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Italian Journal of Food Safety

Italian Journal of Food Safety 2026; 15:12844
doi:10.4081/ijfs.2026.12844

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Assessment of knowledge, attitude, self-reported behavior of food handlers, and the microbial contamination of milk in the school feeding program in Maseru, Lesotho

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Abstract

Food insecurity remains a global challenge, with developing countries enduring more impact. To curb this challenge, school feeding programs (SFP) have played a critical role. Nutrient-rich foods provided through school feeding initiatives must meet strict safety standards to avoid foodborne illnesses. Milk is among the most nutritious foods that are very affordable across the globe; however, it is easily and highly susceptible to contamination. Food safety remains a crucial component of public health, especially in programs targeting vulnerable populations such as school children. Against this background, the present study aimed to investigate the microbial content of milk served to children through the SFP in selected primary schools in Maseru and to assess the knowledge, attitudes, and self-reported behavioral practices of food handlers in relation to milk safety. Pasteurized milk was obtained from a common source by 16 primary schools participating in the SFP. Structured questionnaires were administered to food handlers to gather data on knowledge, attitude, and self-reported behavior. Milk samples were examined for microbial quality using selective microbiological agars. On average, 13% of the food handlers expressed a lack of knowledge of the diseases that are transmitted through contaminated milk, while 44% perceived that clean water could be identified with the naked eye. Less than 50% of the food handlers understood that cold milk implied safe milk, even without refrigeration. Coliforms (2×10^0 and 2.33×10^2 CFU mL^{-1}) and yeast and molds (1.43×10^2 to 9.3×10^3 CFU mL^{-1}) occurred above threshold limits in all the samples. *Escherichia coli* counts ranged from 2×10^0 to 2.3×10^1 CFU mL^{-1}, which is a call for concern. The total bacterial counts indicate the presence/growth of microorganisms in all the milk samples, thus suggesting contamination. The knowledge, attitude, and self-reported behavior of the food handlers reported in the study could guide the food safety routine program.

Key words: microbial contamination, milk, school feeding programme, food handlers, knowledge, attitude.

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Introduction

The entire world is suffering from chronic foodborne illnesses since time immemorial, with an estimated 600 million cases, including 420,000 deaths per year (WHO, 2017). The major drivers of foodborne illnesses are unhygienic food handling techniques and/or the lack of cleanliness. In addition, several research studies associated the foodborne illnesses with the actions and attitudes of food handlers (Aljasir, 2023). Food handlers play a major role in food contamination, and indeed, human handling errors have been responsible for most outbreaks of food poisoning. According to Sibanyoni *et al*. (2017), the food handlers often lack basic food safety knowledge, specifically relating to temperature control, personal hygiene, and the prevention of cross-contamination. Post pasteurization, milk can also be recontaminated with microorganisms, which may even be fatal to human health. Milk quality can largely be affected by the hygiene practices around milking, storage, transportation, and preparation processes. Personal hygiene plays the most integral part in the control of milk contamination and food poisoning, together with the handling and storage of milk following the milking process. Transporting milk while the cold chain is broken is another factor that can affect the quality of milk, whether the milk is contaminated or not (Lurdes *et al*., 2021). A milk sample, producing a high number of colonies on plate count agar (PCA), could reasonably be assumed to be a public health hazard; therefore, investigations to analyze further the microorganisms that were present become crucial.

The Kingdom of Lesotho is categorized as a developing country, and it is among those countries that are affected by poverty and malnutrition. A quarter of the population (447,000 people) was said to be food insecure in August 2014 (Stephen *et al.,* 2018). Most of the children in Lesotho are nutrient deficient; therefore, nutrient replacement can be attained through forms that would be affordable, such as providing milk and other proteins through the School Feeding Program (SFP) (Tessema & Tibbo, 2009). Precisely, milk is served on the SFP menu, among others, to supplement some of the nutrients that are lacking in the children. The SFP began in 1961 and had been disseminated throughout the 10 districts of the country. Food handlers are involved in the program

and are responsible for food preparation. Recent studies highlighted that most of the food handlers usually believe that food safety can be measured in terms of the appearance of the food. However, there is a gap in the knowledge of milk handling for the food handlers, posing a great risk of food safety in general. Milk is proven to be one of the most nutritious foods due to its high content of protein, vitamins, and other minerals that are essential for growth, bone density, and overall health (Owusu-kwarteng *et al.,* 2020). It is one of the proteinaceous sources that are affordably accessed; hence, most schools are serving milk within their menus in the SFPs. Milk is essential for children since it is a very important source of protein, boosting calcium and vitamin D levels, which are supplements that help to promote bone health, treat calcium deficiency, and protect against osteoporosis (Owusu-Kwarteng *et al*., 2020). Further, it also boosts cognitive performance while improving general nutrition and promoting brain growth.

Upon secretion from the udder, milk is sterile, but it becomes contaminated by bacteria immediately after it leaves the udder since bacteria are pervasive. However, in the case of mastitis or other infections, the milk is contaminated with disease-causing microorganisms from within (Vidal *et al.*, 2017). Unfortunately, milk has been identified as the source of almost three times more hospitalizations than any other foodborne disease source, making it one of the world's most dangerous food products. This is due to its great nutritious content, capable of harboring microorganisms and facilitating their growth, thus prone to contamination, causing infections and diseases to consumers after consumption (da Vitória *et al*., 2021). Recently, studies revealed that most food handlers have a common knowledge that pasteurized milk is sterile, meaning free of microorganisms. Thus, provoking the investigation to unravel the reality on the ground. Various studies indicated that the probabilities of having good food handling practice are usually 3.4 times higher among trained food handlers compared to those who are untrained (Azanaw *et al*., 2019).

Several people working in the milk industry have the knowledge that milk must be transported while in a chilled environment or on ice or while maintaining the cold chain, but the opposite seems to be practiced (Farmers and July, 2016). Apparently, there is a tendency in Lesotho of not observing standards governing milk handling at various food processing levels, including milk handling, transportation, and storage (researcher's observations). Hence, there are no up-to-date legal documents on milk handling in the country. Recently, there has been a paucity of information on the microbiological quality of milk consumed by children attending primary schools in Lesotho, even though milk is served in almost all the schools. In addition, the mode of transportation and storage of milk at these schools, participating in the SFP, were not in tandem with the milk standards. Moreover, there were records of children's absenteeism in schools following milk consumption, yet there were neither clinical records nor further investigations relating to the gastrointestinal infections observed (Tan *et al.*, 2013). In addition to providing an extensive overview of the hygiene status and challenges of the SFP, this paper quantifies the bacterial burden of milk served to children and assesses the knowledge, attitude, and self-reported behavioral practices on milk handling in selected primary schools.

The findings obtained from this study will ultimately serve as a source of relevant information to the policymakers and the public health practitioners to develop recommendations, priorities, and regulations that will go a long way to assist in improving the implementation of the feeding program.

Materials and Methods

Study setting

The study was conducted in Maseru, the capital district of Lesotho. It involved 16 primary schools and 48 food handlers. Schools were chosen by their proximity to the dairy facility to ensure same-day transport and analysis of samples at the university laboratory in Bloemfontein, South Africa. These schools were purposely selected to assess milk safety and food handling practices within the context of the national feeding initiative aimed at improving child nutrition.

Study period, study design

This study employed a cross-sectional design incorporating both qualitative and quantitative approaches. Structured questionnaires were administered to gather relevant data from food handlers regarding their knowledge, attitudes, and self-reported practices related to milk handling. The questionnaires were self-developed by the researcher and translated into the local language by a qualified linguist to ensure clarity and comprehension.

Milk sample collection and data gathering were conducted in two separate batches during the months of March and April 2023. The maximum recorded atmospheric temperatures in Maseru during the collection periods were 28°C on the 15th of March and 23°C on the 12th of April, respectively. These environmental conditions were noted, as they may influence milk storage and microbial activity.

Sampling technique

Purposive sampling was used to select 16 primary schools based on their proximity to a single dairy, which served as the common source of milk. A total of 18 milk samples were collected: 2 from the dairy and 1 from each school. Samples were collected aseptically in two intervals [end of summer (March) and beginning of winter (April)] to assess seasonal variation. At each school, milk temperatures were recorded upon arrival and before serving. Trained data collectors assisted with sample collection due to the distance between schools. There were 48 food handlers (3 from each school) who participated in the study through questionnaire responses. A pilot study and a laboratory dry run were conducted to ensure accuracy and standardization of procedures.

Questionnaire design

A total of 48 food handlers from 16 primary schools were involved in this study, and the choice of schools in the study was also based on convenience during sampling. The primary schools were selected based on their proximity to the dairy (the sole source of sample collection). A cross-sectional, qualitative, and quantitative design was carried out under which questionnaires were administered to gather pertinent data from the respondents (Sibanyoni *et al*., 2017). The qualitative data were obtained from the honest or unbiased responses offered by the food handlers through the questionnaires, regarding their demographic information as well as information obtained *via* assessing their knowledge, attitude, and behavior to key parameters or indicators pertaining to food safety, as presented in Tables 1-4. The questionnaires were developed using English and translated into the home language of the respondents (Sesotho) but reported in English.

To minimize personal bias during the administration of self-reported behavior questions, the study employed several control measures. First, the questionnaire was carefully designed to

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include neutral, non-leading language to reduce the influence of the researcher's expectations. Second, anonymity and confidentiality were guaranteed to all participants, which encouraged honest and accurate responses without fear of judgment or repercussions. Third, the questionnaires were translated into the local language by a qualified linguist to ensure clarity and cultural appropriateness, reducing misinterpretation. Lastly, data collectors were trained to maintain objectivity, avoid influencing respondents, and follow a standardized administration procedure across all schools. To complement the self-reported data and further control personal bias, an observational checklist with Yes/No questions was also used by the researcher to assess the actual practices of food handlers.

Milk sample collection

Samples were collected in two intervals, at the end of the summer and at the beginning of the winter seasons. In general, a total of 18 samples was aseptically collected; the first sample was collected at the dairy, while two other samples were collected at each school. Accordingly, a milk sample was taken on arrival at the schools, and the second sample was taken just before the children could take their lunch. Prior to each collection, the temperature of the milk was recorded at the dairy, after the arrival at each school, and before serving commenced. The distance traveled from the dairy to each school was also noted.

All 16 schools were represented using letters to maintain confidentiality. They were denoted as A, B, C, D, E, F, G, H, I, J, K, L, M, N, P, and Q, while the letter O was used to represent the dairy. O1 represented the first sample from the dairy, and O2 represented the sample obtained from the dairy in the second batch. The labeling of the samples was consistent throughout the whole study. Immediately, the samples were transported to the lab on ice to maintain the cold chain until further analysis (Ortiz *et al*., 2019).

Determination of microbiological parameters

The microbial analysis was conducted using the 10-fold serial dilution of samples as previously reported by Ortiz *et al*. (2019), resulting in dilutions ranging from 10^{-1} to 10^{-3}. Aseptically, aliquots (100 µL) of the different dilutions for each sample were used to inoculate several and selective microbiological agar [Brilliance *Listeria* agar (Biolab Diagnostics, South Africa), Rose Bengal chloramphenicol agar (Biolab Diagnostics, South Africa), Slanetz and Bartley (Biolab Diagnostics, South Africa), Harlequin chromogenic agar (Biolab Diagnostics, South Africa), PCA (Biolab Diagnostics, South Africa), De Man Rogosa and Sharpe agar (Biolab Diagnostics, South Africa) and Baird Parker agar (Biolab Diagnostics, South Africa)] by the streak plate technique. Inoculated plates were incubated at appropriate temperatures and

Table 1. Demographic data of food handlers in school feeding programs.

Variables	Frequency	Occurrences (%)
Gender		
Female	36	75
Male	12	25
Age		
35-45 years	5	10
46-55 years	30	63
56-65 years	3	6
Education level		
None	10	21
Primary level	19	40
High school level	18	38
Tertiary level	1	2

Table 2. Assessment of food handler's knowledge.

Variables	Answer	Frequency	Occurrences (%)
Is it important to wash hands before handling food?	Yes	48	100
	No	0	0
Is washing hands with soap important?	Yes	47	98
	No	1	2
Can safe water be identified by the way it looks?	Yes	21	44
	No	27	56
Can wiping clothes spread microorganisms?	Yes	40	83
	No	8	17
Can milk transmit any diseases?	Yes	42	88
	No	6	12
Can one come to work when sick with diarrhea?	Yes	8	17
	No	40	40
Is timely delivery important?	Yes	37	77
	No	11	23
Can milk temperature be taken 20 minutes after delivery?	Yes	34	71
	No	14	29
Can pasteurized milk be left at room temperature overnight and be served next day?	Yes	10	21
	No	38	79
Can refrigerated foods lower bacterial growth?	Yes	35	73
	No	13	27
Can expired milk be consumed?	Yes	6	12
	No	42	88
Can raw foods be stored separately from cooked food?	Yes	5	10
	No	43	90

days for the growth of *Listeria monocytogenes*, yeast and mold, Enterococci, *Escherichia coli* and coliforms, total plate counts, Lactobacilli and *Staphylococcus aureus*, respectively. Growth of emergent colonies was counted as colony-forming units per milliliter (cfu/mL) and recorded on respective tables.

Results and Discussion

Demographic data of food handlers

In this study, a total of 48 Lesotho national study participants responded at a 100% rate. The socio-demographic characteristics of respondents are shown in Table 1, among which the vast majority were females (75%). The food handlers were categorized in subgroups, where the range of 46-55 years was the largest (63%), with the age group 35-45 years constituting 10%, and the most elderly group of 56-65 years being only 6%. The majority of the food handlers (40%) had a primary-level education. Studies indicated that for older people, it becomes more difficult for them to learn new concepts, grasp, and practice without being reminded of the newly introduced concepts (Yin, 2022). Therefore, having a vast majority being above 46-55 years of age may negatively affect the training.

Knowledge of the food handlers

The findings stemming from the knowledge of the food handlers are indicated in Table 2. While 100% of the food handlers agreed that hand washing must be done before handling food, that food safety training courses are important as well, and that a clean working environment promotes good health, it was observed that none of them washed their hands prior to commencing with their children's feeding routines. None of them washed their hands during food preparation, even though they engaged in other activities prior to the actual serving, like making the fire and stirring the pap pots. The participants' responses did not reflect their actions on the ground. Handwashing is the global critical point of disease prevention; hence, the lack of this practice remains a sign of danger. This is an imperative aspect that must always be taken into consideration because the hands of the food handlers could serve as mechanical vectors for foodborne illnesses, following the presence of microbial load (Allam *et al*., 2016).

Approximately 44% of the participants had a poor perception of how to identify if the water they used to perform their activities was clean or not; they highlighted that potable water could be identified from its appearance. In addition, the source of water and how the water could be carried to the schools were not important; also, some diseases could result from the consumption of contaminated water. The use of water collected from a non-reliable source or that had been contaminated after being collected from a reliable source is one of the important causes of unsafe food (Shin *et al*., 2023). This raised a suspicion that even the safety of milk can be determined by its appearance, meaning if it still looks white, it should be safe for consumption, regardless of the mode of storage or transportation to the schools. Most of the food handlers believed that food safety can be measured in terms of the appearance of the food. About 13% of the food handlers affirmed that milk that had expired cannot be consumed, though none of the food handlers checked the expiry date of the milk nor tasted the milk before serving it. Proper food handling methods are vital in ensuring the production of safe food. With food safety training, the knowledge of the food handlers can be improved, though that does not guarantee positive adjustments in food handling behavior and attitude. Less than 50% of the study population understood that cold milk meant safe milk. This explains the reason the food handlers were never bothered by milk being transported while the cold chain was not

Table 3. Assessment of food handlers' attitude (n=48).

Variables	Frequency	Occurrences (%)
Does frequent handwashing during preparation with extra time?		
Agree	48	100
Disagree	0	0
Does keeping kitchen surface clean reduce the risk of illness?		
Agree	46	96
Disagree	2	4
Inspecting food for freshness and wholeness is valuable?		
Agree	46	96
Disagree	2	4
Does keeping raw and cooked food separate help to prevent illness?		
Agree	21	44
Disagree	19	40
Not sure	8	17
I think it is unsafe to leave cooked food in the refrigerator for 2 hours.		
Agree	37	77
Disagree	6	13
Not sure	5	10
Can milk be put on direct sunlight?		
Agree	15	31
Disagree	21	44
Not sure	12	25
Does sieving the milk play an important role?		
Agree	38	79
Disagree	4	8
Not sure	6	13

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observed. A much lower percentage (13%) of the population expressed a lack of knowledge about the diseases that can be transmitted *via* contaminated milk. The common knowledge of the participants who were involved in the investigation revealed that pasteurized milk cannot transmit diseases. Additionally, the food handlers had no knowledge of cross-contamination; even when the milk had been pasteurized, it can be recontaminated, rendering it unfit for human consumption. Handwashing with soap and clean water is a paramount step to prevent the contamination of food through food handlers as well as for personal hygiene (Toney-Butler *et al*., 2024). All food handlers agreed that frequent handwashing during food preparation is worth an extra amount of time, yet none of them took the time to wash their hands intermittently throughout their routine for a day. In all 16 schools that were assessed, there were no hand-washing facilities with running water. Only in 3 (19%) schools, wherein handwashing was performed, though the hand-washing technique was not carried out properly in 2 of the said schools, as soap was not used. Most studies indicated that food safety training could improve the knowledge of the food handlers, though gender, age, and educational level also play a significant role. When women are engaged in food processing processes, evidence suggests that there are substantial food safety practices compared to when men are undertaking the same exercise (Khanal *et al*., 2023).

Attitude of the food handlers

Table 3 harbors information on the attitude of the food handlers. The assessment consisted of 3 options, including "agree, disagree and not sure". The answer "not sure" was adopted when the respondent could not give a precise response. The findings based on the attitude of the participants gave an elevated hope in comparison to the reality on the ground. The majority of the questions were answered correctly, although the observation tool reflected the opposite of the responses given by the food handlers. On average, 81% of the overall questions were answered correctly. Additionally, 96% of the respondents highlighted that keeping the kitchen surfaces clean can reduce the risk of acquiring illness and that inspection of food is very important, though the observations recorded were opposite. If the correct knowledge about food safety, as indicated by those high scores, had been practiced while handling the food, then the results of the attitude would then tally with the actions of the food handlers.

In all the schools, the inspection of the milk on arrival was done by the data collectors, and milk temperatures were measured. In only 4 (25%) schools, the surfaces were kept clean. It was realized during the pilot study that the milk was usually served from a third container; therefore, there was a great likelihood of introducing extrinsic materials into the milk. Sanlibaba (2022) noted that food contamination can take place *via* food handlers, food-producing animals, food contact surfaces, food processing utensils/equipment, as well as dust and air, as microorganisms are described to be ubiquitous in nature. A preponderance of 79% agreed that sieving of milk can be salient, though none of the food handlers implemented the idea. In addition, 77% of the food handlers indicated that milk must not be kept out of the refrigerator for more than 2 hours, yet the milk was delivered before 8:30 a.m. to all the schools, and it was only served between 12 noon and 1:00 p.m. Even though they knew that the milk was transported without maintaining the cold chain.

Table 4. Assessment of food handlers' self-reported behavior (n=48).

Variables	Frequency	Occurrences (%)
I wash my hands before and during food preparation.		
Always	38	79
Most times	10	21
I clean surfaces and equipment used for food preparation before re-using on other food.		
Always	35	73
Most times	13	28
I store any leftovers in a cool place within two hours.		
Always	34	71
Most times	3	6
Never	3	6
Sometimes	8	17
I separate raw and cooked food during storage.		
Always	36	75
Most times	5	10
Not often	1	2
Sometimes	6	13
I mix my left-over milk which was not refrigerated with the milk that has been newly delivered.		
Always	15	32
Most times	15	32
Never	6	13
Not often	2	4
Sometimes	9	19
I check and throw away food beyond its expiry date.		
Always	37	77
Most times	5	10
Never	2	4
Sometimes	4	8

Behavior of the food handlers

The respondents were given five options to choose from when assessing their behavior (Table 4). Apparently, what the data collectors observed was contrary to the responses uttered by the food handlers. It is worth mentioning that the observations during a study are more valuable than the responses obtained *via* questionnaires, where the participants can react positively even to aspects that they do not practice. The food handlers did not get 100% in any of the 8 questions that were asked to assess their behavior. The 5 options included "always", "most times", "sometimes", "most often", and "never".

A significant number of the respondents (64%) acknowledged that they mixed the leftover milk from the previous day with the freshly delivered milk for that day, even though the milk was not refrigerated for more than 2 hours. The issue of milk refrigeration was not of concern to all the food handlers, in conjunction with the issue of maintaining a cold chain from the source of production (manufacturer) to the schools. Rather, they estimated the temperature of the milk by touching the container, using the back of the palm, and all concluded that if the milk was cold, it was therefore safe for consumption. Furthermore, the food handlers (44%) indicated that milk must not be kept or placed under direct sunlight yet the milk was kept in the wheelbarrows, and at some serving points, it was kept under direct sunlight. Also, 96% of the food handlers agreed that food must be inspected on arrival to determine if it is fit for human consumption, but it was never done. The said observations corroborate those made in several studies, emphasizing that food handlers have knowledge of the right activities to undertake, yet tend to focus only on the production of the food (Ohkubo *et al*., 2019).

A total of 20 elements were observed without the knowledge of the food handlers, except for those areas where a question had to be posed to acquire the desired information. Observation is the most reliable data collection method and works well when the audience is not aware that data is being collected. The observation tool had only "yes" or "no" alternative answers, together with the space for comments, where necessary. Approximately 40% of the best practices that were supposed to be there in the 16 schools were not found.

Considering the external and environmental factors that might influence the hygienic and microbiological quality of the food, it was revealed that all the schools had no rodent or vector control systems in place. The milk from the dairy was poured into a plastic bucket prior to serving in all 16 schools; this practice could be the main source of contamination of the milk (Sanlibaba, 2022). Not all the 16 schools had a kitchen from where the food was served; the floors, walls, and ceilings were not in good condition in all the schools, and none of the schools had a fridge. Clearly, for any facility to be used for serving food, it must be of a certain standard to minimize the likelihood of contamination of the food. However, it was registered in this study that the milk was kept in any convenient place awaiting the children to exit their classrooms for lunch. A situation viewed to be implicating, more especially, as microorganisms are said to be found everywhere (Gupta *et al*., 2016).

Only 38% of the food handlers covered their hair while preparing and serving the food and 19% of the food handlers wore clean aprons. It is imperative for the food handlers to wear clean aprons to ensure proper hygiene and food safety. If aprons are worn, there will be no possibility of any contaminants falling off from the food handlers' regular clothes, as they can gather various pathogens. Of remarkable concern, 31% of the toilets were closer to the classrooms, used in serving the pupils. Thus, the availability of houseflies in the environment was very high during the serving of the food to the children. Houseflies are notable vectors of transmission of pathogens from one surface to another, carrying them with the hair on their feet and body or by sucking and regurgitating on the food (Olagunju, 2022).

In addition, 29% of the milk pitchers that were used to serve milk were of plastic origin, and most seemed to be in good form, although proper washing and handling prior to use could not be assured. Only 6% of the food handlers provided the children with soap and running water to wash their hands before eating their meals. A total of 96% of the food handlers had visible abrasions on

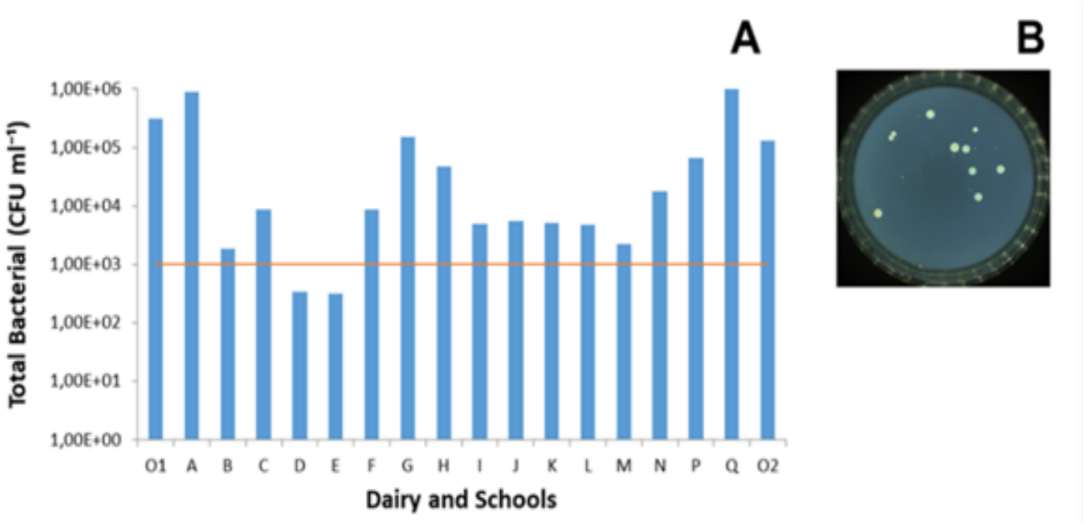

Figure 1. A) Total bacterial counts present in all the samples, 16 samples exceeding the threshold limit; **B**) white colonies on plate count agar suggestive of the bacteria counted in the milk samples.

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their hands due to fire-making; open wounds can harbor pathogens, which ultimately could be transmitted to the food (Tom *et al*., 2019). Hence, such food handlers must be prohibited from handling food until they are fully recovered.

Microbial assessment

Microbiological evaluation is an established tool in monitoring the safety and quality of milk and its products. The Food and Agriculture Organization and World Health Organization have highlighted threshold limits of a particular bacterium that is permitted in food that is regarded as safe for human consumption (Murutu *et al*., 2013). The growth of cells counted above the specified threshold levels, set for a specific bacterium, is described as contamination. The counts reflected the sanitary quality, sensory acceptability, and conformance of the milk. All the samples were positive for microbial growth, with large numbers of colonies represented as colony-forming units per milliliter of sample, yielding a 100% occurrence/prevalence rate. The samples from the dairy during both sampling periods showed growth of colonies on the PCA (Figure 1). A total bacterial count lower than 10^3 CFU mL^{-1} in the pasteurized milk was satisfactory in quality, and only two samples were not beyond the threshold.

The most preferred temperature range for bacteria responsible for foodborne illnesses is 4-60°C, the known danger zone, because the food spoilage bacteria grow very fast in this temperature range (Messing, 2015). Therefore, food that spoils easily must never be kept or stored at a temperature occurring in the danger zone for more than 2 hours to avoid bacterial growth. Nonetheless, it is noteworthy that the milk that was served through all 16 schools was left in the danger zone for more than 2 hours.

The absence of handwashing facilities, added to the lack of practice thereof, accelerates the possibilities of milk contamination, since microorganisms, by nature, are readily present in the human body. Accordingly, *Staphylococcus* spp are found on the skin and the nasal tracts of humans as part of the normal flora (Gebremedhin *et al*., 2022). Whenever food handlers do not observe appropriate personal hygiene, there is a high chance that *Staphylococcus* can be transferred into the milk. During data collection, it was observed that the food handlers did not fully understand that they can transmit microbes into the milk even when they are not feeling sick. Both samples that were collected at the dairy during the two sampling periods demonstrated the presence of staphylococci. The hygienic status of the schools, added to the lack of maintenance of the cold chain during the transportation and the storage of milk, could have negatively affected the milk, allowing the proliferation of microorganisms. *Staphylococcus* species were detected in 100% of the samples, in the range 1×10^1 to 4.07×10^3 CFU mL^{-1} (Figure 2). *Staphylococcus* species should not exceed 1×10^3 CFU mL^{-1} in pasteurized milk (Minister of Health, 2016; Gazette and Notice, 2024).

Mesophilic bacteria indicate the microbiological quality and the hygiene parameters of raw and pasteurized milk. Huge numbers of these microorganisms revealed the poor conditions in the production, storage, and processing of the milk, adding to the possible presence of pathogens. Even though the dairy stated that the milk was pasteurized, various microorganisms were detected in the milk dispatched to schools from the dairy. Especially, the milk provided during the second sampling event (O2) contained *Enterococci spp*., unlike the milk from the first sampling event (O1). This high microbial load, coupled with the lack of cold chain during delivery to schools, is a problematic combination when milk hygiene is considered.

The fact that these microorganisms cannot survive the heat treatment in pasteurization means that their presence in milk indicates contamination post pasteurization; therefore, the hygienic status of the source, alongside that of the food handlers, becomes questionable. Harlequin selective agar was used for the cultivation of both *E. coli* and coliforms on a single plate. Beige colonies were also evident on Harlequin agar, which was suggestive of *Pseudomonas aeruginosa*, a rod-shaped encapsulated Gram-negative bacterium. This finding conforms to those of Aaku *et al*. (2004), who reported the presence of *Pseudomonas cichorii*, a psychrotroph among other bacteria, in pasteurized milk procured from

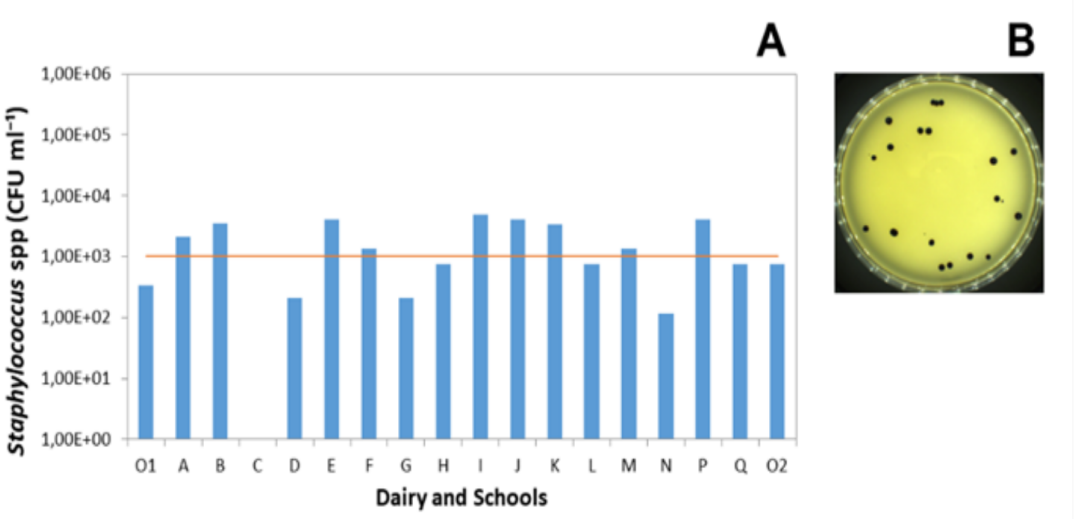

Figure 2. A) *Staphylococcus* spp. counts in 15 samples, 9 exceeded the threshold limit; **B**) black colonies on Baird Parker agar suggestive of Staphylococcus spp. in milk.

two processing plants in Gaborone, Botswana. The authors attributed the presence of the bacterium to poor sanitary conditions after pasteurization, emphasizing that the psychrotroph is not part of the normal microflora of the udder. The coliforms and *E. coli* are always present in the digestive tracts of mammals, and therefore, some are classified as fecal indicator organisms. In this study, all the samples contained coliforms (100%), with counts that ranged between 2×10^0 and 2.33×10^2 CFU mL^{-1}, and the samples E, F, P, and O2 had the highest coliform counts (Figure 3). The coliform counts must not exceed 1×10^3 CFU mL-^{1} in pasteurized milk. On the other hand, the counts for *Escherichia coli* ranged from 2×10^0 to 2.3×10^1 CFU mL^{-1} and the threshold limit is zero count per 100 mL. The findings agree with those of Carrillo-Gómez *et al*. (2022), who equally noted the presence of *E. coli* though at a different level of contamination in pasteurized milk (between 1×10^6 and 1×10^{-2} CFU mL^{-1}). However, the presence of *E. coli* in the milk samples is a call for concern as the bacterium is associated with several pathotypes harboring an assortment of virulence factors that can lead to milk-borne outbreaks, and the treatment of infections caused by *E. coli* is fraught with challenges of multidrug antibiotic resistance (Ntuli *et al*., 2016).

Furthermore, air is viewed as one of the major sources of contamination, presenting a way of dispersing fungal spores in the dairy environment, affecting the equipment and the milk itself (Naranjo-Ortiz and Gabaldón, 2019). Moreover, yeast and mold spores are said to be stable even in UHT, with a potential for rapid growth at optimum temperatures (Ohkubo *et al.*, 2019), considering that the cold chain was broken for hours. Evidently, yeast and mould were present in all the 18 samples with counts ranging from 1.43×10^2 to 9.3×10^3 CFU mL^{-1} (Figure 4), described as too numerous to count (TNTC). Due to pasteurization, the shelf life of fresh milk is set at 5×10^1 CFU mL^{-1}. This could be explained by the pos-

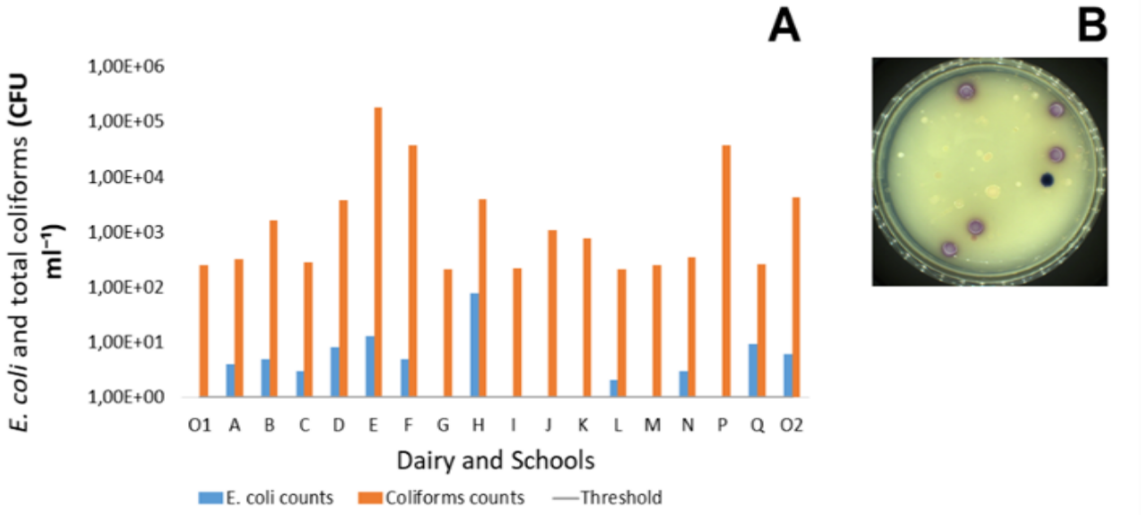

Figure 3. A) Coliforms were present in all samples and *Escherichia coli* in 69% of the samples from the schools and the dairy, exceeding the threshold limits; **B**) blue-green colonies are considered presumptive *Escherichia coli* and salmon pink coliforms on Harlequin agar.

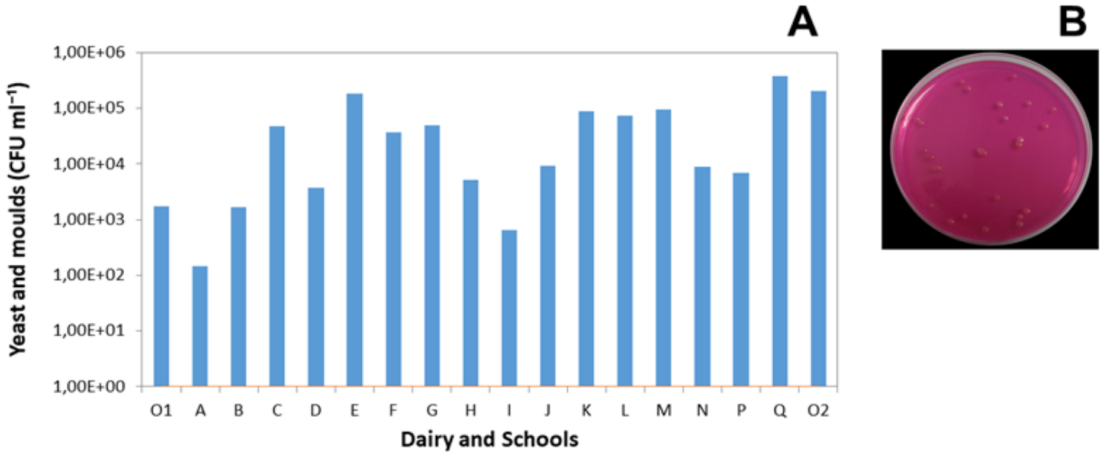

Figure 4. A) Yeast and mold counts were suggestive in all samples, exceeding the set threshold limit of yeast and mold in pasteurized milk; **B**) the light pink colonies on Rose Bengal Chloramphenicol agar are presumed to be yeast spp.

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sibility of proliferation, which might have occurred while the cold chain was not maintained. Secondly, the milk might have been re-contaminated post the pasteurization process. The yeast and mold might have also been available in the environment, such as the surfaces that were not cleaned (Gupta *et al*., 2016).

Conclusions

It is worth concluding that the knowledge, behavior, and attitude of food handlers toward storage and preparation of food were critically lacking. This was evident as microorganisms grew on selective microbiological media, following inoculation with serially diluted milk samples, even though the milk samples were subjected to pasteurization. Pasteurization is a process performed to effectively eliminate all microbes but the thermostable microbes as well as, occasionally, Gram-negative rods in milk, thereby extending its shelf life. 44% of the study population (n=48) had hypothetically believed that the cleanliness of water can be measured by the naked eye; therefore, by analogy, even milk safety could be assessed by its appearance. Notwithstanding, the study did not uncover the actual microbial population found in the milk samples. There was growth of other microorganisms, alongside the organisms of interest within the scope of the research. These organisms were found in various petri dishes containing the media, Harlequin, Baird Parker, and Brilliance *Listeria* agar. Further isolation, identification, and confirmation of these microorganisms would have added more value to the study. Further research, involving other utensils used during the feeding routine, *e.g*., the cup that was used to measure milk for each child, will bring additional information to the study.

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Received: 24 July 2024; Accepted: 29 July 2025; Early view: 22 January 2026.

Contributions: all the authors contributed equally. All the authors read and approved the final version of the manuscript and agreed to be accountable for all aspects of the work.

Conflict of interest: the authors declare that they have no conflicting interests.

Ethics approval and consent to participate: this study obtained ethical clearance from the Ministry of Health Research and Ethics Committee with the reference:ID66-2024. Before data collection, informed consent was secured from each participating school and all food handlers involved in the study. The researchers ensured that participation was voluntary, and all participants were assured of the confidentiality of the information they provided.

Availability of data and materials: all data generated or analyzed during this study are included in this published article.

Acknowledgments: the authors appreciate the serene atmosphere and moral support provided by members of the Centre of Applied Food Sustainability and Biotechnology, Department of Life Sciences, Faculty of Health and Environmental Sciences, Central University of Technology. Immense appreciation also goes to the food handlers, who voluntarily offered their assistance in terms of time, energy and knowledge to ensure the realization of this study.

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