

Antibiotic Use and Stewardship Gaps among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: A One Health Perspective

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Running Title

Antibiotic use and stewardship gaps among Fulani women vendors, Nigeria

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Tables and Figures

Tables: 1, Figures: 5, Supplementary files: 2

Keywords

Antibiotic use; antimicrobial stewardship; Fulani women; informal dairy markets; One Health; Nigeria

Declarations

- **Ethics approval and consent to participate:** Ethical approval was obtained from the Ahmadu Bello University Committee on Human Subjects Research (ABUCUHSR202229) before the start of the study. Written informed consent was secured from all participants at the beginning of the questionnaire process. Participation was voluntary, and respondents were informed they could withdraw at any time without penalty.
- **Funding:** This research received no external funding.
- **Competing interests:** The authors declare no competing interests.
- **Data availability:** The datasets generated and analysed during the current study are provided in Supplementary File 2, with the structured questionnaire available in Supplementary File 1. These materials are integral to readers' understanding of the

study and are openly shared alongside the manuscript. A completed STROBE checklist is provided in Supplementary File 3 to document adherence to reporting guidelines. All supplementary files have been deposited in Zenodo to ensure transparency and reproducibility (DOI: [10.5281/zenodo.19454635](https://doi.org/10.5281/zenodo.19454635)).

- **Supplementary File 1:** Structured questionnaire (PDF)
- **Supplementary File 2:** Response dataset (XLSX)
- **Supplementary File 3:** STROBE checklist for cross-sectional studies (PDF)
- **.Use of Artificial Intelligence:** "In the preparation of this manuscript, the authors made use of the following artificial intelligence (AI)-assisted tools: Grammarly (Grammarly Inc., San Francisco, CA, USA) for grammar checking, spelling correction and stylistic refinement; QuillBot (Course Hero Inc., Redwood City, CA, USA) for paraphrasing assistance and sentence restructuring; Perplexity AI (Perplexity AI Inc., San Francisco, CA, USA) for literature identification, reference verification and manuscript drafting support; and Microsoft Copilot (Microsoft Corporation, Redmond, WA, USA) for writing assistance and text refinement during manuscript preparation. All AI-generated or AI-assisted content was critically reviewed, verified and edited by the authors, who take full and sole responsibility for the accuracy, integrity, originality and ethical compliance of the final manuscript. No AI tool was used to generate, fabricate or manipulate data, figures or references. No AI tool is listed in the Acknowledgements section, in accordance with ICMJE guidelines and WHO Bulletin editorial policy.

Antibiotic Use and Stewardship Gaps Among Fulani Women Dairy Vendors in Informal Dairy Markets, Sabon-gari and Zaria, Nigeria: A One Health Perspective

Abstract

Objective: To characterise knowledge, attitudes, and practices (KAP) regarding antibiotic use among Fulani women milk vendors in Sabon Gari and Zaria, Nigeria, within a One Health framework

Methods: A cross-sectional survey of 77 itinerant Fulani women milk vendors employed a structured questionnaire adapted from validated KAP instruments for livestock producers. Items assessed vendor characteristics, antibiotic knowledge, attitudes towards antimicrobial use (AMU), practices, and self-reported use of 21 antibiotics. Data were analysed descriptively in SPSS (version 25). Knowledge and practice items were dichotomised (appropriate=1, inappropriate/“don’t know”/missing=0), converted to percentage scores, and categorised as good ($\geq 80\%$), moderate (50–79%), or poor ($< 50\%$). Attitudes were summarised as 7-point Likert means, with scores ≥ 4.0 interpreted as permissive.

Findings: Vendors were exclusively itinerant traders, predominantly marketing fermented products (*nono*, *kindirmo*). Knowledge deficits were profound: 55.8% had heard of antibiotics, 31.2% recognised their action against bacteria, and none specified side-effects. Overall, 0% achieved good knowledge, 2.6% moderate, and 97.4% poor scores. The mean attitude score was 4.41, indicating uniformly permissive orientations. Practices were frequently unsafe: 59.7% routinely added antibiotics to feed or water, 45.5% retained leftovers, and 22.1% shared them, yielding 2.6% good, 26.0% moderate, and 71.4% poor practice scores.

Conclusion: Fulani women vendors in Zaria’s informal dairy markets exhibit profound knowledge deficits, permissive norms, and hazardous AMU behaviours, substantially shaping consumer exposure to antibiotic residues and resistant organisms. These findings underscore

their importance as priority targets for gender-responsive One Health stewardship interventions.

MeSH Keywords: Antibiotic use; Antimicrobial stewardship; Fulani women; Informal dairy markets; One Health; Nigeria; Food safety; Knowledge, attitudes, and practices (KAP)

What was already known

Antimicrobial resistance (AMR) is a critical public health threat, with the misuse of antibiotics in livestock and dairy systems recognised as a major driver, especially in informal value chains in low- - and middle-income countries.[1–8,11–16] In Nigeria, microbial contamination of nono and kindirmo and the central socio-economic role of Fulani women vendors are well documented. However, their knowledge, attitudes, and practices (KAP) regarding antimicrobial use (AMU) had not been systematically assessed.[10,17–19,25,29,35]

What this study adds

This study reveals that Fulani women vendors in Zaria’s informal dairy markets exhibit widespread deficiencies in AMU stewardship. Findings show poor knowledge, permissive attitudes, and unsafe practices, including routine prophylactic antibiotic use, improper storage and disposal, and reliance on informal prescribers. By situating these results within a One Health framework, the study demonstrates that vendor-level AMU practices are systemic rather than isolated, directly shaping consumer exposure to antimicrobial residues and resistant pathogens. These insights highlight the urgent need for culturally tailored, gender-responsive interventions and for integrating informal dairy chains into Nigeria’s AMR control strategies.

Introduction

The World Health Organization (WHO) recognises antimicrobial resistance (AMR) as one of the greatest global health threats of the 21st century (1–3). Resistance to essential antibiotics

undermines food security, healthcare systems, and economic stability, with recent WHO alerts emphasising the urgency of coordinated global action (1–3). Misuse of antibiotics in food production is a major driver of AMR (4–6). Intensive livestock systems often rely on antimicrobials for growth promotion and prophylaxis, accelerating resistant pathogens. Overuse in agriculture further spreads resistant strains through food chains and the environment (4–6). Informal dairy chains in low- and middle-income countries are particularly vulnerable, as weak regulation and limited awareness exacerbate misuse and complicate integration into formal value chains (7–9).

Nigeria exemplifies these dynamics. Informal dairy markets such as Sabon Gari and Zaria are hubs for fresh milk and traditional fermented products, notably nono and kindirmo, which remain central to Fulani livelihoods and nutrition (10–16). These markets are sustained largely by Fulani women vendors, who play pivotal roles in milking, fermentation, and retailing, blending pastoral heritage with market-based subsistence and oral knowledge transfer (11–13). However, microbial contamination and poor quality control in these informal products pose persistent food safety risks (17–22). The microbiological and residue-related dimensions of these risks are examined in detail in a companion paper from this survey cohort [cite 23, MANU-RES.docx upon submission].

The socioeconomic role of Fulani women in Nigerian informal dairy chains is well established (11–13). Their dual role as producers and vendors positions them at the intersection of community livelihoods and public health, yet vendor-level knowledge, attitudes, and practices (KAP) regarding antimicrobial use (AMU) remain poorly described. AMR concept-level KAP among this group is reported in a companion paper [cite AMR.docx 25 upon submission]. This gap is critical. Informal dairy chains operate largely outside formal regulation, leading to inconsistent antibiotic use, weak adherence to withdrawal periods, and limited veterinary consultation. Evidence from India and other settings shows that milk vendors often lack

awareness of withdrawal times and rely on informal veterinary advice, contributing to residues in marketed milk and potential spread of resistance genes through foodborne pathways (2–8,17–22). Documenting vendor-level practices is therefore essential to safeguard public health, strengthen informal dairy systems, and align Nigeria’s dairy sector with global AMR action plans (1–3,13). Hygiene concept-level KAP among this group is reported in a companion paper [cite 24, MANU-RES.docx upon submission].

This article presents the antibiotic-use and stewardship findings from the informal dairy cohort; residue-related KAP and detailed hygiene and value-chain practices from the same respondents are analysed separately in manuscripts focusing on antimicrobial residues and on milking, storage, and transport behaviours.

Methods

Study design and setting

This descriptive cross-sectional study was conducted in informal dairy markets in Zaria and Sabon-gari, Kaduna State, northern Nigeria, where Fulani pastoral and agropastoral households supply raw and fermented milk directly to consumers through itinerant vending. The AMU component of the broader survey focused on antibiotic use and stewardship behaviours among women vendors who bridge household production and urban demand. Data collection took place during routine market activity, capturing typical patterns of antibiotic access and use rather than responses to an outbreak or targeted intervention.

Data Collection

This study formed part of a broader investigation of informal dairy value chains in Kaduna State, focusing specifically on antibiotic use among Fulani women vendors in Sabon-gari and Zaria. From a pool of 100 women actively selling raw milk and traditionally fermented products (nono, kindirmo), 77 met eligibility criteria, provided written informed consent, and

completed the structured questionnaire; 23 declined participation, citing time constraints or expectations of compensation. All respondents self-identified as Fulani women and had at least six months of vending experience, ensuring that the sample captured those most directly responsible for everyday antibiotic-related decisions along the dairy chain.

Data were collected using a 40-item questionnaire adapted from previous KAP studies on antimicrobial use in dairy and livestock systems in Africa and Asia, with emphasis on informal chains and milk safety (8,20–22,25,27,29–31,37). The instrument comprised five domains: (i) general information (vendor characteristics, product types, milk sources, education); (ii) knowledge (antibiotics, withdrawal periods, biosecurity, side effects); (iii) attitudes (beliefs about AMU on 7-point Likert scales); (iv) practices (prescription sources, record keeping, dosing, storage, disposal); and (v) antibiotic usage patterns across 21 agents. Questionnaires were administered in English with translation support in Hausa and Fulfulde.

The study adhered to the World Medical Association’s Declaration of Helsinki (Seoul 2008) and STROBE guidelines for cross-sectional studies, with a completed checklist provided as Supplementary File 3. The structured questionnaire, anonymised dataset, and STROBE checklist are openly available on Zenodo (DOI: 10.5281/zenodo.19454634) (26). As all participants were female, sex disaggregation was inherent, consistent with SAGER principles. This manuscript reports antibiotic use and stewardship practices from the cohort; companion papers address antimicrobial residue-related KAP and AMR concept-level KAP [cite 23,24,25].

Data analysis

Responses were coded and analysed in SPSS (version 25). Frequencies and proportions were calculated for categorical variables, and “no response” categories were retained. Cross-tabulations were explored where relevant, although analyses were primarily descriptive

with significance set at $p < 0.05$. Bias was minimised through anonymous coding, neutral prompting, and translation support. Non-responses were retained and reported transparently. Item-level distributions were summarised in five supplementary tables (S1–S5), and interpretation was informed by relevant livestock KAP literature (8,27–38). Chi-square tests were conducted to examine associations between key demographic variables (education level, training received) and KAP outcome categories. Statistical significance was set at $p < 0.05$. All analyses were performed using Python (SciPy library, version 1.13).

KAP scoring and categorisation

Categorical KAP scores were derived using standard livestock stewardship methods (8,27–38). Knowledge items (K-AMU1–K-AMU7) were coded as 1 for correct or stewardship-aligned responses and 0 for incorrect, “do not know,” or missing responses. Correct responses included familiarity with antibiotics, recognising that they act against bacteria, rejecting early cessation of treatment and routine use to increase milk yield, and acknowledging biosecurity, withdrawal periods, and side-effects. Scores ranged from 0 to 7 and were converted to percentages.

Attitude items (A-AMU1–A-AMU9) were scored on a 7-point Likert scale (1=strongly disagree to 7=strongly agree), and an overall mean attitude score was calculated. Agreement with items endorsing inappropriate AMU (e.g., unsupervised dose modification, routine prophylaxis, growth promotion, lay prescribing, or the belief that antibiotics can treat any disease) was interpreted as permissive. In contrast, agreement with items emphasising biosecurity, vaccination, judicious use, and economic impacts was interpreted as stewardship-oriented.[8,27–37]

Practice items (P-AMU1–P-AMU9) were classified as appropriate (score 1) or inappropriate (score 0) using antimicrobial stewardship principles drawn from farm-level AMU studies and One Health guidance.[27–29,31,33–34,38–40] Appropriate responses were: veterinarian as

main recommender, always keeping treatment records, completing courses, using single-drug or case-dependent regimens, avoiding routine feed or water supplementation, storing drugs in a storeroom or refrigerator, always following prescriptions, burning or burying leftovers, and consulting manufacturer leaflets. Scores were summed (0–9) and converted to percentages.

For knowledge and practice, scores $\geq 80\%$ were classified as “good”, 50–79% as “moderate”, and $< 50\%$ as “poor” (8,27–29,31,34–36). For attitudes, mean scores ≥ 4.0 (scale midpoint) were interpreted as permissive and < 4.0 as stewardship-oriented, consistent with previous KAP studies in dairy and poultry systems (8,27–29,31,34–36).

Results

General information

Of 100 vendors approached, 77 completed the survey; 23 declined, mainly citing lack of interest. Missing responses were minimal and coded as “no response”. All analysed respondents were itinerant vendors who transported raw milk, *nono* and *kindirmo* directly to customers, typically on foot or using informal transport, with no shop-based retailers represented. Most sourced milk from their own or household herds, and smallholder-scale yields predominated, with the majority reporting 5–10 litres per animal per milking session and rapid sale of products within two days of collection.

Vendors marketed traditionally fermented products, with *kindirmo* (40.3%) and *nono* (24.7%) most common, while raw milk (20.8%) and yoghurt (9.1%) together accounted for less than one-third of sales. Most respondents sourced products from cattle (77.9%) and obtained milk directly from animals (51.9%), reflecting close integration with primary production. Nearly half relied on a single milk source (46.8%), whereas the remainder drew from multiple suppliers. Educational attainment was low: about one-third reported only Qur’anic schooling,

9.1% had no formal education, and 44.2% had completed secondary or tertiary education. Just over half (55.8%) reported having received training on antibiotic use and resistance.

Knowledge of antimicrobial use

Slightly more than half of vendors (55.8%) had heard of antibiotics, but only about one third (31.2%) correctly identified that antibiotics act specifically against bacteria. Misconceptions were common, with some believing antibiotics act against viruses, fungi, or all pathogens. Awareness of withdrawal periods was limited (36.4%), and fewer than half (44.2%) recognised that antimicrobials can have side-effects; none could specify examples. Only 16.9% reported knowledge of biosecurity measures. Composite scoring showed that no vendor achieved “good” knowledge. Only 2.6% had “moderate” knowledge, while 97.4% fell into the “poor” category. Overall, knowledge of AMU was partial and fragmented, with major gaps in withdrawal periods, side-effects, and biosecurity.

Attitudes toward antimicrobial use

The mean attitude score was 4.41, exceeding the decision mean of 4.00 and indicating generally permissive attitudes. Many vendors agreed or strongly agreed that altering antibiotic doses without consulting a prescriber could improve results (mean 4.99) and that routinely using the same antibiotic for prevention yields better outcomes (mean 4.61). At the same time, respondents strongly agreed that biosecurity, vaccination, and good management can reduce antimicrobial use (mean 5.30). Responses to statements about stopping treatment when animals appear healthy, and the belief that antimicrobials can treat any disease, suggested uncertainty about treatment duration and spectrum. Using the 4.0 threshold, all vendors were classified as having permissive attitudes. Attitudes thus combined endorsement of preventive husbandry with acceptance of unsafe AMU behaviours.

Practices related to antimicrobial use

Biosecurity and hygiene practices were mixed. Only 41.6% of farms were fenced, 51.9% allowed visitors into animal sheds, 31.2% reported wild animal intrusion, and 41.6% had footbaths. Just over half of the drinkers (53.2%) and feeders (49.4%) were cleaned daily. Most respondents (72.7%) reported vaccinating animals at scheduled times.

Veterinarians were the main source of antibiotic recommendations (54.5%), but paraprofessionals, other farmers, and informal practitioners were also influential. Many vendors reported adding antibiotics to feed or water (59.7%), using combined or uncertain dosage regimens, and not always completing prescribed courses (14.3% admitted non-completion). Storage was often suboptimal: antibiotics were kept in storerooms (45.5%) or household spaces (18.2%). Leftovers were commonly stored for future use (45.5%) or shared with other farmers (22.1%); only a minority used safer disposal. About half reported following withdrawal periods (53.2%) and reading prospectuses (58.4%), and only 45.5% always kept treatment records.

Composite KAP Scores

Composite scoring revealed marked deficiencies across all three domains. The Knowledge dimension averaged 32.9%, with only 2.6% of respondents achieving moderate scores and none reaching the “good” threshold. The Attitudes dimension yielded a mean Likert score of 4.41 (equivalent to 63.0%), exceeding the decision mean of 4.0 and indicating uniformly permissive orientations toward antimicrobial use. The Practices dimension averaged 52.0%, with 2.6% classified as good, 26.0% as moderate, and 71.4% as poor. Taken together, the Composite KAP score was 49.3%, underscoring a substantial stewardship gap among Fulani women milk vendors in Zaria’s informal dairy markets. Routine feed supplementation, poor storage and disposal practices, inconsistent record-keeping, and reliance on informal prescribers were key drivers of poor practice.

Chi-square analyses revealed no statistically significant association between education level and knowledge category ($\chi^2 = 0.49$, $df = 4$, $p = 0.974$), education level and practice category ($\chi^2 = 1.83$, $df = 4$, $p = 0.768$), training received and knowledge category ($\chi^2 = 0.91$, $df = 2$, $p = 0.635$), or training received and practice category ($\chi^2 = 1.67$, $df = 2$, $p = 0.434$). Withdrawal period compliance also showed no significant association with training received (Fisher's exact test, $p = 1.000$). These findings indicate that poor KAP scores were uniformly distributed across all education levels and regardless of prior training, reinforcing the need for interventions that address structural and economic constraints rather than relying solely on formal education or training.

Antibiotics frequently used

Amoxycillin (35.1%), sulpha drug combinations (25.9%), and ampicillin (22.1%) were the most frequently reported antibiotics. A range of other classes, including tetracyclines, macrolides, fluoroquinolones, cephalosporins, and aminoglycosides, were used by smaller proportions of vendors. This pattern reveals both dominance of a few broad-spectrum agents and wide exposure to multiple drug classes, creating cumulative selection pressure for diverse resistance mechanisms.

Discussion

This analysis reveals a pronounced stewardship deficit in antibiotic use practices among Fulani women vendors at the retail end of Nigeria's informal dairy chains, despite their central role in connecting household livestock to urban consumers. Composite scoring confirmed near-universal deficiencies: 97.4% had poor knowledge, 100% had permissive attitudes, and 71.4% had poor practices, yielding an overall composite score of 49.3%. The pattern of partial awareness, permissive norms, and unsafe dosing, storage, and disposal behaviours underscores

that current AMR messaging has scarcely reached this group in a form that changes everyday practice.

Knowledge gaps extended beyond terminology. Only one-third of respondents recognised that antibiotics act against bacteria, and awareness of withdrawal periods, side effects, and biosecurity was very low. These deficiencies persisted despite reported prior training, suggesting that existing education is poorly tailored or not retained. Formal education level and prior training exposure were not significantly associated with knowledge, practice, or withdrawal compliance outcomes ($\chi^2 = 0.49\text{--}1.83$, all $p > 0.05$). Vendors with tertiary education were no more likely to demonstrate good scores than those with Qur'anic or no formal schooling. Similarly, 55.8% of vendors who reported receiving training showed no significant improvement compared with untrained peers. These findings echo observations from Ghana, Malawi, and Uganda, where training has likewise failed to improve stewardship behaviours, reinforcing the need for interventions that address economic constraints, informal prescribing networks, and structural access barriers (8-9,14-16,44).

Attitudinal findings showed universal permissiveness: vendors endorsed unsupervised dose modification and routine prophylaxis while simultaneously valuing biosecurity and vaccination. This cognitive dissonance, recognising stewardship principles but normalising risky behaviours, has been documented elsewhere and likely reflects economic and structural constraints, in which antibiotics are perceived as affordable, flexible tools to protect livelihoods rather than investments in infrastructure or veterinary care (4-6,15,27-29,44-45).

Practice-level data confirmed widespread unsafe behaviours. Routine supplementation of feed or water, incomplete adherence to prescriptions, household storage, retention or sharing of leftovers, and inadequate disposal together create conditions that favour resistant bacteria. The

implications of these practices for antibiotic residue levels in marketed milk are examined in a companion paper [cite MANU RES.docx upon submission] (23-25).

The central role of Fulani women vendors in milking, fermentation, and retailing has important gender and equity implications. Operating under limited formal education, constrained veterinary access, and minimal regulatory oversight, they make everyday decisions that shape consumer exposure to antimicrobial residues and resistant organisms [17–19,25,29,35,36]. Residue and milk handling dimensions are detailed in a companion paper from this cohort [cite MANU RES.docx upon submission] (23-25). From a One Health perspective, the patterns documented here mirror syntheses highlighting informal livestock and food systems as blind spots in AMR surveillance and control, underscoring the need to integrate informal dairy chains into national AMR strategies (38-40,44,47-48).

Strengths and limitations

A major strength of this study is its focus on an underserved but critical population. Fulani women vendors, whose AMU practices directly influence consumer exposure yet remain absent from surveillance and policy dialogues. The use of a validated KAP framework adapted to local dairy contexts enhances reliability and cultural relevance, while composite scoring provides a transparent measure of stewardship gaps. Limitations include the exclusive focus on Fulani women vendors and the absence of personal demographic data (e.g., age, marital status) to preserve confidentiality, which restricts socio-demographic disaggregation and generalisability. The cross-sectional design also captures practices at a single point in time, without assessing seasonal variation or longitudinal change. Despite these limitations, the study offers novel insights into AMU stewardship in Nigeria's informal dairy sector and highlights urgent intervention entry points.

Lessons for Policy and Practice

Stewardship efforts in Nigeria must extend beyond farms to address vendor-level behaviours in informal dairy markets, where antibiotics are selected, managed, and communicated to consumers (1–3,26,28). Culturally tailored training that builds on oral traditions, peer learning, and trusted community networks is essential (17–19,35). Informal prescribing networks, including shopkeepers and paraprofessionals, should be regulated and integrated into community-based initiatives (21–24,31). Finally, informal dairy chains must be incorporated into national One Health surveillance platforms so that AMU behaviours and AMR patterns are systematically monitored alongside formal farm and clinical data (2,23,26,34,36–40).

Conclusion

Fulani women vendors in Zaria’s informal dairy markets exhibit marked gaps in antibiotic-use stewardship, with 97.4% had poor knowledge and 100% had permissive attitudes. [d 71.4% poor AMU practices, despite reported strengths in vaccination and hygiene (8-9,15,33). These deficiencies position informal dairy vendors as critical yet underserved actors in Nigeria’s AMR landscape (10-13,17) Addressing them will require gender-responsive interventions that build practical understanding of antibiotics, withdrawal periods, resistance risks, and non-antibiotic alternatives, alongside regulation and engagement of informal prescribing networks and integration of informal dairy chains into One Health surveillance and national AMR action plans (1–3,13,27-29,31-34,41-45).

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Authors contribution

CRedit Role	Authors
Conceptualisation	MMF
Methodology	MMF, JSO
Data curation	RF, SG, ERA
Formal analysis	MMF, RF, JSO
Investigation	RF, SG, ERA
Resources	SG, ERA
Visualisation	MMF, RF, JSO
Writing — original draft	MMF
Writing — review and editing	RF, JSO, SG, ERA
Project administration	MMF

Supplementary Materials

Supplementary File 1: Structured questionnaire used in the survey (PDF). Supplementary File 2: Response dataset from 77 Fulani women milk vendors (Excel). Supplementary File 3: STROBE checklist for cross-sectional studies (PDF).

All supplementary files are openly available via Zenodo at DOI: [insert Zenodo DOI once published].

References:

1. World Health Organization. Antimicrobial resistance. Geneva: WHO; 2023. Available from: <https://www.who.int/news-room/fact-sheets/detail/antimicrobial-resistance> (accessed 21 March 2026).
2. World Health Organization. Global antibiotic resistance surveillance report 2025. Geneva: WHO; 2025. Available from: <https://www.who.int/publications/i/item/9789240116337> (accessed 21 March 2026)
3. World Health Organization. WHO warns of widespread resistance to common antibiotics worldwide. Geneva: WHO; 2025 Oct 13. Available from: <https://www.who.int/news/item/13-10-2025-who-warns-of-widespread-resistance-to-common-antibiotics-worldwide> (accessed 21 March 2026).
4. FAIRR Initiative. Antibiotic use in intensive animal agriculture. London: FAIRR; 2026 Feb 26. Available from: <https://www.fairr.org/resources/knowledge-hub/antibiotics-use-in-intensive-animal-agriculture> (accessed 21 March 2026).
5. Kumar D. WAAW 2025: Challenges and pathways for sustainable animal health management in rural India. New Delhi: Down To Earth; 2025 Nov 12. Available from: <https://www.downtoearth.org.in/health/waaw-2025-challenges-and-pathways-for-sustainable-animal-health-management-in-rural-india> (accessed 21 March 2026).
6. Earth.Org. Antibiotic overuse in food production is fueling a global health crisis. Hong Kong: Earth.Org; 2025. Available from: <https://earth.org/antibiotic-overuse-in-food-production-is-fueling-a-global-health-crisis/> (accessed 21 March 2026).
7. Gebru GG, Muthupandian S, Kassaye E. Prevalence and antimicrobial resistance of *Escherichia coli* and *Klebsiella* spp in dairy farm in the Tigray Region, Northern

- Ethiopia. BMC Microbiol. 2025;25(1):159. doi:10.1186/s12866-025-04643-8.
Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC12836893/> (accessed 21 March 2026).
8. Sharma G, Leahy E, Deka RP, Shome BR, Bandyopadhyay S, Dey TK, Goyal NK, Lundkvist Å, Grace D, Lindahl JF. Antibiotic use, knowledge, and practices of milk vendors in India's informal dairy value chain. *Front Sustain Food Syst*. 2022;6:1058384. doi:10.3389/fsufs.2022.1058384. Available from: <https://www.frontiersin.org/articles/10.3389/fsufs.2022.1058384/full> (accessed 21 March 2026).
 9. International Livestock Research Institute (ILRI). Integrating informal milk markets into formal value chains in Eastern and Central Africa. Nairobi: ILRI; 2011. Available from: <https://www.ilri.org/research/projects/integrating-informal-milk-markets-formal-value-chains-eastern-and-central-africa> (accessed 21 March 2026).
 10. Ugwu DS. Dairy production among small and medium scale farmers in Nigeria: A case study of Kaduna and Kano States. *World J Agric Sci*. 2009;6(1):1–6. Available from: [https://www.idosi.org/wjas/wjas6\(1\)/1.pdf](https://www.idosi.org/wjas/wjas6(1)/1.pdf) (accessed 21 March 2026).
 11. Waters-Bayer A. Dairy farming by settled Fulani agropastoralists in central Nigeria: The role of women and implications for dairy development. *Africa (Lond)*. 1985;55(4):389–416. doi:10.2307/1160134. Available from: <https://www.jstor.org/stable/1160134> (accessed 21 March 2026).
 12. 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. Available from: <https://reference-global.com/article/10.2478/contagri-2020-0010>

13. Adesulu-Dahunsi AT, Ezeb EE, Adeleke AJ, James FA, Ayodele PF, Osueke CO. Sustainable dairy development: a panacea to food insecurity in Nigeria (a review). *FUW Trends Sci Technol J*. 2023;8(3):222–230. Available from: https://tau.edu.ng/assets/publications/213_sustainable-dairy-development-a-panacea-to-food-insecurity-in-nigeria-a-review.pdf (accessed 21 March 2026).
14. International Livestock Research Institute (ILRI). Milk quality and hygiene practices among smallholder dairy producers and traders in East Africa. Nairobi: ILRI; 2025. Available from: <https://www.ilri.org/knowledge/publications/milk-quality-and-hygiene-knowledge-attitudes-and-practices-smallholder-dairy> (accessed 21 March 2026).
15. Smith LC, Stringer A, Owuor KO, Ndenga BA, Winter C, Gerken KN. Moving milk and shifting risk: A mixed methods assessment of food safety risks along informal dairy value chains in Kisumu, Kenya. *One Health*. 2024;19:100914. doi:10.1016/j.onehlt.2024.100914. Available from: <https://www.sciencedirect.com/science/article/pii/S2352771424002404> (accessed 21 March 2026).
16. Emdin F, Galiè A, Moodley A, Rogers Van Katwyk S. Gender and antimicrobial resistance: a conceptual framework for researchers working in livestock systems. *Front Vet Sci*. 2025;11:1456605. doi:10.3389/fvets.2024.1456605. Available from: <https://www.frontiersin.org/journals/veterinary-science/articles/10.3389/fvets.2024.1456605/full> (accessed 21 March 2026).
17. Mohammed K, Biyabra MI. Incidence of bacterial contaminants in fermented milk (nono/kindirmo) sold by Fulani women to consumers in Wukari Metropolis, Taraba State, Nigeria. *Sahel J Life Sci*. 2024;2(1):195–203. doi:10.33003/sajols-2024-0201-024. Available from

- <https://saheljls.fudutsinma.edu.ng/index.php/saheljls/article/view/78> (accessed 21 March 2026).
18. Ikele OM, Ogu CT, Jiang X, Cavender GA. Evaluation of different lactic acid bacteria as starter cultures for nono—A West African fermented dairy product. *Foods*. 2024;13(19):3030. doi:10.3390/foods13193030. Available from: <https://www.mdpi.com/2304-8158/13/19/3030> (accessed 21 March 2026).
 19. Uzoaga GO, Umeokonkwo CD, Kia GS, Okolocha EC. Bacteriological quality of nono, a milk product sold at retail outlets in Federal Capital Territory, Nigeria. *J Interv Epidemiol Public Health*. 2020;3(1):5. doi:10.37432/JIEPH.2020.3.2.25. Available from: <https://www.ajol.info/index.php/jieph/article/view/225741/213017> (accessed 21 March 2026).
 20. Bello A, Ejeh EF, Lawan FA, Bitrus AA. Assessment of the bacteriological quality of locally fermented cow milk (nono) consumed in Maiduguri, northeastern Nigeria. *Indian J Vet Anim Sci Res*. 2023;55(4):812–819. DOI:10.56093/ijvasr.v47i3.137843. Available from: <https://epubs.icar.org.in/index.php/IJVASR/article/view/137843> (accessed 21 March 2026).
 21. Shittu AO, David MS, Aliyu A, Bello RH, Olajide RO. Bacteriological quality of locally fermented milk (nono) and commercial yoghurts marketed in Ilorin. *J Pharm Res Dev Pract*. 2016;1:48–59. Available from: <https://uilspace.unilorin.edu.ng/bitstreams/e17f0f35-ca19-4244-9c99-eb9330a6d27a/download> (accessed 21 March 2026).
 22. Musa A, Ibrahim S, Abdullahi M, Yusuf H, Danladi A. Chemical and microbiological properties of nono sold at Bayero University, Kano, Nigeria. *Niger J Anim Prod*. 2024;51(3):601–611. doi:10.51791/njap.v51i3.5593. Available from: <https://njap.org.ng/index.php/njap/article/view/5593> (accessed 21 March 2026).

23. RES
24. Hygiene
25. AMR
26. Fathuddin, MM, Fathuddin, R, Solomon Obidah, J, Garba, S, & Ameh, ER.
Supplementary Data – Antibiotic Use and Stewardship Gaps among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: A One Health Perspective [Data set]. Zenodo. 2026. Available from: <https://doi.org/10.5281/zenodo.19454635> (accessed 07 April 2026).
27. Kallu SA, Kebede N, Kassa T, Wubaye AM, Kainga H, Mekonnen H, Simuunza MC. Knowledge, attitudes, practices, and risk perception of antimicrobial use and antimicrobial resistance among dairy farm owners/workers in Addis Ababa, Ethiopia. *Infect Drug Resist.* 2024;17:1839–1861. doi:10.2147/IDR.S453570. Available from: <https://www.dovepress.com/knowledge-attitudes-practices-and-risk-perception-of-antimicrobial-use-peer-reviewed-fulltext-article-IDR> (accessed 21 March 2026).
28. Gonah L, Nyoka R, Murapa B. Knowledge, attitudes, and practices of dairy farmers on antibiotic use and their effects on health in Gweru District, Zimbabwe. *Food Hum.* 2024;3:100384. doi:10.1016/j.foohum.2024.100384. Available from: <https://www.sciencedirect.com/science/article/abs/pii/S2949824424001599> (accessed 21 March 2026).
29. Farrell S, McKernan C, Benson T, Elliott C, Dean M. Understanding farmers’ and veterinarians’ behaviour in relation to antimicrobial use and resistance in dairy cattle: A systematic review. *J Dairy Sci.* 2021;104(4):4584–4603. doi:10.3168/jds.2020-19693. Available from: <https://www.sciencedirect.com/science/article/pii/S0022030221001739> (accessed 21 March 2026).

30. Kimambo J, Kimera ZI, Niccodem E, Kunambi P, Mgaya FX, Matee MIN. Antibiotic use in small-scale dairy farming and residue levels of tetracyclines and sulphonamides in milk from Eastern Tanzania. *Bull Natl Res Cent.* 2026;50:7. doi:10.1186/s42269-026-01393-z. Available from: <https://link.springer.com/article/10.1186/s42269-026-01393-z> (accessed 21 March 2026).
31. Hackman HK, Annison L, Arhin RE, Aidoo EK, Wilberforce EA, Mensah AC, Appiah L, Annison S, Ayim-Akonor M. Awareness of antimicrobial resistance and antibiotic use among poultry farmers in Accra, Ghana: A cross-sectional survey. *PLoS One.* 2025;20(12):e0337531. doi:10.1371/journal.pone.0337531. Available from: <https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0337531> (accessed 21 March 2026).
32. Smith LC, Stringer A, Owuor KO, Ndenga BA, Winter C, Gerken KN. Moving milk and shifting risk: A mixed methods assessment of food safety risks along informal dairy value chains in Kisumu, Kenya. *One Health.* 2024;19:100914. doi:10.1016/j.onehlt.2024.100914. Available from: <https://www.sciencedirect.com/science/article/pii/S2352771424002404> (accessed 21 March 2026).
33. Tufa TB, Regassa F, Amenu K, Stegeman JA, Hogeveen H. Livestock producers' knowledge, attitude, and behavior regarding antimicrobial use in Ethiopia. *Front Vet Sci.* 2023;10:1167847. doi:10.3389/fvets.2023.1167847. Available from: <https://www.frontiersin.org/journals/veterinary-science/articles/10.3389/fvets.2023.1167847/full> (accessed 21 March 2026).
34. Dankar I, Hassan H, Serhan M. Knowledge, attitudes, and perceptions of dairy farmers regarding antibiotic use: Lessons from a developing country. *J Dairy Sci.*

2022;105(2):1519–1532. doi:10.3168/jds.2021-20528. Available from:
<https://www.sciencedirect.com/science/article/pii/S0022030221011012> (accessed 21
March 2026).

35. Rahman ML, Ahsan MI, Ahmed S, Islam MK, Mahbub-E-Elahi AT, Uddin MB, Ahmed SS. Knowledge, attitudes, and practices regarding antibiotic use and resistance in ruminants and chickens among prescribers and farmers in Bangladesh. *Journal of Global Antimicrobial Resistance*. Published online 2025 Oct 28. doi:10.1016/j.jgar.2025.10.018. Available from:
<https://www.sciencedirect.com/science/article/pii/S2213716525002383> (accessed 21 March 2026).
36. Dhangar, M., Kolhe, S., Waskar, V., Khanvilkar, A., Sonawane, G. and Kolhe, R. Assessment of dairy farmer's knowledge, attitude and practices on antibiotics and antimicrobial resistance. *The Haryana Veterinarian* 2023;62(SI-2): 6-1
37. Endale H, Tilahun S, Mekonnen E. Knowledge, attitudes and practices regarding antimicrobial use, resistance and residues among poultry producers in Southern Ethiopia. *Food Safety and Risk*. 2026;14(2):145–58. doi:10.1186/s40550-026-00141-5
38. Hassen KA, Fafetine J, Augusto L, Mandomando I, Garrine M, Sileshi GW. Antimicrobial resistance in selected foodborne pathogens in Sub-Saharan Africa: A systematic review and meta-analysis. *Antibiotics (Basel)*. 2026;15(1):87. doi:10.3390/antibiotics15010087. Available from: <https://www.mdpi.com/2079-6382/15/1/87> (accessed 21 March 2026).
39. Abdullahi YB, Ahmed NI, Abdi YH, Bashir SG, Abdi MS, Hussein SA, Osman MM, Hassan MM, Hussein AA, Mohamed FA, Mohamed AH. A One Health perspective on antimicrobial resistance in Sub-Saharan Africa: synthesizing human, animal, and environmental evidence for integrated action. *Discov Public Health*. 2026;23:348.

doi:10.1186/s12982-026-01721-8. Available from:

<https://link.springer.com/article/10.1186/s12982-026-01721-8> (accessed 21 March 2026).

40. Altevogt BM, Taylor P, Akwar HT, Graham DW, Ogilvie LA, Duffy E, Essack SY. A One Health framework for global and local stewardship across the antimicrobial lifecycle. *Commun Med (Lond)*. 2025;5(1):414. doi:10.1038/s43856-025-01090-4. Available from: <https://www.nature.com/articles/s43856-025-01090-4> (accessed 21 March 2026).
41. Kuboka MM. Food safety in informal markets: Hazard assessment for food in East African Community countries. Doctoral dissertation. Uppsala, Sweden: Swedish University of Agricultural Sciences; 2026. doi:10.54612/slupub-145511 Available from: <https://cgspace.cgiar.org/bitstreams/e7eb10b7-f8de-4416-9444-4b77ffad189c/download>
42. Mpatswenumugabo JP. Biosecurity and milk production among smallholder dairy farmers in Rwanda: Effects on child nutrition and prevention of zoonotic diseases. Doctoral dissertation. Uppsala, Sweden: Swedish University of Agricultural Sciences; 2024. (*Acta Universitatis Agriculturae Sueciae*, 2024:89). Available from: <https://pub.epsilon.slu.se/> (accessed 21 March 2026).
43. Donkor ES, Odoom A, Osman AH, Darkwah S, Kotey FCN. A systematic review on antimicrobial resistance in Ghana from a One Health perspective. *Antibiotics (Basel)*. 2024;13(7):662. doi:10.3390/antibiotics13070662. PMID:39061344; PMCID:PMC11274323. Available from: <https://pmc.ncbi.nlm.nih.gov/articles/PMC11274323/> (accessed 21 March 2026).

44. Food And Agriculture Organization. Codex Standards & Antimicrobial Resistance. Rome: FAO; 2025. Available from: Codex standards and antimicrobial resistance (accessed 21 March 2026).
45. Food and Agriculture Organization of the United Nations (FAO). One Health in 2025: Achievements, turning points, and the road ahead. Rome: FAO; 2025 Nov 27. Available from: <https://www.fao.org/one-health/highlights/one-health-in-2025--achievements--turning-points-and-the-road-ahead/en> (accessed 21 March 2026)

Table 1. Composite KAP Scores on Antimicrobial Use (AMU)

Legend description: This table presents knowledge, attitudes, and practices related to antimicrobial use. Knowledge is categorised by performance thresholds, attitudes by permissiveness vs stewardship orientation, and practices by compliance levels.

Domain	Category	Frequency (n)	Percent (%)
Knowledge	Good ($\geq 80\%$)	05	06.5
	Moderate (50–79%)	15	19.5
	Poor ($< 50\%$)	57	74.0
Attitudes	Permissive (mean ≥ 4.0)	60	77.9
	Stewardship-oriented (mean < 4.0)	17	22.1
Practices	Good ($\geq 80\%$)	08	10.4
	Moderate (50–79%)	25	32.5
	Poor ($< 50\%$)	44	57.1

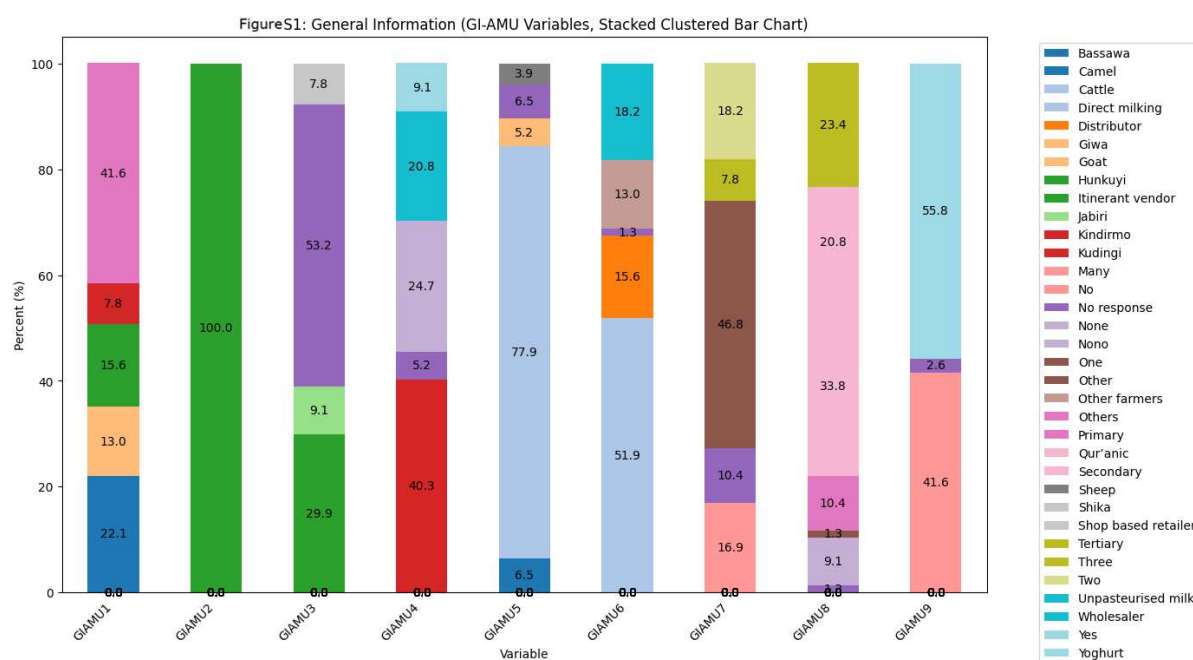


Figure S1. Distribution of general information variables (GI-AMU1–GI-AMU9) among milk vendors in Zaria, Nigeria. Stacked bars show the percentage composition of responses for each variable, including village of origin, vendor category, point of sale, product type, source species, provenance, supply sources, education level, and participation in training on antimicrobial resistance. The figure highlights the predominance of itinerant vendors, the dominance of fermented products such as Kindirmo and Nono, reliance on cattle as the main source species, modest educational attainment, and uneven exposure to formal training. Source: Authors' survey.

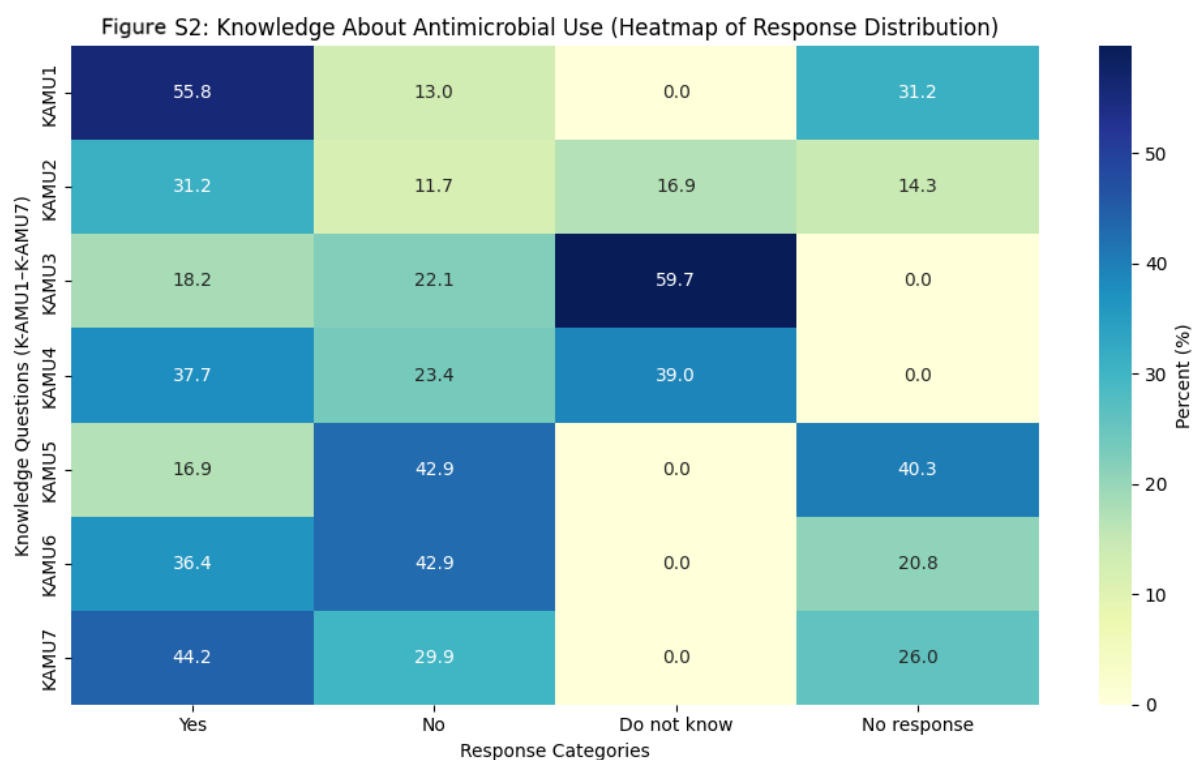


Figure S2. Knowledge about antimicrobial use among milk vendors in Zaria, Nigeria (K-AMU1–K-AMU7). The heatmap shows the proportions of respondents who answered “Yes,” “No,” “Do not know,” or did not respond to each knowledge item. The figure highlights partial awareness, frequent misconceptions about antibiotic function, poor understanding of biosecurity and withdrawal periods, and uneven recognition of potential side effects. Source: Authors’ survey.

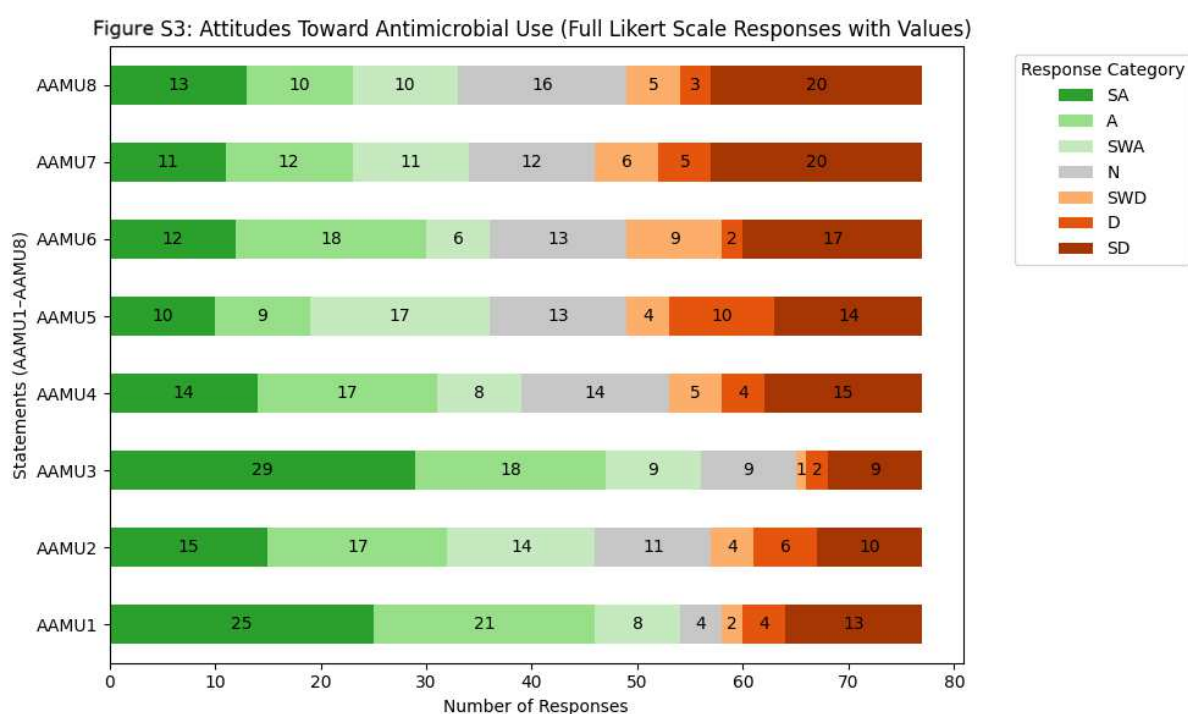


Figure S3. Attitudes toward antimicrobial use among milk vendors in Zaria, Nigeria (A-AMU1–A-AMU8). Stacked bars show the distribution of responses across the full Likert scale (strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree, strongly disagree), with numeric values annotated inside each segment. The figure highlights strong endorsement of preventive measures such as biosecurity and vaccination, alongside tolerance for modifying prescribed doses and routine prophylactic use. Ambivalence persisted on treatment adherence and universal efficacy beliefs, underscoring the need for clearer stewardship guidance. Source: Authors' survey.

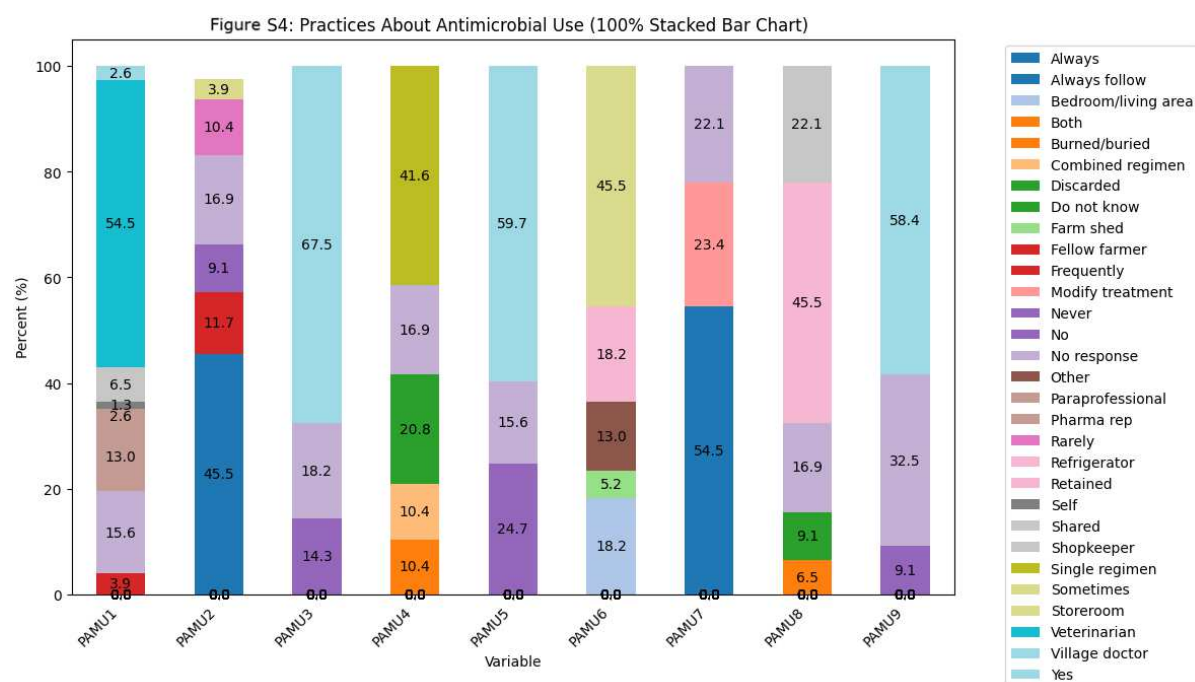


Figure S4. Practices related to antimicrobial use among milk vendors in Zaria, Nigeria (P-AMU1–P-AMU9). Stacked bars show the proportion of respondents across practice categories. The figure highlights reliance on veterinarians for authorization, inconsistent record-keeping, frequent incorporation of antibiotics into feed or water, and risky practices such as retaining leftovers for future use or storing drugs in living areas. Source: Authors' survey.

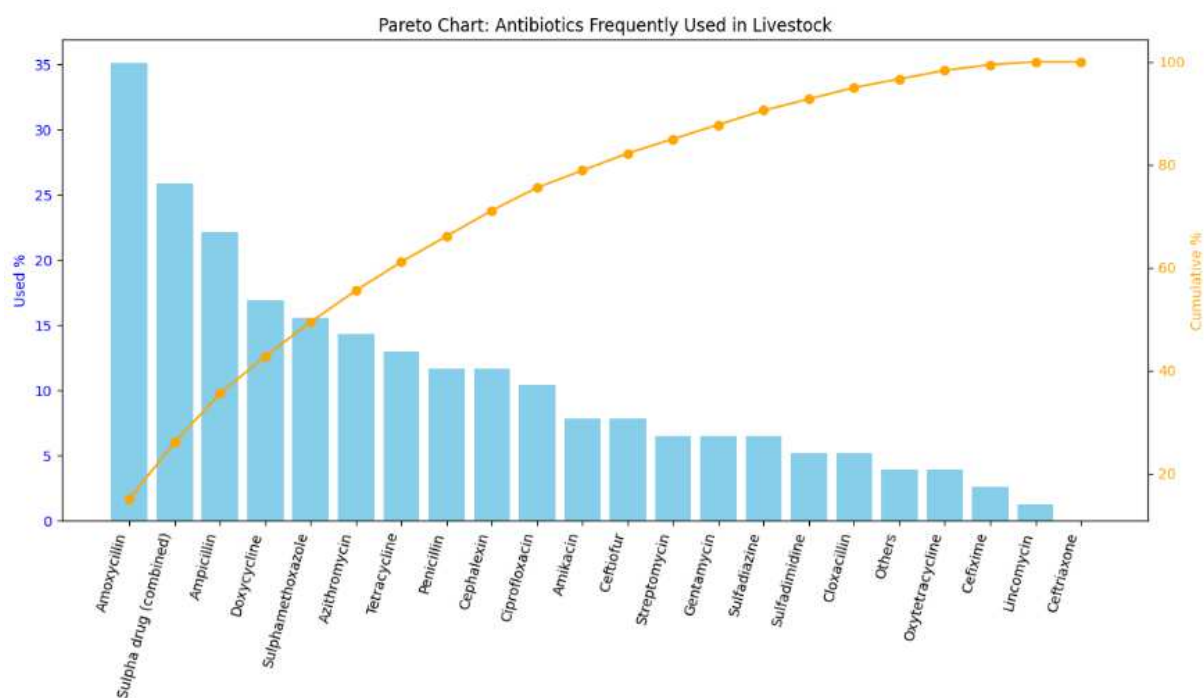


Figure 5. Antibiotics are most frequently used in livestock among milk vendors in Zaria, Nigeria. The Pareto chart shows the proportion of respondents reporting use of each antibiotic (bars) and the cumulative contribution (line). The figure highlights that amoxycillin, sulpha drugs, and ampicillin account for most reported usage, while cephalosporins and macrolides are rarely used. Source: Authors' survey.

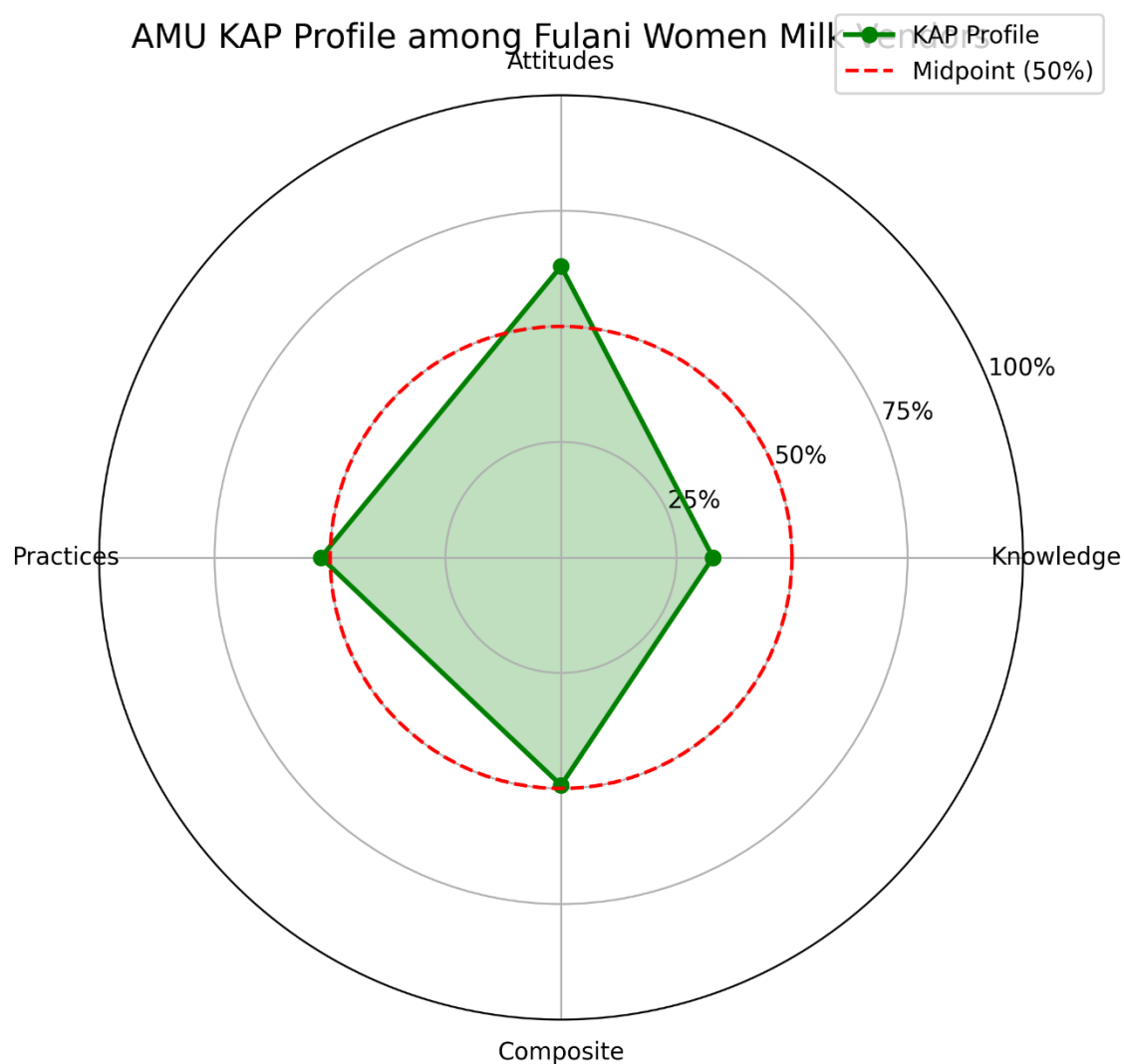


Figure 6: Composite KAP Scores on Antimicrobial Use (AMU)

Legend description:

- *Green polygon: Observed scores for Knowledge, Attitudes, and Practices related to antimicrobial use.*
- *Red dashed polygon: Benchmark threshold set at 50%.*
- *Numeric labels: Percent values for each axis tip.*
- *Subtitle: Composite score = 49.3%.*

Supplementary Files

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

- [SupplementaryFile1Questionnaire.pdf](#)
- [SupplementaryFile2Responses.xlsx](#)
- [SupplementaryFile3STROBEChecklist.pdf](#)