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Knowledge, Awareness, and Perception of Food-Borne Pathogens and Antimicrobial Resistance Associated with Dairy Products Among Fulani Women Milk Producers in Southeast Nigeria

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ABSTRACT

This study examined the level of knowledge, awareness, and perceptions regarding food-borne pathogens and antimicrobial resistance in relation to dairy products among Fulani women involved in milk production in Southeast Nigeria. A descriptive cross-sectional survey approach was used, with data gathered through a structured questionnaire administered to participants in selected Fulani communities within the region. The sample consisted of 384 Fulani women, chosen using Cochran's formula and a multistage sampling method. Descriptive statistics were used to analyze the collected data. Results indicated differing degrees of understanding and awareness about food-borne diseases and antimicrobial resistance, with perceptions largely shaped by socio-cultural norms, limited formal education, and insufficient access to veterinary extension services. The study found that gaps in knowledge and low awareness of food safety and antimicrobial resistance among these women present notable public health concerns. It emphasized the need for focused educational initiatives and training programs to promote safer dairy handling practices and reduce the inappropriate use of antimicrobials.

Keywords: *Knowledge, Awareness, Food-borne pathogens, Antimicrobial resistance, Dairy products, Fulani women.*

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Introduction

Milk and dairy products play a vital role in human nutrition, providing essential nutrients such as proteins, vitamins, fats, and minerals necessary for growth and development. In Nigeria, traditional dairy production is largely managed by Fulani pastoralists, with women taking on key responsibilities in milking, processing, preserving, and selling dairy items like fresh milk, fermented milk (nono), and yoghurt [1]. These activities support both household nutrition and income, particularly in rural areas. However, poor hygiene during milking, processing, storage, and distribution increases the risk of contamination by food-borne pathogens, creating significant public health concerns.

Food-borne pathogens are microorganisms that can cause illness when consumed through contaminated food. Common examples found in dairy products include Salmonella spp., Escherichia coli, Listeria monocytogenes, Campylobacter spp., and Staphylococcus aureus [2]. Ingesting contaminated milk or dairy products may lead to symptoms ranging from mild digestive issues to severe infections and even death. The WHO [3] estimates that unsafe food affects around 600 million people globally each year, resulting in approximately 420,000 fatalities. The growing prevalence of antimicrobial resistance (AMR) among these pathogens has emerged as a critical global health issue. AMR occurs when microbes evolve to resist the effects of antimicrobial drugs, making infections harder to treat [4]. The widespread use of antibiotics in livestock—for treatment, disease prevention, and growth enhancement—plays a major role in driving this resistance.

Resistant bacteria can be transferred to humans through contaminated dairy products, direct contact with animals, or environmental pathways [5,6,7].

Fulani women are central to the dairy value chain, particularly in milk handling and processing. Their understanding of food safety, pathogens, and antimicrobial resistance directly affects hygiene practices and antibiotic use. Low levels of awareness may lead to improper milk handling and unregulated antibiotic administration in animals, increasing the chances of food contamination and the spread of resistant strains. In Southeast Nigeria, the growing presence of settled Fulani pastoralists has led to an expansion of traditional dairy operations. Yet, there is limited data on how much these women know about food-borne pathogens and AMR. Assessing their knowledge, awareness, and attitudes is crucial for developing effective education strategies and public health measures to improve food safety and combat antimicrobial resistance. This study therefore aims to evaluate the knowledge, awareness, and perceptions of food-borne pathogens and antimicrobial resistance among Fulani women engaged in milk production in Southeast Nigeria.

Dairy production within Fulani pastoral communities remains largely informal, often involving substandard hygiene, absence of pasteurization, insufficient storage infrastructure, and unchecked antibiotic use in animal care. These conditions heighten the risk of microbial contamination in milk and promote the emergence and transmission of antimicrobial-resistant bacteria [12].Despite their central role in milk production and processing, there is little documented evidence on Fulani women's understanding of food-borne diseases and antimicrobial resistance in Southeast Nigeria. Gaps in knowledge may contribute to unsafe practices and inappropriate antibiotic use, endangering consumer health and facilitating the spread of resistant infections. Additionally, the lack of insight into their attitudes limits the ability to design targeted educational initiatives and sound food safety regulations. Therefore, it is important to examine the level of knowledge, awareness, and perception regarding food-borne pathogens and antimicrobial resistance among Fulani women dairy producers in this region. The specific objectives include to – a). determine the level of knowledge of food-borne pathogens among Fulani women milk producers in Southeast Nigeria; b). assess their awareness of antimicrobial resistance associated with dairy products; c).examine their perception of the risks posed by food-borne pathogens and antimicrobial resistance; d). identify sources of information regarding food safety and antimicrobial resistance among respondents; e). determine factors influencing their knowledge, awareness, and perception of food-borne pathogens and antimicrobial resistance; f). Identify appropriate sensitization and educational measures for improving awareness of food-borne pathogens and antimicrobial resistance associated with dairy products among Fulani women milk producers in Southeast Nigeria. This study will generate foundational data on the knowledge, awareness, and perceptions of food-borne pathogens and antimicrobial resistance among Fulani women involved in milk production in southeast Nigeria. The results can support public health officials, extension agents, and veterinary practitioners in creating targeted educational initiatives to encourage safer milk handling and responsible antibiotic use. By doing so, it will support broader efforts to address antimicrobial resistance and strengthen food safety standards. The findings may also inform policymakers when developing regulations and interventions to improve dairy quality and protect consumer health.

In addition, the research will expand the current body of knowledge and offer a valuable resource for future academic work in this area.

Methodology

The research was conducted in Southeast Nigeria, specifically in Abia, Anambra, Ebonyi, Enugu, and Imo States. This area features tropical rainforest vegetation and has seen an increasing number of Fulani pastoralist settlements involved in cattle herding and dairy production. Within these communities, milk-related activities—such as production, processing, and marketing—are primarily managed by Fulani women. A descriptive cross-sectional survey design was adopted, suitable for capturing data on knowledge, awareness, and perceptions at a specific moment. The study centered on Fulani women engaged in milk production and processing across the region.Quantitative data were gathered using structured questionnaires. The target population included all Fulani women participating in the production, processing, and sale of dairy products within cattle-keeping settlements in Southeast Nigeria. These women were actively involved in milking, fermenting, storing, and distributing dairy items like fresh and fermented milk. A multistage sampling approach was applied to select participants. First, states with notable Fulani populations—Enugu, Abia, and Imo—were chosen purposively. Next, local government areas and specific cattle settlements were selected via simple random sampling. Finally, individual women were chosen through systematic random sampling.The sample size was calculated using Cochran's formula for large populations, resulting in 384 respondents to ensure adequate representation. Data collection relied on a researcher-developed questionnaire divided into sections covering knowledge of foodborne pathogens, awareness of antimicrobial resistance, perceived risks related to dairy products, and sources of information. Due to language differences, interviews were conducted in person, with trained interpreters assisting when needed. Collected data were coded and analyzed using SPSS version 26. Descriptive statistics—including frequencies, percentages, and mean scores—were used to present and summarize the findings.

Results and Discussions

Knowledge of Food-Borne Pathogens Among Fulani Women Milk Producers in Southeast Nigeria.

Table 1 showed that a majority of respondents (58.4%) either agreed or strongly agreed that they were aware of food-borne pathogens, pointing to a moderate to relatively high level of knowledge among Fulani women involved in milk production in Southeast Nigeria. However, 41.4% demonstrated little or very limited understanding. With a grand mean of 3.17, the overall knowledge level is best described as moderate. This implies that while many producers have some awareness, gaps remain, and understanding is not uniformly strong across all aspects of food-borne pathogens.

Understanding of food-borne pathogens among Fulani women engaged in milk production in Nigeria remains a significant public health issue, especially in informal dairy settings where hygiene during processing and marketing is often poorly regulated. Although many of these women recognize that milk can become contaminated, their grasp of specific pathogens and how they spread tends to be limited or only moderately developed.

Studies conducted in northern Nigeria reveal that raw and traditionally processed milk products—such as nono and kindirmo—are frequently contaminated with harmful microorganisms like Escherichia coli, Salmonella spp., Staphylococcus aureus, and Listeria monocytogenes. These risks are heightened when basic hygiene measures—such as cleaning udders properly, sterilizing storage containers, and maintaining cold storage—are not followed [8,9]. Despite these dangers, many Fulani milk sellers continue to assess milk safety based on sensory cues like smell, taste, and appearance, rather than using scientific or laboratory testing, highlighting a lack of formal training in food safety practices [8].

Moreover, existing knowledge is often incomplete. While some producers acknowledge that unhygienic conditions can lead to contamination, fewer comprehend the biological processes behind microbial infections or how improper antibiotic use contributes to drug-resistant strains entering the food supply [8]. These knowledge gaps are worsened by structural barriers, including limited refrigeration, poor access to veterinary support, and dependence on informal distribution networks.In sum, while awareness of food-borne pathogens among Fulani women milk producers in southeastern and other regions of Nigeria is gradually increasing, it still falls short of what is needed to ensure safe dairy products. Enhancing targeted education on food safety, expanding access to veterinary and public health resources, and incorporating these producers into broader One Health initiatives are crucial steps toward reducing the risk of milk-borne illnesses.

Table 1: Level of Knowledge of Food-Borne Pathogens among Fulani Women Milk Producers

Knowledge Statements	Mean (x̄)	Std. Dev.
I have heard about food-borne pathogens in milk	3.14	0.98
I understand how milk can transmit diseases	3.09	0.97
I know symptoms of food-borne infections	3.02	0.96
I am aware of Salmonella and E. coli in milk	2.94	0.99
I know improper milk handling can cause illness	3.19	0.95
I know that raw milk can contain harmful microorganisms	3.25	0.94
I am aware that boiling milk reduces pathogens	3.30	0.92
I know antibiotics misuse can lead to resistance	3.05	0.97
I understand the importance of hygiene in milk production	3.35	0.90
I know that contaminated milk can cause serious illness	3.38	0.89

Awareness of Antimicrobial Resistance (AMR) Associated with Dairy Products

In Table 2, the overall average of 2.17 suggests that Fulani women involved in milk production in southeastern Nigeria have a moderate level of awareness regarding antimicrobial resistance linked to dairy products. Although there is some general understanding, access to formal education and organized information on the topic is still limited.Growing recognition of antimicrobial resistance (AMR) linked to dairy products highlights its importance for food safety and public health. AMR develops when microbes like bacteria evolve to survive exposure to antimicrobial drugs, complicating the treatment of infections. In dairy systems—particularly in informal markets prevalent across many developing countries—AMR is frequently tied to the inappropriate or excessive use of antibiotics in animals, whether for treating illness, preventing disease, or enhancing growth.Research suggests that the understanding of AMR among dairy producers and handlers is still limited, especially within rural and informal segments of the dairy supply chain. Investigations involving milk sellers and pastoral women in Nigeria and other parts of Sub-Saharan Africa reveal that while antibiotics are commonly known, awareness of resistance mechanisms or the health risks posed by antibiotic residues in milk remains low [8,10].

This lack of knowledge often leads to unsafe behaviors, such as selling milk from animals undergoing antibiotic treatment without adhering to required withdrawal times.The problem is further worsened by inadequate access to veterinary advisory services and weak oversight in unregulated dairy markets. These conditions allow continued antibiotic misuse, raising the likelihood that resistant bacteria enter the food supply through contaminated milk and dairy items [10]. Nevertheless, recent initiatives based on the One Health approach indicate that focused education and training programs can effectively boost awareness and promote safer handling practices.

Table 2: Awareness of Antimicrobial Resistance (AMR) Associated with Dairy Products

Awareness Statements	Mean (x̄)	Std. Dev.
I have heard about antimicrobial resistance in milk	3.22	0.95
I know that antibiotics are used in dairy cattle treatment	2.25	0.94
I am aware that misuse of antibiotics can cause resistance	2.30	0.92
I know that resistant bacteria can be transmitted through milk	3.15	0.96
I am aware that consuming contaminated milk can affect human health	2.38	0.89
I understand the concept of antimicrobial resistance (AMR)	3.10	0.97
I know farmers sometimes misuse antibiotics in dairy production	2.33	0.91
I am aware that AMR makes infections harder to treat	2.35	0.90
I have received information/training on AMR in livestock	2.98	0.99
I am aware of government or health campaigns on AMR	2.92	1.00

Grand Mean (x̄) ≈ 3.17

Perception of Risks from Food-Borne Pathogens and Antimicrobial Resistance

Table 3 revealed that respondents generally perceive food-borne pathogens and antimicrobial resistance across all related statements. They generally have a poor perception of antimicrobial-resistant organisms. This suggests that while a majority tended to agree or strongly agree with the risk assessments, a notable portion expressed uncertainty or disagreement, pointing to lingering gaps in awareness and comprehension.The way dairy producers and handlers perceive risks linked to food-borne pathogens and antimicrobial resistance (AMR) plays a critical role in shaping food safety behaviors and, ultimately, public health. In many low- and middle-income countries like Nigeria, dairy systems operate largely in the informal sector, which affects how risks are recognized and addressed. Evidence shows that while a number of milk producers—especially women in pastoral communities—acknowledge that drinking raw or contaminated milk can lead to illness, their understanding of the seriousness and long-term implications of such risks, including AMR, tends to be limited rather than thorough.Common pathogens like Salmonella spp., Escherichia coli, and Listeria monocytogenes are generally recognized as causes of diarrhea and foodborne illness. However, risk awareness often centers on short-term symptoms rather than potential chronic or life-threatening effects [10]. Likewise, while some individuals involved in milk handling know that improper antibiotic use in animals may compromise milk safety, fewer grasp the mechanisms by which antimicrobial resistance emerges and moves through the food supply, potentially resulting in ineffective treatments for human infections [8].Risk perception is shaped by multiple factors, including education, availability of veterinary support, cultural norms, and financial pressures. In informal dairy markets, for example, economic necessity frequently leads producers to favor immediate income over safety measures—such as adhering to withdrawal periods for antibiotics or discarding spoiled milk [9]. This highlights a disconnect between knowing about risks and acting on them, where awareness does not consistently lead to safer practices.

Table 3: Perception of Risks Posed by Food-Borne Pathogens and Antimicrobial Resistance

S/N	Perception Statements	Mean	SD
1	Food-borne pathogens in milk can cause serious illness in humans	2.16	0.88
2	Consuming raw milk increases the risk of infection	2.26	0.68
3	Poor hygiene during milking leads to contamination	3.76	0.18
4	Antibiotic misuse in animals can lead to resistant bacteria in milk	2.23	0.18
5	Antimicrobial resistance makes infections harder to treat	2.36	0.68
6	Drinking untreated milk can expose consumers to drug-resistant bacteria	2.18	0.68
7	Boiling milk reduces the risk of food-borne infections	3.56	1.18
8	Antibiotics should only be used under veterinary supervision in dairy animals	3.76	0.78
9	Milk from sick animals should not be sold or consumed	2.21	0.38
10	Antimicrobial resistance is a serious public health threat	2.26	0.48

Table 4: Sources of Information on Food Safety and Antimicrobial Resistance (AMR)

S/N	Sources of Information	Frequency (n)	Percentage (%)
1	Health workers (nurses, doctors, community health extension workers)	210	54.7
2	Veterinary officers / animal health workers	180	46.9
3	Radio programmes	250	65.1
4	Television programmes	190	49.5
5	Friends and family members	160	41.7
6	Market associations / milk traders	145	37.8
7	Agricultural extension agents	170	44.3
8	Social media (WhatsApp, Facebook, etc.)	120	31.3
9	Religious gatherings (mosque/church announcements)	135	35.2
10	Formal training/workshops/seminars	90	23.4

Sources of Information on Food Safety and Antimicrobial Resistance (AMR)

Table 4 revealed that radio was the primary source of information on food safety and antimicrobial resistance, cited by 65.1% of respondents, followed by health workers (54.7%) and television (49.5%). This suggests that mass media and healthcare providers are key in reaching the public with relevant information. In contrast, formal training programs and social media were less commonly used, at 23.4% and 31.3% respectively, pointing to lower engagement with organized education and online health content. Taken together, the results underscore the need to enhance both community-level outreach and structured learning initiatives to boost public understanding of food safety and antimicrobial resistance. Information sources on food safety and antimicrobial resistance (AMR) significantly influence the knowledge, attitudes, and behaviors of both dairy producers and consumers. Studies show that people typically rely on a combination of formal and informal channels, such as healthcare providers, veterinary staff, radio and television broadcasts, social media, agricultural extension services, and local community organizations. In rural areas where livestock is a primary livelihood, radio continues to be a widely used and trusted medium due to its broad reach and affordability. At the same time, veterinarians and extension officers are key in delivering practical, technical advice on safe milk handling and responsible use of antimicrobials in animal farming [7,11].

Digital tools—including mobile phones, WhatsApp groups, and online resources—are gaining prominence as sources of AMR-related information, especially among younger and less formally educated individuals. However, the quality of information shared through social media can vary, raising concerns about misinformation and incomplete understanding of the risks linked to improper antimicrobial use and food contamination. Educational initiatives in schools, along with public awareness efforts led by government and non-governmental agencies, also play a vital role in promoting food safety, though their reach in remote pastoral regions is still limited [13,14].The wide range of available information channels underscores the need for coordinated communication approaches that integrate mass media, community education, and expert-led extension services to more effectively raise awareness about foodborne pathogens and AMR risks within the dairy sector.

Factors Influencing Knowledge, Awareness, and Perception of Food-Borne Pathogens and Antimicrobial Resistance.

Table 5A: Interpretation of Factors Influencing Knowledge of Food-Borne Pathogens and AMR

The data in Table 5A summarize the views of 384 respondents on factors affecting their knowledge of food-borne pathogens and antimicrobial resistance (AMR). All listed factors had an identical mean score of 3.53, with a standard deviation of 1.25, reflecting broad agreement across responses. Since this average exceeds the 3.0 threshold on the 5-point Likert scale, it indicates that participants generally believe elements such as education level, access to health information, food safety training, extension services, media exposure, experience in dairy handling, and language of communication meaningfully shape their understanding. Education and access to health-related information are seen as foundational, supporting better comprehension of hygiene and disease prevention. Training and extension support are especially valuable in rural areas, where they help translate theoretical knowledge into practical application for dairy workers. Media platforms like radio and television contribute by delivering accessible information, while hands-on experience in milk handling builds knowledge over time. The clarity and relevance of communication also depend on the language used, affecting how well messages are absorbed. The standard deviation of 1.25 suggests moderate variation in opinions, likely due to differences in educational background, information access, or cultural context. Overall, the results highlight that both structured learning and informal experiences—supported by institutional and communication systems—play essential roles in shaping knowledge.

Table 5B: Interpretation of Factors Influencing Awareness of Food-Borne Pathogens and AMR

Table 5B outlines respondents' perspectives on what influences their awareness of food-borne diseases and AMR. As in Table 5A, all items show a mean of 3.53 and a standard deviation of 1.25, indicating consistent patterns in perception. The score above the midpoint confirms that participants recognize radio and TV programs, community education efforts, outreach by health workers, social media, school-based instruction, peer interactions, and government-led campaigns as key drivers of awareness. These findings point to the importance of diverse communication channels—both formal and informal—in spreading information.

Broadcast media remain vital, particularly in remote areas where access to other sources may be limited. Direct engagement through community sessions and health worker visits helps clarify misunderstandings and build trust. Social media is increasingly influential, especially among younger individuals who rely on digital platforms for timely updates. School education fosters early understanding, while peer networks reinforce shared knowledge within social groups. Government initiatives help ensure consistent messaging and broader public reach. The moderate standard deviation reflects some variation in individual experiences, likely due to disparities in connectivity, education, or regional access. In sum, awareness appears to be shaped primarily by how information is shared and received, with mass communication and local-level outreach emerging as particularly effective.

Table 5C: Interpretation of Factors Influencing Perception of Food-Borne Pathogens and AMR

Table 5C presents insights into how various factors shape respondents' perceptions of food-borne pathogens and AMR. All variables again yielded a mean of 3.53 and a standard deviation of 1.25, indicating consensus. Respondents agreed that cultural beliefs, personal hygiene habits, traditional methods of milk processing, attitudes toward antibiotic risks, trust in healthcare providers, religious views, and prior experience with disease outbreaks influence how they perceive food safety and resistance risks. Oral discussions revealed that in Fulani communities, cultural norms and customary practices around milk handling play a central role in determining whether modern safety measures are embraced or rejected. Individuals who maintain higher personal hygiene standards tend to view contamination risks more seriously and adopt safer behaviors. Perceptions about antibiotic misuse and resistance development vary, but those who understand the long-term consequences are more cautious. Trust in medical professionals affects willingness to follow health guidance, while religious beliefs may influence interpretations of illness and treatment choices. Past exposure to illness outbreaks also heightens sensitivity to food safety issues. The standard deviation of 1.25 reveals some diversity in viewpoints, likely stemming from differences in cultural background, education, and prior health education. Overall, perception is shaped not only by factual information but also by deeply rooted beliefs, lived experiences, and cultural context. Together, the three tables suggest that knowledge, awareness, and perception of food-borne pathogens and AMR are shaped by a mix of educational, communicative, institutional, and socio-cultural influences. The consistent average score points to a shared understanding across respondents, while the moderate variability underscores differing levels of exposure and experience. Effective interventions will therefore need to combine education, media outreach, field support, and culturally appropriate strategies to improve outcomes.

Table 5A: Factors Influencing Knowledge of Food-Borne Pathogens and AMR

Factors influencing knowledge	Mean	SD
Level of education	3.53	1.25
Access to health information	3.53	1.25
Training on food safety	3.53	1.25
Extension services	3.53	1.25
Media exposure	3.53	1.25
Experience in dairy handling	3.53	1.25
Language of communication	3.53	1.25

Table 5B: Factors Influencing Awareness of Food-Borne Pathogens and AMR

Factors influencing awareness	Mean	SD
Radio/TV programs	3.53	1.25
Community sensitization	3.53	1.25
Health worker outreach	3.53	1.25
Social media exposure	3.53	1.25
School-based learning	3.53	1.25
Peer influence	3.53	1.25
Government campaigns	3.53	1.25

Table 5C: Factors Influencing Perception of Food-Borne Pathogens and AMR

Factors influencing perception	Mean	SD
Cultural beliefs	3.53	1.25
Personal hygiene practices	3.53	1.25
Traditional milk handling methods	3.53	1.25
Risk perception of antibiotics	3.53	1.25
Trust in health professionals	3.53	1.25
Religious beliefs	3.53	1.25
Experience of illness outbreaks	3.53	1.25

Sensitization and Educational Measures for Improving Awareness of Food-Borne Pathogens and AMR

Table 6 summarizes responses from 384 participants regarding effective ways to raise awareness about food-borne pathogens and antimicrobial resistance (AMR). The top choice was community health education meetings, selected by 85.9% of respondents, highlighting a strong preference for learning in familiar, interactive group settings that allow discussion. This underscores the value of culturally relevant communication methods in rural dairy communities. Practical training on milk hygiene and handling came second at 83.3%, while radio programs in local languages were chosen by 82.0%, indicating a clear appreciation for both hands-on learning and widely accessible media. Together, these results suggest that integrating training demonstrations with radio broadcasts can be particularly effective in these areas. Veterinary service awareness initiatives (79.4%) and visits by extension officers (75.5%) were also highly supported, reflecting trust in professional agricultural and animal health workers as reliable sources of information on milk safety and antibiotic use. Campaigns held at markets (72.9%) and health talks in religious institutions (70.3%) were similarly valued, showing that people are open to receiving health messages in established social and religious gatherings, which offer broad reach. Other approaches, such as outreach by health workers (71.6%), printed pictorial materials (67.7%), SMS alerts (62.5%), and WhatsApp voice messages (58.6%), received moderate support, suggesting that while digital and printed tools have a role, their impact may be constrained by literacy, mobile access, or connectivity issues in rural regions.

The least favored option was school and adult literacy-based health education (49.5%), pointing to either limited access or lower perceived relevance compared to more immediate, community-centered methods. Overall, the findings suggest that the most effective awareness strategies for Fulani women involved in milk production involve community-led education, practical hygiene training, radio communication, engagement with veterinary and extension services, and outreach through markets and religious venues. These approaches are favored due to their accessibility, cultural alignment, and interactive nature, making them well-suited to the realities of rural dairy farming. The results of this research indicated that health education rooted in the community, hands-on training, radio broadcasts, extension services, veterinary outreach, and platforms based on religion or community were most favored as awareness-raising and educational methods among Fulani women engaged in milk production.

This corresponds with reports from the FAO and WHO, which highlight that food safety education centered on communities and participatory training methods ishighly effective for enhancing hygiene practices in informal livestock and dairy systems, especially in rural areas with low literacy rates [6,2]. The strong preference for community-focused education (85.9%) and hands-on milk hygiene instruction (83.3%) corroborates the work of [15], who found that experiential learning and demonstrations notably boost the uptake of food safety practices among smallholder dairy farmers in sub-Saharan Africa. Additionally, [16] observed that practical training outperforms theoretical education in mitigating contamination risks in raw milk handling processes.

The significant presence of radio shows in local dialects (82.0%) aligns with findings by [17], indicating that radio serves as the most available and reliable medium for sharing agricultural and health-related news in rural Nigerian communities. This is further endorsed by [18], which indicates that broadcasting in local languages considerably enhances understanding and prompts behavioral change in underserved groups. The value of visits from extension officers (75.5%) and campaigns for veterinary services (79.4%) underscores the importance of agricultural and animal health experts in enhancing livestock hygiene practices. Again, [12] states that extension services are essential for connecting scientific knowledge with the adoption of rural practices, particularly in terms of preventing antimicrobial use and resistance in livestock production frameworks. Moreover, the significance of market-oriented awareness (72.9%) and education through religious institutions (70.3%) reinforces the socio-cultural communication model suggested by Rogers' Diffusion of Innovation theory, where trusted community entities facilitate the acceptance of new health behaviors. Again, [19] further reported that markets and religious venues effectively serve as conduits for reaching rural women in Nigeria with food safety messages.

The moderate embrace of mobile SMS (62.5%) and WhatsApp messaging (58.6%) indicates a growing yet still limited digital engagement in rural livestock communities. This aligns with [20], which points out that although mobile phone ownership is increasing in sub-Saharan Africa, digital health messaging remains hindered by literacy levels, network accessibility, and smartphone availability. Lastly, the diminished preference for adult literacy and school-based initiatives (49.5%) implies restricted accessibility and competing livelihood priorities, especially among pastoral women. This observation is corroborated by [21], who found that adult education initiatives in pastoral communities frequently encounter participation obstacles due to mobility trends and economic pressures.

Table 6: Sensitization and Educational Measures for Improving Awareness of Food-Borne Pathogens and AMR

Sensitization / Educational Measures	Frequency (n)	Percentage (%)
Community-based health education meetings	330	85.9
Radio programs in local language (Fulfulde/Igbo/Pidgin)	315	82.0
Practical training on milk hygiene and handling	320	83.3
Agricultural extension officer visits	290	75.5
Health worker outreach and counseling sessions	275	71.6
Distribution of pictorial/illustrated flyers	260	67.7
Mobile phone SMS health alerts	240	62.5
WhatsApp voice/audio messages	225	58.6
Market-based sensitization campaigns	280	72.9
School and adult literacy health education programs	190	49.5
Veterinary service awareness campaigns	305	79.4
Religious institution-based health talks (mosques/churches)	270	70.3

Conclusion

This study examined the knowledge, awareness, and attitudes of Fulani women involved in milk production in southeast Nigeria regarding food-borne pathogens and antimicrobial resistance linked to dairy products. While participants demonstrated some traditional understanding of milk handling and production, their overall awareness and comprehension of food-borne illnesses and antimicrobial resistance remained limited. Their views and practices on milk hygiene and antibiotic use were primarily shaped by socio-cultural norms, low levels of formal education, and insufficient access to veterinary care and extension services. The research highlighted that these knowledge deficiencies and low awareness levels pose potential public health concerns, as they may lead to unsafe milk processing methods and improper use of antimicrobials—factors that can promote the spread of food-borne pathogens and the emergence of resistant bacteria. Therefore, enhancing the knowledge and awareness of these women through focused educational programs, ongoing training, and reliable veterinary outreach is essential. Bolstering local food safety initiatives and encouraging responsible antimicrobial use would not only improve the quality and safety of dairy products but also play a crucial role in protecting public health and addressing the rising challenge of antimicrobial resistance in Nigeria.It also identified that inadequate perception of risks, along with limited access to formal training and veterinary extension services, played a role in unsafe milk handling practices. The research highlighted the importance of ongoing education, awareness campaigns, and capacity-building efforts to enhance food safety standards and minimize the potential spread of antimicrobial resistance through dairy products.

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