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Staphylococcus aureus Contamination of Milk and Cheese: Assessment of Consumers and Vendors Knowledge, Attitudes and Practices in Ilorin, Nigeria

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ABSTRACT

Mishandling milk and cheese can promote the growth of harmful bacteria such as *Staphylococcus aureus* (*S. aureus*), making it important to ensure their safety for public consumption. This study investigated the knowledge, attitudes, and practices of fresh milk/cheese vendors and consumers in Ilorin, Nigeria, regarding the contamination of these products with *S. aureus*. A questionnaire-based cross-sectional survey of 150 participants involving milk and cheese consumers and vendors was carried out in Ilorin, Nigeria. Data obtained were subjected to descriptive and inferential statistics. Results revealed that all vendors were female, 45 (100.0%), and almost half of the consumers, 47 (44.8%). Vendors 37 (82.2%) displayed unsatisfactory knowledge scores compared to consumers 33 (31.4%), with educational level significantly associated with knowledge among vendors. Consumers' age category and higher educational levels were associated with positive attitudes among the population groups, while none of the sociodemographic characteristics were significantly associated with practices among the respondents in this survey. Vendors at the secondary level of education were more likely to have satisfactory knowledge (OR: 48.0, 95% CI: 2.3, 997.0, p = 0.02) than those without formal education. In addition, adult consumers were more likely to display acceptable attitudes (OR: 3.2; 95% CI: 1.2, 8.2; p = 0.03) than adolescent consumers. These findings have implications for policymakers, suggesting the need for targeted interventions to improve the handling of milk and cheese in Nigeria while ensuring the safety of these products for public consumption.

INTRODUCTION

Food can become a source of human infection through contamination at various stages, from production to consumption, of which sound practices of food handlers can play a vital role in curbing food-borne diseases (Odetokun *et al.*, 2022a; Ghali-Mohammed *et al.*, 2023a). Food-borne diseases are of significant global public health issue, causing around 600 million cases and 420,000 deaths worldwide (Kirk *et al.*, 2015). Milk and dairy products are important sources of essential nutrients in humans (Fusco and Quero, 2014). Bacterial pathogens in milk are of significant public health concern, accounting for approximately 90% of all dairy-related diseases (Amenu *et al.*, 2019; Berhe *et al.*, 2020). Dores *et al.* (2013) described a high incidence of cheese contamination with *Staphylococcus aureus* (*S. aureus*) and other microorganisms as

high risk to consumers. *S. aureus* can produce enterotoxins in contaminated food and products that survive cooking or pasteurization (Kadariya *et al.*, 2014). When enterotoxins produced by *S. aureus* are consumed, they can lead to diarrhoea and/or vomiting. Humans and livestock are considered major reservoirs for the transmission of *S. aureus*, but environmental sources can also contribute to the contamination of food and food products (Fisher *et al.*, 2018; Shoaib *et al.*, 2023), causing food-borne diseases of public health importance (Odetokun *et al.*, 2018).

The Nigerian dairy industry features formal and informal value chains, where the informal segment primarily focuses on milk production from pastoral systems, constituting the nation's main and largest source of milk

supply (CSIRO, 2021). Unpasteurized milk is commonly sold to consumers, primarily by small-scale vendors, in Nigeria's rural and urban areas (CSIRO, 2021). Neglecting proper hygiene in milk handling within the informal sector poses a significant public health risk, increasing the likelihood of consuming unsafe milk (Odetokun and Adetunji, 2016; Okeke et al., 2016). Most studies in Nigeria have highlighted the contributory factors to the occurrence and contamination of *S. aureus* in various animal-derived foods, such as sausage, raw and roasted meat, fish, and shrimp, with few reports on the processing of milk and milk-derived products (Odetokun et al., 2021). However, specific information on handlers related to *S. aureus* contamination of milk and dairy products is lacking. Thus, assessing the knowledge, attitudes, practices, risk factors, and drivers of milk contamination among consumers and vendors within Nigeria's dairy production value chain is crucial.

In developing countries, including Nigeria, the production and consumption of various dairy products are often performed under unhygienic conditions, lack of refrigeration, and inadequate pasteurization (Ghali-Mohammed et al., 2022; Odetokun et al., 2023). In the milk market value chain, unhygienic handling can further facilitate its contamination with pathogenic microbes such as *S. aureus* (Makita et al., 2012). Dairy animals can shed *S aureus* into the milk supply or be introduced by environmental sources such as water, soil, air, or human contact (Fischer-Tenhagen et al., 2018; Leuenberger et al., 2019). The reported prevalence of *S. aureus* in Nigerian milk and milk products recently ranged from 3.5% to 31.1% (Ghali-Mohammed et al., 2022; 2023b).

This study represents a pioneering investigation into the knowledge, attitudes, and practices regarding *S. aureus* contamination among milk and cheese vendors and consumers in Ilorin, Nigeria, filling a crucial gap in the existing literature. This study focused on understanding the specific knowledge, attitudes, and practices dynamics within the local dairy supply chain, particularly among vendors who play a pivotal role in transmitting food-borne pathogens. Expounding the disparities in knowledge and practices between vendors and consumers and identifying sociodemographic factors influencing these disparities will provide valuable insights for designing targeted interventions to improve food safety practices and mitigate the risk of *S. aureus* contamination in dairy products, especially in resource-constrained settings of Nigeria. Therefore, the present study assessed consumers' and vendors' knowledge, attitudes, and practices regarding staphylococcal contamination of milk and cheese in Ilorin, Nigeria.

MATERIALS AND METHODS

Study design, area and sampling

An epidemiological paper-based pre-tested questionnaire survey was carried out from February to March 2022. The targeted respondents are the consumers and vendors of milk and cheese across the major markets of Ilorin, Kwara State, Nigeria. Ilorin is located in North Central Nigeria at the geographical coordinates of latitudes 8° 32' 48" N to 8° 34' 30" N and longitudes 4° 32' 15" E to 4° 34' 83" E. The city encompasses a total land area of approximately 13.6 km², with an elevation of 319m above sea level (Bitrus, 2021). Presently, Ilorin has an estimated population of 1,030,498 (WPR, 2023). Ilorin hosts diverse ethnic groups, including *Yoruba*, *Fulani*, *Hausa*, and *Nupe*, alongside other Nigerian communities (Ghali-Mohammed et al., 2023a). Ilorin was chosen as the study area because of its high number of milk consumers and the presence of large markets and vendors, particularly the "Fulanis," known for their involvement in cattle rearing and the sale of milk and dairy products, such as indigenous cheese (Wara) in Ilorin. Notably, Ilorin's strategic geographical location between the Northern and Southern states facilitates access for many consumers, including those from neighbouring states, thereby driving the demand for these dairy products.

The major milk markets, Gambari, Kulende, Oja Oba, and Ipata, were chosen purposefully for sampling. Vendors (n = 45) and consumers (n = 105) were recruited for the study during the sampling period (February to March 2022). All vendors in the various markets were sampled after meeting and approval with the vendors' heads. The vendors were approached in their stalls, usually in the afternoon, and at most twice during the week. We purposefully targeted customers buying milk and cheese from these vendors during each visit to the study sites. The sample size for proportion was calculated using the Open Source Epidemiologic Statistics for Public Health (OpenEpi v3.01), based on an expected prevalence (p) of 76.7% (Odetokun et al., 2018), level of confidence (z = 1.96), absolute precision (d = 0.07), and a design effect of 1.

Questionnaire design

The questionnaire design used closed-ended questions (Supplementary file 1). This approach was chosen to mitigate inconsistencies and variations in the obtained responses, enhance precision, and simplify subsequent data analysis procedures. Questions included in the survey tool were obtained via the review of pieces of literature (Ayele et al., 2017; Lindahl et al., 2018; Khadayata and Aggarwal, 2020; CSIRO, 2021; Nyokabi et al., 2021; Ghali-Mohammed et al., 2022) and suggestions from food safety and epidemiology experts. The questionnaire consists of four distinct sections. The initial section contained the demographic information of the participants in this survey. This encompassed variables such as age, gender, educational level, market, years of experience, and the respondent's status, whether they were vendors selling or consumers consuming milk/cheese products. The second section included questions to gauge participants' knowledge of staphylococcal infections. This section consisted of 14 questions that probed the respondents' familiarity with *S. aureus* infection, transmission of *S. aureus*, storage methods for milk and dairy products, and

related aspects. The respondents were prompted to answer each question using a binary "yes" or "no" format.

In the third section, the questionnaire featured questions concerning respondents' attitudes toward handling milk and dairy products, concerns about food-borne illnesses, and overall hygiene practices. These questions were structured on a 5-point Likert scale, allowing participants to express their viewpoints on a spectrum from "strongly disagree" to "strongly agree." Concluding the questionnaire, the fourth section concentrated on the behaviours and practices of the respondents. This section incorporated ten queries that revolved around personal hygiene, food safety, cleanliness of food premises, and preventive measures for food hygiene. Participants addressed these items using a categorical response format, indicating "Yes," "No," or "I don't know."

Questionnaire pre-test

The questionnaire was created to ensure precise data collection and simplify data analysis. Before the pre-test, the questionnaire was reviewed by two experts in food safety and epidemiology for content validity. Comments from the experts were used to improve the quality of the survey tool. In the pre-test phase, 10 copies were distributed to five consumers and five vendors in the Ipata market. Insights from the pre-test were used to refine the questionnaire, making it more effective and improving it before the main survey distribution and administration. The reliability statistic was calculated using Cronbach's alpha test, which revealed a value of 0.768. A reliability score above 0.7 demonstrated the internal consistency and reliability of the questionnaire administered (Santos, 1999; Tay and Jebb, 2017).

Questionnaire administration

The final questionnaire was administered to 150 participants, 59 males and 91 females, including 105 consumers and 45 milk/cheese vendors from various markets in Ilorin. Four major markets were purposefully sampled. Based on our observations during sampling, the vendors were usually within the range of 8 - 16 at each visit in each market. All vendors were recruited into the study while consumers were approached randomly. A typical milk market in Ilorin, Nigeria, is part of a larger informal market setting where several other items are sold to buyers, making it almost impossible to determine the precise number of milk consumers patronizing vendors. However, we ensured that active milk buyers were randomly approached and enrolled on the study after obtaining their consent. Participants in the survey were ensured that they were adults (at least 18 years of age) and had over one year of experience in buying or selling milk and cheese. Participants were allowed to provide verbal or written consent and freedom to withdraw from the survey at any point. To ensure effective communication, a Fulani/Hausa-speaking individual administered the questionnaire to vendors comfortable with those dialects, whereas other enumerators conducted the survey in

Yoruba for participants not fluent in English, Hausa, or Fulani. The enumerators underwent training to proficiently administer paper-and-pencil questionnaires before questionnaire administration. The study engaged consumers of milk products like "Fura" and cheese products like "Wara", as well as active vendors, to gather comprehensive insights and experiences for robust survey findings. The Ethical Review Committee of the Faculty of Veterinary Medicine, University of Ilorin, Nigeria, approved the study (FVM/UERC/2021/15/32TA011).

Data management and statistical analysis

The data gathered from the questionnaire responses were compiled using Microsoft Excel 2016 (Microsoft Corporation, Redmond, WA, USA) and analyzed using SPSS version 25 (IBM Corporation, Armonk, NY, USA). Descriptive statistics were computed for frequencies and percentages. To assess the levels of knowledge, attitudes, and practices (considered outcome variables) among the respondents, the data on sociodemographic characteristics (treated as independent variables) were initially calculated as percentages. Subsequently, the outcome variables were computed based on the relevant sections of the questionnaire.

We adopted a numeric scoring system to establish satisfactory levels (Table 1) of knowledge, attitudes, and practices regarding *S. aureus* contamination in milk and cheese among respondents (Odetokun *et al.*, 2020). This involved computing the knowledge, attitudes, and practice scores separately using a predefined scoring methodology as previously described (Odetokun *et al.*, 2021; 2022b). Correct responses to knowledge and practice questions were assigned a score of "1," while incorrect responses were marked as "0." For attitude-related questions, responses were scored on a scale of "4," "3," "2," "1," and "0" corresponding to "strongly agree," "agree," "neutral," "disagree," and "strongly disagree" options provided by the respondents. The total correct scores for each outcome variable were determined as the aggregate of scores obtained from the questions answered correctly by the respondents.

These computed outcome variables were further transformed into binary variables based on a cut-off point (mean) derived from the respondents' scores (Elnadi *et al.*, 2020). Scores above and below the cut-off points were categorized as satisfactory and unsatisfactory. The association between sociodemographic characteristics and computed outcome variables was examined using the Chi-square test, with Fisher's exact test applied for 2×2 variables when applicable. Significant sociodemographic variables identified through the chi-square test underwent stepwise backward binary logistic regression model analysis. The Hosmer-Lemeshow test was employed as an assessment tool to evaluate the model's goodness of fit. All statistical analyses were conducted at 95% confidence intervals, with the significance level at $p < 0.05$.

Table 1: Description of scores for the outcome variables obtainable by the respondents

Outcomes	Scores received by respondents			Maximum obtainable score	Satisfactory n (%)	Unsatisfactory n (%)
	Minimum	Maximum	Mean ± S.D			
γVendors (n = 45)						
Knowledge	1.0	12.0	4.3 ± 2.9	14.0	8 (17.8)	37 (82.2)
Attitudes	13.0	35.0	24.8 ± 5.9	40.0	26 (57.8)	19 (42.2)
Practices	4.0	18.0	9.9 ± 3.3	20.0	12 (26.7)	33 (73.3)
∞Consumers (n = 105)						
Knowledge	1.00	14.00	8.7 ± 3.6	14.0	72 (68.6)	33 (31.4)
Attitudes	9.00	31.00	28.6 ± 7.2	40.0	72 (68.6)	33 (31.4)
Practices	5.00	15.00	11.7 ± 3.2	20.0	54 (51.4)	51 (48.6)

Cut-off marks: mean (γKnowledge = 4.3; ∞Knowledge = 8.7, γAttitudes = 24.8; ∞Attitudes = 28.6, γPractices = 9.9; ∞Practices = 11.7). Satisfactory scores: scores > cut-off scores obtained by respondents. γ – Vendors. ∞ – Consumers. SD – Standard Deviation.

RESULTS

Sociodemographic data of the respondents

Table 2 shows the respondents' sociodemographic characteristics. The majority were 105 (70.0%) consumers, and the remaining 45 (30.0%) were vendors. Of all vendors, 45 (100.0%) were female, while almost half of the consumers, 47 (44.8%) were female. Most respondents (consumers and vendors) were adults (at least 78.1%). The distribution of vendors across markets ranged from 8 (17.8%) to 16 (35.6%), with at least 21 (20.0%) consumers recorded from each market. The number of vendors decreased with an increasing level of education, in contrast to consumers. Regarding experience, 40 vendors (88.9%) had less than 30 years of experience selling milk/cheese. About half of the consumers, 56 (53.3%), have less than 10 years of buying milk/cheese from the markets.

Association of sociodemographic characteristics of the respondents with knowledge, attitudes, and practices on *Staphylococcus aureus* contamination of milk and cheese

In the survey, vendors exhibited a high percentage of unsatisfactory knowledge level 37 (82.2%) and unacceptable practices, while their positive attitudes were above average 26 (57.8%) regarding *S. aureus* contamination of milk and cheese in Ilorin, Nigeria (Table 1). However, consumers participating in this study showed highly satisfactory knowledge 72 (68.6%), positive attitudes 72 (68.6%), and acceptable practices 54 (51.4%) (Table 1).

The sociodemographic characteristics of the respondents associated with knowledge are presented in Table 3. The vendors' level of education was significantly associated with their knowledge levels. Vendors with a secondary

educational level had higher knowledge level 3 (75.0%) than others. None of the consumers' sociodemographic characteristics was significantly associated with knowledge. However, consumers displayed satisfactory knowledge levels across various sociodemographic categories.

Of the sociodemographic characteristics, only the age category and educational level of consumers were associated with attitudes (p < 0.05) (Table 4). Adult consumers 61 (74.4%) and those with tertiary education 62 (78.5%) demonstrated satisfactory attitudes. None of the sociodemographic characteristics of the vendors were significantly associated with attitudes.

None of the vendors' and consumers' sociodemographic characteristics were associated with satisfactory practices regarding *S. aureus* contamination of milk and cheese across dairy product markets in Ilorin (Table 5), despite the average satisfactory responses on practices scores received by the consumers. Only vendors with secondary education levels received satisfactory practice scores compared to other vendors' categories.

Sociodemographic factors affecting the knowledge and attitudes of the respondents to this survey on *S. aureus* contamination of milk and cheese in the study area are presented in Table 6. Vendors at the secondary level of education were significantly more likely to have satisfactory knowledge (OR: 48.0, 95% CI: 2.3, 997.0, p = 0.02) than those without formal education, while consumers' satisfactory knowledge is associated with an increasing number of years of purchasing dairy products. Also, adult consumers were more likely to display acceptable attitudes (OR: 3.2; 95% CI: 1.2, 8.2; p = 0.03) than adolescent consumers regarding *S. aureus* contamination in milk and cheese in Ilorin, Nigeria.

Table 2: Sociodemographic distribution of respondents

Characteristics	Categories	Vendors n (%)	Consumers n (%)
Gender	Male	0 (0.0)	58 (55.2)
	Female	45 (100.0)	47 (44.8)
Age	Adolescent	6 (13.3)	22 (21.9)
	Adult	39 (86.7)	82 (78.1)
Level of education	Primary	19 (42.2)	2 (1.9)
	Secondary	4 (8.9)	24 (22.9)
	Tertiary	5 (11.1)	79 (75.2)
	None	17 (37.8)	0 (0.0)
Market	Ipata	16 (35.6)	21 (20.0)
	Oja oba	9 (20.0)	26 (24.8)
	Gambari	8 (17.8)	34 (32.4)
	Kulende	12 (26.7)	24 (22.9)
Years of experience	< 10	20 (44.4)	56 (53.3)
	11 – 19	10 (22.2)	20 (19.0)
	20 – 29	10 (22.2)	23 (21.9)
	30 – 39	1 (2.2)	6 (5.7)
	> 40	4 (8.9)	0 (0.0)

Years of experience: represents the years the vendors have been selling or the consumers have milk purchasing/consuming milk and cheese.

Table 3: Sociodemographic characteristics of respondents associated with knowledge of *Staphylococcus aureus* contamination of milk and cheese in Ilorin, Nigeria

Sociodemographic characteristics	Knowledge level (Vendors)				Knowledge level (Consumers)			
	Unsatisfactory n (%)	Satisfactory n (%)	χ^2	*P*-value	Unsatisfactory n (%)	Satisfactory n (%)	χ^2	*P*-value
Gender$^\gamma$								
Male	-	-	-	-	20 (34.5)	38 (65.5)	0.6	0.53
Female	37 (82.2)	8 (17.8)			13 (27.7)	34 (72.3)		
Age$^\gamma$								
Adolescent	5 (26.3)	1 (73.7)	1.0	0.70	10 (43.5)	13 (56.5)	1.9	0.13
Adult	32 (82.1)	7 (17.9)			23 (28.1)	59 (71.9)		
Level of education								
None	16 (94.1)	1 (5.9)	10.7	0.01*	-	-	1.9	0.38
Primary	16 (66.7)	3 (33.3)			1 (50.0)	1 (50.0)		
Secondary	1 (25.0)	3 (75.0)			10 (41.7)	14 (58.3)		
Tertiary	4 (80.0)	1 (20.0)			22 (27.8)	57 (72.2)		
Market								
Ipata	11 (68.8)	5 (31.2)	4.0	0.3	4 (19.1)	17 (80.9)	3.1	0.38
Oja oba	8 (88.9)	1 (11.1)			8 (30.8)	18 (69.2)		
Gambari	8 (100.0)	0 (0.0)			14 (41.2)	20 (58.8)		
Kulende	10 (83.3)	2 (16.7)			7 (29.2)	17 (70.8)		
Years of experience								
< 10	15 (75.0)	5 (25.0)	6.3	0.2	25 (44.6)	31 (55.4)	12.8	0.01*
10-19	10 (100.0)	0 (0.0)			6 (30.0)	14 (70.0)		
20-29	9 (90.0)	1 (10.0)			2 (50.0)	21 (50.0)		
30-39	1 (100.0)	0 (0.0)			0 (0.0)	6 (100.0)		
>40	2 (50.0)	2 (50.0)			-	-		

*Significant at $P < 0.05$; χ^2 – Chi-square value; γ – Fisher's exact test.; Years of experience: represents the number of years the vendors have been selling, or the consumers have milk purchasing/consuming milk and cheese.

Table 4: Sociodemographic characteristics of respondents associated with attitudes of *Staphylococcus aureus* contamination of milk and cheese in Ilorin, Nigeria

Sociodemographic characteristics	Attitudes level (Vendors)				Attitudes level (Consumers)			
	Unsatisfactory n (%)	Satisfactory n (%)	χ²	P-value	Unsatisfactory n (%)	Satisfactory n (%)	χ²	P-value
Gender^γ								
Male	-	-	-	-	14 (24.1)	44 (75.9)	3.2	0.09
Female	19 (42.2)	26 (57.8)			19 (40.4)	28 (59.6)		
Age^γ								
Adolescent	1 (20.0)	5 (80.0)	0.0	1.0	12 (52.2)	11 (47.8)	5.9	0.02*
Adult	18 (46.2)	21 (53.8)			21 (25.6)	61 (74.4)		
Level of education								
None	7 (41.2)	10 (58.8)	0.7	0.9	-	-	14.7	0.00*
Primary	9 (47.4)	10 (52.6)			1 (50.0)	1 (50.0)		
Secondary	1 (25.0)	3 (75.0)			15 (62.5)	9 (37.5)		
Tertiary	2 (40.0)	3 (60.0)			17 (21.5)	62 (78.5)		
Market								
Ipata	8 (50.0)	8 (50.0)	9.4	0.0	7 (33.3)	14 (66.7)	0.9	0.84
Oja oba	7 (77.8)	2 (22.2)			8 (30.8)	18 (69.2)		
Gambari	1 (12.5)	7 (87.5)			9 (26.5)	25 (73.5)		
Kulende	37 (80.4)	9 (19.6)			9 (37.5)	15 (62.5)		
Years of experience								
< 10	5 (50.0)	5 (50.0)	6.3	0.2	20 (35.7)	36 (64.3)	2.7	0.44
10-19	10 (100.0)	0 (0.0)			7 (35.0)	13 (65.0)		
20-29	9 (90.0)	1 (10.0)			4 (17.4)	19 (82.6)		
30-39	1 (100.0)	0 (0.0)			2 (33.3)	4 (66.7)		
>40	2 (50.0)	2 (50.0)			-	-		

*Significant at $P < 0.05$; χ² – Chi-square value; γ – Fisher's exact test; Years of experience: represents the number of years the vendors have been selling or the consumers have milk purchasing/consuming milk and cheese

Table 5: Sociodemographic characteristics of respondents associated with practices of *Staphylococcus aureus* contamination of milk and cheese in Ilorin, Nigeria

Sociodemographic characteristics	Practices level		χ²	P-value	Practices level		χ²	P-value
	Unsatisfactory n (%)	Satisfactory n (%)			Unsatisfactory n (%)	Satisfactory n (%)		
Gender^γ								
Male	-	-	-	-	24 (41.4)	34 (58.6)	2.7	0.08
Female	33 (73.3)	12 (26.7)			27 (57.4)	20 (42.6)		
Age^γ								
Adolescent	4 (66.7)	2 (33.3)	0.7	0.51	12 (52.2)	11 (47.8)	0.2	0.81
Adult	29 (74.4)	10 (25.6)			39 (47.6)	43 (52.4)		
Level of education								
None	13 (76.5)	4 (23.5)	5.3	0.15	-	-	2.7	0.26
Primary	15 (78.9)	4 (21.1)			0 (0.0)	2 (100.0)		
Secondary	1 (25.0)	3 (75.0)			10 (41.7)	14 (58.3)		
Tertiary	4 (80.0)	1 (20.0)			41 (51.9)	38 (48.1)		
Market								
Ipata	11 (68.8)	5 (31.2)	0.3	0.92	12 (57.1)	9 (42.9)	2.9	0.40
Oja oba	7 (77.8)	2 (22.2)			9 (34.6)	17 (65.4)		
Gambari	6 (75.0)	2 (25.0)			18 (52.9)	16 (47.1)		
Kulende	9 (75.0)	3 (25.0)			12 (50.0)	12 (50.0)		
Years of experience								
< 10 years	16 (80.0)	4 (20.0)	3.1	0.55	30 (53.6)	26 (46.4)	1.9	0.58
10-19 years	8 (80.0)	2 (20)			10 (50.0)	10 (50.0)		
20-29 years	6 (60.0)	4 (40.0)			9 (39.1)	14 (60.)9		
30-39	1 (100.0)	0 (0.0)			2 (33.3)	4 (66.7)		
>40 years	2 (50.0)	2 (50.0)			-	-		

*Significant at *P* < 0.05; χ² – Chi-square value; γ – Fisher's exact test; Years of experience: represents the number of years the vendors have been selling or the consumers have milk purchasing/consuming milk and cheese.

TABLE 6. Sociodemographic factors influencing respondents' knowledge, attitudes, and practices of respondents on *Staphylococcus aureus* contamination of milk and cheese

Sociodemographic factors	Vendors					Consumers				
	Unsatisfactory n (%)	Satisfactory n (%)	OR	95% CI	*P-value*	Unsatisfactory n (%)	Satisfactory n (%)	OR	95% CI	*P-value*
Knowledge										
Level of education										
None	16 (94.1)	1 (5.9)	1.0							
Primary	16 (66.7)	3 (33.3)	3.0	0.3, 319	0.69					
Secondary	1 (25.0)	3 (75.0)	48.0	2.3, 990	0.02*					
Tertiary	4 (80.0)	1 (20.0)	4.0	0.2, 78.8	0.82					
Years of experience										
< 10 years						25 (44.6)	31 (55.4)	1.0	-	-
10-19 years						6 (30.0)	14 (70.0)	1.9	0.6, 5.6	0.38
20-29 years						2 (50.0)	21 (50.0)	8.5	1.8, 39.6	0.00*
30-39						0 (0.0)	6 (100.0)	121	0.5, 310	0.06
>40 years						-	-	-	-	-
Attitude										
Age$^\gamma$										
Adolescent						12 (52.2)	11 (47.8)	1.0	-	-
Adult						21 (25.6)	61 (74.4)	3.2	1.2, 8.2	0.03*
Level of education										
None						-	-	-	-	-
Primary						1 (50.0)	1 (50.0)	1.0	-	-
Secondary						15 (62.5)	9 (37.5)	0.6	0.0, 10.8	>0.99
Tertiary						17 (21.5)	62 (78.5)	3.6	0.2, 61.4	0.79

* – Significant at p < 0.05; CI – Confidence interval

DISCUSSION

This study assessed food safety knowledge, attitudes, and practices among vendors and consumers regarding *S. aureus* contamination of milk and cheese in Ilorin, Nigeria. We found that all vendors were female, and about half of the consumers. Vendors displayed unsatisfactory knowledge scores compared to consumers, with educational levels being significantly associated with knowledge among vendors. Consumer's age category and higher educational levels were associated with positive attitudes among the population groups, while none of the sociodemographic characteristics was significantly associated with practices among the respondents in this survey. To our knowledge, this study is a pioneering report among vendors and consumers on the knowledge, attitudes, and practices related to *S. aureus* contamination in milk/cheese in Nigeria. Milk and cheese are abundant protein sources in Nigeria, and perceived health benefits and cost-effectiveness drive the rising population of milk consumers compared with meat and fish.

The number of female respondents outnumbering the males in this study could be due to the belief that men do not participate in milk-related chores. Similarly, more

females have been documented in milk-related tasks (Mandefero and Yeshibelay, 2018). This is also a clear indication of the involvement of women in market activities, and more attention is being paid to what they consume as well as to their respective families.

Educating respondents is vital for the safety of milk and cheese sold or bought in the study area. The display of unsatisfactory knowledge scores among vendors compared to consumers signifies the need to enlighten respondents, particularly vendors, on the contamination of milk and the safety of products vended for public consumption. Our findings are similar to an earlier report from Ethiopia (Ayele *et al.*, 2017), where uneducated farmers had higher raw milk consumption due to concerns about microbial contamination than those with basic literacy. Education significantly correlates with vendors' knowledge of *S. aureus* contamination in milk and cheese. Similarly, Mandefero and Yeshibelay (2018) reported that some respondents' lack of formal knowledge about milkborne zoonosis contributed to their poor understanding, attitude, and practices. Another study revealed that dairy farmers were aware of milk-borne diseases but lacked knowledge of specific diseases (Ekuttan, 2006).

Our study revealed that adult consumers and higher educational levels were associated with positive attitudes among the two population groups toward *S. aureus* contamination of dairy products in the study area. Among vendors, fewer than 15% had satisfactory attitudes. These vendors usually milk cows before supplying milk to the markets. Many vendors (55%) consumed raw milk, with 87% unaware of its associated food-borne illnesses. Additionally, 75% of vendors admitted that teat cleaning before milking and hand washing was not practised, although they acknowledged cleaning the utensils used in milk collection. Isolation of *S. aureus* from milk (Ghali-Mohammed *et al.*, 2023b) showed that vendors are ignorant of the value of good milking procedures in reducing microbial contamination of milk, generating public health concerns.

None of the sociodemographic characteristics were significantly associated with practices among the respondents in this survey. Only 20% of the respondents in this study agreed with boiling milk to make it safer for consumption, and 63.3% did not agree, which seems to be a cause for concern because boiling has been found to bring about a reduction in the number of bacterial loads found in milk and its products. This is in accordance with a study by Kilango *et al.* (2011), where the presence of milk-borne pathogens was investigated to examine the effect of boiling and subsequent handling of milk served hot at milk kiosks. In addition, we found that vendors' practices of hand washing, personal hygiene, and safe food handling were relatively poor. A previous study (Zain and Naing, 2002) established that food handlers and vendors must be reminded to practice thorough hand hygiene, especially before and after handling raw ingredients, to ensure food safety. Handwashing is a crucial daily habit for food producers and vendors. Factors such as remoteness, inadequate health facilities, poor extension services, lack of training in animal rearing and product handling, and financial constraints affect the safety of milk and its products (Ameni and Erkihun, 2007). Low literacy rates significantly contribute to limited awareness of diseases and infections among smallholder dairy farmers, including *S. aureus*. Furthermore, many African cultures equate diseases shared by livestock and humans with misbehaviour, wrongdoing, witchcraft, and spells (Marcotty *et al.*, 2009). These practices result from insufficient information or a lack of resources at the farm level and on-farm knowledge of milk quality difficulties related to dairy farming.

Our logistic regression results on the sociodemographic characteristics influencing KAPs of the respondents on *S. aureus* contamination of milk and cheese showed that education is an important consideration in addressing the poor knowledge, attitude, and practice scores exhibited by some vendors and consumers, especially adolescents. This observation is similar to reports from previous studies (Lindahl *et al.*, 2018; Khadayata and Aggarwal, 2020; Nyokabi *et al.*, 2021), where a higher level of education (especially among the elite) translated to satisfactory knowledge and practices regarding food safety issues.

Poor market and consumer hygiene compromise the safety and quality of milk. To ensure milk safety, there is a need for social and behaviour change training to engage respondents and help them adopt acceptable attitudes and practices (Farnworth *et al.*, 2023) to reduce milk contamination with pathogens. Cultural beliefs, economic factors, and preferences influence people's knowledge, attitudes, and practices regarding *S. aureus* contamination of milk and cheese. For instance, some believe that raw dairy products are more nutritious, whereas economic constraints can hinder access to hygiene facilities and quality control measures. These factors affect individuals' willingness to adopt preventive measures or change their behaviour to reduce the risk of *S. aureus* contamination.

The findings of this study have profound implications for public health and policy, particularly in food safety and the prevention of food-borne illnesses in Ilorin, Nigeria. The significant gap in knowledge and practices between vendors and consumers underscores the need for targeted educational programs aimed at vendors, who are critical players in the dairy supply chain. The fact that all vendors were female yet demonstrated lower knowledge and unsatisfactory practices highlights a pivotal area where public health interventions can be tailored. Training these vendors on safe handling, hygiene, and the risks associated with *S. aureus* contamination will ensure that the overall safety of dairy products can be improved. This is essential to protect consumers and empower women who form a significant part of the local economy through their involvement in dairy production and sales.

For policymakers, the study's results emphasized the importance of integrating food safety education into broader public health strategies. The association of higher educational levels with better knowledge and attitudes among consumers suggests that improving general education and specifically incorporating food safety into educational curricula can have long-term benefits. Moreover, the lack of significant association between sociodemographic characteristics and practices indicates a need for practical, hands-on training and continuous support to instil safe practices. Policies should aim to improve infrastructure for hygiene, such as access to clean water and sanitation facilities, and provide regular training for vendors. Public health campaigns addressing cultural beliefs and economic constraints could also foster a better understanding and adoption of safe food handling practices. These policy measures can significantly reduce the incidence of foodborne illnesses and improve the quality of dairy products, thereby enhancing public health outcomes.

The study's limitations include its exclusive focus on milk and cheese vendors and consumers in Ilorin, preventing the generalization of the findings to broader milk sellers and consumer populations in the country. The use of a questionnaire completed by respondents may have introduced response bias, even though the questionnaire was pre-tested and had a high-reliability coefficient. Furthermore, the study did not analyze individual

knowledge, attitudes, and practice items separately but aggregated scores. Future research should consider longitudinal or observational surveys of milk and cheese vendors and consumers to validate knowledge, attitudes, and practices and ensure response accuracy.

CONCLUSION

This study highlights significant knowledge and practice gaps among milk and cheese vendors in Ilorin, Nigeria, with vendors displaying unsatisfactory knowledge and practices regarding *Staphylococcus aureus* contamination while consumers showed better awareness and attitudes. These findings underscore the critical need for targeted educational interventions and hands-on training programs for vendors to enhance their food safety practices. Improving the education of vendors, particularly women who dominate this sector, is vital for reducing contamination risks. Policymakers should prioritize integrating food safety education into public health initiatives, enhancing infrastructure for hygiene, and conducting regular training sessions. Addressing these gaps through multifaceted strategies will improve the safety of dairy products, protect public health, and empower vendors within the local economy.

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REFERENCES

Ameni, G., and Erkihun, A. (2007). Bovine tuberculosis on small-scale dairy farms in Adama Town, central Ethiopia, and farmer awareness of the disease. *Revue Scientifique et Technique*, *26*(3), 711–719.

Amenu, K., Grace, D., Nemo, S., and Wieland, B. (2019). Bacteriological quality and safety of ready-to-consume milk and naturally fermented milk in Borana pastoral area, southern Ethiopia. *Tropical Animal Health and Production*, *51*(7), 2079–2084. [Crossref]

Ayele, Y., Gutema, F. D., Edao, B. M., Girma, R., Tufa, T. B., Beyene, T. J., Tadesse, F., Geloye, M., and Beyi, A. F. (2017). Assessment of *Staphylococcus aureus* along milk value chain and its public health importance in Sebeta, central Oromia, Ethiopia. *BMC Microbiology*, *17*(1), 141. [Crossref]

Berhe, G., Wasihun, A. G., Kassaye, E., and Gebreselasie, K. (2020). Milk-borne bacterial health hazards in milk produced for commercial purpose in Tigray, northern Ethiopia. *BMC Public Health*, *20*(1), 894. [Crossref]

Bitrus, D. E. (2021). Developing geo - database for housing and facilities management in Sobi Barracks Ilorin, Kwara state, Nigeria.

Commonwealth Scientific and Industrial Research Organisation (CSIRO). (2021). Dairy production in Nigeria. research.csiro.au Accessed 25 January, 2024

Dores, M. T., Dias, R. S., Arcuri, E. F., Nobrega, J. E., and Ferreira, C. L. L. F. (2013). Enterotoxigenic potential of *Staphylococcus aureus* isolated from Artisan Minas cheese from the Serra da Canastra – MG, Brazil. *Food Science and Technology,* 33, 271–75. [Crossref]

Ekuttan, C. E. 2006. Biological and chemical health risks associated with smallholder dairy production in Dagoretti Division, Nairobi. Department of Community Health, University of Nairobi.

Elnadi, H., Odetokun, I. A., Bolarinwa, O., Ahmed, Z., Okechukwu, O., & Al-Mustapha, A. I. (2021). Correction: Knowledge, attitude, and perceptions towards the 2019 Coronavirus Pandemic: A bi-national survey in Africa. *PloS One*, *16*(2), e0247351. [Crossref]

Farnworth, C. R., Jumba, H., Otieno, P. E., Galiè, A., Ouma, E., Flax, V. L., Schreiner, M-A., and Colverson, K. (2023). Gender roles and masculinities in leveraging milk for household nutrition: Evidence from two districts in Rwanda. *Food Policy*, 118, 102486. [Crossref]

Fischer-Tenhagen, C., Theby, V., Krömker, V., and Heuwieser, W. (2018). Detecting *Staphylococcus aureus* in milk from dairy cows using sniffer dogs. *Journal of Dairy Science*, *101*(5), 4317–4324. [Crossref]

Fisher, E. L., Otto, M., and Cheung, G. Y. C. (2018). Basis of Virulence in Enterotoxin-Mediated Staphylococcal Food Poisoning. *Frontiers in Microbiology*, *9*, 436. [Crossref]

Fusco, V., and Quero, G. M. (2014). Culture-Dependent and Culture-Independent Nucleic-Acid-Based Methods Used in the Microbial Safety Assessment of Milk and Dairy Products. *Comprehensive Reviews in Food Science and Food Safety*, 13(4), 493–537. [Crossref]

Ghali-Mohammed, I., Odetokun, I. A. Raufu, I.A., and Adetunji, V. O. (2022). Handling practices and contamination of raw milk sold for consumption in markets of Kwara State. Nigeria. *Sokoto Journal of Veterinary Sciences,* 20, 50–58. [Crossref]

Ghali-Mohammed, I., Odetokun, I.A. Raufu, I. A., Alhaji, N. B., and Adetunji, V. O. (2023a). Prevalence of *Escherichia coli* O157 isolated from marketed raw cow milk in Kwara State, Nigeria. *Scientific African,* 19, e01469. [Crossref]

Ghali-Mohammed, I., Ade-Yusuf, R. O., Adewoye, A. O., Adetona, M. A., Ahmed, A. O., Alhaji, N. B., and Odetokun, I. A. (2023b). Prevalence and antimicrobial susceptibility profile of *Staphylococcus aureus* isolated from marketed milk and cheese in Ilorin, Nigeria. *Journal of Sustainable Veterinary and Allied Sciences,* 5, 47-54.

Kadariya, J., Smith, T. C., and Thapaliya, D. (2014). *Staphylococcus aureus* and staphylococcal food-borne disease: an ongoing challenge in public

health. *BioMed Research International, 2014*, 827965. [**Crossref**]

Khadayata, V., and Aggarwal, D. (2020). Knowledge, Attitude, and Practice about Hygiene among Livestock Keepers in Peri-Urban Area of Vadodara District, Gujarat. *Indian Journal of Community Medicine, 45*(S1), S16–S20. [**Crossref**]

Kilango, K., Makita, K., Kurwijila, L., and Grace, D. (2012). Boiled milk, food safety and the risk of exposure to milk borne pathogens in informal dairy markets in Tanzania. Paper Presented at the World Dairy Summit Conference, 4-8th November 2012, Cape Town, South Africa, November 2012, 4–8.

Kirk, M. D., Pires, S. M., Black, R. E., Caipo, M., Crump, J. A., Devleesschauwer, B., Döpfer, D., Fazil, A., Fischer-Walker, C. L., Hald, T., Hall, A. J., Keddy, K. H., Lake, R. J., Lanata, C. F., Torgerson, P. R., Havelaar, A. H., and Angulo, F. J. (2015). World Health Organization Estimates of the Global and Regional Disease Burden of 22 Food-borne Bacterial, Protozoal, and Viral Diseases, 2010: A Data Synthesis. *PLoS Medicine*, 12(12), e1001921. [**Crossref**]

Leuenberger, A., Sartori, C., Boss, R., Resch, G., Oechslin, F., Steiner, A., Moreillon, P., and Graber, H. U. (2019). Genotypes of *Staphylococcus aureus*: On-farm epidemiology and the consequences for prevention of intramammary infections. *Journal of Dairy Science, 102*(4), 3295–3309. [**Crossref**]

Lindahl, J. F., Deka, R. P., Asse, R., Lapar, L., and Grace, D. (2018). Hygiene knowledge, attitudes and practices among dairy value chain actors in Assam, north-east India and the impact of a training intervention. *Infection Ecology and Epidemiology, 8*, 1555444. [**Crossref**]

Makita, K., Desissa, F., Teklu, A., Zewde, G., and Grace, D. (2012). Risk assessment of staphylococcal poisoning due to consumption of informally-marketed milk and home-made yoghurt in Debre Zeit, Ethiopia. *International Journal of Food Microbiology*, 153(1-2), 135–141. [**Crossref**]

Mandefero, D., and Yeshibelay, G. (2018). Assessment of community knowledge, attitude and practice on milk borne zoonoses disease in Debre- Birhan town, north Shewa, Ethiopia. *Journal of Public Health and Epidemiology, 10*, 123–31. [**Crossref**]

Marcotty, T., Matthys, F., Godfroid, J., Rigouts, L., Ameni, G., Gey van Pittius, N., Kazwala, R., Muma, J., van Helden, P., Walravens, K., de Klerk, L. M., Geoghegan, C., Mbotha, D., Otte, M., Amenu, K., Abu Samra, N., Botha, C., Ekron, M., Jenkins, A., Jori, F., … van den Bossche, P. (2009). Zoonotic tuberculosis and brucellosis in Africa: neglected zoonoses or minor public-health issues? The outcomes of a multi-disciplinary workshop. *Annals of Tropical Medicine and Parasitology*, 103(5), 401–411. [**Crossref**]

Nyokabi, S., Luning, P. A. de Boer, I. J. M., Korir, L., Muunda, E., Bebe, B. O., Lindahl, J., Bett, B., and

Oosting, S. J. (2021). Milk quality and hygiene: Knowledge, attitudes and practices of smallholder dairy farmers in central Kenya. *Food Control,* 130: 108303.

Odetokun, I. A., and Adetunji V. O. (2016). Prevalence and persistence of *Listeria monocytogenes* in dairy and other ready-to-eat food products in Africa, p. 349-362. *In* Garg, N., S. M. Abdel-Aziz, and A. Aeron. (eds.), Microbes in Food and Health, vol. 1. Springer International Publishing, Switzerland. [**Crossref**]

Odetokun, I. A., Ballhausen, B., Adetunji, V. O., Ghali-Mohammed, I., Adelowo, M. T., Adetunji, S. A., and Fetsch, A. (2018). *Staphylococcus aureus* in two municipal abattoirs in Nigeria: Risk perception, spread and public health implications. *Veterinary Microbiology*, 216, 52–59. [**Crossref**]

Odetokun, I. A., Borokinni, B. O., Bakare, S. D., Ghali-Mohammed, I., and Alhaji, N. B. (2021). A cross-sectional survey of consumers' risk perception and hygiene of retail meat: a Nigerian study. *Food Protection Trends,* 41, 274–83.

Odetokun, I. A., Ghali-Mohammed, I., Alhaji, N. B., Nuhu, A. A., Oyedele, H. A., Ameen, S. A., and Adetunji, V. O. (2020). Occupational health and food safety risks in Ilorin, Northcentral Nigeria: a cross-sectional survey of slaughterhouse workers. *Food Protection Trends,* 40, 241–250.

Odetokun, I. A., Adetona, M. A., Ade-Yusuf, R. O., Adewoye, A. O., Ahmed, A. N., Ghali-Mohammed, I., Al-Mustapha, A. I., and Fetsch, A. (2023). *Staphylococcus aureus* contamination of animal-derived foods in Nigeria: a systematic review, 2002—2022. *Food Safety and Risk,* 10, 6. [**Crossref**]

Odetokun, I. A., Maurischat, S., Adetunji, V. O., and Fetsch, A. (2022a). Methicillin-Resistant *Staphylococcus aureus* from Municipal Abattoirs in Nigeria: Showing Highly Similar Clones and Possible Transmission from Slaughter Animals to Humans. *Food-borne Pathogens and Disease*, 19(1), 56–61. [**Crossref**]

Odetokun, I. A., Afolaranmi, Z. M., Nuhu, A. A., Borokinni, B. O., Ghali-Mohammed, I., Cisse, H., and Alhaji, N. B. (2022b). Knowledge and self-reported food safety practices among meat consumers in Ilorin, Nigeria. *Dialogues in Health, 1*, 100039. [**Crossref**]

Okeke, K. S., Makun, H. A., Damisa, D., and Akoma, O. (2016). Microbiological survey and appraisal of local milk production in Kwara and Niger State, Nigeria. *Global Journal of Biology, Agriculture and Health Sciences,* 5, 139-153.

Santos, J. R. A. 1999. Cronbach's alpha: a tool for assessing the reliability scale. *J. Ext.* 37: 1–4.

Shoaib, M., Aqib, A. I., Muzammil, I., Majeed, N., Bhutta, Z. A., Kulyar, M. F., Fatima, M., Zaheer, C. F., Muneer, A., Murtaza, M., Kashif, M., Shafqat, F., and Pu, W. (2023). MRSA compendium of epidemiology, transmission, pathophysiology,

treatment, and prevention within one health framework. *Frontiers in Microbiology*, 13, 1067284. **[Crossref]**

Tay, L., and Jebb, A. (2017). Scale development. In: Rogelberg S, editor. The SAGE encyclopedia of industrial and organizational psychology. Thousand Oaks, CA: Sage.

World Population Review (WPR). (2023). Ilorin Population 2023. Ilorin Population.

Zain, M. M., and Naing, N. N. (2002). Sociodemographic characteristics of food handlers and their knowledge, attitude and practice towards food sanitation: a preliminary report. *The Southeast Asian Journal of Tropical Medicine and Public Health*, 33(2), 410–417.