

Hygiene, Milking, Storage, Transport and Consumption Practices among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: Implications for Antimicrobial Resistance Exposure

Muhammad Muhsin Fathuddin

muhsinfathuddin@gmail.com

Ahmadu Bello University <https://orcid.org/0000-0001-9948-4081>

Saleh Alhaji Ado

Ahmadu Bello University <https://orcid.org/0000-0002-4923-3484>

Muhammad Bashir Tijjani

Ahmadu Bello University <https://orcid.org/0000-0003-0215-8357>

Haruna Makonjuola Kazeem

Ahmadu Bello University <https://orcid.org/0000-0001-8873-9034>

Research Article

Keywords: Knowledge, Attitudes, and Practices (KAP), Biosecurity gaps, Food Safety Governance

Posted Date: April 27th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9516193/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Additional Declarations: The authors declare no competing interests.

Full title: Hygiene, Milking, Storage, Transport and Consumption Practices among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: Implications for Antimicrobial Resistance Exposure

Running title: Hygiene, milking, storage and consumption practices among Fulani women vendors, Nigeria

Authors: [Muhammad Muhsin Fathuddin]¹ ORCID: [0000-0001-9948-4081]

[Saleh Alhaji Ado]² ORCID: [0000-0002-4923-3484]

[Muhammad Bashir Tijjani]³ ORCID: [0000-0003-0215-8357]

[Haruna Makonjuola Kazeem]⁴ ORCID: [0000-0001-8873-9034]

Affiliations: ^{1, 2, 3}Department of Microbiology, Faculty of Life Sciences, Ahmadu Bello University, Zaria – 810211, Kaduna State, Nigeria.

⁴Department of Veterinary Microbiology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria – 810211, Kaduna State, Nigeria.

Corresponding author: Muhammad Muhsin Fathuddin, Department of Microbiology, Faculty of Life Sciences, Ahmadu Bello University, Zaria – 810211, Kaduna State, Nigeria, Email: muhsinfathuddin@gmail.com

Manuscript type: Research | **References:** 39 | **Figures:** 9 | **Word count:** 2321

Hygiene, milking, storage, transport, and consumption practices in informal dairy value chains in Nigeria: implications for antimicrobial resistance exposure

What is already known about this topic?

Antibiotic residues and antimicrobial-resistant bacteria have been detected in raw milk and fermented dairy products sold through informal markets in Nigeria and across sub-Saharan Africa. Informal dairy value chains, which supply the majority of urban and peri-urban consumers in low- and middle-income countries, operate outside formal regulatory oversight.

What does this study add?

This study provides the first systematic, indicator-based mapping of 42 practice domains spanning farm hygiene, udder management, storage, processing, transport and consumer handling across informal dairy value chains in Kaduna State, Nigeria. It identifies specific behavioural and structural gaps that sustain residue persistence and microbial contamination and generates actionable evidence for national biosecurity policy and global antimicrobial resistance action plans.

Abstract

Objective

To systematically evaluate knowledge, attitudes, and practices (KAP) related to hygiene, milking, storage, transport, and consumption within informal dairy value chains in Kaduna State, Nigeria, and to identify behavioural and infrastructural gaps that potentiate antimicrobial resistance (AMR) exposure.

Methods

A descriptive cross-sectional survey was conducted among 77 Fulani women vendors in Zaria and Sabon Gari markets between June and December 2024. A structured questionnaire captured 10 knowledge items, 10 attitude statements, and 42 practice indicators. Responses were analysed as proportional frequencies, and composite KAP scores were calculated to quantify performance across domains.

Findings

Knowledge was markedly weak (33.6%): although vaccination adherence was high (72.7%), misconceptions were entrenched; only 16.9% understood biosecurity, 18.2% recognised laboratory testing as necessary, and nearly half erroneously believed milk is routinely tested before sale. Attitudes were moderately positive (60.3%), with strong agreement that biosecurity reduces antimicrobial use (mean = 5.30) and residues are harmful (mean = 4.10). Yet unsafe orientations persisted, including acceptance of selling milk during treatment (mean = 3.69). Practices were mixed (44.8%): daily cleaning and vaccination were common, but udder hygiene was poor (23.4% dual-phase cleaning, 5.2% detergent use), and cold chain continuity was rare (32.5% during transport). The composite KAP score of 46.2% revealed a substantial knowledge–practice gap.

Conclusion

Nigeria's informal dairy chains exhibit systemic deficiencies that facilitate the transmission of AMR. Strengthening biosecurity, improving udder hygiene, expanding cold chain infrastructure, and embedding residue surveillance, alongside behaviourally grounded and gender-responsive training, are urgent priorities. These measures must be aligned with Nigeria's National Biosecurity Policy and harmonised with global AMR frameworks, thereby advancing food safety governance and mitigating consumer exposure to antimicrobial hazards.

Introduction

Antimicrobial resistance (AMR) has emerged as one of the most formidable global public health challenges of the twenty-first century. Murray et al. [2022] (1) estimated that AMR directly caused 1.27 million deaths in 2019 and was associated with an additional 4.95 million fatalities, a burden comparable to HIV/AIDS and tuberculosis. The Global Action Plan on AMR, endorsed by the World Health Assembly in 2015, underscores that selective pressure is not confined to clinical environments but extends into food animal production and informal markets (2).

Raw milk and informally traded dairy products constitute major vectors of foodborne illness. WHO estimates that unsafe food causes 600 million illnesses and 420,000 deaths annually, with disproportionate impacts in sub-Saharan Africa (SSA) and South-East Asia, where informal markets dominate (3). In SSA alone, foodborne disease accounts for 137,000 deaths and 91 million illnesses each year, with informal channels responsible for up to 80% of cases in low-income countries (4).

Nigeria epitomises these challenges. With over 20 million cattle and more than 90% of milk produced through low-input pastoral systems, the majority of dairy flows into informal chains (5,6,7). Fulani herders and peri-urban vendors supply cities such as Kaduna, Kano, and Lagos

with raw milk, *kindirmo*, *nono*, and other products, typically without pasteurisation, cold storage, or microbial testing (8,9,10). Prior studies in Kaduna documented antibiotic residues in milk and fermented products, confirming direct consumer exposure (11). Yet upstream practices that shape residue persistence and microbial proliferation remain poorly characterised.

Hygiene and biosecurity practices influence microbial load and entry of residues; udder management determines mastitis pathogens; cold chain continuity governs microbial growth; and consumer handling shapes the final risk (12,13,14). Against this backdrop, the present study conducted a cross-sectional survey of 42 practice indicators (PMS1–PMS42) among smallholder dairy farmers and vendors in Kaduna State to identify domains most consequential for AMR exposure and to generate evidence for policy interventions aligned with Nigeria’s biosecurity strategy and global AMR action plans (2).

This manuscript maps hygiene, milking, storage, transport, and consumption practices along the informal dairy chain. Companion publications from the same survey describe antibiotic-use stewardship gaps, antimicrobial-residue knowledge, attitudes, and practices (KAP), and AMR concept-level awareness among Fulani women vendors. Together, these four papers provide a comprehensive and integrated picture of AMR risks in Nigeria’s informal dairy sector (15,16,17).

Methods

Study design and setting

This descriptive cross-sectional study interrogated informal dairy value chains serving Zaria and Sabon Gari in Kaduna State between June and December 2023. These chains are dominated by smallholder Fulani households, with milk and fermented products traded primarily through itinerant vendors outside formal cold chain and inspection systems.

Participants

Eligibility required active involvement in milk production, processing, or vending. A total of 100 Fulani women vendors were identified during systematic market walks. Of these, 77 consented and completed the survey, representing the full accessible population during the data collection period. This census-based approach, consistent with sub-Saharan African practice-mapping surveys, ensured comprehensive coverage.

The enrolment process is illustrated in Figure 1, which depicts the flow of participants through the study. Of 100 eligible vendors, 23 declined participation citing livelihood demands, while 77 consented, completed the survey, and were included in the final analysis. No exclusions occurred after enrolment, and retention was complete.

Survey instrument and measurement

A structured questionnaire captured 72 items across four domains: General Information, Knowledge, Attitude, and Practice. Practices were assessed through 42 indicators spanning farm management, milking hygiene, storage and processing, and transport and consumption. Item development drew on WHO hygiene guidance (18), FAO dairy protocols (19,20), and SSA KAP literature (21,22,23). The instrument was pretested among 20 respondents not included in the analysis to refine wording and reduce ambiguity. All participants were interviewed face-to-face by trained Hausa-, Fulfulde-, and English-speaking researchers, using neutral prompts to minimise interviewer bias.

Outcomes and statistical analysis

The primary outcomes were composite Knowledge, Attitude, and Practice (KAP) scores on milk safety and antimicrobial resistance. Responses were recorded across categorical frequency options. Composite indices were dichotomised: Knowledge and Attitude scores into Poor versus Not Poor, and Practice indicators into Poor (<50%) versus Fair ($\geq 50\%$).

Frequencies were calculated for each indicator and visualised as bar charts and heatmaps (Figures 2–8). Chi-square tests assessed associations between demographic variables and practice categories; $p < 0.05$ was considered significant. Sensitivity analyses were conducted by cross-validating results in IBM SPSS Statistics (version 26) and Python (SciPy and Pandas libraries).

Bias mitigation and ethics

Potential sources of bias were addressed through questionnaire pretesting, interviewer training, and neutral prompting. Nonetheless, social desirability bias remains a limitation, as respondents may have overstated hygienic practices. The study complied with the Declaration of Helsinki and the STROBE guidelines. Participation was voluntary, informed consent was obtained, and no personal identifiers were collected. Ethical approval was granted by Ahmadu Bello University, Zaria (ABUCUHSR/2022/29).

Results

Participant characteristics

Demographic and background information are summarised in Figure 2. Respondents were aged 25–45 years, all engaged in itinerant milk vending. Settlements included Basawa, Hunkuyi, Giwa, Kudingi, and others. The average time spent in the vending experience was 8 years. Cattle milk dominated (77.9%), supplemented by camel, goat, and sheep. Over half (51.9%) obtained milk directly from animals, while others sourced it from wholesalers or distributors. *Kindirmo* was the leading product marketed (40.3%), followed by *nono* (24.7%), raw milk (20.8%), and yoghurt (9.1%). Educational attainment was modest: Qur’anic education (33.8%) was most common, followed by tertiary, secondary, primary, and no formal schooling. Despite limited education, 55.8% had prior training on milk hygiene or AMR.

Knowledge (K-MS1–10)

Knowledge indicators are visualised in Figure 3. Vaccination adherence was strong (72.7%), and half of the respondents (50.6%) had heard of antibiotic residues. However, only 16.9% correctly defined residues, and 42.9% lacked knowledge of biosecurity. Misconceptions were widespread: 44.2% believed milk could be sold during treatment, 49.4% assumed routine testing occurs, and only 18.2% recognised laboratory testing as the correct method for confirming antibiotic-free milk. Composite knowledge scoring averaged 33.6%, indicating that most respondents were poor.

Attitudes (A-MS1–10)

Attitudinal orientations are depicted in Figure 4. Attitudes were moderately favourable, with a corrected cumulative mean of 4.22 ($\approx 60.3\%$). Respondents strongly agreed that biosecurity reduces antimicrobial use (mean = 5.30) and residues are harmful (mean = 4.10). They rejected sensory detection as reliable (mean = 4.44). Yet unsafe orientations persisted: acceptance of selling milk during treatment (mean = 3.69), belief that residues improve product quality (mean = 3.73), and ambivalence about routine testing (mean = 3.94).

Practices (P-MS1–42)

Practice indicators are presented across four figures:

- Figure 5 illustrates farm management and hygiene practices (PMS1–PMS9), showing inconsistent biosecurity measures such as perimeter fencing (41.6%) and visitor access (31.2%).
- Figure 6 depicts milking routines and udder hygiene (PMS10–PMS20), highlighting weak adherence to dual-phase cleaning (23.4%) and minimal detergent/disinfectant use (5.2%).

- Figure 7 summarises storage, processing, and fermentation practices (PMS21–PMS35), with limited cold storage (35.1%) and rare cold chain continuity during transport (32.5%). *Kindirmo* conversion was common (32.5%).
- Figure 8 presents transport, marketing, and consumption practices (PMS36–PMS42), underscoring the absence of systematic cold chain infrastructure and reliance on informal consumer handling.

Composite KAP outcomes

Aggregate scores are visualised in Figure 9, which compares composite knowledge, attitudes, and practices against a benchmark threshold of 50%. Knowledge (33.6%) and practices (44.8%) fell below the median line, while attitudes (60.3%) rose above it. The composite score of 46.2% reflects a substantial knowledge–practice gap. Chi-square tests revealed no significant associations between education level or hygiene training and practice scores (all $p > 0.05$). Sensitivity analyses confirmed reproducibility.

Discussion

This study mapped 10 knowledge items, 10 attitude statements, and 42 practice indicators across informal dairy chains in Kaduna State, revealing the mechanisms through which antimicrobial resistance (AMR) risks are propagated from cattle sheds to household cups.

Summary of key results in relation to objectives

This investigation sought to delineate hygiene, milking, storage, transport, and consumption practices within Kaduna’s informal dairy chains and to identify mechanisms that potentiate antimicrobial resistance (AMR) risk. The findings revealed a paradoxical juxtaposition: while routine husbandry tasks such as vaccination (72.7%) and daily cleaning of waterers and floors (53–58%) were relatively well-adhered to, practices most critical to AMR containment were

profoundly deficient. Udder hygiene was strikingly weak, with only 23.4% adherence to dual-phase cleaning and only 5.2% reporting detergent or disinfectant use. Cold chain continuity was rare, maintained by only 32.5% during transport, and biosecurity was compromised, with over half permitting visitor entry and nearly one-third reporting wild-animal intrusion.

Knowledge emerged as the weakest domain (33.6%), characterised by entrenched misconceptions: nearly half of respondents assumed routine milk testing occurs before sale, and 44.2% accepted milk sales during treatment. Attitudes were moderately favourable (60.3%), with strong endorsement of biosecurity and recognition of residues as harmful, yet unsafe orientations persisted, including the belief that residues enhance product quality. These results underscore a pronounced knowledge–practice gap, a phenomenon consistently documented in food safety literature (20,24,25).

Interpretation and comparison with other evidence

The findings resonate with Madjdian et al. [2024] (24), who demonstrated that hygiene awareness among informal food handlers in West Africa responds positively to structured educational interventions. They also align with broader evidence indicating that routine husbandry tasks are more readily internalised than complex safety behaviours such as cold chain management or teat disinfection (20). The present study complements residue analyses in Kaduna State (10) by linking observed antibiotic residues to specific upstream practice failures, thereby constructing an evidence-based causal chain from farm-level antimicrobial use to consumer-level AMR exposure. Comparable deficiencies have been reported in The Gambia and Senegal (26), in Nigerian *nono* markets (27), and across informal milk chains globally (28,29).

Limitations

This study relied on self-reported practices, which introduces social desirability bias and likely

inflates compliance rates. The census approach ensured full coverage of consenting vendors but restricted generalisability beyond Kaduna State. Subgroup analyses by education and prior hygiene training were underpowered and yielded no significant associations. Categorical rather than continuous measures constrained analytical precision. Despite these constraints, the comprehensive 42-indicator mapping strengthens confidence in the observed knowledge–practice gap and provides actionable evidence for policy and intervention design.

Generalisability

While the findings are most directly applicable to peri-urban dairy chains in Kaduna State, parallels with other sub-Saharan African contexts (11,26) suggest broader relevance. Nevertheless, extrapolation to regions with divergent regulatory frameworks, infrastructural capacities, or cultural practices must be undertaken with caution.

Overall interpretation

Taken together, the evidence highlights that behavioural capacity for hygiene compliance exists but is unevenly applied, with critical gaps in practices most consequential for AMR transmission. The persistence of deficiencies despite prior training underscores the need for pedagogically redesigned, behaviourally grounded interventions. National and regional policy frameworks already identify hygiene and cold chain weaknesses as priority targets (30,31). This study provides granular, practice-level evidence to guide intervention design and implementation, reinforcing the imperatives of WHO’s Global Action Plan on AMR (2).

Conclusion

This study demonstrates that Nigeria’s informal dairy chains are characterised by systemic weaknesses in hygiene, biosecurity, and cold chain continuity, which collectively create compounding pathways for antimicrobial residues and resistant bacteria to reach consumers. While routine cleaning and vaccination provide partial safeguards, poor udder hygiene,

permissive attitudes toward milk sales during treatment, and the absence of cold chain infrastructure critically undermine milk safety. The composite KAP score of 46.2% reflects a pronounced knowledge–practice gap: attitudes were moderately favourable, yet insufficient to catalyse safe behaviours.

Addressing these vulnerabilities requires technically robust and socially responsive interventions. Priority measures include subsidised cold chain infrastructure, residue surveillance embedded within informal markets, and gender-responsive training tailored to Fulani women vendors. Such interventions must be harmonised with Nigeria’s National Biosecurity Policy (30) and regional frameworks on livestock and dairy value chains (31), while simultaneously reinforcing the imperatives of WHO’s Global Action Plan on AMR (2).

By situating practice-level evidence within global AMR governance, this study underscores the urgency of bridging the knowledge–practice divide. Only through integrated, evidence-driven strategies can Nigeria’s informal dairy sector be transformed from a reservoir of antimicrobial risk into a safer, more resilient contributor to public health.

Data availability: The raw frequency dataset supporting the findings of this study, together with the structured survey instrument, is publicly available in the Zenodo repository under the digital object identifier [<https://doi.org/10.5281/zenodo.19625682>]. Additional data requests may be directed to the corresponding author.

Acknowledgements: We extend thanks to the Fulani women vendors whose participation illuminated everyday practices, and to the community leaders who ensured respectful engagement. The dedication of field researchers and assistants in administering questionnaires and providing translation support was invaluable. We further acknowledge ethical review by the Ahmadu Bello University Committee on Human Subjects Research and institutional

support from departments and faculties across Ahmadu Bello University and partner institutions.

Use of artificial intelligence: Artificial intelligence language tools were used to assist with manuscript drafting, structural organisation, and language editing during the preparation of this work. All factual content, data interpretation, scientific conclusions and intellectual contributions are entirely those of the authors, who take full and sole responsibility for the accuracy, integrity and originality of all material presented herein. AI use is disclosed in accordance with the requirements of the Bulletin of the World Health Organization and the recommendations of the International Committee of Medical Journal Editors (ICMJE).

Competing interests: None declared.

Funding: This study received no specific grant from any funding agency in the public, commercial or not-for-profit sectors. All costs associated with data collection, field research coordination and manuscript preparation were borne by the authors through their own resources and institutional support at the Department of Microbiology, Faculty of Life Sciences, and the Department of Veterinary Microbiology, Faculty of Veterinary Medicine, Ahmadu Bello University, Zaria, Nigeria.

Authors' contributions:

- MMF: Conceptualization; Methodology; Investigation; Data curation; Formal analysis; Writing – original draft; Project administration.
- SAA: Supervision; Validation; Writing – review & editing.
- MBT: Supervision; Resources; Writing – review & editing.
- HMK: Supervision; Validation; Writing – review & editing.

Muhammad Muhsin Fathuddin: Conceived and designed the study; developed the methodology; coordinated data collection and analysis; interpreted findings; and drafted the manuscript.

Saleh Alhaji Ado, Muhammad Bashir Tijjani, and Haruna Makonjuola Kazeem: Provided supervisory oversight; contributed to study design refinement; ensured ethical compliance; guided interpretation of results; and critically revised the manuscript for intellectual content.

All authors reviewed and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

References

1. Murray CJL, Ikuta KS, Sharara F, Swetschinski L, Robles Aguilar G, Gray A, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet*. 2022;399(10325):629–55. doi:10.1016/S0140-6736(21)02724-0
2. World Health Organization. Global action plan on antimicrobial resistance. Geneva: WHO; 2015.
3. World Health Organization. WHO estimates of the global burden of foodborne diseases: Foodborne Disease Burden Epidemiology Reference Group 2007–2015. Geneva: WHO; 2015.
4. Arias-Granada Y, Henson S, Gulati A. Foodborne diseases and food safety in sub-Saharan Africa. *Afr J Agric Resour Econ*. 2021;16(2):135–52. doi:10.53936/afjare.2021.16(2).12

5. CSIRO Research. Dairy production in Nigeria. LiveGAPS [Internet]. 2020 [cited 2025 Nov 10]. Available from: <https://research.csiro.au/livegaps/findings/livestock-production/dairy-production-in-nigeria/>
6. Nigeria Investment Promotion Commission. Market analysis and strategy: dairy sector. Abuja: NIPC; 2020.
7. Sahel Capital. Dairy sector in Nigeria. Newsletter Volume 20. Lagos: Sahel Capital; 2019.
8. Ndudi W, Edo GI, Samuel PO, Jikah AN, Opiti RA, Ainyanbhor IE, Essaghah AE, Ekokotu HA, Oghrora EA, Agbo JJ. Traditional fermented foods of Nigeria: microbiological safety and health benefits. *Journal of Food Measurement and Characterization*. 2024 Jun;18(6):4246-71. <https://doi.org/10.1007/s11694-024-02490-1>
9. Christiana Cudjoe D, Balali GI, Titus OO, Osafo R, Taufiq M. Food safety in sub-Saharan Africa, an insight into Ghana and Nigeria. *Environmental Health Insights*. 2022 Dec;16:11786302221142484.
10. Fathuddin MM, Ado SA, Tijjani MB, Kazeem HM, Fathuddin R, Obidah JS. Quantification and risk assessment of antibiotic residues among milk and fermented milk products vended around Zaria and Sabon-gari Local Government Areas, Kaduna State, Nigeria. *J Sci Univ Kelaniya*. 2024;17(2).
11. Owusu-Kwarteng J, Akabanda F, Agyei D, Jespersen L. Microbial safety of milk production and fermented dairy products in Africa. *Microorganisms*. 2020;8(5):752. doi:10.3390/microorganisms8050752

12. Mpatswenumugabo JP, Habimana R, Tuyishimire J, Gashugi E. A systematic literature review of milk consumption and associated bacterial zoonoses in Africa. *J Appl Microbiol.* 2023;134(4):lxad080. doi:10.1093/jambio/lxad080
13. Olatoye IO, Ehinmowo AA, Forsythe SJ. Screening of antibiotics and chemical analysis of penicillin residue in fresh milk and dairy products marketed in Nigeria. *Vet World.* 2016;9(9):948–55. doi:10.14202/vetworld.2016.948-955
14. Wallace F, McEntire CL, Frye S, Hollenbeck J, Greig J, Drews S, et al. Vendor knowledge, attitudes, and practices related to food safety in low- and middle-income countries. *J Food Prot.* 2022;86(1):100011. doi:10.1016/j.jfp.2022.100011
15. Fathuddin MM, Fathuddin R, Obidah JS, Garba S, Ameh ER. Antibiotic Use and Stewardship Gaps among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: A One Health Perspective [Preprint]. Research Square; 2024 [posted 2024 Apr 24; cited 2026 Apr 24]. doi: <https://doi.org/10.21203/rs.3.rs-9472430/v1>
16. Fathuddin MM, Fathuddin R, Obidah JS, Garba S, Ameh ER. Antimicrobial Residues and Milk-Handling Practices among Fulani Women Vendors in Informal Dairy Markets, Northern Nigeria: A Cross-Sectional Survey [Preprint]. Research Square; 2024 [posted 2024 Apr 24; cited 2026 Apr 24]. doi:<https://doi.org/10.21203/rs.3.rs-9475442/v1>
17. RES
18. Five keys to safer food manual. Geneva: World Health Organization; 2006. Available from: <https://www.who.int/publications/i/item/9789241594639> [accessed 2026 Apr 24].

19. Code of hygienic practice for milk and milk products (CXC 57-2004). Rome: Food and Agriculture Organization of the United Nations; 2004 (Revised 2007, 2009). Available from: fao.org [accessed 2026 Apr 24].
20. Food safety in informal markets in developing countries. Rome: Food and Agriculture Organization of the United Nations and World Health Organization; 2018. Available from: fao.org [accessed 2026 Apr 24]
21. Gemed BA, Amenu K, Magnusson U, Dohoo I, Skjerve E, Grace D. Antimicrobial use in livestock and fish production in Sub-Saharan Africa: a systematic review of knowledge, attitudes and practices. *Front Vet Sci*. 2020 Aug 14;7:454. doi: [doi.org](https://doi.org/10.3389/fvets.2020.00454)
22. Odeyemi OA, Sani NA, Obadina AO, Saba CK, Bamidele FA, Abughoush M, Asghar A, Dongmo FF, Macer D, Aberoumand A. Food safety knowledge, attitudes and practices among consumers in developing countries: An international survey. *Food research international*. 2019 Feb 1;116:1386-90.
23. Nawawi WW, Ramoo V, Chong MC, Abdullah KL. A systematic review of the knowledge, attitude, and practices (KAP) of food safety among street food handlers. *International Food Research Journal*. 2022 Nov 1;29(6):1226-39.
24. Madjdian DS, de Kok BP, Rietberg K, Smit H. Training and tool supply to enhance food safety behaviours of food handlers in informal markets. *Food Control*. 2024;163:110551. doi:10.1016/j.foodcont.2024.110551
25. Elelu N, Aiyedun JO, Mohammed IG, Odetokun IA, Mohammed KM, Ambali AG, et al. Neglected zoonotic diseases in Nigeria: role of the public health veterinarian. *Pan Afr Med J*. 2019;32:36. doi:10.11604/pamj.2019.32.36.16403

26. Bankole SO, Secka A. Risk behaviours for milk-borne disease transmission along the milk chain in The Gambia and Senegal. *Sci Afr*. 2022;15:e01079. doi:10.1016/j.sciaf.2022.e01079
27. Mihrete YM, Soria LM, Biratu GS. Bacteriological quality of *nono*, a milk product sold at retail outlets in Federal Capital Territory, Abuja, Nigeria. *Afenet J Epidemiol Public Health*. 2020;3(5):1–10.
28. Supriya K, Karabasanavar N, Madhavaprasad CB, et al. Milk supply chain as a reservoir of antimicrobial-resistant *Staphylococcus* species. *J Biosci*. 2024;49:60. doi:10.1007/s12038-024-00422-1
29. Chavan P, Vashishth R. Antimicrobial resistance in foodborne pathogens: consequences for public health and future approaches. *Discov Appl Sci*. 2025;7:623. doi:10.1007/s42452-025-07015-z
30. Federal Republic of Nigeria. National Biosecurity Policy 2022–2026. Abuja: Federal Ministry of Agriculture and Rural Development; 2022.
31. Food and Agriculture Organization of the United Nations; Economic Community of West African States. Review of the livestock/meat and milk value chains and policy framework in West Africa. Rome: FAO; 2016.

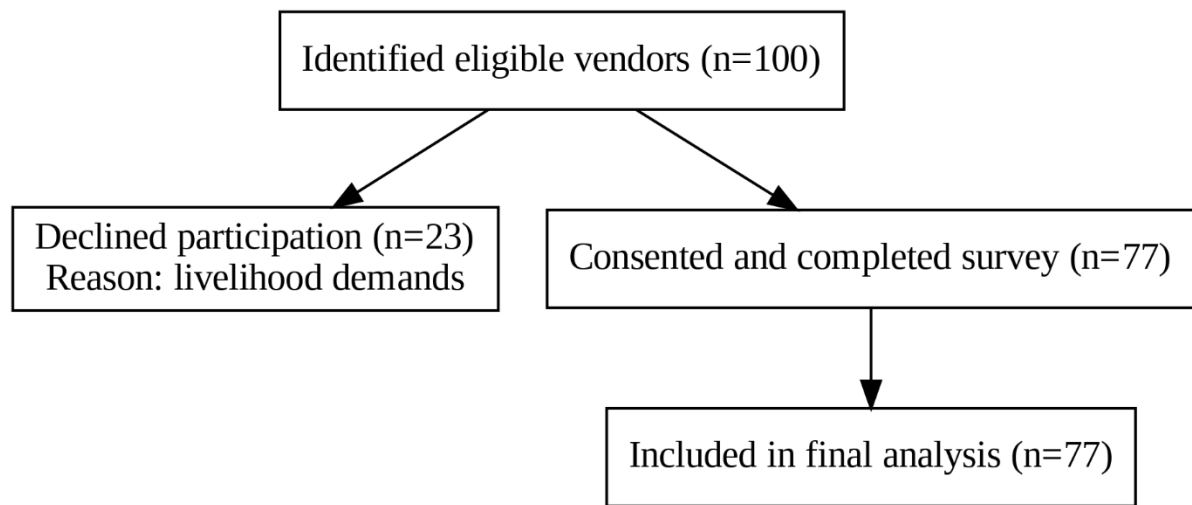


Fig 1. Flow of participants through the study

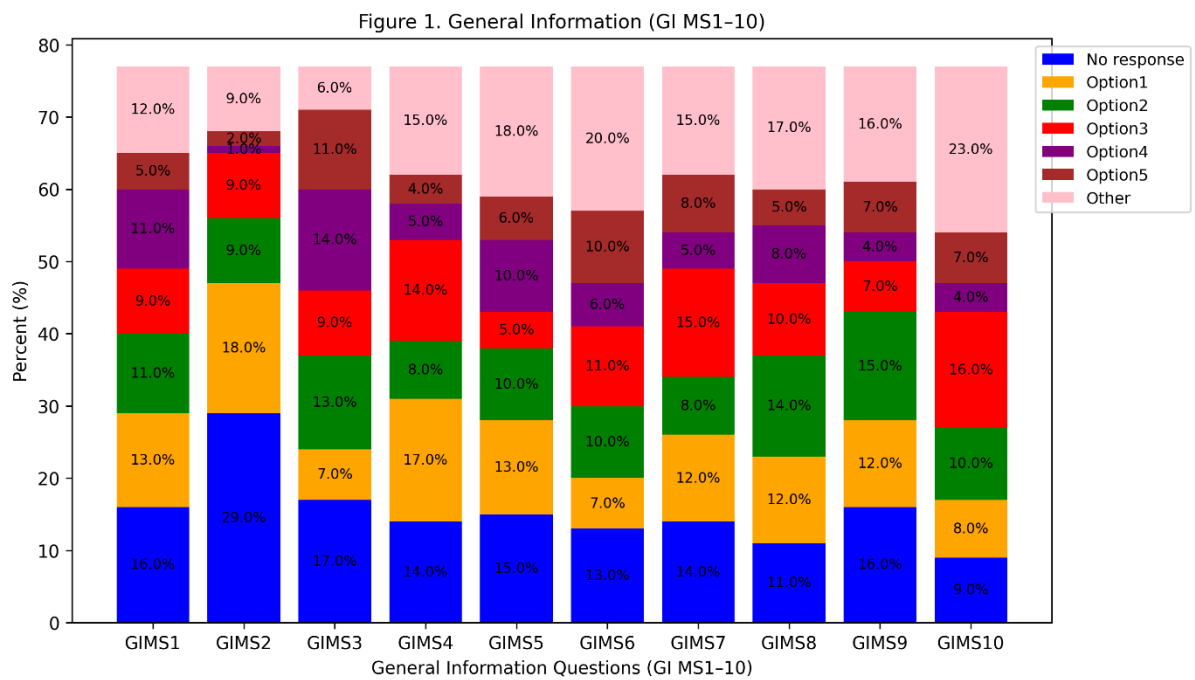


Fig. 2. General information (GIMS1–GIMS10)

Responses of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77). Bars show the proportion of respondents selecting each response category for demographic and background information items.

Figure 2. Knowledge Regarding Milk Safety and Antibiotic Residues (KMS1–10)

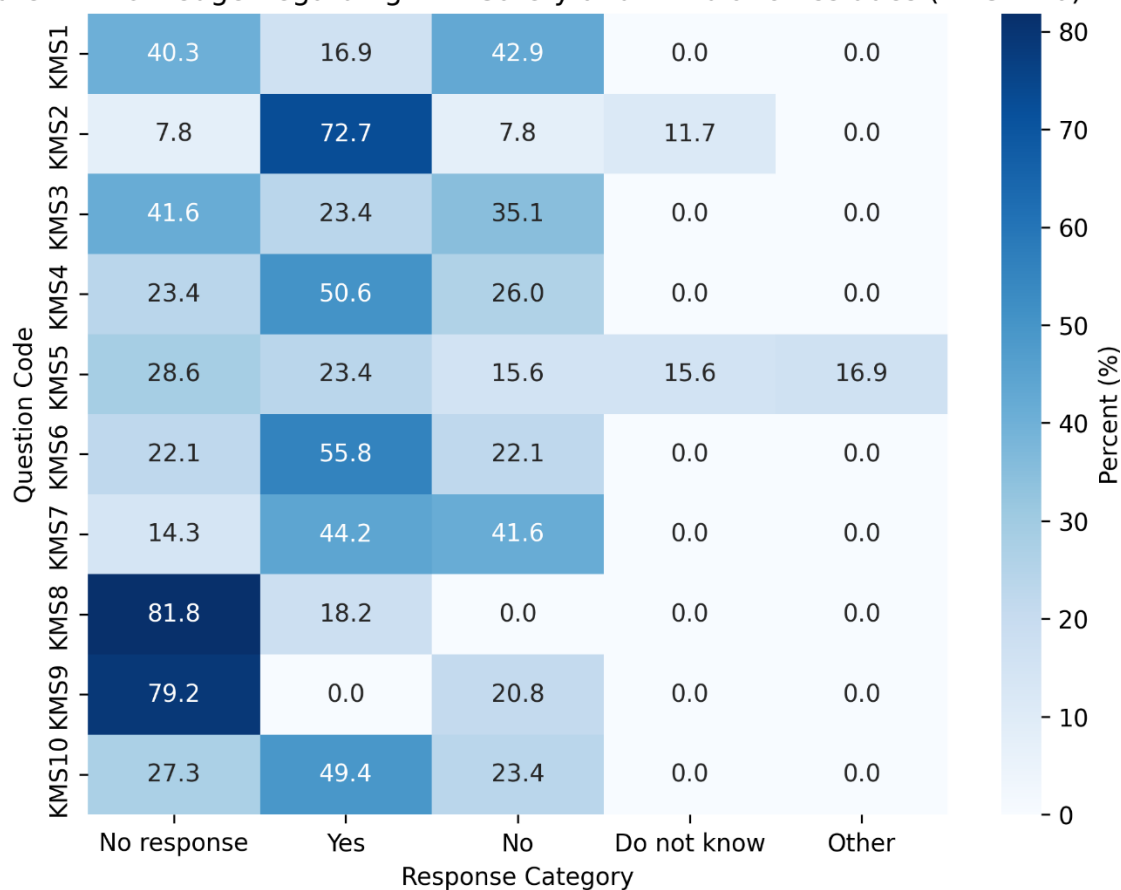


Fig. 3. Knowledge regarding milk safety and informal dairy value chains (KMS1–KMS10)

Responses of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77). Heatmap cells show the percentage of respondents answering “Yes,” “No,” “Do not know,” “Other,” or “No response” for each knowledge item.

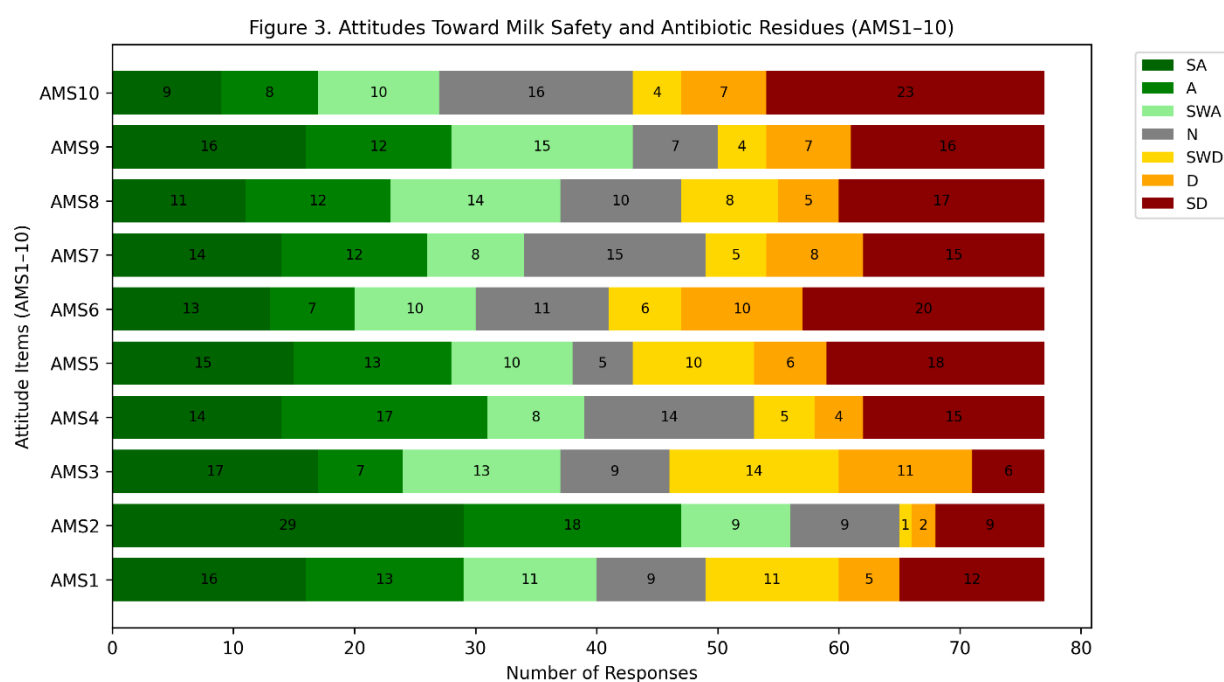


Fig. 4. Attitudes toward milk safety and informal dairy value chains (AMS1–AMS10)

Responses of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77). Bars show the number of respondents across seven attitudinal categories: strongly agree, agree, somewhat agree, neutral, somewhat disagree, disagree and strongly disagree.

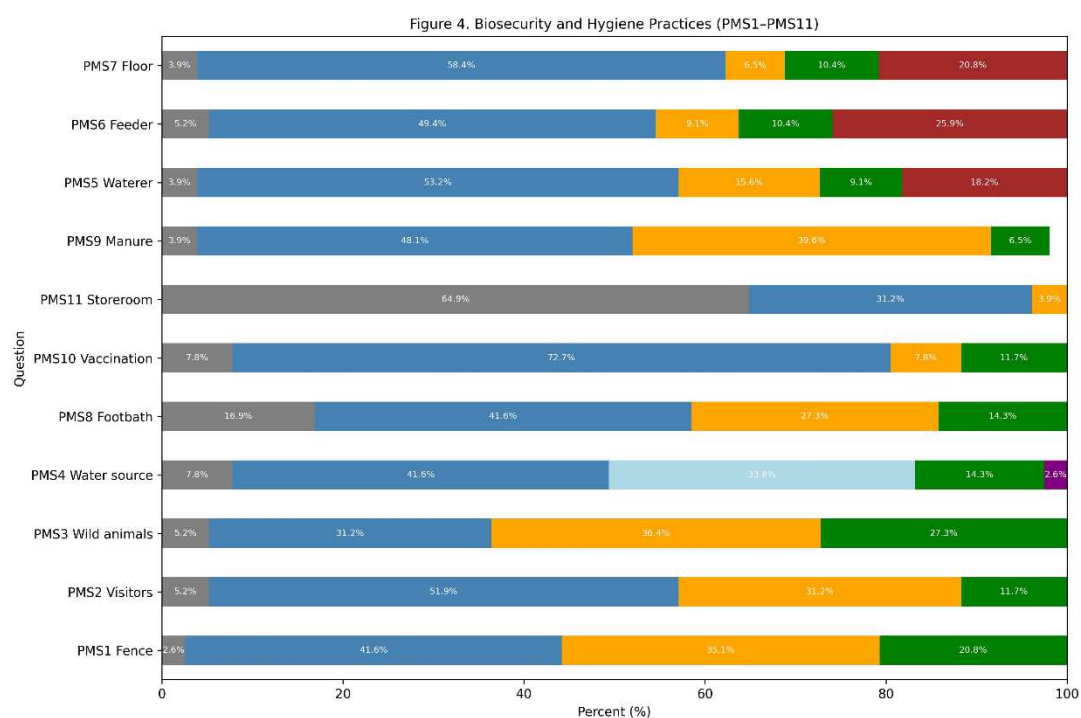


Fig. 5. Farm management and hygiene practices (PMS1–PMS9)

Responses of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77). Bars show the proportion of respondents reporting each frequency category for farm hygiene and biosecurity practices.

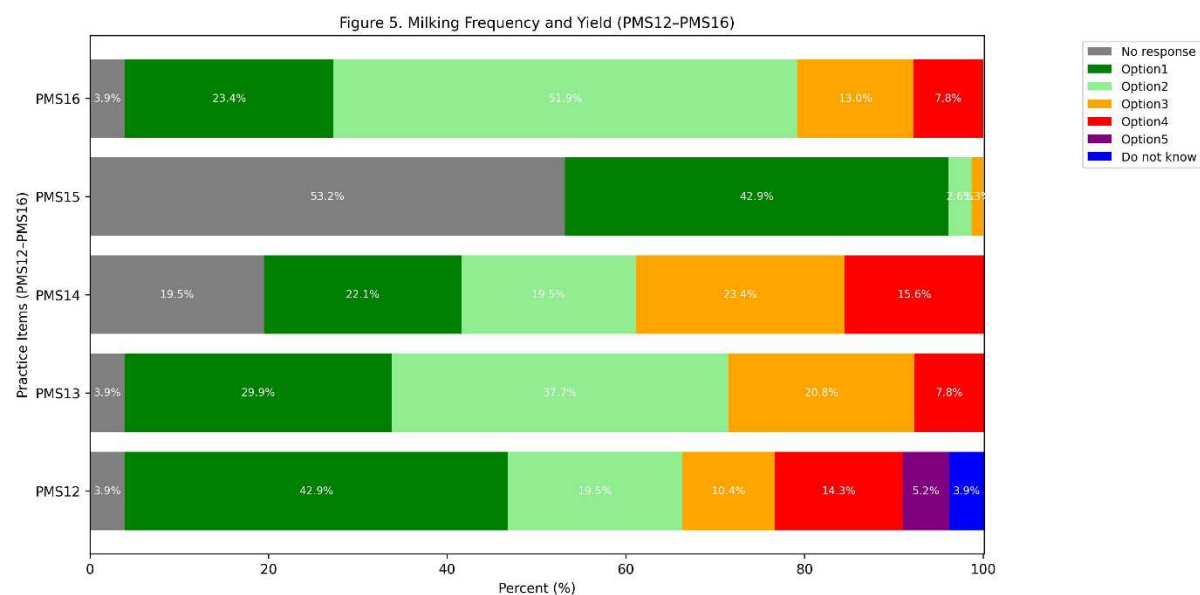


Fig. 6. Milking frequency and udder hygiene practices (PMS10–PMS20)

Responses of smallholder dairy farmers in Kaduna State, Nigeria (n = 77). Bars show the proportion of respondents reporting each frequency category for milking routines and udder hygiene measures.

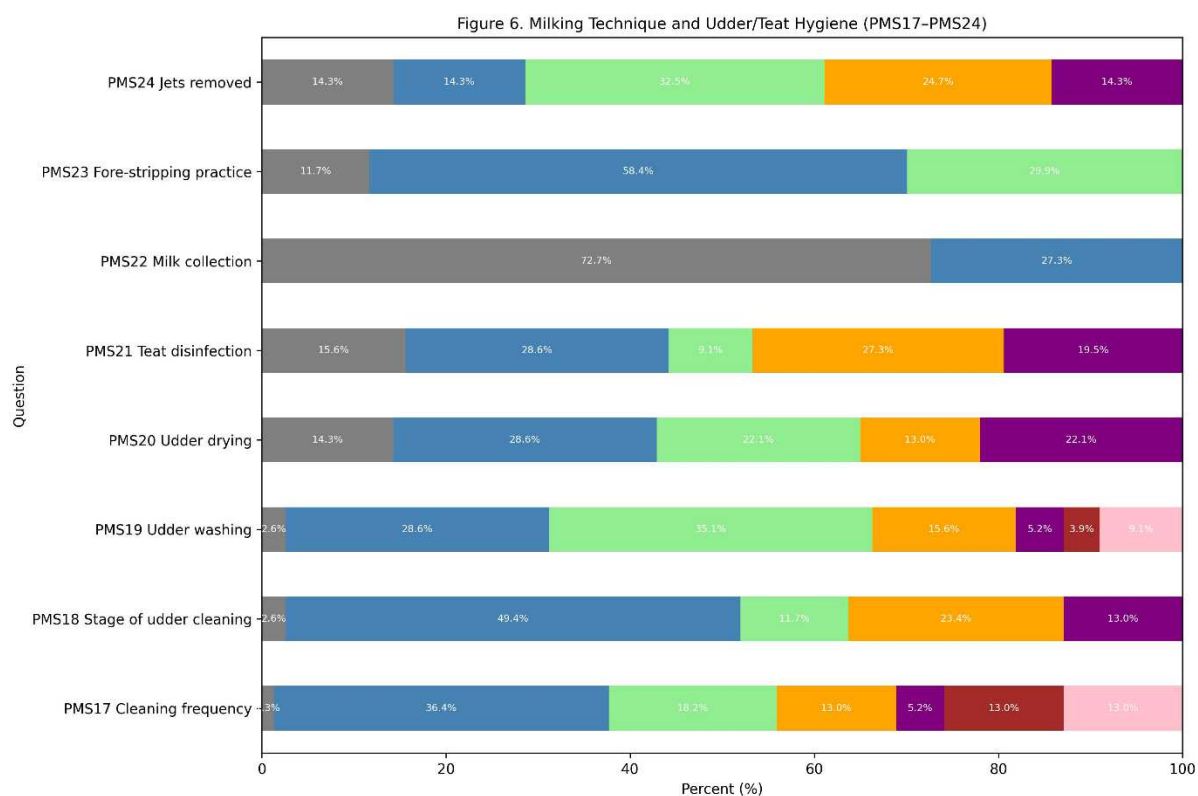


Fig. 7. Milk storage, processing and fermentation practices (PMS21–PMS35)

Responses of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77). Bars show the proportion of respondents reporting each frequency category for storage, preservation and processing practices. *Kindirmo* refers to a traditional Nigerian fermented milk product.

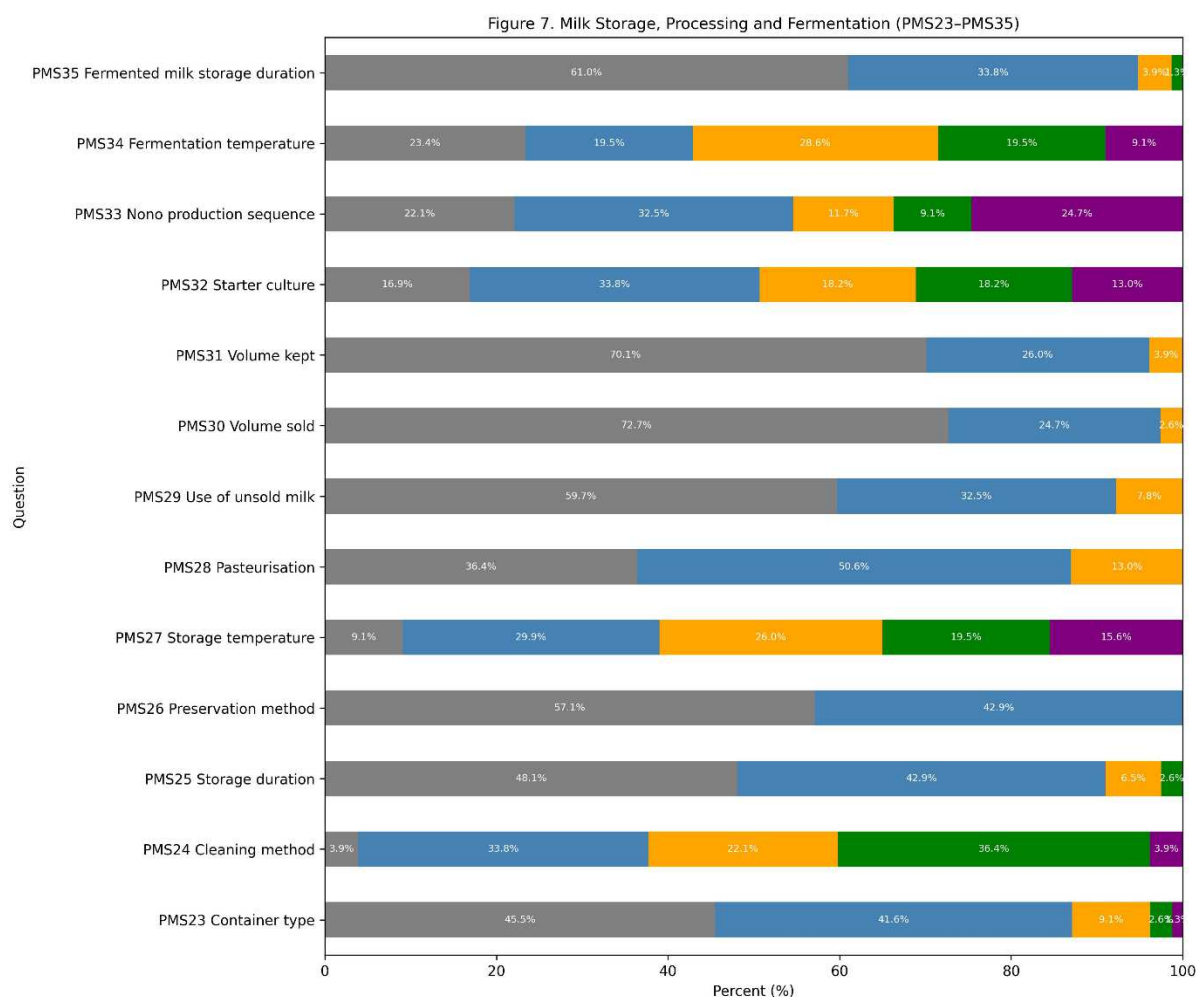


Fig. 8. Transport, marketing and consumption practices (PMS36–PMS42)

Responses of milk vendors in Kaduna State, Nigeria ($n = 77$). Bars show the proportion of respondents reporting each frequency category for transport methods, marketing practices and consumer handling of milk.

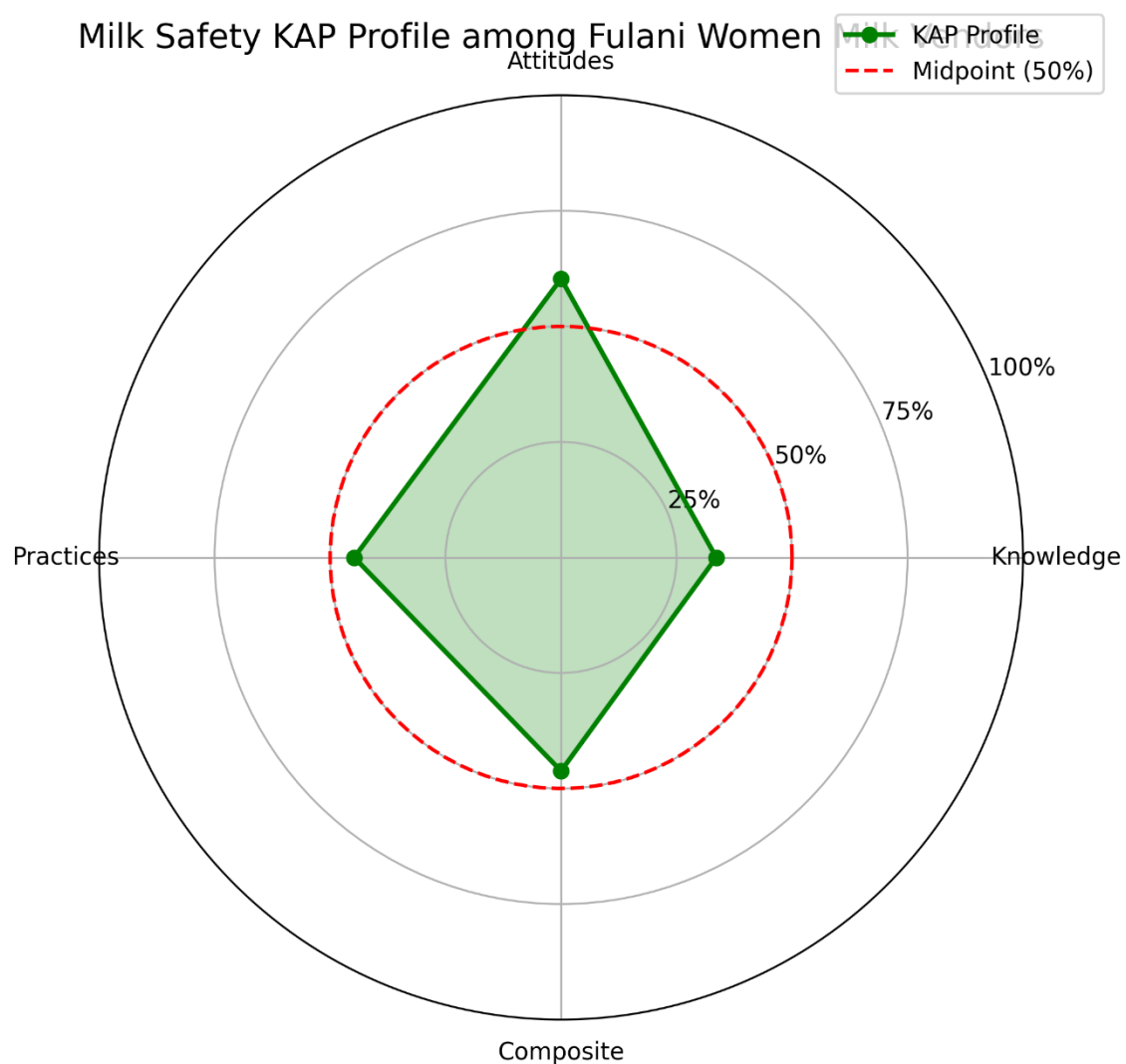


Fig. 9. Composite knowledge, attitudes, and practices (KAP) scores

Aggregate scores of smallholder dairy farmers and vendors in Kaduna State, Nigeria (n = 77).

The radar chart compares composite knowledge, attitudes, and practices scores against a benchmark threshold of 50%.

Supplementary Files

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

- [S1QuestionnaireMS.pdf](#)
- [S3STROBEChecklistMS.pdf](#)
- [S2ResponseMS.xlsx](#)