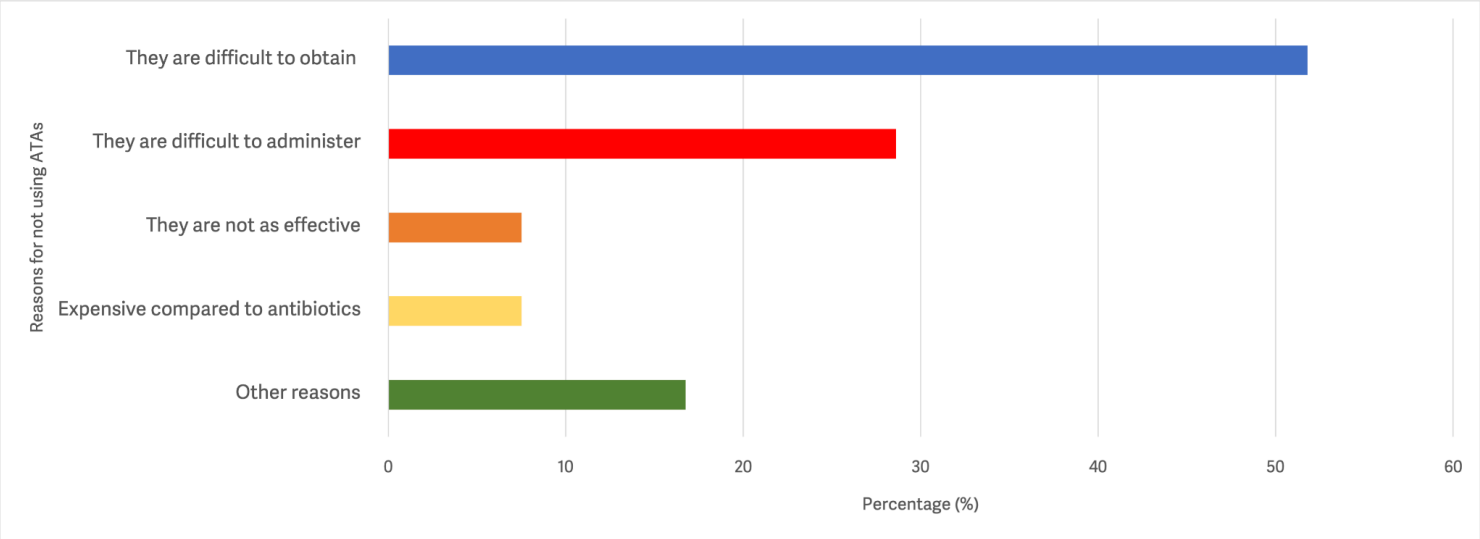


Figure 6

Reasons why farmers do not use herbal ATAs (n = 388).

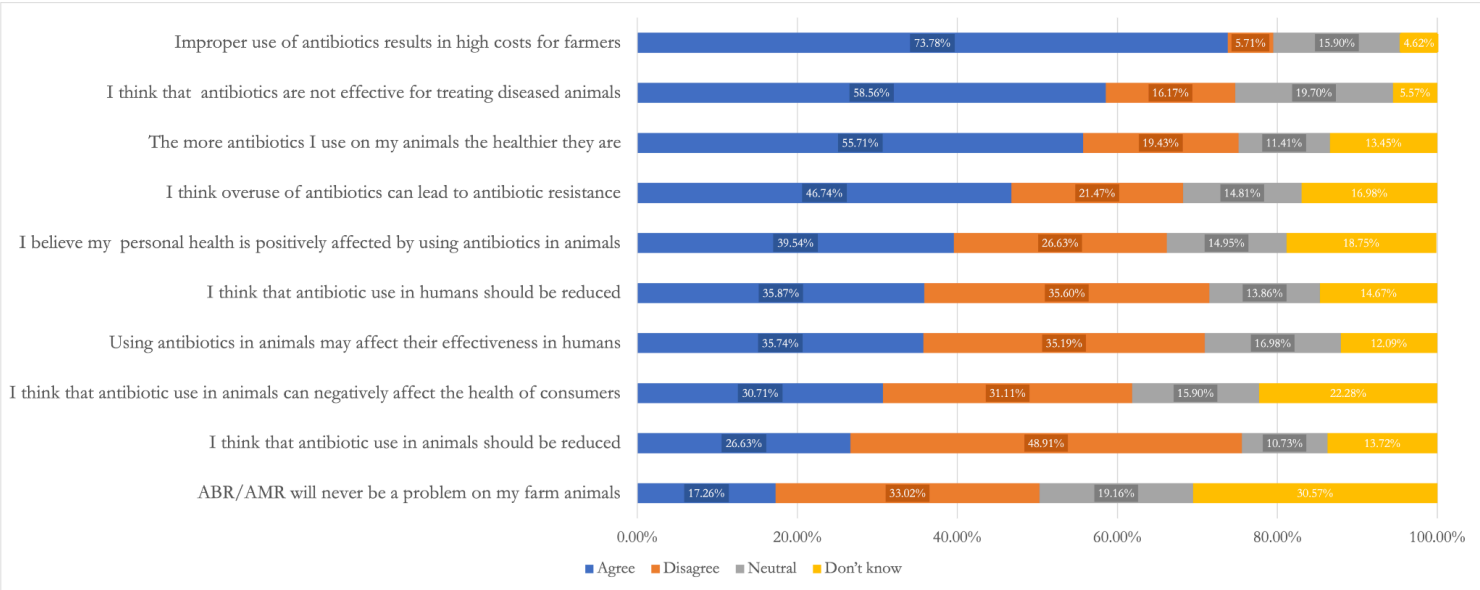


Figure 7

Attitudes regarding the use of antibiotics and AMR.

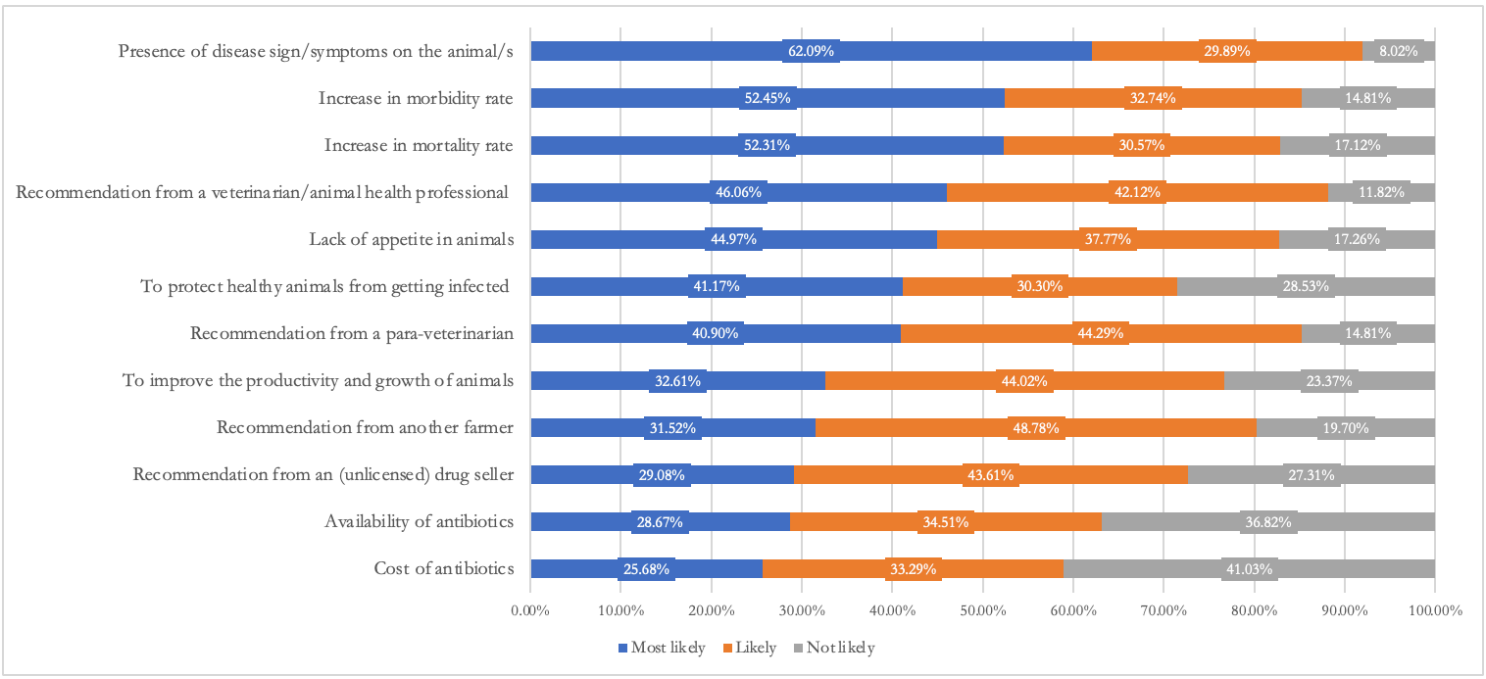


Figure 8

Factors influencing farmers' antibiotic practices in their herd.

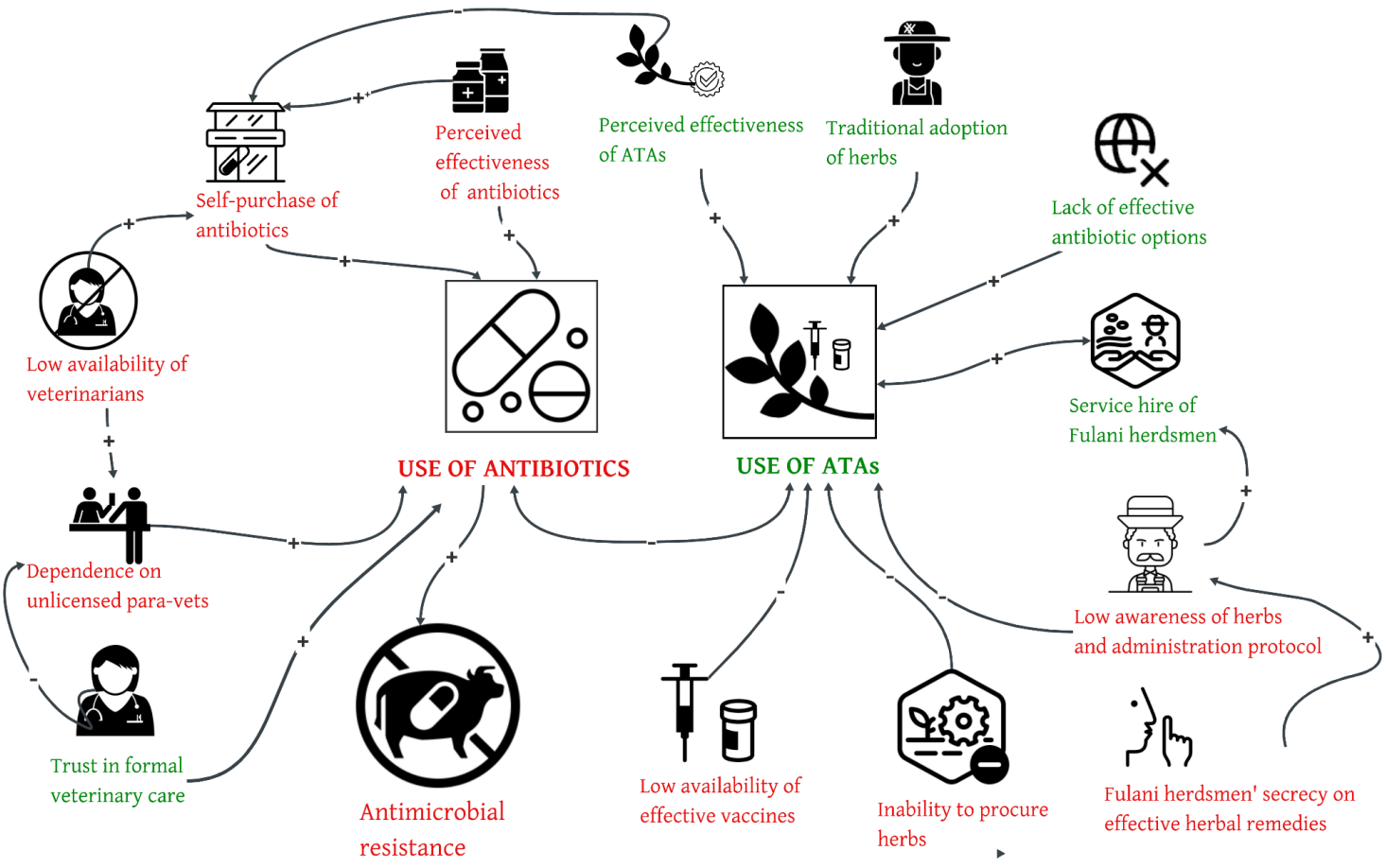


Figure 9

The interactions of factors affecting farmers' use of antibiotics and ATAs. Positive arrows (+) indicate a positive causal relationship between the preceding and the succeeding factor. Negative arrows (-) represent the opposite. ATAs include herbal remedies, vaccines, and agents utilised by the farmers as earlier described. Para-vets include all unlicensed professionals whom farmers consulted for animal health services that resulted in the administration of antimicrobials. Fulani herdsmen include traditional pastoralists from the Fulani tribe who were sometimes employed by both Fulani and non-Fulani farmers to herd and treat their animals with herbal remedies.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- AdditionalFile1Questionnaire.docx
- AdditionalFile2InterviewGuide.docx
- AdditionalFile3Herdcharacteristics.docx
- AdditionalFile4DiseasePrevalence.png
- AdditionalFile5Sourceofantibiotics.jpg
- AdditionalFile6Bivariatestatistics.docx
- GraphicalAbstract.docx