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Milk handling practices and milk spoilage along the informal dairy value chain of Uganda

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Abstract

In low- and middle-income countries such as Uganda, smallholder dairy farmers rely heavily on milk production for income, nutrition, and livelihood security. However, improper milk handling and weak enforcement of food safety regulations remain major challenges. This study assessed awareness and milk handling practices among key actors in the informal dairy value chain. A cross-sectional survey was conducted from January to April 2024 across Uganda's six milk sheds using a multistage cluster sampling design. A total of 384 farmers, 231 Milk Collection Centres (MCCs), and 70 Small and Medium Enterprises (SMEs) were surveyed. Data were analyzed using descriptive statistics and mixed-effects logistic regression. Among farmers, common vices included long nails (48%), improper handwashing (34%), and unguided coughing or sneezing. Poor hygienic practices, such as failure to wash udders before milking (50.9%), use of a common udder cloth for multiple cows (33.3%), and inadequate cleaning of milking containers, were significantly associated with milk spoilage ($p < 0.05$). Independent predictors among farmers included inadequate udder hygiene (Odd ratio (OR) = 6.94; 95% Confidence Interval (CI): 1.19–40.38), handwashing before milking (OR = 0.054; 95% CI: 0.006–0.497), drying hands before milking (OR = 11.05; 95% CI: 1.26–96.87), and aluminium versus plastic containers (OR = 0.103; 95% CI: 0.012–0.899). At MCCs, body scratching (OR = 32.05; 95% CI: 1.08–948.57), finger licking (OR = 0.231; 95% CI: 0.060–0.886), milk testing (OR = 34.06; 95% CI: 2.53–458.07), and use of gumboots (OR = 0.115; 95% CI: 0.022–0.595) were significant predictors. Among SMEs, spoilage was associated with working as a Quality Controller (OR = 23.82; 95% CI: 1.89–299.51) or Operator (OR = 99.92; 95% CI: 3.29–3039.56) and using a cloth for filtering milk (OR = 0.064; 95% CI: 0.005–0.830). Overall, poor hygienic practices were the strongest determinant of contamination along the informal dairy value chain. These findings highlight the urgent need for targeted training and technical support to improve milk handling practices and protect consumer health.

Key words: *Informal Dairy Value Chain; Milk; Milk-handling; Milk handling practices; Milk spoilage*

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Introduction

Milk and dairy products are important sources of essential nutrients for humans (Berhe *et al*., 2020; Nyokabi *et al.,* 2021). However, about 90% of infections linked to milk consumption are caused by bacteria, including *Staphylococcus aureus*, *Salmonella spp*., *Listeria monocytogenes*, *Escherichia coli* O157:H7, and Campylobacter (Berhe *et al.,* 2020; Nyokabi *et al.,* 2021). The microbiological quality of raw milk is influenced by animal health, milking practices, milk handling, farming methods, hygiene, storage temperature, and equipment sanitation (Murphy *et al.,* 2016; Owusu-Kwarteng *et al.,* 2020). Although the Food and Agriculture Organization of the United Nations (FAO) has established evidence-based guidelines for milk handling to ensure safety and quality from production to consumption (FAO, 2011), these are often not followed, particularly in developing countries (Lemma *et al.,* 2018). The FAO guidelines emphasize hygienic milking procedures, proper udder preparation, use of clean and food-grade equipment, rapid cooling of milk to recommended temperatures, safe storage and transportation, regular health monitoring of dairy animals, and application of Hazard Analysis and Critical Control Point (HACCP) principles along the dairy value chain.

In Africa, milk handling practices vary by country and production system (Amenu *et al*., 2019), with common challenges including limited access to clean water, inadequate knowledge and training, and poor infrastructure (Nyokabi *et al.,* 2021). Initiatives by FAO and partners aim to address these gaps through training, improved water access, and better transport infrastructure (FAO, 2022). Proper milk handling involves steps to prevent contamination, including maintaining udder and equipment hygiene, clean milking environments, and good animal health (Wangalwa *et al*., 2016; Berhe *et al*., 2020). Poor practices, or vices, can introduce spoilage and pathogenic bacteria at any stage of the dairy value chain (Berhe *et al.,* 2020). In addition to microbial contamination, milk adulteration particularly the addition of water and other substances to increase volume has been reported within informal dairy value chains in Uganda, posing risks to consumer safety and economic losses to processors and traders (Dairy Development Authority [DDA], 2021).

In Uganda, milk handling varies with farm size, type, and farmer knowledge (Wangalwa *et al*., 2016). Common good practices include maintaining clean cow housing, nutritious feeding, maintaining a short distance from the farm to the market, proper milk transportation by authorized milk vans, regular milking, health monitoring, and waste management (Wangalwa *et al.,* 2016). Uganda does not rely solely on FAO guidelines; milk safety and quality are regulated under national frameworks such as the Dairy Industry Act and guidelines issued by the Dairy Development Authority (DDA), which provide standards for milk production, collection, transportation, and marketing. These national regulations align with international food safety principles, including hygienic production, cold chain maintenance, and prevention of adulteration and contamination. Despite these frameworks, microbial contamination often arises from diseased cows, unhygienic milking, poor personal and equipment hygiene, inadequate storage, and lack of clean water (Berhe *et al.,* 2020). Cultural preferences against boiling milk further increase the risk of milk-borne diseases (Amenu *et al.,* 2019). Ensuring milk quality and safety requires clean milking areas, food-grade containers, rapid cooling, and pasteurization or boiling before consumption (Amenu *et al.,* 2019), practices often missing in smallholder systems.

Therefore, despite international, regional, and national guidelines, poor milk handling remains a critical problem in Uganda, leading to food poisoning, milk-borne diseases, and spoilage (Grace *et al.,* 2020). The objective of this study was to assess the awareness and milk handling practices of key actors in Uganda's informal dairy sector, with findings aimed at identifying weaknesses and informing timely interventions to enhance milk safety and trade.

Materials and methods

Study Area

The study was conducted across the six recognized milk sheds of Uganda, namely South-western, Mid-western, Northern, Central, North Eastern (Karamoja), and Eastern, as classified by the Dairy Development Authority (DDA). These milk sheds represent the major dairy production zones of the country and vary in milk production potential, infrastructure, and market access.

Study Design

This study used a cross-sectional analytical survey design involving a multistage cluster sampling approach to investigate awareness levels and milk handling practices among actors in the informal dairy value chain of Uganda. The design accounted for clustering at the levels of milk shed, district, sub-county, and respondent category (farmers, Milk Collection Centres (MCCs), and Small and Medium Enterprises (SMEs)). The survey was conducted between January and April 2024.

Sampling Procedure and Sample Size Determination

Sampling was conducted in three stages. In the first stage, districts within each milk shed were purposively selected based on documented milk production potential according to Dairy Development Authority reports (2021). Only districts categorized as medium to high milk producers were included in the sampling frame. In the second stage, sub-counties within the selected districts were purposively selected based on milk production volumes and active participation in the informal dairy value chain. Lists of eligible sub-counties were obtained from District Veterinary Officers and Agricultural Extension Offices. In the third stage, respondents were selected from compiled sampling frames at sub-county level.

Lists of active dairy farmers participating in the informal dairy value chain were generated with support from extension personnel and veterinary authorities, and farmers were selected using simple random sampling. A complete list of registered MCCs per milk shed was obtained from the Dairy Development Authority (total N = 547 nationally), and MCCs were randomly selected within each milk shed. SMEs were identified through linkages with selected MCCs, and where multiple SMEs were associated with one MCC, one SME was randomly selected to avoid overrepresentation.

Eligible participants included dairy farmers actively producing and selling milk within the informal dairy value chain during the study period, operational MCCs handling raw milk in selected districts, and SMEs involved in processing or resale of milk sourced from selected MCCs. Respondents were required to be aged 18 years or older and willing to provide written informed consent. Farmers not actively producing milk at the time of the survey, non-operational MCCs or SMEs, and individuals unwilling to consent were excluded.

The sample size for farmers was determined using Cochran's (1977) formula for cross-sectional studies where the population size is unknown ($n = z^2pq/e^2$), assuming a 95% confidence level ($z = 1.96$), $p = 0.5$, and a margin of error of 0.05. This yielded a minimum sample size of 384 farmers. The sample was proportionally allocated according to each milk shed's contribution to national milk production: 96 from South-western, 46 from Mid-western, 42 from Northern, 92 from Central, 27 from North Eastern, and 81 from Eastern milk sheds.

For MCCs, the sample size was calculated using Cochran's correction formula for finite populations, considering N = 547 nationally, 95% confidence level, 5% margin of error, and $p = 0.5$. A total of 231 MCCs were sampled and apportioned proportionally across milk sheds. A total of 70 SMEs were selected through backward tracing from sampled MCCs, and key informant interviews were conducted with SME owners or managers.

Data Collection

Data were collected using three structured questionnaires tailored to farmers, MCC operators, and SME respondents. The instruments were pre-tested prior to administration. Enumerators were recruited locally within each milk shed and trained through practical demonstrations on survey content, interviewing techniques, and accurate data recording procedures. The questionnaires were developed

in English and translated into local languages where necessary to facilitate comprehension. Completed questionnaires were cross-checked daily by the research team to minimize recording errors and ensure data quality.

Study Variables

The outcome variable was reported milk spoilage/contamination (yes/no), defined based on reported milk rejection, abnormal organoleptic characteristics, or failure to meet acceptable handling standards during storage or transportation. This outcome applied to farmers and MCC operators who are directly involved in primary milk handling.

Independent variables included socio-demographic characteristics, farm or enterprise factors, and awareness of milk handling vices, hygiene practices, storage and transportation methods, and training exposure. These variables were selected based on biological plausibility and prior evidence.

Data Analysis

Data were analyzed using STATA version 15. Descriptive statistics were generated to summarize respondent characteristics and milk handling practices.

Bivariate logistic regression was first performed to identify candidate variables associated with milk spoilage ($p \leq 0.20$). Variables meeting this criterion were included in a multivariable logistic regression model to determine independent predictors while controlling for confounding. Given the multistage cluster sampling design, clustering was accounted for using mixed-effects logistic regression with milk shed included as a random effect and respondent category (farmer or MCC) included as a fixed effect. Statistical significance was set at $p < 0.05$, and results were reported as adjusted Odds Ratios with 95% confidence intervals.

Ethical Considerations

Voluntary written informed consent was obtained from all participants prior to data collection. Respondents were informed about the purpose and objectives of the study, assured of confidentiality, and informed of their right to withdraw at any time without consequence. All collected data were securely stored under the custody of the principal investigator. The study was also approved by Mbarara University Research ethics committee and the Uganda National Council for Science and Technology**.**

Results

Demographic characteristics of respondents

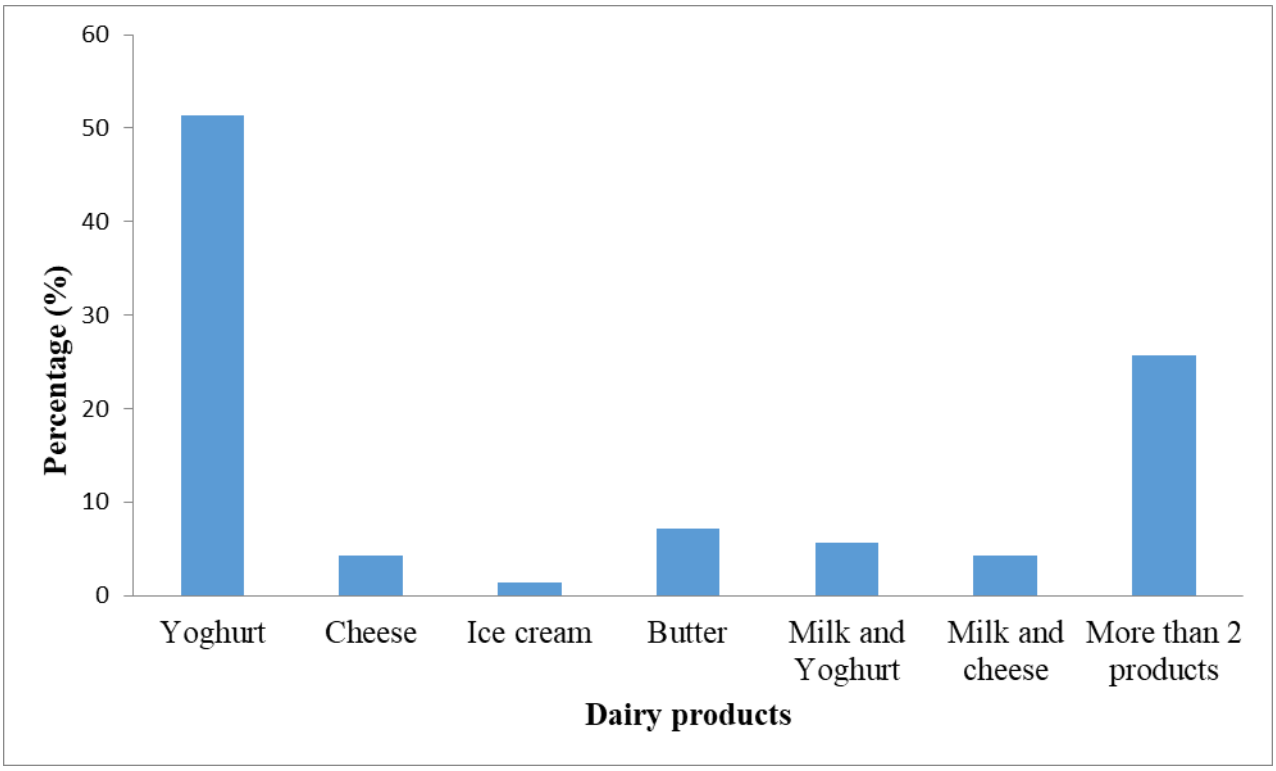
The study sampled a total of 384 farmers, 231 Milk Collection Centres (MCCs), and 70 SMEs across Uganda's six milk sheds. Among the farmers, the majority was from the South-western (28%) and Eastern (25%) milk sheds, predominantly male (80%) and heads of households (61%), with education levels ranging from primary (30%) to tertiary (12%). MCC respondents were mainly from the South-western milk shed (59%), mostly male (62%) and employed as managers (42%). SME respondents were largely from the Mid-western milk shed (26%), with 57% males and 39% having attained tertiary education. Farmers primarily used extensive grazing systems (44%). Training in milking and milk handling was reported by 28% of farmers, 87% of MCC staff, and 71% of SME respondents, with durations ranging from less than one month to over six months.

Products made from the milk received by SME

Findings in Figure 1 indicated that more than half (51%), 26%, 7%, 6%, 4%, 4% and 1% of the respondents reported that the SMEs were respectively producing: yoghurt; more than 2 milk products; butter; milk and yoghurt; cheese; milk and cheese and ice cream.

Figure 1

Products Made from the Milk Received by Small and Medium Enterprises (SME) in Uganda



Awareness of vices in Milk handling by the farmers, MCC and SME

Of the 384 farmers studied, majority of them (94%) reported awareness of improper milk handling practices, while 6% indicated they were unaware. Among the specific vices identified, farmers highlighted coughing/sneezing (69%), poor handwashing (88%), long nails (43%), smoking (42%), finger licking (23%), nose picking (50%), and body scratching (30%) as common milk handling faults. Similarly, out of the 231 MCC respondents, 71% acknowledged knowledge of milk handling vices, citing poor hand hygiene (86%), coughing/sneezing (49%), smoking (25%), long nails (16%), finger licking (22%), nose picking (18%), and body scratching (8%). Among 70 SME respondents, 97% were aware of improper practices, with high recognition of poor handwashing (91%), long nails (66%), coughing/sneezing (59%), body scratching (59%), smoking (53%), nose picking (53%), and finger licking (49%).

Milking and milk handling practices

Farmers

The findings in Table 1 showed that 99% of the farmers washed their hands before milking while 1% did not. Furthermore, 73%, 26% and 1% of the farmers who washed their hands used water and soap, water only and others, respectively. The results however indicated that 34% of the farmers did not dry their hands before milking while 66% did. Out of all those that dried their hands before milking, 62%, 31% and 7% reported that they used a re-usable cloth, hot air and disposable paper towels, respectively. The results also showed that slightly more than half (51%) of the farmers did not wash the cows' udder before milking while 49% did. Majority (82%) of those that washed the udders reported that they did so before milking only while 17% and 2% of the farmers respectively washed the udder "before and after milking" and after milking only. The data also revealed that 93% of the farmers used an udder cloth while 7% used disposable towels to wash the cows' udders. The findings indicated

that 67% of the farmers who used an udder cloth mentioned that they used a separate cloth for each cow while 33% did not. Furthermore, 93%, 4% and 3% of the farmers washed the cloth daily, weekly and other, respectively. In addition, 72%, 15%, 12% and 1% of the farmers used cold unboiled water, boiled warm water, warm water and cold boiled water, respectively to wash the cloth. The findings indicated that only 5% of the farmers used a sanitizer to wash the udder while 95% did not. Also, 31% used a milking cream while 69% did not. In terms of milking containers used, 52%, 42%, 4% and 1% of the farmers respectively reported that they used aluminium cans, plastic jerry cans, stainless steel cans and other milking containers. Majority (72%) of respondents reported that they washed the milking containers before and after every use while 17% and 11% washed the containers after ever use and before every use, respectively. Majority (88%) of the farmers reported that they used personal protective equipment (PPE) while 12% did not. The findings in Figure 2 indicated that majority (98%), 33%, 24%, 23% used gumboots, overcoat, gloves and hair cap PPE, respectively during milk handling.

Table 1

Farmers' Milk Handling Practices and Hygiene Measures in Dairy Production in Uganda

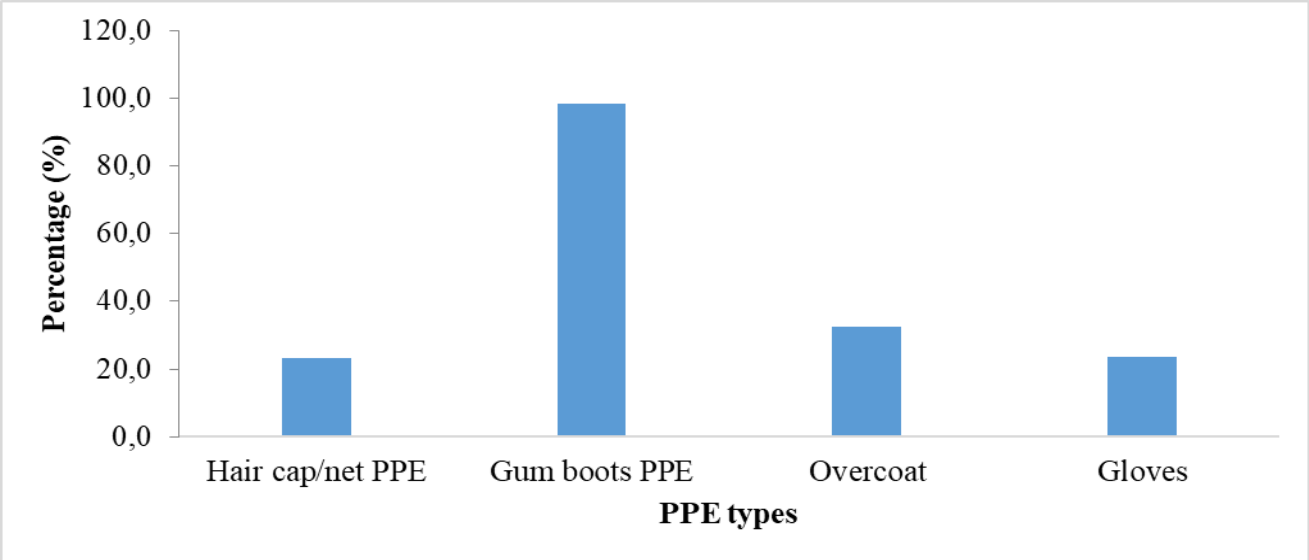
Practice	Frequency	Percentage (%)
Cools milk before sale		
No	327	97.6
Yes	8	2.4
Hand washing before milking		
No	5	1.4
Yes	346	98.6
What is used for hand washing before milking		
Water only	91	26.2
Water and soap/disinfectant	254	73.2
Other	2	0.6
Drying hands before milking		
No	117	33.5
Yes	232	66.5
Material used for washing hands		
Hot air	70	30.7
Disposable paper towels	16	7.0
Re-usable cloth	142	62.3
Washing cow's udder before milking		
No	178	50.9
Yes	172	49.1
When cow udder is washed		
Before milking only	138	81.7
After milking only	3	1.8
Before and after milking	28	16.6
Material used to wash udder		
Udder cloth	152	92.7
Disposable towels	12	7.3
Use of separate cloth for each cow to wash udder		

Practice	Frequency	Percentage (%)
No	50	33.3
Yes	100	66.7
Frequency of washing the cloth used to clean udder		
Daily	142	92.8
Weekly	6	3.9
Other	5	3.3
Type of water used to wash udder		
Warm water	19	12.5
Boiled warm water	22	14.5
Cold unboiled water	110	72.4
Cold boiled water	1	0.7
Use of sanitizer to wash udder		
No	151	94.4
Yes	9	5.6
Use of milking cream		
No	241	68.9
Yes	109	31.1
Type of milking containers used		
Plastic jerrycan	148	42.5
Aluminium can	182	52.3
Stainless steel can	15	4.3
Other	3	0.9
Frequency of washing the milking container		
Before every use	39	11.3
After every use	58	16.8
Before and after every use	248	71.9
Use of PPEs		
No	40	11.8
Yes	299	88.2

Note. Percentages are based on valid responses for each practice. PPE = personal protective equipment.

Figure 2

Personal Protective Equipment (PPE) Types Used by Farmers in Uganda



Milk Collection Centers

The majority of MCC respondents (97%) reported washing their hands, with most using both water and soap or disinfectant, while a small fraction (3%) used water only. Most respondents (94%) washed their hands both before and after handling milk, whereas 5% washed only before and 1% only after handling milk. All respondents reported drying their hands, with 40% using a reusable cloth, 40% using hot air, and 20% using disposable paper towels.

Regarding milk handling practices, 99% of respondents filtered milk upon receipt, primarily using metallic sieves (85%) or cloth (15%). Cooling of milk before sale was reported by 97% of respondents, mostly using grid electricity (80%), with others relying on generators (16%) or solar power (4%). Cleaning practices for milk coolers were largely consistent, with 94% cleaning before and after each use.

For milk containers, 88% of respondents used aluminum cans, while plastic jerry cans and stainless steel cans were used by 8% and 4%, respectively. Cleaning of containers involved cold water and soap (75%), hot water and soap (15%), hot water alone (7%), and detergent with water (3%). Storage practices included hanging (56%), placing on rafts (31%), or drying on the ground (13%). Milk testing was conducted by 87% of respondents, with 52% doing so to meet regulatory requirements and 48% following management instructions.

Use of personal protective equipment (PPE) was reported by 99% of respondents, with specific usage including gumboots (85%), overcoats (53%), hair nets/caps (23%), gloves (23%), and beard nets (2%).

Table 1

Milk Collection Center's Milk Handling Practices and Hygiene Measures in Uganda

Practice	Frequency	Percentage (%)
Handwashing before handling milk		
No	6	2.6
Yes	225	97.4
Handwashing material		
Water alone	6	2.7
Water and soap/disinfectant	219	97.3
Timing of washing hands		
Before handling the milk	12	5.4
After handling the milk	1	0.5
Before and after handling the milk	210	94.2
Hand drying materials		
Hot air	89	39.6
Disposable paper towels	46	20.4
Re-usable cloth	90	40.0
Milk filtering		
No	3	1.4
Yes	216	98.6
Filtering material		
Sieve	188	85.1
Piece of cloth	33	14.9
Cooling milk before sale		
No	6	2.7
Yes	219	97.3
Source of energy for coolers		
Grid electricity	177	80.5
Generator	34	15.5
Solar	9	4.1
Frequency of cleaning milk coolers		
Before every use	14	6.4
Before & after every use	206	93.6
Milk containers used		
Plastic Jerry can	17	7.6
Aluminium can	199	88.4
Stainless steel can	9	4.0
Frequency of washing the milk container		
Before every use	1	0.5
After every use	2	0.9
Before and after every use	220	98.7
Materials used to wash milk container		
Cold water alone	1	0.4
Hot water alone	15	6.7
Cold water & soap	168	74.7
Hot water & soap	34	15.1
Detergent & water	7	3.1
Method of storing containers		
On rafts	69	30.8
Hanging them	125	55.8
On the ground	29	13.0

Practice	Frequency	Percentage (%)
Other	1	0.5
Milk tests before receiving		
No	27	12.9
Yes	183	87.1
Milk tests used		
Alcohol test	16	8.1
Clot on boiling test	20	10.2
Density test	89	45.2
Alcohol & clot on boiling test	18	9.1
Alcohol and density test	24	12.2
Clot on boiling & density test	30	15.2
Reason for tests		
Regulatory requirement	102	52.3
Management instruction	93	47.7
Use of PPE		
No	1	0.5
Yes	212	99.5
PPE used		
Hair net	53	22.9
Gum boots	197	85.3
Overcoat	122	52.8
Gloves	54	23.4
Beard net	5	2.2

Note. *N = 231 milk collection center workers. Percentages are based on valid responses for each practice. Multiple-response items (such as PPE used, milk tests used, drying materials) may exceed 100% because respondents could select more than one option. PPE = personal protective equipment.*

SME

All SME respondents reported washing their hands before receiving milk, with the majority (93%) using both water and soap or disinfectant, while 7% used water only. Most respondents washed their hands both before and after handling milk (87%), while 7% washed only after, and 6% only before handling milk. Hand drying was universally practiced, with 53% using a reusable cloth, 35% hot air, and 12% disposable paper towels.

Regarding milk handling, 94% of respondents filtered milk upon receipt, primarily using metallic sieves (80%) or cloth (20%). Milk containers were mainly aluminum cans (50%), with stainless steel (37%) and plastic jerry cans (13%) also used. Cleaning practices involved cold water and soap (45%), detergent with water (36%), hot water and soap (17%), or hot water alone (2%). Cooling of milk upon receipt was reported by 76% of respondents, using grid electricity (81%), generators (11%), or solar power (8%). Cooler cleaning was consistently performed, with 89% cleaning before and after each use. Milk testing was conducted by 71% of respondents, mostly for regulatory compliance (86%), with the remainder following management instructions (14%).

In terms of manufacturing practices, 99% of SMEs reported having effective cleaning and disinfection plans 90% had pest control plans, and 89% maintained proper water quality management. Temperature control throughout processing was practiced by 87% of SMEs to maintain the cold chain, and 69% confirmed that all workers were trained in food safety management systems. Furthermore, 86% had waste management plans, 83% performed milk quality control before processing, and 97% implemented measures to prevent microbial contamination. Use of personal protective equipment (PPE) was reported by 94% of respondents, with gumboots (94%), overcoats (63%), hair nets/caps (59%), gloves (54%), and beard nets (34%) being the most commonly used.

Table 3

Milk Handling Practices and Hygiene Measures in Small and Medium Enterprises (SMEs) in Uganda

Practice	Frequency	Percentage (%)
Material used to wash hands		
Water alone	5	7.1
Water & soap/disinfectant	65	92.9
Timing of hand washing		
Before handling the milk	4	5.7
After handling the milk	5	7.1
Before & after handling the milk	61	87.1
Material used for drying hands		
Hot air	24	35.3
Disposable paper towels	8	11.8
Re-usable cloth	36	52.9
Milk filtering		
No	4	5.8
Yes	65	94.2
Material used for filtering		
Sieve	51	79.7
Piece of cloth	13	20.3
Type of milk containers used		
Plastic Jerrycan	9	12.9
Aluminium can	35	50.0
Stainless steel can	26	37.1
Method of washing milk containers		
Hot water alone	1	1.5
Cold water & soap	31	44.9
Hot water & soap	12	17.4
Detergent & water	25	36.2
Source of water for cleaning containers		
Municipal water	38	54.3
Bore hole	14	20.0
Rain water	19	27.1
Milking cooling on reception		
No	17	24.3
Yes	53	75.7
Source of energy for coolers		
Grid electricity	43	81.1
Generator	6	11.3
Solar	4	7.6
Timing of cleaning coolers		
Before every use	1	1.9
After every use	5	9.4
Before & after every use	47	88.7
Milk testing		
No	20	28.6
Yes	50	71.4
Type of test used		
Alcohol test	2	4.0
Clot on boiling test	7	14.0
Density test	2	4.0
Alcohol & clot on boiling test	15	30.0

Practice	Frequency	Percentage (%)
Alcohol and clot on density test	15	30.0
Clot on boiling & density test	9	18.0
Reason for testing		
Regulatory requirement	43	86.0
Management instruction	7	14.0
Effective cleaning and disinfection plan		
No	1	1.4
Yes	69	98.6
Existence of effective pest control plan		
No	7	10.0
Yes	63	90.0
Quality water management		
No	8	11.4
Yes	62	88.6
Controlled temperature		
No	9	13.2
Yes	59	86.8
Workers trained on milk safety		
No	22	31.4
Yes	48	68.6
Existence of waste management plan		
No	10	14.3
Yes	60	85.7
Milk control prior to processing		
No	12	17.1
Yes	58	82.9
Measures to avoid microbial contamination		
No	2	2.9
Yes	68	97.1
Use of PPE		
No	4	5.8
Yes	65	94.2
PPE used		
Hair net/cap	41	58.6
Gumboots	66	94.3
Overcoat	44	62.9
Gloves	38	54.3
Beard net	24	34.3
Promoter of PPE use		
Self-initiative	52	85.3
Manager/supervisor	9	14.8

Note. *N = 70 small and medium enterprise (SME) milk handlers. Percentages are calculated based on valid responses for each practice item. Items allowing multiple responses (such as materials used for drying hands, filtering materials, types of PPE used, and reasons for testing) may sum to more than 100%. PPE = personal protective equipment.*

Milk spoilage in the dairy value chain

The study revealed that most farmers (87%) reported that their milk had never spoiled before delivery, while 13% experienced spoilage. Among MCC respondents, 46% reported milk spoilage before delivery, occurring weekly (67%), monthly or occasionally (25%), and daily (8%). Additionally, 67% of MCC respondents experienced milk rejection, with 33% reporting no rejection. The respondents attributed microbial contamination primarily to the surrounding environment (31%), water used (30%), personnel

(20%), and holding containers (19%).

Among SMEs, 42% of respondents reported milk spoilage before delivery, and 36% experienced milk rejection. The perceived causes of microbial contamination included the surrounding environment (44%), holding containers (40%), water used (8%), and personnel (8%).

Figure 3

Farmer's Reported Milk Spoilage before Delivery in Uganda

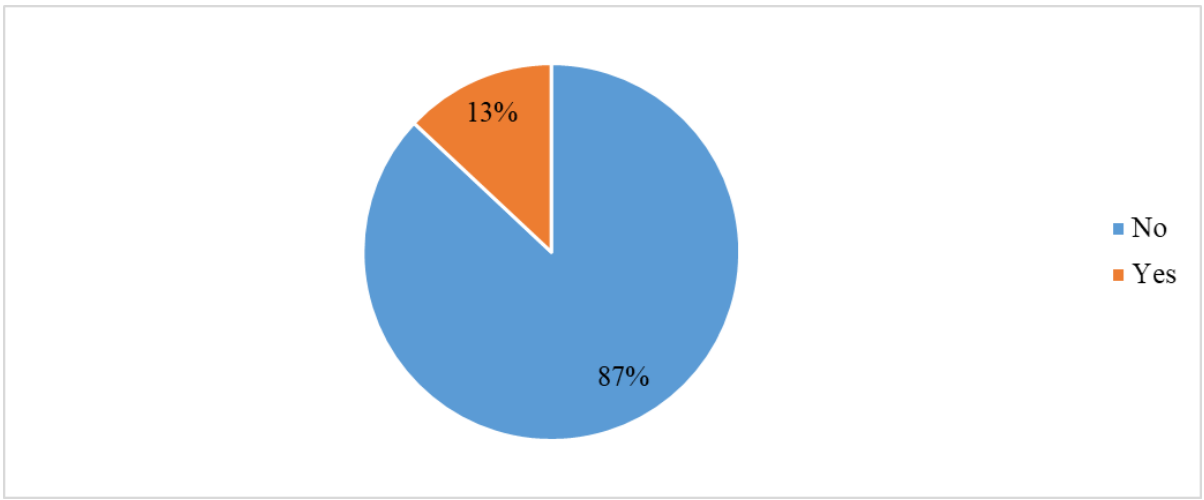


Table 2

Reported Milk Spoilage and Perceived Causes among MCCs and SMEs in Uganda

Aspect	Frequency	Percentage (%)
Milk Collection Centers (MCCs)		
Milk spoilage before delivery		
No	123	54.4
Yes	103	45.6
Frequency of milk spoilage		
Daily	8	8.2
Weekly	66	67.4
Monthly/sometimes	24	24.5
Milk rejection		
No	34	33.0
Yes	69	67.0
Perceived microbial source of contamination		
Water used	28	29.8
Holding container	18	19.2
Personnel	19	20.2
Surrounding environment	29	30.9
Small and Medium Enterprises (SMEs)		
Milk spoilage before delivery		
No	40	58.0
Yes	29	42.0
Milk rejection		
No	44	63.8
Yes	25	36.2
Perceived cause of microbial contamination		
Water used	2	8.0
Holding container	10	40.0
Personnel	2	8.0
Surrounding environment	11	44.0

Note. N = 226 milk collection center (MCC) respondents and N = 69 SME respondents. Percentages are based on valid responses for each spoilage or contamination aspect. Multiple-response items (such as perceived microbial sources or causes of contamination) may sum to more than 100% because respondents could select more than one contributing factor.

Association between vices, milk handling practices and milk spoilage along the dairy value chain

Binary logistic regression identified key factors influencing milk spoilage reporting among farmers. Awareness of long nails as a milking vice, washing and drying hands before milking, and washing cows' udders before milking significantly increased the likelihood of reporting milk spoilage (OR=7.51*, 95% CI=1.62–34.81; OR=11.05*, 95% CI=1.26–96.87; OR=6.94*, 95% CI=1.19–40.38, respectively). In contrast, washing hands before milking, using aluminum rather than plastic milking containers, and attaining advanced secondary education were associated with reduced odds of spoilage (OR=0.054*, 95% CI=0.006–0.497; OR=0.103*, 95% CI=0.012–0.899; OR=0.009*, 95% CI=0.000–0.300, respectively). Other factors such as coughing/sneezing, smoking, finger licking, nose picking, body scratching, and use of PPE were not statistically significant. These findings highlight that hygiene practices, education level, and equipment choice play a critical role in influencing milk quality outcomes among farmers.

Table 3

Adjusted Odds Ratios for Factors Associated with Reporting Milk Spoilage by Farmers

Variable	OR	95% CI	p-value	Significant
Long nails (Yes vs No)	7.51	1.62–34.81	0.010	*
Coughing/sneezing (Yes vs No)	0.42	0.06–2.83	0.373	
Handwashing vice (Yes vs No)	1.14	0.20–9.54	0.882	
Smoking vice (Yes vs No)	1.05	0.20–5.42	0.957	
Finger licking vice (Yes vs No)	0.094	0.006–1.58	0.100	
Nose picking vice (Yes vs No)	2.60	0.51–13.32	0.250	
Body scratching vice (Yes vs No)	3.48	0.71–17.15	0.125	
Cooling milk before sale (Yes vs No)	0.93	0.04–23.05	0.965	
Handwashing before milking (Yes vs No)	0.054	0.006–0.497	0.010	*
Drying hands before milking (Yes vs No)	11.05	1.26–96.87	0.030	*
Washing cow's udder (Yes vs No)	6.94	1.19–40.38	0.031	*
Use of milking cream (Yes vs No)	0.41	0.07–2.34	0.314	
Type of milking containers – Aluminium vs Plastic	0.103	0.012–0.899	0.040	*
Type of milking containers – Other vs Plastic	0.073	0.004–1.40	0.082	
Frequency of washing container – After every use vs Before every use	0.915	0.031–27.47	0.959	
Frequency of washing container – Before and after every use vs Before every use	2.74	0.19–38.77	0.455	
Uses Hair cap/net PPE (Yes vs No)	0.263	0.037–1.89	0.184	
Use Overcoat PPE (Yes vs No)	2.14	0.38–12.10	0.389	
Gender – Female vs Male	0.601	0.088–4.10	0.603	
Education – Primary vs No formal	0.568	0.104–3.10	0.514	
Education – Secondary O'level vs No formal	0.237	0.033–1.69	0.151	
Education – Secondary A'level vs No formal	0.009	0.000–0.30	0.008	*
Education – Tertiary vs No formal	0.163	0.005–5.33	0.308	
Household member attended training (Yes vs No)	0.516	0.078–3.40	0.492	
Farming experience (per year)	1.052	0.993–1.114	0.082	
Number of cattle	1.948	0.482–7.877	0.350	
Ever used antibiotics to treat animals (Yes vs No)	7.101	0.821–61.426	0.075	

Note. Notes: OR = odds ratio; 95% CI = confidence interval; PPE = personal protective equipment; * indicates $p < 0.05$.

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Among MCC respondents, reporting handwashing and finger-licking vices, as well as using gumboots as PPE, significantly reduced the likelihood of milk spoilage (OR=0.139*, 95% CI=0.026–0.750; OR=0.231*, 95% CI=0.060–0.886; OR=0.115*, 95% CI=0.022–0.595, respectively). Conversely, body scratching as a vice, testing milk before receipt, and attaining primary or advanced secondary education increased the odds of spoilage (OR=32.05*, 95% CI=1.08–948.57; OR=34.06*, 95% CI=2.53–458.07; OR=13.60*, 95% CI=1.29–143.87; OR=21.83*, 95% CI=2.07–230.63, respectively). Other factors including long nails, coughing/sneezing, smoking, nose picking, and other PPE uses were not statistically significant. These findings suggest that hygiene behaviors, PPE use, pre-receipt testing, and education levels substantially influence milk quality outcomes at collection centers.

Table 6

Adjusted Odds Ratios for Factors Associated with Reporting Milk Spoilage at Milk Collection Centers (MCC)

Variable	OR	95% CI	p-value	Significant
Long nails (Yes vs No)	0.873	0.134–5.670	0.887	
Coughing/sneezing (Yes vs No)	3.179	0.921–10.972	0.067	
Handwashing vice (Yes vs No)	0.139	0.026–0.750	0.022	*
Smoking vice (Yes vs No)	2.669	0.726–9.817	0.140	
Finger licking vice (Yes vs No)	0.231	0.060–0.886	0.033	*
Nose picking vice (Yes vs No)	0.191	0.034–1.077	0.061	
Body scratching vice (Yes vs No)	32.048	1.083–948.569	0.045	*
Drying hands after washing (Yes vs No)	0.947	0.048–18.830	0.971	
Milk filtering (Yes vs No)	0.052	0.000–14.723	0.305	
Milk containers – Aluminium vs Plastic	1.123	0.159–7.940	0.908	
Milk containers – Stainless steel vs Plastic	1.605	0.077–33.408	0.760	
Milk tests before receiving (Yes vs No)	34.059	2.532–458.067	0.008	*
Uses Hair cap/net PPE (Yes vs No)	2.273	0.701–7.367	0.171	
Uses Gumboots PPE (Yes vs No)	0.115	0.022–0.595	0.010	*
Uses Overcoat PPE (Yes vs No)	0.978	0.297–3.221	0.970	
Uses Gloves PPE (Yes vs No)	0.484	0.082–2.870	0.424	
Uses Beard net PPE (Yes vs No)	0.080	0.002–3.295	0.183	
Gender – Female vs Male	0.728	0.244–2.176	0.570	
Education – Primary vs No formal	13.597	1.285–143.874	0.030	*
Education – Secondary O'level vs No formal	2.951	0.301–28.919	0.353	
Education – Secondary A'level vs No formal	21.832	2.067–230.625	0.010	*
Education – Tertiary vs No formal	6.328	0.630–63.589	0.117	
Number of people working at collection center	1.161	0.776–1.736	0.469	
Someone trained on milking and milk handling (Yes vs No)	10.752	0.968–119.363	0.053	
Years of Business/work experience (per year)	0.933	0.784–1.110	0.433	

Notes: OR = odds ratio; 95% CI = confidence interval; PPE = personal protective equipment; * indicates $p < 0.05$.

Among SME respondents, occupational role significantly influenced milk spoilage reporting. Quality Controllers and Operators were more likely to report milk spoilage compared to managers or supervisors (OR=23.82*, 95% CI=1.89–299.51; OR=99.92*, 95% CI=3.29–3039.56, respectively). Conversely, using a piece of cloth rather than a sieve to filter milk upon reception was associated with reduced odds of spoilage (OR=0.064*, 95% CI=0.005–0.83). Other factors, including long nails, handwashing vices, smoking, finger licking, body scratching, milk cooling, milk testing, and milk quantity received, were not statistically significant. These findings highlight that both staff roles and milk handling practices affect spoilage risk in SMEs.

Table 7

Adjusted Odds Ratios for Factors Associated with Reporting Milk Spoilage at Small and Medium Enterprises (SME) in Uganda

Variable	OR	95% CI	p-value	Significant
Long nails (Yes vs No)	0.951	0.009–95.666	0.983	
Handwashing vice (Yes vs No)	0.044	0.000–233.551	0.475	
Smoking vice (Yes vs No)	0.085	0.000–27.757	0.404	
Finger licking vice (Yes vs No)	9.557	0.062–1470.037	0.380	
Body scratching vice (Yes vs No)	10.469	0.010–10722.290	0.507	
Milking cooling on reception (Yes vs No)	8.204	0.242–278.402	0.242	
Quantity of milk (litres/day)	1.009	0.997–1.021	0.154	
Milk testing (Yes vs No)	3.234	0.053–196.172	0.575	
Position – Quality Controller vs Manager/Supervisor	23.820	1.894–299.508	0.014	*
Position – Operator vs Manager/Supervisor	99.924	3.285–3039.559	0.008	*
Material used for filtering – Piece of cloth vs Sieve	0.064	0.005–0.830	0.036	*

Notes: OR = odds ratio; 95% CI = confidence interval; * indicates $p < 0.05$. Wide confidence intervals reflect limited precision due to small sample sizes.

Discussion

The study identified that the most commonly recognized milking handling vices among farmers, MCC, and SME respondents were those likely to introduce bacteria or other contaminants, including long nails, coughing/sneezing, handwashing practices, smoking, finger licking, nose picking, and body scratching. Among farmers, factors associated with milk spoilage included awareness of long nails as a vice, handwashing and drying before milking, washing cows' udders, the type of milking containers used, and the farmer's education level.

Farmers

Farmers who reported knowing long nails as a milking vice were 7.5 times more likely to report having ever experienced milk spoilage. This is likely because even when they knew that long nails could harbor bacteria and dirt, which can contaminate milk during milking, they or the other people that handled milk may have practiced the vice (Knight-Jones *et al.,* 2016).

Hand washing was associated with a reduced risk of reporting milk spoilage, which is consistent with general hygiene practices. Farmers who reported washing their hands before milking were less likely to report having experienced milk spoilage. This is because hand washing is essential for removing bacteria from the hands that could contaminate milk (Knight-Jones *et al.,* 2016). Farmers who reported that they washed and dried their hands before milking were more likely to report experience of milk spoilage compared to those who reported otherwise. This implies that the cause of milk spoilage may have originated elsewhere. These findings were partly in line with those of a study conducted in Kenya which revealed that lack of hand washing, or washing without drying were farm practices that predisposed milk to microbial contamination (Orwa *et al.,* 2017). Our findings also partly concurred with studies conducted in Ethiopia which indicated that poor practice of hand washing before milking was partly linked to poor milk quality (Gemechu *et al.,* 2014; Amentie *et al.,* 2016). Similarly, farmers who reported that they washed the cow's udder before milking had 6.9 times higher odds of reporting having experienced milk spoilage compared to their counterparts who reported that they did not wash the udder before milking. These findings may be due to improper washing by the farmers but this requires further study (Knight-Jones *et al.,* 2016). The findings in our study partly disagreed with studies done elsewhere (Gemechu *et al.,* 2014; Orwa *et al.,* 2017; Abunna *et al.,* 2018; Amenu *et al.,*

2019) which all reported that cleaning of the udder of cows before milking is one of the most important hygienic practices required to ensure clean milk production.

Compared to farmers who used plastic milking jerry cans, those who used aluminium cans had reduced odds of reporting milk spoilage. This could be attributed to the fact that aluminium cans are easier to clean as compared to plastic jerry cans. This is in line with other studies that found plastic milking containers to be associated with high risk of milk spoilage. For instance, a study done in Kenya reported that plastic milking containers contribute to high microbial counts (Orwa *et al.,* 2017). Similarly, the findings in this study partly concurred with those of a study conducted in Ethiopia which indicated that plastic containers were difficult to clean and disinfect and thus contributed to poor quality of the milk (Gemechu *et al.,* 2014).

Milk Collection Centres

The results demonstrated that Milk Collection Center respondents who pointed out hand washing as a milk handling practice had a lower risk of reporting milk spoilage than those who did not mention it. These findings partly concurred with a study conducted in Nakasongola district of Uganda which revealed that milk quality was affected by poor hygienic practices (Majalija *et al.,* 2020). This study aligned with previous studies that emphasized the significance of adequate hand hygiene in preventing contamination from bacteria often found on hands, such as *Escherichia coli* and *Staphylococcus aureus*, which can spoil milk (Knight-Jones *et al.,* 2016; Fusco *et al.,* 2020).

In comparison to those who did not mention finger licking as a milk handling vice, MCC respondents who reported it were less likely to report having milk spoilage at the MCCs. These findings were partially in concordance with a research conducted in the Nakasongola district of Uganda, which found that milk quality was reduced by improper milk handling techniques (Majalija *et al.,* 2020). Finger licking is a common behavior that quickly transmits bacteria from hands to milk. Hands come into contact with various surfaces and items during the day, so they can host various bacterial species, some of which could lead to milk spoilage (Lu and Wang, 2017; Fusco *et al.,* 2020). These bacteria can proliferate fast in warm milk, causing spoilage and even foodborne disease.

This study also indicated that respondents who used gum boots as personal protective gear were less likely to report milk spoilage at the MCC compared to those who never reported using the boots. Wearing gumboots creates a barrier between the workers' feet and the MCC environment. The environment may be contaminated from a variety of causes (Lu and Wang, 2017; Fusco *et al.,* 2020). MCC experiences a high volume of foot traffic, which can cause a buildup of dirt, manure, and other organic pollutants on the floor. Gumboots assist to shield workers' feet from contact with these contaminants, lowering the possibility of them being passed to milk. Furthermore, MCCs frequently experience milk leaks. These spills can provide a breeding environment for bacteria, contaminating other milk. The sanitation condition has been reported as a critical factor in influencing milk quality (Odeyemi *et al.,* 2020). Gumboots can serve to shield workers' feet from contact with spilled milk and reduce the danger of contamination. The findings from this study partly concurred with a study conducted in Nakasongola district of Uganda which revealed that milk quality was affected by poor hygienic, handling and transportation practices (Majalija *et al.,* 2020).

Respondents who mentioned body scratching as a milk handling vice had a higher odds of reporting that they experienced milk spoilage at the MCC. These findings in part were congruent with a research conducted in the Luwero district of Uganda, which indicated that milk quality was influenced by inadequate hygiene and handling practices (Odeyemi *et al.,* 2020). Body scratching transfers bacteria from beneath the fingernails or from the skin's surface directly into the milk (Odeyemi *et al.,* 2020).

Respondents who stated that they tested the milk before receiving it at the MCC were more likely to say they experienced milk spoilage compared to those who did not perform milk test. This could be because spoilage is a natural process that is possible even under the ideal conditions, and hence reliable milk tests would be more likely to detect and reject spoiled milk. This is in

agreement with the view that routine milk quality checks are important for early spoilage detection (Lu *et al.,* 2013).

The findings revealed that MCC respondents who had attained primary and advanced secondary education were more likely to report milk spoilage at the center compared to those who had attained no formal education. Education has been reported to significantly influence hygienic milking practices (Lencho and Seblewongel, 2018). This is because limited awareness of appropriate milk handing techniques diminishes the quality of milk (Ayele *et al.,* 2017).

Small and Medium Enterprises

The findings from this study suggested an increased likelihood of reporting milk spoilage among SME respondents who stated that they worked as Quality Controllers and Operators in the SME. Quality controllers and operators reported greater spoilage rates compared to managers/supervisors, which is partly because the former are often involved in quality testing (Daud *et al.,* 2015).

The study discovered that respondents who reported that they filtered milk using a piece of cloth as soon as they received it were less likely to report milk deterioration than those who revealed that they used a sieve filter. Generally, milk filtration practices influence the possibility of milk spoilage (Knight-Jones *et al.,* 2016; Fusco *et al.,* 2020). It is however important to look into the possibility that cloth filters, as opposed to metallic sieve filters, are linked to less reported spoilage.

Limitations of the Study

The findings in this study should be understood to be based on self-reports. This suggests that not all farmers, MCC and SME respondents may have disclosed all of the vices related to milking handling that they are aware of. The results in the present study may therefore be an underestimation or overestimation of the actual prevalence of milking handling vices in the Ugandan informal dairy value chain. This is because farmers, MCC and SME respondents could have been hesitant to report vices that they are aware of for fear of punishment or stigma. Moreover, informal dairy value chains in Uganda have different dimensions which could variably influence the overall results. For instance, there are chains such as (1) farmer-bicycle-consumer; (2) road-side milk vendors; (3) restaurants, among others, all of which could involve different practices that could lead to different sources of contamination posing variable rates of spoilage.

Conclusions

A significant number of respondents especially those from MCCs and SMEs reported that their milk had been spoiled or rejected prior to delivery. The study discovered that poor milk handling practices increased the odds of milk spoilage. This suggests that farmers and milk collectors and SME operators need more training and support on how to handle milk safely and hygienically. Overall, this study highlights that whereas awareness of some vices was protective against milk spoilage; other vices were associated with an increased risk of experiencing milk spoilage. This calls for the need for further studies on comprehensive knowledge of particular vices and the practices by the value chain players to avoid the vices for better milk quality.

Recommendations

Based on the findings, it is recommended that targeted training and continuous capacity building be provided to farmers, milk collectors, and SMEs to enhance their knowledge and practices in hygienic milk handling. Strengthening extension services and enforcing adherence to food safety regulations are crucial to minimize contamination risks along the dairy value chain. Establishing community-based quality assurance systems and promoting access to clean water, proper milking equipment, and sanitation facilities would further improve milk safety and quality. Collaborative efforts among government agencies, dairy cooperatives, and stakeholders are essential to ensure sustainable improvements in public health and the competitiveness of Uganda's dairy industry. This study could benefit from further information about the type of cloth used for milk filtration and its mesh dimension in comparison to the metallic sieves. Therefore, future research could look at this to acquire a better knowledge of the factors driving milk spoilage.

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Declaration of interest statement

The authors report that there are no competing interests to declare.

Data Availability Statement

The data set associated with this manuscript can be made available upon request by the Editor-in-chief if the need arises.

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