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Evaluation of Hazard Analysis and Critical Control Points Implementation in Milk Collection Centers in Qalyubia Governorate

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Abstract

Hazard Analysis and Critical Control Point (HACCP) is a system that concerns with the identification, evaluation and management of risks that have a potential impact on food safety and quality; especially in a highly nutritious yet easily perishable food like milk and dairy products that can be easily contaminated with contain such biological, physical, and chemical hazards. Therefore, this study aimed to evaluate the returns from HACCP implementation in dairy farms and milk collecting centers (MCCs) located in Qalubiya governorate, Egypt through assessment of the quality, safety and potential adulteration in the collected raw milk samples, along with environmental swabbing for the sanitary condition monitoring pre- and post HACCP implementation, which included an overall improvement in sanitary and hygienic quality of milking, transportation, storage, and personnel conditions, along with documentation and traceability processes at the examined farms and MCCs. Statistical analyses were conducted to compare findings before and after a one-month duration of HACCP application. The results revealed a significant improvement ($p \leq 0.05$) in the physico-chemical and microbiological quality of milk samples at both farm and MCC levels. This improvement directly reflected on the quality and fitness of milk for human consumption. In conclusion, the application of HACCP effectively controlled various hazards during milk production, even adulteration, and improved the hygienic quality of raw milk. Therefore, it is highly recommended for HACCP implementation in milk production facilities, with continuous monitoring for optimal results.

KEYWORDS
Bulk tank milk, HACCP, Mastitis, Milk adulteration, Quality.

INTRODUCTION

Raw milk, being a highly perishable food of animal origin, is a rich medium for various microbial growth, including those causing foodborne diseases (Owusu-Kwarteng *et al*., 2020). Its consumption may pose health risks due to the presence of microbial contamination, environmental pollution, and unhygienic practices during collection, storage, and retail selling (Orwa *et al*., 2017). If microbial contamination exceeds certain thresholds, the milk becomes unsafe for human consumption (Melini *et al*., 2017).

In Egypt, over 60% of milk sales occur through retail or traditional milk markets, which include farmer dairy cooperatives, small traders (using bicycles and public or private transportation), and small retail outlets. These channels often lack quality checks, leading to high levels of microbial loads in the milk sold (ILO, 2020). This poses a risk of zoonotic infections and other milk-borne illnesses to the consumers, Likewise, recent research into the microbiological quality of raw milk sold in Egypt found relatively high levels of microbial loads, including *Escherichia coli*, *Staphylococcus aureus* and fungal contamination (El-Shinawy *et al*., 2018).

HACCP, as defined by the FAO (2009), is a system designed to identify, evaluate, and manage risks that significantly affect food safety. When applied to milk marketing, HACCP should form an integral part of the overall strategy for ensuring milk safety. It allows for the establishment of Critical Control Points (CCPs) at various stages of the process to minimize the risk of zoonotic infections in humans, resulting in a sustained reduction of pathogens at relevant points.

Implementing HACCP system, and consumer's food safety education along with conducting risk analyses on health concerns associated with milk-borne pathogens is crucial to mitigate or eliminate these risks; which can guide the creation of supportive policies for market participation at every level of the milk production and marketing chain (Attrey, 2017). However, there are limited studies assessing the quality and health returns of HACCP implementation in farm levels and milk collecting centers in Qalubiya governorate, Egypt. Hence, the focus is on improving the chemical and microbiological quality of raw milk samples in this region.

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MATERIALS AND METHODS

The application of HACCP system principles and required tasks in the studied dairy farms and milk collecting centers (MCCs) were carried out according to ISO 22000 (2018). Application of HACCP system in dairy farms included overall improvement in feeding system, milking hygienic practices, equipment, animal culling, and worker's education. Additionally, in MCCs, overall improvement in receiving, cleaning and sanitation practices, calibration and monitoring of milk temperature and quality before, during and after receiving milk were performed. Moreover, pasteurization system was used in QM-1 and QM-2 MCCs, while quick chiller was used in all investigated MCCs. Furthermore, documentation and traceability were applied for precise monitoring.

Study area

This study was conducted on six MCCs and their corresponding suppliers located at the pointed localities in Fig. 1. Three points from Toukh province (2 from Met-kinana (TM-1 and TM-2) and 1 from Arab elrwashda (TA) districts), two points from Qalub province (met halfa district (QM-1 and QM-2)), and 1 from Benha province (Marsafa district (BM)).

Production system

Dairy animals in the study area were kept in rural traditional herd farms. They were kept under smallholder intensively managed dairy herds (≤20 cross-bred animals of all ages, Egyptian and Italian breeds). They were confined in an enclosure with dirt or concrete flooring. Hand milking is the only way for milk collection.

Production pathway

Raw milk production flow chart starting from milk collection to MCC storage is described in Fig. 2.

Fig. 1. Location of milk collection points.

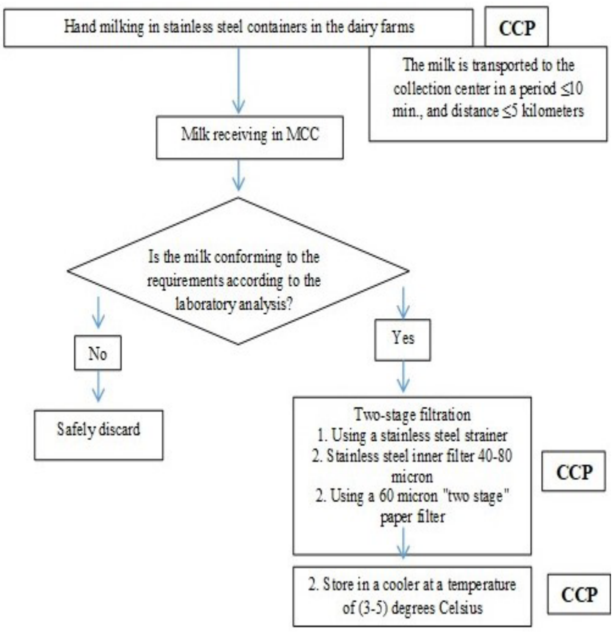

Fig. 2. Milk production Flowchart.

Collection of milk samples

At the farm level

A total of 60 samples of raw, recently collected buffalo milk samples were collected in sterilized containers from six milk farms (10 of each) before HACCP system implementation accompanied by the suitable corrective measures, and a month later during May 2023. The present examined farms were the current suppliers of the followed examined six milk collecting centres (MCCs).

At milk collecting centre level

Six samples of raw buffalo milk were collected from the bulk tanks at the examined MCCs. Additionally, swabs were collected from the hands of workers, suction pipes, and the interiors of the milk collecting tanks. These collected samples were then subjected to physico-chemical and microbiological evaluations.

Physico-chemical evaluation of the collected milk samples

Milk fat, proteins, pH, formaldehyde, added water and urea contents were evaluated using calibrated milk analyzer (Milkoscan FT1- 91830939). Somatic cell count (SCC) was evaluated by an automated BacSomatic-SCC dye.60070030 according to ISO 13366-2 (2006). Estimation of aflatoxin M1 was performed by fluorimeter (VICAM-series- 4EX 03459) according to Dragacci *et al.* (2001). Detection of addition of palm oil was measured according to Sharma *et al.* (2020). Finally, antibiotic residue was investigated in each milk sample using Delvotest®.

Microbiological examination of milk samples

Samples were prepared according to ISO 6887-1 (2017), followed by counting of total bacterial count (TBC), *Staphylococcus aureus*, *Escherichia coli* and total fungal counts according to ISO 4833-1 (2013), ISO 6888-1(2003), ISO 16649-2 (2001), and ISO 21527-1 (2008), respectively. Moreover, detection of *Salmonella* sp., *Listeria monocytogenes*, *Bacillus cereus* and *Clostridium perfringens* were performed according to ISO 6579 (2017), ISO 11290-1 (2017), ISO 7932 (2020), and ISO 7937 (2004), respectively.

Statistical Analysis

One-way ANOVA, t-test, and Duncan's post hoc analysis were performed using the SPSS software for Windows (Version 16), considering a p-value of ≤0.05 as statistically significant.

RESULTS

Physico-chemical components

A shown in Table 1, the physico-chemical components of raw buffalo milk samples from various collecting centres were analysed. After the implementation of the HACCP system, all milk samples showed a significant increase in protein and fat percentages. However, the milk differed based on Somatic Cell Count (SCC) and aflatoxin M1 levels. All samples were within permissible SCC limits, but most exceeded MPLs of aflatoxin M1, except for those from the TM-2 centre (46.70±5.37 ppt). Post-HACCP implementation, all samples showed significantly lower SCC and aflatoxin M1 levels. pH values remained relatively unchanged before and after HACCP application.

Adulteration of milk samples with substances like palm oil, formaldehyde, urea, antibiotic residue, and added water was examined as shown in Table 2. Prior to the implementation HACCP system, the highest proportion of palm oil adulteration was found in samples from TM-1 (40%), followed by QM-1, BM, and TM-2 with incidence (%) of 30, 30 and 20, respectively. However, no palm oil adulteration was detected post-HACCP application.

Urea was found in all samples, with the highest concentration in QM-1 (70.36 mg/100 mL), but its levels significantly decreased after HACCP application. No formaldehyde or added water adulteration was detected in any samples.

Before HACCP application, antibiotic residues were found in 40% of TM-1 samples, 10% of TM-2 samples, 20% of QM-1 samples, and 30% of BM samples. However, no antibiotic residues were detected post-HACCP application.

Microbiological quality of milk samples

Bacteriological assessment of milk samples at the farm level as shown in Fig. 3 revealed that samples from TA had the highest APC of 5.6 log CFU/mL, and TM-2 had the highest fungal count before the implementation of HACCP system. However, these

Table 1. Statistical analytical results of chemical examination of raw buffalo milk samples from MCCs before and after HACCP application (n=10).

		pH	Fat (%)	Protein (%)	SCC (x10^3/ml)	Aflatoxin-M1 (ppt)
TM-1	Before	6.5±0.06	5.88 ± 0.174	3.30 ± 0.156	330.20±16.7	94.30±5.17
	After	6.8±0.05	7.79 ± 0.94*	4.62±0.086*	78.30±5.23*	35.50±1.93*
TM-2	Before	6.4±0.05	6.09 ± 0.256	3.19±0.139	444.0±45.77	46.70±5.37
	After	6.6±0.06	7.93 ± 0.10*	4.45±0.162*	42.10±3.49*	30.40±2.71*
TA	Before	6.4±0.07	6.59 ± 0.216	3.28±0.177	517.1±45.9	249.3±21.62
	After	6.7±0.05	8.021 ± 0.21*	4.34±0.127*	111.7±10.3*	23.30±2.62*
QM-1	Before	6.6±0.06	6.41 ± 0.18	2.95±0.149	398.6±23.26	62.90±3.206
	After	6.7±0.07	8.12 ± 0.19*	4.54±0.101*	125.0±11.6*	38.80±2.13*
QM-2	Before	6.5±0.06	6.33 ± 0.177	3.02 ± 0.77	296.7±26.28	184.7±26.88
	After	6.7±0.05	8.04 ± 0.20*	4.65±0.062*	88.90±8.95*	20.80±1.37*
BM	Before	6.6±0.07	6.51 ± 0.221	2.85±0.156	197.1±15.57	74.40±6.58
	After	6.7±0.06	7.74 ± 0.90*	4.58±0.064*	90.70±7.42*	31.20±3.34*

* P<0.05 Values are means of 10 samples ± SD.

TM-1 and TM-2 (Toukh province, Met-kinana district), TA (Toukh province, Arab elrwashda district), QM-1 and QM-2 (Qalub province, Met- halfa district), BM (Benha province, Marsafa district).

counts significantly reduced to less than 1 log CFU/mL for *S. aureus* in QM-1 and QM-2, and for *E. coli* and fungal counts in all samples after HACCP application.

Furthermore, Findings in Fig. 4 showed a significant reduction in the APC of more than 2 log CFU/mL was observed in milk samples from MCCs after HACCP application. Additionally, *E. coli*, *S. aureus*, and fungal counts were reduced to less than 1 log CFU/mL in all examined milk samples post-HACCP application.

Microbiological quality of the examined swab samples

Aseptic swabs were collected from milk tanks, pipes, and workers' hands to assess surface and personal hygiene. The results, presented in Tables 3 and 4, indicated low hygienic quality

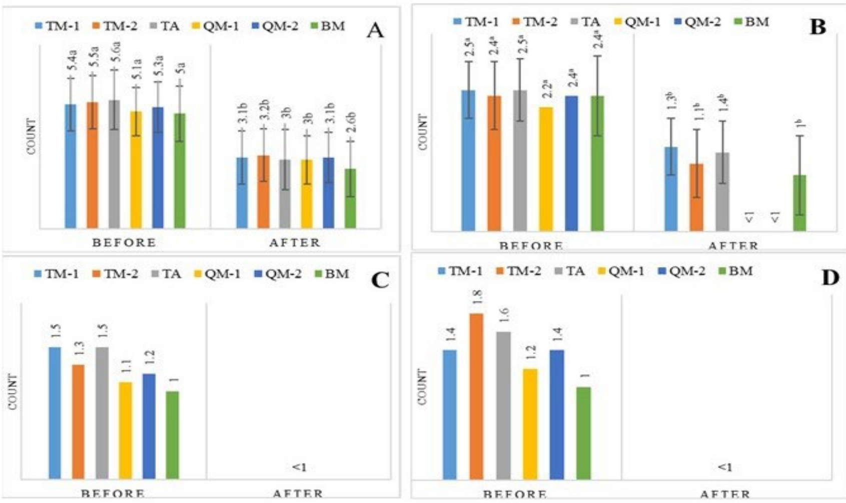

Fig. 3. Mean values of APC (A), *Staphylococcus aureus* (B), *Escherichia coli* (C) and total fungal count (D) (log_{10} CFU/g) of the examined milk samples on the farm.

Table 2. Incidence of milk adulteration with palm oil and formaldehyde, and urea concentrations in the examined milk samples before and after HACCP application (n=10).

		Palm oil (%)	Formaldehyde (%)	Urea mg/100ml	Antibiotic residue	Added water
TM-1	Before	40 (4/10)	ND	31.94±0.86	40 (4/10)	ND
	After	ND	ND	28.44±1.34*	ND	ND
TM-2	Before	20 (2/10)	ND	46.42±3.11	10 (1/10)	ND
	After	ND	ND	24.53±1.51*	ND	ND
TA	Before	ND	ND	52.53±2.96	ND	ND
	After	ND	ND	23.32±1.38*	ND	ND
QM-1	Before	30 (3/10)	ND	70.36±2.75	20 (2/10)	ND
	After	ND	ND	29.14±1.88*	ND	ND
QM-2	Before	ND	ND	27.60±1.53	ND	ND
	After	ND	ND	26.79±1.97	ND	ND
BM	Before	30 (3/10)	ND	51.33±5.17	30 (3/10)	ND
	After	ND	ND	30.89± 1.57*	ND	ND

* P<0.05 Values are means of 10 samples ± SD.

Table 3. Microbiological quality (log CFU/cm2) of the examined swabs before and after HACCP application.

		APC			Fungal count		
		Hand	Tank	Pipe	Hand	Tank	Pipe
TM-1	Before	6.5±0.5	5.2±0.4	5.5±0.5	1.0±0.1	2.0±0.2	1.8±0.2
	After	2.5±0.1*	3.0±0.2*	2.5±0.1*	<1	<1	<1
TM-2	Before	5.5±0.4	6.0±0.4	6.1±0.7	1.1±0.1	1.5±0.2	2.0±0.4
	After	2.4±0.2*	2.8±0.1*	2.6±0.2*	<1	<1	<1
TA	Before	6.2±0.6	5.8±0.5	6.0±0.5	1.3±0.1	1.8±0.2	2.5±0.3
	After	2.0±0.2*	3.1±0.2*	2.4±0.2*	<1	<1	<1
QM-1	Before	5.7±0.4	6.1±0.7	6.2±0.5	<1	1.0±0.1	1.5±0.2
	After	2.3±0.2*	2.5±0.2*	2.3±0.1*	<1	<1	<1
QM-2	Before	5.6±0.5	5.6±0.6	5.6±0.6	<1	1.2±0.1	2.0±0.3
	After	2.4±0.3*	2.4±0.1*	2.1±0.3*	<1	<1	<1
BM	Before	4.5±0.4	5.2±0.4	5.5±0.7	<1	1.0±0.1	1.0±0.1
	After	2.2±0.2*	2.2±0.3*	2.0±0.1*	<1	<1	<1

*Means are of significant difference when p ≤ 0.05. Values are presented as means± SE.

Table 4. Pathogenic bacteria in the examined swabs before and after HACCP application.

		E. coli			*S. aureus*		
		Hand	Tank	Pipe	Hand	Tank	Pipe
TM-1	Before	1.0±0.2	1.5±0.2	1.1±0.1	2.0±0.3	1.8±0.2	1.5±0.1
	After	<1	<1	<1	<1	<1	<1
TM-2	Before	<1	1.3±0.1	1.3±0.1	2.5±0.3	2.0±0.3	1.8±0.2
	After	<1	<1	<1	<1	<1	<1
TA	Before	1.1±0.1	1.0±0.1	1.0±0.1	2.7±0.3	2.5±0.4	1.3±0.1
	After	<1	<1	<1	<1	<1	<1
QM-1	Before	1.2±0.1	1.1±0.1	1.0±0.1	2.1±0.2	1.5±0.2	1.0±0.1
	After	<1	<1	<1	<1	<1	<1
QM-2	Before	1.5±0.1	2.0±0.2	<1	2.3±0.2	2.1±0.3	1.5±0.1
	After	<1	<1	<1	<1	<1	<1
BM	Before	1.0±0.1	1.0±0.1	<1	2.0±0.3	1.5±0.2	1.0±0.1
	After	<1	<1	<1	<1	<1	<1

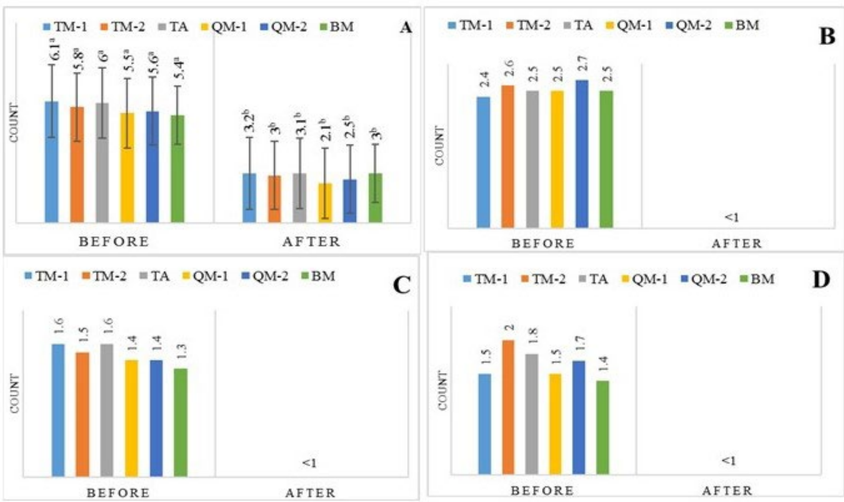

Fig. 4. Mean values of APC (A), *Staphylococcus aureus* (B), *Escherichia coli* (C) and total fungal count (D) (log10 CFU/g) of the examined bulk tank milk samples on the MCC level.

in all swab samples, as evidenced by APC and the presence of *E. coli* on workers' hands. However, after the implementation of the HACCP system, there was a significant reduction in contamination levels. The APC decreased by more than 2 logs, while *E. coli*, *S. aureus*, and fungal contamination reduced to less than 1 log CFU/g.

DISCUSSION

The milk supply chain is vulnerable to chemical and biological risks at various stages starting from the milking process to the end point of serving and consumption, which can lead to inferior quality milk or even threaten food safety (Owusu-Kwarteng *et al*., 2020). Therefore, HACCP system can be implemented as a preventive measure, that identify and analyse hazardous process points, risk factors, and potential risk levels to establish corrective control points (CCPs) for disciplinary action (Abbas *et al*., 2023). These CCPs are linked to hazards and can reduce or eliminate risks. The adaptability of the HACCP system allows it to be explicitly designed for a particular facility or system, which makes it a crucial tool for successful milk production (USFDA, 2022).

The results of this research provide an important data that can be significantly useful for future investigations into contamination pathways, and for the development of HACCP system in the field of raw buffalo milk production. This study provides insights into chemical parameters such as fat, protein, SCC, urea, and aflatoxin M1 levels, as well as possible adulteration with substances such as added water, palm oil, and formaldehyde, facilitating an assessment of the nutritional value of buffalo milk. As indicated in Table 1, after the application of the HACCP system, significant increase ($p \leq 0.05$) in the average fat and protein values of the milk samples examined, which confirms the results of Farag *et al*. (2023) and Tawfik *et al*. (2022). Conversely, Nam (2017) reported that implementation of the HACCP system had no significant impact on the fat and protein content of raw milk. These discrepancies could be due to the chemical composition of buffalo milk, which varies significantly depending on factors such as breed, climatic conditions, and lactation period (Mottram *et al*., 2022).

Chemical hazards such as mycotoxins, most notably aflatoxin M1, and antibiotic residues have also been identified as potential food hazards that could be detected in the milk of animals grazing on infected grains (Moudgil *et al*., 2019). As shown in Tables 1 and 2, the raw milk samples after HACCP application were free from chemical hazards such as aflatoxin M1 and antibiotic residues, that agree with the results of Nasr *et al*. (2017), who confirmed the possibility of contamination of raw milk with various chemical hazards prior to the enforcement of the HACCP system from raw materials during manufacturing or as a result of chemical spoilage. After HACCP implementation, the raw milk obtained was free of these chemical hazards. In addition, Nirwal *et al*. (2013) noted that positive detection of aflatoxin M1 and antibiotic residues is considered a serious problem, as adulterated milk originates mainly from feed contaminated with aflatoxin-producing fungi and/or mastitis treatment by intramammary infusion of antibiotics.

Implementing the HACCP system in dairy farms has been associated with improving of farm hygiene practices, that help in controlling animal diseases, increase productivity and reduce the risk of foodborne infections through the application of the pre-requisite programs such as good agriculture practices (GAP) and good hygienic practices (GHP) (MAFF, 2022).

Milk somatic cell count (SCC) is considered a key factor in grading milk quality standards for mastitis and, hence, milk safety (Mottram *et al*., 2022). Bacterial and somatic cell counts can be influenced by several variables, including mastitis management and hygienic management protocols on dairy farms. Table (1) revealed that, with the enforcement of the HACCP system, the number of SCC in the examined milk samples decreased significantly, which came consistent with the findings of Daneluz *et al*. (2020) and Mihajlović *et al*. (2022) who recorded that applying the HACCP program on dairy producing establishments could result in higher milk quality with a reduction in SCC and total bacterial count.

The high average of SCC and bacterial counts may be caused by soiled animals, particularly those with dirty udders and teats, subclinical mastitis from improper teat sanitation, poor cooling conditions, and inadequate milk tank disinfection. Additionally, dirty animals and hot, humid weather encourage microbial growth, which negatively impacts the health of the udder and increases exposure to mastitis pathogens, resulting in a high prevalence of mastitis, which have been reported to be controlled after HACCP application (Cheng and Han, 2020).

However, the application of the HACCP system has been shown to significantly reduce the levels of adulterants such as urea and palm oil in raw milk, it is extremely dangerous and could result in food poisoning, gastrointestinal issues, cardiac issues, and even cancer, which was estimated to contribute in about 87% of developing cancer by 2025 (Chauhan *et al*., 2019). Additionally, toxic preservatives such as formaldehyde are sometimes added to milk to extend its shelf life, although this can lead to serious health consequences, such as hepatic and renal failure or cancer (Adeela *et al*., 2014).

According to the recorded results in Table 2, strict monitoring of HACCP program on the dairy farms and MCCs eliminated the previously recorded milk adulteration with urea, palm oil, formaldehyde, antibiotic residues, and additional water, which came in line with the recorded results of Poonia *et al*. (2016) and Brindha *et al*. (2017).

Milk in dairy farms can be loaded with different microorganisms from various sources such as the udder and teats, milking equipment, and mastitis pathogens within the udder. High microbial counts are often due to poor hygiene during milk handling, ineffective sanitation, and lack of proper training for workers. The HACCP system plays a significant management role in controlling the microbial risks of raw milk. Referring to the current results, implementation of HACCP system in raw milk production at the dairy farm and MCCs led to significant improvement in the microbiological quality with notable reduction in the microbial counts; which came in line with the findings of Abbas *et al*. (2023) who found a noticeable reduction in TBC, coliforms, *E. coli*, and *S. aureus* after the implementation of HACCP, leading to a marked improvement in milk microbial quality. Notably, *Salmonella* and Listeria were not detected in any milk sample before or after HACCP system implementation.

The current study found that the examined farm's milk samples had higher levels of microbial contamination compared to those from milk collection centers, likely due to the protective measures employed by MCCs such as quick cooling, strict hygiene, and pasteurization processes. The results obtained align with the findings of Meshref *et al*. (2021), who observed higher bacteriological counts in farm milk samples. However, this contradicts the findings of Tobar-Delgado *et al*. (2020) who reported higher bacterial counts in the MCC than at farm level. The quality of farm-produced milk is largely determined by farm management practices that affect the initial microbial load of raw milk at the farm level.

Referring to the current obtained results of the microbiological quality (CFU/mL) of the collected milk samples, results came in line with those of Senarath and Adikari (2017) (TBC= $6.3x10^6$ and $3.3x10^6$ for tank and farm milk samples from Sri Lanka, respectively), and El-Shinawy *et al*. (2020) ($5.7x10^6$, $6.7x10^2$ for TBC and *S. aureus* counts, while higher fungal count was detected ($7.9x10^4$) for farm raw milk samples from Egypt). Lower results of count were previously recorded by Chorfi *et al*. (2020) ($3.7x10^5$ and $1.36x10^3$ for TBC and fungal count in Algeria, respectively); Tobar-Delgado *et al*. (2020) ($4.1x10^4$ in Colombia), and Deepthi and Siriwardhana (2021) ($1.5x10^6$ from Sri Lanka) for farm raw milk; and Tekilegiorgis (2018) ($8.1x10^4$ from Ethiopia) for bulk tank samples. While, higher results were mentioned by Ebissa and Aki (2017) ($1.2x10^7$ and 2.6x10 CFU/mL in farm and bulk tank samples, respectively); Mchiouer *et al*. (2017) (TBC and *S. aureus* counts ranged from $1.7x10^6$ to $3.1x10^7$ and $3x10^2$ to $3x10^6$ in the examined bulk milk samples in Morocco, respectively); Yeserah (2019) ($1.2x10^7$, $1.3x10^4$ and $2.3x10^3$ for TBC, fungal count and *S. aureus* count in the examined samples from Ethiopia, respectively in farm milk samples), indicating differences in milk quality standards and farming practices across regions.

Factors such as contamination, high ambient temperatures, failure to maintain a cold chain during transport, and unsanitary milking practices can contribute to a high bacterial count in raw milk (Kakati *et al*., 2021). The absence of cold chain maintenance by milk vendors can further increase microbial growth in the milk due to its favorable environment with suitable pH, high water activity, and excellent growth medium.These variations in TBC, fungal count, and *S. aureus* count across different studies highlight the impact of factors such as collection season, collection points, and hygiene measures implemented at these points on the microbial quality of milk (Meshref *et al*., 2021).

The screening for pathogenic bacteria detection in raw milk samples revealed absence of *Salmonella* species, *Listeria monocytogenes*, *Bacillus cereus*, and *Clostridium perfringens*. This aligns with the findings of Assy *et al*. (2022), but contradicts Msalya (2017) results, who identified various food poisoning bacteria in the milk samples tested in Tanzania. Proactive strategies, such as the adoption of good hygiene practices and procedures applied in HACCP system, are primarily utilized to guarantee food safety through enhancing safety and hygienic standards (Owusu-Kwarteng *et al*., 2020).

As was shown in the current recorded results of the microbiological quality of the examined milk samples (Figures 3 and 4), and the environmental hygienic quality represented by the examined swabs (Tables 3 and 4) before and after HACCP implementation, significant lower microbial counts were recorded after HACCP application and the prerequisite practices. The current study showed the importance of the implementation of HACCP and assumed practices to improve hygienic quality of milk in MCC. This aligns with the findings of Nam (2017) and Nada *et al*. (2022), who also reported a significant improvement in raw milk quality and safety after HACCP application.

CONCLUSION

The implementation of the HACCP system has been shown to play a crucial role in improving the overall quality of raw milk, both in terms of its physical and chemical properties and its microbiological safety. This is particularly important as raw milk may be contaminated with several hazards, either chemical or microbiological in nature. By applying HACCP principles, farmers and producers can work to identify and mitigate potential risks, ensuring their raw milk is of the highest possible quality.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFERENCES

Abbas, S., Khan, M., Naqvi, A., Kaif, K., Tabassum, N., Mirani, Z., Khan, A., Siddiqui, A., Hussain, M., 2023. Hazard analysis critical control point (HACCP) system implementation in the dairy supply chain (Karachi-Pakistan). J. Food Nutr. Res. 11, 244-250.

Adeela, A., Misbah, N., Ali, A., Rehana, M., Furhan, A., 2014. A study on chemical composition and detection of chemical adulteration in tetra pack milk samples commercially available in Multan. Pak. J. Pharma. Sci. 27, 183.

Assy, R., El-Sayed, M., Abdelkhalek, A., Kasem, N., El-Baz, A., 2022. Application of HACCP system to food preparation and services kitchens in Mansoura University hostels. Mansoura Vet. Med. J. 23, 40-47.

Attrey, D.P., 2017. Role of risk analysis and risk communication in food safety management. Food Safety in the 21st Century. 2017, 53–68.

Brindha, N., Chitra, P., Janarthanan, R. and Murali, A., 2017. A Study on detection of adulteration in milk samples from different regions of Thuraiyur district in Tamil Nadu, India. Int. J. Curr. Microbiol. App. Sci. 6, 3303-3310.

Chauhan, S.L., Priyanka, Mandal, K.D., Paul, B.R., Maji, C., 2019. Adulteration of milk: A Review. Int. J. Chem. Stud. 7, 2055-2057.

Cheng, W.N., Han, S.G., 2020. Bovine mastitis: risk factors, therapeutic strategies, and alternative treatments-A review. Asian-Australasian J. Anim. Sci. 33, 1699-1713.

Chorfi, K., Bendjemana, K., Ayachi, A., Mahdi, F., Bouzidi, N.A., 2020. Effect of using treated wastewater on the bacteriological quality of raw cow's milk: A case of a farm in Northeastern Algeria. African J. Microbiol Research., 14, 436-446.

Daneluz, M.O., Canever, M.D., Lima, H. G.D., Bermudes, R.F., Ribeiro, F.G., 2020. Effectiveness of milking management practices for SCC and TBC levels in milk. RevistaBrasileira de Zootecnia 49, 20190130.

Deepthi, G., Siriwardhana, B., 2021. Evaluation of microbiological and compositional quality of raw cow's milk (household and bulk) in Lankapura, Polonnaruwa, Sri Lanka. Europ. J. Agricult. Food Sci. 3, 166-175.

Dragacci S., Grosso F., Gilbert J., 2001. Immunoaffinity column cleanup with liquid chromatography for determination of aflatoxin M1 in liquid milk: collaborative study. Journal of AOAC International 84, 437-443.

Ebissa, T., Aki, A., 2017. Bacteriological quality assessment of raw cow's milk in and around Asossa, Ethiopia. Biomed. Nurs. 3, 69-80.

El-Shinawy, S.H., ElKholy, A.M., Zeinhom, M.M., 2020. Quality assurance of yoghurt during processing. Bs. Vet. Med. J. 6th Sci. Conf. 20, 1, 188-194.

El-Shinawy, S.H., Hassan, G.S., El-Shater, M.A., Abd El-Aziz, S., 2018. Studies on some milk borne pathogens. Assiut Vet. Med. J. 64, 159, 12-20.

FAO (Food and Agriculture Organization) 2009. Food hygiene: Basic text. 4th Ed., available at: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj.

Farag, M.A., Ashaolu, T.J., Guirguis, H., Khalifa, I., 2023. Implementation of HACCP in the production of Egyptian cheeses: A review. Food 4, 69.

ILO (International Labour Organization) 2020. Developing the dairy value chain in Egypt's delta. Accessed in 2 Sept., 2023. https://www.ilo.org/wcmsp5/groups/public/---africa/---ro-abidjan/---sro-cairo/documents/publication/wcms_754764.pdf

ISO (International Organization for Standardization), 2003. International Organization for Standardization No. 6888-1:1999 + A1:2003. Microbiology of food and animal feeding stuffs-Horizontal method for the enumeration of coagulase-positive staphylococci (*Staphylococcus aureus* and other species) Part 1: Technique using Baird-Parker agar medium

ISO (International Organization for Standardization), 2006. International Organization for Standardization. 13366-2:2006 | IDF 148-2:2006. Milk — Enumeration of somatic cells — Part 2: Guidance on the operation of fluoro-opto-electronic counters.

ISO (International Organization for Standardization), 2008. No.21527-1. Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of yeasts and moulds — Part 1: Colony count technique in products with water activity greater than 0.95.

ISO (International Organization for Standardization), 2017. International Organization for Standardization. No. 11290-1. Microbiology of the food chain — Horizontal method for the detection and enumeration of *Listeria monocytogenes* and of Listeria spp. — Part 1: Detection method.

ISO (International Organization for Standardization), 2017. International Organization for Standardization. No.6579-1. Microbiology of the food chain Horizontal method for the detection, enumeration and serotyping of *Salmonella* - Part1: Detection of *Salmonella* spp.

ISO (International Organization for Standardization), 2017. International Organization for Standardization. No.6887-1. Microbiology of the food chain — Preparation of test samples, initial suspension and decimal dilutions for microbiological examination — Part 1: General rules for the preparation of the initial suspension and decimal dilutions.

ISO (International Organization for Standardization), 2020. International Organization for Standardization. No. 7932:2004/AMD 1: 2020. Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of presumptive *Bacillus cereus* — Colony-count technique at 30 degrees C — Amendment 1: Inclusion of optional tests.

ISO (International Organization of Standardization), 2004. International Organization for Standardization No.7937. Microbiology of food and animal feeding stuffs — Horizontal method for the enumeration of Clostridium Perferingens- Colony-count technique.

ISO (International Organization of Standardization), 2013. International Organization for Standardization No.4833-1. Microbiology of the food chain — Horizontal method for the enumeration of microorganisms — Part 1: Colony count at 30°C by the pour plate technique.

ISO (International Organization of Standardization), 2001. International Organization for Standardization. No.16649, part 2. Microbiology of food and animal feeding stuffs –Horizontal method for the enumeration of glucuronidase-positive *Escherichia coli*.

ISO (International Organization of Standardization), 2018. No. 22000. Food safety management systems — Requirements for any organization in the food chain.

Kakati, S., Talukdar, A., Hazarika, R.A., Raquib, M., Laskar, S.K., Saikia, G.K., Hussein, Z., 2021. Bacteriological quality of raw milk marketed in and around Guwahati city, Assam, India. Vet. World 14, 3, 656-660.

MAFF (Ministry of Agriculture Forestry and Fisheries), 2022. The improvement of the breeding hygiene management standard in the stage of production of the domestic animal. http://www.maff.go.jp/j/syouan/douei/katiku_yobo/k_haccp/index.htmL [accessed March 11, 2022].

Mchiouer, K., Bennani, S., El-Gendy, N.S., Meziane, M., 2017. Evaluation of the Hygienic Quality of RawCow's Milk in Oujda City Morocco. Biosci. Biotech. Res. Asia 14, 587-591.

Melini, F., Melini, V., Luziatelli, F., Ruzzi, M., 2017. Raw and heat-treated milk: From public health risks to nutritional quality. Beverages 3, 54-87.

Meshref, A., Hassan, G., Tamam, M., 2021. Bacteriological quality of raw milk in Beni-Suef governorate, Egypt. J. Vet. Med. Res. 28, 45-51.

Mihajlović, L., Cincović, M., Nakov, D., Stanković, B., Miočinović, J., Hristov, S., 2022. Improvement of hygiene practices and milk hygiene due to systematic implementation of preventive and corrective measures. Acta Veterinaria 72, 76-86.

Mottram, F., Den, T.T., Uijl, I., 2022. Health and welfare monitoring of dairy cows. Digital Agritechnology: Robotics and Systems for Agriculture and Livestock Production, pp. 113–142.

Moudgil, P., Bedi, J.S., Aulakh, R.S., Gill, J.P.S., 2019. Antibiotic residues and mycotoxins in raw milk in Punjab (India): a rising concern for food safety. J. Food Sci. Technol. 56, 5146-5151.

Msalya, G., 2017. Contamination levels and identification of bacteria in milk sampled from three regions of Tanzania: Evidence from literature and laboratory analyses. Vet. Med. Int. 2017, 9096149.

Nada, S., Abd-Elaaty, E., Gaffer, M., 2022. HACCP system application to enhance milk quality in some collecting centers at El Menofiya governorate, Egypt. Egypt. J. Anim. Hlth. 2, 62-70.

Nam, I.S., 2017. Effects of HACCP system implementation on reproduction, milk quality, and milk sanitation on dairy farms in Korea. Emirates J. Food Agricult. 29, 685-689.

Nasr, N.F., El-Gizawy, S.A., Zahra, M.K., 2017. Application of quality assurance programs in small dairy plants. J. Nutr. Hlth Food Eng. 7, 214-220.

Nirwal, S., Pant, R., Rai, N., 2013. Analysis of milk quality, adulteration and mastitis in milk samples collected from different regions of Dehradun. Int. J. Pharm. Tech. Res. 5, 359-364.

Orwa, J.D., Matofari, J.W., Muliro, P.S., 2017. Handling practices and microbial contamination sources of raw milk in rural and peri urban small holder farms in Nakuru County, Kenya. Int. J. Livestock Prod.

8, 5-11.
Owusu-Kwarteng, J., Akabanda, F., Agyei, D., Jespersen, L., 2020. Microbial safety of milk production and fermented dairy products in Africa. Microorganisms 8(5), 752.
Poonia, A., Jha, A., Sharma, R., Singh, H., Rai, A.K., Sharma, N., 2016. Detection of adulteration in milk: A review. Int. J. of Dairy Tech. 70, 1, 23-42.
Senarath, H., Adikari, A., 2017. Microbiological quality of raw milk at selected chilling centers in Anuradhapura district of Sri Lanka. Int. J. Sci. Res. Public. 7, 328- 333.
Sharma, R., Gandhi, K., Battula, S.N., Mann, B., 2020. Detection of milk fat adulteration. In: Dairy Fat Products and Functionality, Ch. 6, T. Truong (Ed.), Springer Nature Switzerland AG, pp.109-131.
Tawfik, E.M., Elsherbini, M., Kasem, N.G., ElMetwaly, M.F., Abdelkhalek, A.A., 2022. Effect of food safety management practices on milk quality and subclinical mastitis in dairy cow farms. J. Adv. Vet. Res. 12, 371-378.
Tekilegiorgis, T., 2018. Microbiological quality analysis of raw and pasteurized milk samples collected from Addis Ababa and its surrounding in Ethiopia. Approaches in Poultry, Dairy and Veterinary Sciences 4, 374-381.
Tobar-Delgado, M.E., Rodríguez-Bautista, J.L., Patiño-Burbano, R.E., Argote-Vega, F.E., Castro-Rincón, E., Mogollón-García, H., 2020. Quality of raw milk in the highland tropics of Nariño, Colombia. Agronomía Mesoamericana 13, 695-707.
USFDA (US Food and Drug Administration), 2022. HACCP principles and application guidelines. Accessed., 2023. Available at: https://www.fda.gov/food/hazard-analysis-critical-control-point-haccp/haccp-principles-application-guidelines
Yeserah, B., 2019. Microbiological quality of raw cow’s milk in and around Bahir Dar City, Ethiopia. Food Sci. Qual. Manage. 8, 1-10.