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Research Article

Effect of Structural Condition of Milk Processing Facilities and Food Safety Systems on *Escherichia coli* and Coliforms Presence in Cultured Buttermilk

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The study investigated the effect of structural conditions of milk processing facilities and food safety systems on *E. coli* and coliform presence in buttermilk. Milk records collected by Dairy Services Zimbabwe (DSZ) from large-scale dairy milk processors ($n = 12$) and small-scale farms ($n = 15$) were analysed. Binomial logistic regression was used to estimate the likelihood of *E. coli* or coliforms being present in cultured buttermilk as a function of the hygiene level and structural adequacy of the processors. The likelihood of having *E. coli* and coliforms in cultured milk from processors with poor sanitary premises was two times higher than that from processors with good sanitary premises ($P < 0.05$). Milk processors that used unfiltered water were 1.77 times more likely to produce cultured buttermilk contaminated with *E. coli* ($P < 0.05$). Processors without food safety systems like hazard analysis critical control point (HACCP) systems were more than twice likely to produce cultured buttermilk contaminated by *E. coli* and coliforms ($P < 0.05$). Poor structural condition of roofs, windows, insect-proof screens, and drainage in small- and large-scale processing facilities results in production of cultured buttermilk that is contaminated by *E. coli* and coliforms.

1. Introduction

Milk is a concentrated dietary source of macro- and micronutrients often consumed as fresh milk or processed milk products. Milk products commonly consumed include yoghurt, ghee, icecream, butter, cheese, and cultured buttermilk [1]. Cultured buttermilk is one of the most commonly produced and consumed milk product because it does not require high levels of expertise or processing equipment as compared to the other dairy by-products [2]. Cultured buttermilk is a nontraditional milk product made by simultaneous fermentation of the standardised heat-treated homogenised milk with *Lactococcus lactis* culture and a cream culture [3]. Cultured buttermilk is an excellent medium for microbial growth and, thus, a delicate product whose quality can easily be compromised if not properly handled during manufacturing [4].

Good manufacturing practices and quality control measures ensure production of safe cultured buttermilk. Buttermilk contamination can occur from different sources such as the milk production conditions, factory surroundings, air, processing equipment, and factory personnel [3, 5]. There are obligatory technological steps such as pasteurization and safety systems set to improve microbial quality of buttermilk during processing. In most developing countries, cultured buttermilk is, however, predominantly sold through the informal sectors [2]. Although cultured buttermilk has been traditionally produced by registered large-scale processors, there has been an increase in the number of small-scale processors, majority of whom are unregistered

[6]. The informal milk processors fill market gap left by large-scale processors in developing countries and, thus, are key to regular cultured buttermilk supply [2]. Some of these informal milk processors do not follow proper handling and manufacturing procedures when processing milk into the cultured buttermilk [2]. Although the small-scale farmers pasteurise the milk during processing, the safety of milk products is not guaranteed [7]. As a result, consumers are at risk of consuming potentially contaminated buttermilk.

The informal milk processors may not always have the equipment, refrigeration, and facilities and at times lack the expertise to manufacture cultured buttermilk safely [2]. Safe milk processing requires processors to follow good manufacturing practices in order to minimise risk of contamination during processing. Most emerging processors in developing countries do not have food safety systems within their operations. This could be because of lack of knowledge or understanding of why good manufacturing practices should be implemented at the processing site. These practices include limiting and controlling access of people, equipment, and vehicles into the processing plant. Good manufacturing practices such as rodent control, disinfection and cleaning, fly-control, dust and air management, chemicals, and waste disposal reduce the risk of introduction of bacterial contaminants such as *E. coli* and coliforms into processing facilities. Use of unclean processing equipment and lack of potable water in some facilities contribute to presence of bacterial contaminants in milk which affects the quality of cultured buttermilk [8, 9]. Doors, roofs, ventilation, and floors in poor structural conditions can harbour extraneous or foreign materials that can contaminate milk or milk products [10].

Although most milk processors encourage their workers to follow strict standards of hand hygiene, there are other often-overlooked sources of hygiene-related contaminations in the milk processing plants. As reported by Pandey and Voskuil [10], doors, floors, walls, and windows in bad structural condition results in high prevalence of microbial pathogens. Doors, floors, walls, and/or windows that are broken or made of rough material can, therefore, be sources of bacterial contamination of buttermilk during manufacturing. It is possible that clean milk produced at the farm can be contaminated by the processor during production of buttermilk. In developing countries, the increase in the demand of milk products has resulted in rise in production and marketing of milk products via the informal dairy sector and emerging dairy processors [11]. In most cases, these informal and emerging dairy processors do pay attention to the structural condition of the processing plants [12].

Implementation of food safety systems such as HACCP during cultured buttermilk processing has the potential to reduce contamination of milk. This study will assist dairy agents and regulators to continue enforcing the need for processing plants to be maintained in adequate structural conditions to minimise risk of transmitting pathogenic organisms like *E. coli.* The microbial quality of processed milk is a major feature in determining quality. Whilst the dairy sector has made significant efforts in promoting use of hazard analysis critical control point (HACCP) systems to eliminate pathogenic bacteria, *E. coli* continues to be enumerated from fresh and fermented milk products including cultured buttermilk [12]. *E. coli* poses a huge challenge to the dairy sector because of its ability to survive very low pH, while other pathogenic organisms like *S. aureus* can be inhibited at pH 5 [7, 11]. The *E. coli* can, thus, survive and grow in cultured buttermilk despite the acidic conditions. Most studies conducted on reducing coliforms in manufacturing environments have focused more on the general milk processing environment and not specifically the contribution of conditions of facilities or state of repair and maintenance of building features. The objective of the current study was, therefore, to determine the effect of structural condition of milk processing facilities and manufacturing practices on presence of *Escherichia coli* and coliforms in cultured buttermilk from large- and small-scale processors.

2. Materials and Methods

2.1. Study Site. Data were obtained from records collected by trained research officers at Dairy Services Zimbabwe (DSZ) from 12 large-scale and 16 small-scale randomly selected milk processors.

2.2. Data Collection. Records on presence or absence of *E. coli* and coliforms in cultured buttermilk were collected from DSZ. The records were generated from cultured buttermilk samples submitted to and analysed by DSZ over a 10-year period from 2006 to 2016 for 16 small-scale and 12 large-scale milk processors. Processors submitted their cultured buttermilk samples for testing to DSZ once a month. All the samples submitted to DSZ were buttermilk samples made by simultaneous fermentation of the standardised heat-treated homogenised milk with *Lactococcus lactis* culture and a cream culture. Each processor provided four samples every month over the 10-year period. A total of 12,960 cultured buttermilk samples were sent for laboratory analyses over the 10-year period.

Information on the structural condition of milk processing facilities was collected three times per year (after every four months) by four DSZ research officers. Each research officer was allocated to 7 factories to follow-up on for one year and allocated another 7 different ones the following year and so on. After four years, the cycle was repeated up to the 10^{th} year. Standardised checklists and recording sheets were used by the research officers to assess manufacturing practices, presence of food safety management systems, and structural condition of floors, roof, drains, doors, ventilation, and walls of the processing facilities. To assess manufacturing practices, the research officers assessed the presence of clear signage, dust proofing, disinfection and rodent control, site drainage, storage of chemicals and control of traffic, and people and equipment into the milk processing facilities. The structural condition of milk processing facilities was classified as either good or poor by research officers.

For every visit, the research officers also assessed the milk processors on the availability of food safety systems such as hazard analysis critical control points (HACCPs). Data recorded included presence or absence of a traceability systems for raw materials used in manufacturing buttermilk, product recall, and withdrawal system for defective or nonconforming products, availability of food safety training programmes, training documentation, and manuals on food safety systems.

2.3. Data Structure and Preparation. Data obtained from DSZ were a merger of data collected from routine dairy factory visits and laboratory data into a single database. Incomplete and mismatching records were excluded from the final analyses. Out of the 12,960 records on *E. coli* and coliforms from the cultured buttermilk samples sent for laboratory analysis, 4,301 records had complete and matching entries with structural condition of processing facilities and manufacturing practices data. Each of the visited factories had representative records in the final data set.

2.4. Laboratory Analyses. Cultured buttermilk samples for coliform counts and *E. coli* determination were collected using sterile 50 ml containers and stored below 4°C and then analysed at the Dairy Services Aglabs using standard methods of examination of dairy products [13]. Presence or absence of coliforms in cultured buttermilk was determined using the plate count method [13]. In this procedure, milk (1.0 mL) was cultured directly on Petrifilm dishes and incubated at 35–37°C for 24 hours. Individual bacterial cells were counted using QUANTOM Tx Microbial automatic counter (Logos Biosystems Ltd, Virginia, USA). The bacteria present in cultured buttermilk were expressed as the number of colony forming units per millilitre (CFU/ml).

2.5. Statistical Analyses. All data were analysed using Statistical Analysis system 9.2 [14]. A chi-square test was used to determine the association between the processor and structural condition of processing facilities [14].

Binomial logistic regression (PROC LOGISTIC) was used to to model the probability of *E. coli* or coliforms being present in cultured buttermilk as a function of the hygiene level and structural adequacy of the processors [14]. The logit model fitted the structural condition of processing facilities' features (poor vs. good), type of processor (small-scale vs. large-scale), good manufacturing practices (presence vs. absence), and food safety systems (absence vs. present) as the predictors. The logit model used was

$$\ln\left[\frac{P}{1-P}\right] = \beta_0 + \beta_1 X_1 + \beta_2 X_2 \cdots + \beta_t X_t + \varepsilon, \quad (1)$$

where P = probability of cultured buttermilk having *E. coli* or coliforms, $[P/1-P]$ = odds ratio (the odds of cultured buttermilk having *E. coli* or coliforms), β_0 = intercept, $\beta_1 X_1$ = regression coefficients of predictors, and ε = random residual error.

3. Results

3.1. Manufacturing Practices. Majority of the large-scale milk processors had clear signage at their processing facility, while a minority of the small-scale producers had clear signage ($P < 0.01$). A large proportion of the large-scale processors had dust proof surroundings of their buildings ($P < 0.05$). A larger proportion of the small-scale milk processors did not have disinfection, rodent control, and access control for the milk processing facilities, whilst a majority of the large-scale processors had disinfection, rodent control, and good access control for their processing sites ($P < 0.05$). More than half of the large-scale milk processors had good drainage around the milk processing site, compared with less than half of small-scale processors who had good drainage ($P < 0.05$). More than half of both small-scale and large-scale processors had acceptable storage for hazardous chemicals ($P > 0.05$).

3.2. Structural Condition of Small- and Large-Scale Processing Plants. Associations between structural condition of milk processing facilities and processing type are shown in Table 1. Majority of large-scale processors had buildings with walls, gutters, drainage, and windows in good structural condition, whilst less than half of small-scale processors had milk processing plants in good structural condition ($P < 0.05$). The larger proportion of the small-scale processors had open receptions that were in poor structural condition, compared to the large-scale processors ($P < 0.01$). More than half of the small-scales processors had processing areas with poor structural condition of walls, ventilation, drains, ceilings, and windows. Less than half of large-scale processors had floors in packaging rooms that were in good structural condition, whilst half of the large-scale processors had floors in good structural condition. More than double the number of small-scale processors had milk processing areas with poor structural condition of walls ($P < 0.05$). A higher proportion of both small-scale and large-scale processors had poor temperature control in the storage rooms. Most of the small-scale processors had poor ventilation and walls in the storage room, whilst less than half the number of the large-scale processors has good ventilation in the storage rooms.

3.3. Manufacturing Practices and Cultured Buttermilk Contamination. The odds ratio estimates of cultured buttermilk having *E. coli* or coliforms are shown in Table 2. Small-scale processors were more likely to produce cultured buttermilk with *E. coli* ($P < 0.05$). Cultured buttermilk from processors without disinfection practices was 2.5 times more likely to have *E. coli* compared with those with disinfection practices ($P < 0.05$). Milk processors without fly proofing were 1.3 times more likely to produce cultured buttermilk that contained *E. coli* compared with those with insect-proof screen systems ($P < 0.05$). The likelihood of cultured buttermilk from processors with buildings that had insect-proof screens having coliforms was 1.8 times higher than those without fly screening ($P < 0.01$). Cultured buttermilk from

Table 1: Frequencies (%) of structural condition of processing facilitates of small-scale and large-scale dairy processors.

	Areas	Large-scale processors		Small-scale processors		Significance
		Good	Poor	Good	Poor	
Buildings	Outer walls	82.1	17.9	47.2	52.8	**
	Gutters	71.4	28.6	58.3	41.7	NS
	Roofing	75.0	25.0	44.4	55.6	*
	Windows	78.6	21.4	41.7	58.3	**
Milk reception	Closed	57.4	42.6	5.6	94.4	**
	Water	53.7	46.3	22.2	77.8	*
	Drainage	50.0	50.0	22.2	77.8	*
	Foot bath	53.6	46.4	11.1	88.9	**
Processing	Walls	53.7	46.3	36.1	63.9	*
	Ventilation	50.0	50.0	41.7	58.3	NS
	Floors	50.0	50.0	33.3	66.7	NS
	Ceilings	42.8	57.2	50.0	50.0	NS
	Drains	50.0	50.0	44.4	56.6	NS
	Windows	46.4	53.6	41.7	58.3	NS
Packaging	Walls	42.8	57.2	33.3	66.7	NS
	Ventilation	64.3	35.7	31.6	69.4	**
	Floors	39.3	60.7	50.0	50.0	NS
	Ceilings	50.0	50.0	55.6	44.4	NS
	Drains	64.3	35.7	38.9	61.1	*
	Windows	53.6	46.4	33.3	66.7	NS
Storage	Temperature control	28.6	71.4	27.8	72.2	NS
	Ventilation	46.4	53.6	30.6	69.4	NS
	Walls	42.9	57.1	27.8	72.2	NS

$^{**}P < 0.01$; $^{*}P < 0.05$; NS: $P > 0.05$.

Table 2: Odds ratio estimate and lower (LCI) and upper confidence interval (UCI) of cultured buttermilk from processors with features which are not in adequate conditions having *E. coli* or coliforms.

Predictors	*Escherichia coli*			Sig.	Coliforms			Sig.
	Odds	LCI	UCI		Odds	LCI	UCI	
Type of processor (small-scale vs. large-scale)	1.18	1.43	3.22	*	1.29	0.46	3.62	NS
Clear signage (absent vs. present)	0.98	0.31	3.08	NS	0.47	0.15	1.48	NS
Dust proofing (absent vs. present)	0.25	0.04	1.30	NS	2.17	0.50	9.45	NS
Disinfection practices (absent vs. present)	2.5	1.53	12.1	*	0.56	0.13	2.47	NS
Insect-proof screens (absent vs. present)	1.33	1.37	5.2	*	0.56	1.14	2.33	**
Drainage (poor vs. good)	1.27	0.52	0.91	*	1.36	1.41	4.27	*
Access and traffic control (absent vs. present)	0.43	0.12	1.54	NS	1.08	0.302	3.83	NS

LCI, lowest confidence interval; UCI, upper confidence interval; sig., significance; NS, not significant ($P > 0.05$); $^{*}P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli*.

processors with poor drainage was 1.25 times more likely to have *E. coli* and coliforms than those with good drainage facilities in their milk processing facilities ($P < 0.05$).

3.4. Association between Structural Condition and Coliform and E. coli Presence in Buttermilk. The odds ratio estimates of cultured buttermilk from processors with different structural conditions and *E. coli* presence in buttermilk are shown in Table 3. Milk processors with buildings and processing areas with windows in poor state were twice more likely to produce cultured buttermilk contaminated with *E. coli* ($P < 0.05$). The likelihood of cultured buttermilk from processors with buildings with good roofs having *E. coli* was 1.01 times higher than those with poor roofs ($P < 0.05$). Cultured buttermilk from processors with enclosed milk reception areas was 2.04 times more likely to have *E. coli* compared with those facilities that had open milk reception areas ($P < 0.05$). The likelihood of cultured buttermilk from processors with unfiltered water having *E. coli* was 1.77 times higher than those with clean filtered water for washing equipment and cleaning the processing facilities ($P < 0.05$). Milk processors with poor drainage systems were 1.11 times more likely to produce cultured buttermilk contaminated with *E. coli* ($P < 0.05$).

The odds ratio estimates of cultured buttermilk from processors with different structural condition facilities (poor vs. good) having coliforms are shown in Table 4. The likelihood of cultured buttermilk from processors with buildings with poor roofs having coliforms was 1.25 times higher than those with good roofs ($P < 0.05$). Cultured buttermilk from processors with buildings that had poor

Table 3: Odds ratio estimate and lower (LCI) and upper confidence interval (UCI) of cultured buttermilk from processors with features which are not in adequate conditions having *E. coli*.

Area	Predictor	Odds	LCI	UCI	Sig.
Buildings	Outer walls (poor vs. good)	3.64	0.81	16.33	NS
	Gutters and pipes (poor vs. good)	1.34	0.34	5.25	NS
	Ceiling (poor vs. good)	0.99	1.21	4.61	*
	Windows (poor vs. good)	2.02	1.44	9.28	*
Milk reception	Isolation (enclosed vs. open)	2.04	1.07	3.23	*
	Washing water (unfiltered vs. filtered)	1.77	2.16	3.68	*
	Drainage (poor vs. good)	1.11	0.84	0.57	*
	Footbath (absent vs. present)	0.43	0.04	4.3	NS
Processing area	Walls (poor vs. good)	3.03	0.93	9.96	NS
	Ventilation (poor vs. good)	0.89	1.32	3.13	*
	Floors (poor vs. goods)	0.72	0.21	2.49	NS
	Drains (poor vs. good)	0.422	0.03	5.55	NS
	Windows (poor vs. good)	2.32	2.04	5.01	*
Packaging	Walls (poor vs. good)	1.04	0.28	3.8	NS
	Ventilation (poor vs. good)	0.53	0.11	2.59	NS
	Floors (poor vs. good)	1.14	0.36	3.63	NS
	Ceilings (poor vs. good)	1.56	0.44	5.52	NS
	Drains (poor vs. good)	3.03	0.87	11.1	NS
	Windows (poor vs. good)	1.21	0.27	5.39	NS
Storage	Temperature (poor vs. good)	1.08	0.25	4.73	NS
	Ventilation (poor vs. good)	0.45	0.13	1.58	NS
	Walls (poor vs. good)	2.65	0.69	10.21	NS

LCI, lowest confidence interval; UCI, upper confidence interval; sig., significance; NS, not significant ($P > 0.05$); $^{*}P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli*.

Table 4: Odds ratio estimate and lower (LCI) and upper confidence interval (UCI) of cultured buttermilk from processors with features which are not in adequate conditions having coliforms.

Area	Predictor	Odds	LCI	UCI	Sig.
Buildings	Outer walls (poor vs. good)	0.68	0.17	2.72	NS
	Gutters and pipes (poor vs. good)	0.92	0.24	3.43	NS
	Ceiling (poor vs. good)	1.25	1.18	3.59	*
	Windows (poor vs. good)	1.33	3.31	5.75	*
Milk reception	Closed (enclosed vs. open)	2.01	1.03	3.13	*
	Washing water (unfiltered vs. filtered)	0.30	0.05	1.83	NS
	Drainage (poor vs. good)	0.52	0.05	5.39	NS
	Footbath (absent vs. present)	0.28	0.01	4.2	NS
Processing	Walls (poor vs. good)	2.39	0.65	8.69	NS
	Ventilation (poor vs. good)	1.82	1.24	2.70	*
	Floors (poor vs. good)	2.09	0.66	2.49	NS
	Drains (poor vs. good)	1.20	3.11	12.75	*
	Windows (poor vs. good)	1.33	0.14	12.46	NS
Packaging	Walls (poor vs. good)	2.61	0.69	9.9	NS
	Ventilation (poor vs. good)	1.70	1.23	5.32	*
	Floors (poor vs. good)	2.98	1.01	3.57	*
	Ceilings (poor vs. good)	0.71	0.19	2.63	NS
	Drains (poor vs. good)	0.46	0.11	1.78	NS
	Windows (poor vs. good)	1.71	1.14	4.68	*
Storage	Temperature control (poor vs. good)	2.46	0.59	10.34	NS
	Ventilation (poor vs. good)	1.00	0.29	3.46	NS
	Walls (poor vs. good)	2.09	0.53	8.1	NS

LCI, lowest confidence interval; UCI, upper confidence interval; sig., significance; NS, not significant ($P > 0.05$); $^{*}P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of coliforms.

windows was 1.33 times more likely to have coliforms compared with those buildings with good windows ($P < 0.05$). The likelihood of cultured buttermilk from processors with an enclosed milk reception area having coliforms was 2 times higher than those with open milk reception areas ($P < 0.05$). Milk processors with poor ventilation in processing areas were 1.8 times more likely to produce cultured buttermilk contaminated with coliforms.

Table 5: Odds ratio estimate and lower (LCI) and upper confidence interval (UCI) of cultured buttermilk from milk processors with different food safety systems (absent vs. present) having *E. coli* or coliforms.

Predictors	*E. coli*			Sig.	Coliforms			Sig.
	Odds	LCI	UCI		Odds	LCI	UCI	
Food safety system in place (HACCP)	1.98	2.24	3.88	*	1.97	0.41	8.89	NS
Traceability	0.95	0.04	1.30	NS	0.57	0.09	3.4	NS
Product withdrawal and recall system	1.10	1.01	1.62	*	1.14	1.02	2.39	*
Availability of food safety training programmes	1.27	1.02	2.52	*	2.08	1.41	7 .27	*
Availability of documentation and quality manuals	0.44	0.15	2.74	NS	1.79	0.302	2.58	NS

LCI, lowest confidence interval; UCI, upper confidence interval; sig., significance; NS, not significant ($P > 0.05$); $^*P < 0.05$. Higher odds ratio estimates indicate greater difference in likelihood of presence of *E. coli* or coliforms. HACCP, hazard analysis critical control point.

Cultured buttermilk from processors with packaging rooms that had poor windows and ventilation in poor state were 1.7 times more likely to have coliforms compared to those packaging rooms with good ventilation and windows.

3.5. Association between Food Safety Systems and Presence of E. coli and Coliforms in Buttermilk. The odds ratio estimates of cultured buttermilk from milk processors with different food safety systems having *E. coli* or coliforms are shown in Table 5. Milk processors without food safety systems like HACCP in place were 2.6 times more likely to produce cultured buttermilk contaminated with *E. coli* ($P < 0.05$). The likelihood of cultured buttermilk from processors without product recall and withdrawal systems having *E. coli* and coliforms was 1.1 times higher than those processors with products recall and withdrawal procedures ($P < 0.05$). Cultured buttermilk from processors without food safety training programmes was 2.08 times more likely to have coliforms than those with food safety training programmes ($P < 0.05$). Milk processors without food safety training programmes were 1.27 times more likely to produce cultured buttermilk contaminated with *E. coli* ($P < 0.05$).

4. Discussion

Understanding the importance of structural condition of processing facilities and good manufacturing practices for milk processing factories and plants enables both dairy service agents and milk processors to put in place structures and systems that minimise contamination of the processed milk products such as buttermilk. It is possible that clean milk produced at the farm can be contaminated by the processor. The finding that a higher proportion of small-scale milk processors did not have disinfection, rodent control, and access control for the milk processing facilities as good manufacturing practices was expected. It is likely that most small-scale processors lack knowledge and understanding of the importance of good management practices in the prevention of the introduction and transmission of pathogenic organisms in dairy processing facilities [15].

The finding that cultured buttermilk from processors with poor disinfection practices was more likely to have *E. coli* compared with those that had good disinfection practices may be a possible indication that the processors are using infective disinfection procedures for personnel and equipment. Yuen et al. [9] reported that *E. coli* contamination of milk can occur when workers practice poor hygiene and sanitation procedures. Similarly, cultured buttermilk manufactured under unsanitary conditions will be expected to be contaminated. Similarly, the finding that milk processors with buildings and processing areas with windows in poor state were more likely to produce cultured buttermilk contaminated with *E. coli* could be due to dust blown into the processing facilities through windows in poor state of repair or structural condition. In agreement with this, Pantoja et al. [16] reported that *E. coli* can be transmitted through polluted air in dairy processing plants.

Enclosed milk reception areas seemed to give protection of the dairy products from contamination by both *E. coli* and coliforms in general. Products from dairies with an open reception were twice more likely to be contaminated than those with enclosed areas. This can be attributed to the fact microorganisms are ubiquitous and are generally transmitted through air [15]. In addition, the open receptions tend to have high human traffic which may lead to contamination from handlers and equipment [15]. Enclosed milk reception areas allow moisture build up due to reduced air circulation and sunshine exposure. This could explain why they were more likely to have *E. coli*. Ventilation limits moisture. Damp indoor spaces foster the growth and transmission of viruses and bacteria. Reducing the moisture by leaving reception areas open can limit microbial growth and, thus, contamination. The same reason can be used to explain the result that cultured buttermilk from processors with an enclosed milk reception area was more likely to have coliforms than that from processors with open milk reception areas. Processors with unfiltered water produced cultured buttermilk with *E. coli* may be because unfiltered water is contaminated with *E. coli*. It is likely that installation of water treatment and filtration facilities reduce the contamination of water by *E. coli*, unlike unfiltered water is most likely to harbour different pathogenic bacteria. In agreement to our findings, Mhone et al. [17] reported that milk can be contaminated from polluted water sources.

Milk processors with poor drainage systems were likely to produce cultured buttermilk contaminated with *E. coli* may be due to introduction of pathogenic bacteria found in stagnated water around the processing plant. The presence of coliforms in milk and processed products generally indicate that milk has been contaminated from the faecal material, indicating ineffective cleaning processes of machinery and equipment [15]. Our findings that the likelihood of cultured buttermilk from processors with buildings with poor roofs having coliforms was higher than those with good roofs suggests that roofs in that are difficult to clean and harbour dust and bacteria contaminating the cultured buttermilk during processing. The same reason can be attributed to the observation that cultured buttermilk from processors with buildings that had poor windows was more likely to have higher levels of coliforms in cultured buttermilk compared with those buildings with good windows.

Windows in poor structural condition and poor ventilation in processing areas and packaging rooms seemed to be sources of coliforms. Holah [18] reported that that poor ventilation hampers the circulation of clean air, thereby increasing the risk of contaminating the milk and its products with bacteria during production. The finding that milk processors without food safety systems like HACCP in place were twice more likely to produce cultured buttermilk contaminated with *E. coli* could possibly be attributed to lack of systems to prevent contamination in milk processing plants. Lack of HACCP and other food safety programs is among the main causes of microbial contamination in food businesses [8]. Implementation of HACCP systems during dairy milk processing results in improvement in the microbial quality of milk products [19]. Milk processors that have no food safety systems can fail to identify or overlook some steps that have potential to introduce or increase the risk of milk contamination during processing [15].

Milk processing plants without training programmes on food safety practices produced buttermilk with coliforms. This implies that training provides processors with knowledge and information of food safety principles which they can use to reduce transmission of bacteria such as *E. coli* in their dairy products. Similarly, Gran et al. [7] attributed presence of *E. coli* in processed milk to lack of knowledge and training in food safety systems as well as poor hygiene. Milk and milk products from dairy enterprises with good access to training and monitoring programmes have lower counts of coliforms, *E. coli*, and *S. aureus* [17]. Training milk processors on food safety and the importance of management of structural condition of processing facilities may be important in minimising the risk of contamination of cultured buttermilk from pathogenic bacteria such as *E. coli.*

5. Conclusions

Cultured buttermilk produced by both small-scale and large-scale milk processors contains coliforms and *E. coli*. Poor structural condition of windows, doors, roofs, and poor ventilation in processing facilities increases the risk of cultured buttermilk contamination by coliforms and *E. coli*. Milk processors without food safety systems such as HACCP and that lacks food safety training programmes are more likely to produce cultured buttermilk with coliforms and *E. coli.*

Data Availability

The records on presence or absence of *E. coli* and coliforms in cultured buttermilk and physical state of housing at the milking processing factories used to support the findings of this study are available from the corresponding author upon request.

Additional Points

Practical Implications. In most developing countries, small-scale milk processors play a big role in cultured buttermilk production. Some of these informal milk processors do not follow proper handling and management procedures when processing milk into the cultured buttermilk. Understanding how structural condition of processing facilities and food safety practices affect *Escherichia coli* and coliforms presence in cultured buttermilk, which is one of the most popular products of milk, enables processors and regulatory agencies to put in corrective action to reduce microbial contamination of cultured buttermilk during processing especially by small-scale milk processors. This helps to reduce the risk of consumption of contaminated buttermilk. The shelf-life of the cultured buttermilk is also improved.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

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