Volume 11, Issue 5, May – 2026 International Journal of Innovative Science and Research Technology
ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may269

Resource-Efficient Programmable Logic Controller Based Clean-in-Place Automation for Sustainable Dairy Processing

Ranganathan S.[1]; Athappan V.[2]; Venkata Prasath D.[3]

[1]Assistant Professor, Department of Electronics & Instrumentation Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India.
[2]Assistant Professor, Department of Electronics & Instrumentation Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India.
[3]Student, Department of Electronics & Instrumentation Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India.

Publication Date: 2026/05/14

Abstract: Clean-in-place (CIP) systems are essential for maintaining hygiene and food safety in dairy processing plants; however, conventional CIP operations are often resource-intensive and highly dependent on operator intervention. This study presents the design, implementation, and analytical evaluation of a fully automated CIP system controlled by a Siemens programmable logic controller (PLC) and human–machine interface (HMI) for an industrial dairy processing facility. The developed system integrates four dedicated cleaning media tanks (normal water, hot water, acid, and caustic), three process tanks operating in cyclic mode, and multiple CIP strategies, including three-stage, five-stage, and seven-stage cleaning sequences. Automation logic incorporates retentive timers, RTD-based temperature-controlled hot water recirculation, and selective reuse of rinse water to enhance sustainability and operational consistency. System performance was analytically compared with conventional manual CIP practices using standard industry operating conditions. The automated CIP system achieved reductions of approximately 20–25% in CIP cycle time, 35–40% in water consumption, and 30–35% in energy usage. In addition, standardized sequencing and closed-loop temperature control improved cleaning repeatability and minimized operator dependency. The results demonstrate that industrial-scale PLC-based automation provides a practical, scalable, and industry-ready solution for sustainable CIP implementation in dairy processing plants.

- ***Graphical Abstract:***

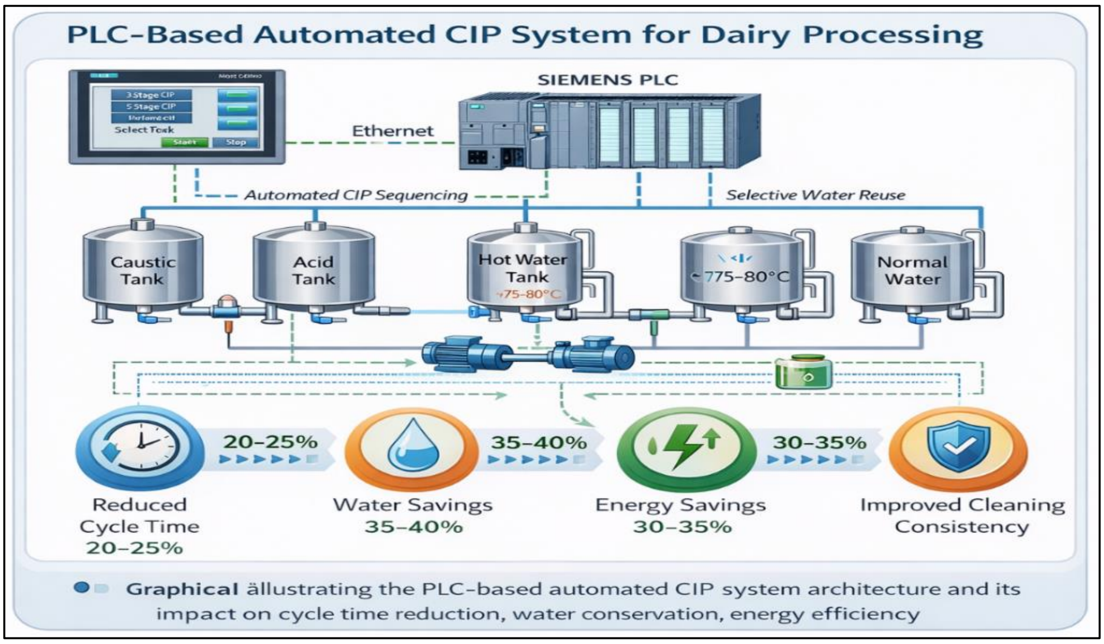

Fig 1 PLC-Based Automated CIP System for Dairy Processing

➢ ***Highlights:***

- **Fully automated PLC-based CIP system implemented in an industrial dairy plant.**
- **Multiple CIP strategies (three-stage, five-stage, and seven-stage) integrated in a single platform.**
- **Water consumption reduced by approximately 35–40% through selective rinse reuse.**
- **Energy usage reduced by 30–35% using RTD-based temperature-controlled recirculation.**
- **Improved cleaning consistency and elimination of operator dependency.**

Keywords: *Clean-in-Place (CIP); Dairy Processing; PLC Automation; Water and Energy Conservation; Process Hygiene; Industrial Sanitation.*

How to Cite: Ranganathan S.; Athappan V.; Venkata Prasath D. (2026) Resource-Efficient Programmable Logic Controller Based Clean-in-Place Automation for Sustainable Dairy Processing. *International Journal of Innovative Science and Research Technology*, 11(5), 147-153. https://doi.org/10.38124/ijisrt/26may269

I. INTRODUCTION

Clean-in-place (CIP) systems are critical to hygiene management in dairy processing facilities, enabling the effective removal of milk residues, fouling deposits, and microbial contaminants from tanks, pipelines, and heat exchangers without equipment dismantling. Proper CIP implementation is essential to ensure food safety, reduce post-pasteurization contamination risks, and maintain regulatory compliance (Asming et al., 2024). However, CIP operations are also among the most resource-intensive processes in dairy plants, contributing significantly to overall water, energy, and chemical consumption (Barton et al., n.d.).

In many dairy industries, CIP operations remain partially or fully manual, relying on operator judgment to determine cleaning sequence, temperature, flow rate, and duration. Such practices often result in excessive rinsing, inconsistent cleaning performance, uncontrolled heating, and increased wastewater generation, leading to higher operating costs and environmental burden (Chung et al., 2023; Maintenance Engineer's Role…, n.d.). These inefficiencies are particularly critical in regions facing water scarcity and rising energy costs.

Recent research efforts have focused on enhancing CIP sustainability through experimental optimization and advanced modeling techniques. Laboratory-scale studies have demonstrated that cleaning efficiency depends strongly on temperature, chemical concentration, turbulence, and contact time (Cvetković et al., 2025; Espíndola et al., 2023). More recently, artificial intelligence (AI) and multi-objective optimization approaches have been applied to CIP systems, reporting substantial reductions in water consumption and cleaning time under controlled conditions (Geetha et al., n.d.). Despite these promising results, the practical implementation of such methods in full-scale dairy plants remains limited due to data requirements, system complexity, and integration challenges.

Industrial dairy operations require robust, scalable, and easily deployable solutions capable of continuous operation under real production constraints. PLC-based automation provides a proven industrial framework to standardize CIP execution, eliminate operator dependency, and enable intelligent reuse of cleaning media through systematic control of pumps, valves, and heating systems (Jaradat et al., 2025).

The objective of the present study is to design, implement, and evaluate a fully automated PLC-controlled CIP system for an industrial dairy processing facility. The system integrates multiple CIP strategies (three-stage, five-stage, and seven-stage), temperature-controlled hot water recirculation, and selective reuse of rinse water to enhance sustainability. System performance is analytically compared with conventional manual CIP practices in terms of water consumption, energy usage, process time, and cleaning consistency.

The remainder of this paper is organized as follows. Section 2 reviews relevant literature on clean-in-place systems, sustainability challenges, and recent optimization and automation approaches in dairy processing. Section 3 describes the materials and methods, including the system configuration, PLC–HMI-based automation architecture, CIP sequence design, and analytical basis for performance evaluation. Section 4 presents the results, focusing on reductions in CIP cycle time, water consumption, energy usage, and improvements in cleaning consistency achieved by the automated system. Section 5 discusses the results in the context of existing literature and industrial applicability. Finally, Section 6 summarizes the main conclusions and highlights the practical significance of the proposed automated CIP system for sustainable dairy processing.

II. LITERATURE REVIEW

CIP system performance has traditionally been investigated from the perspective of cleaning chemistry, fouling mechanisms, and hydrodynamic conditions. Early studies established that effective soil removal depends on the combined action of chemical agents, mechanical force, temperature, and exposure time (Cvetković et al., 2025). Optimization of alkaline and acidic cleaning parameters has been shown to significantly improve the removal of milk fouling deposits (Kowalska, 2024).

With increasing environmental concerns, research focus has shifted toward reducing water and energy consumption in CIP operations. Several studies have explored pulsed flow

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may269

cleaning, variable flow rates, and turbulence enhancement techniques to improve cleaning efficiency while reducing water usage (Espíndola et al., 2023; Liu et al., 2020). Laboratory-scale and benchtop systems have been widely used to evaluate detergent formulations and cleaning performance under controlled conditions (Mpongwana et al., 2024).

Water reuse and wastewater minimization have also gained attention in recent years. Membrane-based recovery of cleaning solutions and process water reuse strategies have been proposed to reduce freshwater demand and effluent discharge in dairy plants (Pant et al., 2023; Pant et al., 2025a). These approaches highlight the importance of integrating CIP optimization with broader water management strategies.

Advanced computational and AI-based techniques have recently been applied to CIP optimization. Machine learning models, including recurrent neural networks combined with multi-objective optimization algorithms, have demonstrated significant reductions in water consumption and rinsing time under laboratory conditions (Geetha et al., n.d.; Pant et al., 2025b). However, such approaches often focus on isolated CIP stages and require extensive experimental datasets, limiting their scalability for industrial implementation.

PLC-based automation has been reported as an effective means of improving CIP repeatability, safety, and operational reliability (Jaradat et al., 2025; van Asselt et al., n.d.). Nevertheless, comprehensive studies describing industrial-scale automated CIP systems that integrate multi-stage cleaning strategies, real-time temperature control, and systematic reuse of cleaning media remain limited in the literature. The present work addresses this gap by demonstrating a practical, automation-driven CIP system implemented in a real dairy processing environment.

III. MATERIALS AND METHODS

➢ *System Configuration*

The CIP system was implemented in an industrial dairy plant and comprises four dedicated cleaning media tanks—normal water, hot water, acid, and caustic solution—each with a capacity of 15,000 L, as illustrated in Figure 1. All tanks are equipped with high-level and low-level sensors to prevent overflow and dry running, while the hot water tank includes a resistance temperature detector (RTD) to enable continuous temperature monitoring and closed-loop control. Three process tanks are connected to the CIP system and operate in a cyclic manner, with one tank under production, one undergoing CIP, and one maintained in a cleaned and ready state. Each process tank is fitted with an individual return pump to enable controlled recirculation of cleaning media during CIP, as shown in Figure 1.

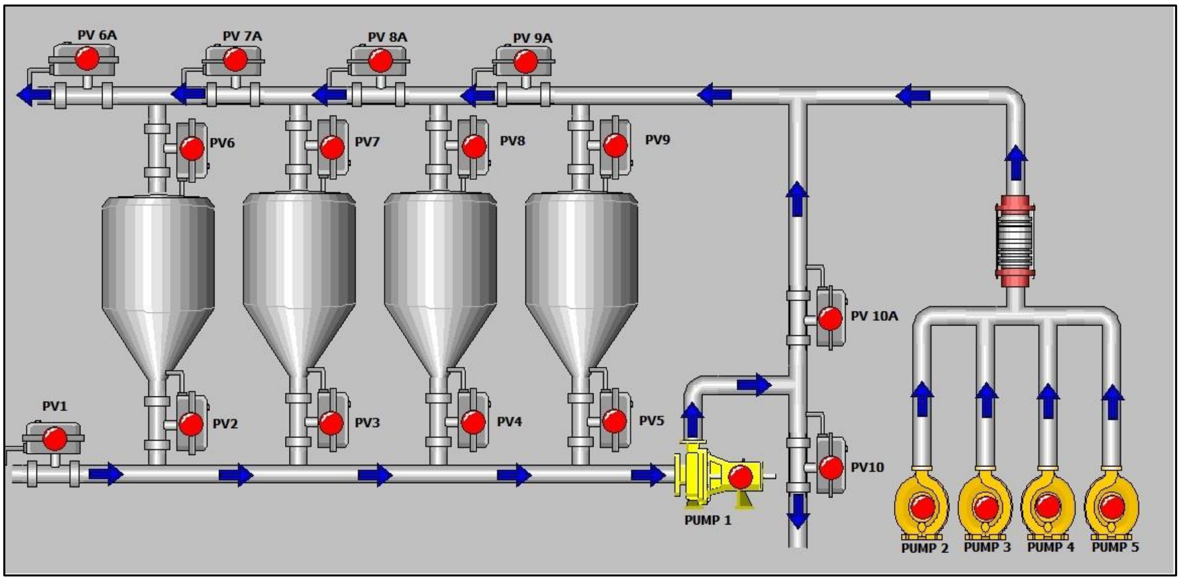

Fig 2 Schematic of the PLC-Based Automated CIP System.

➢ *Automation Architecture*

The CIP system is controlled using a Siemens programmable logic controller (PLC) integrated with a human–machine interface (HMI). Solenoid valves installed at tank inlets and outlets allow precise routing of cleaning media. A main pump delivers cleaning media to the selected process tank, while a parallel outlet enables recirculation through a heater when temperature correction is required.

Operators select the desired CIP mode (three-stage, five-stage, or seven-stage) through the HMI. All CIP sequences are executed automatically once predefined home conditions are satisfied, including sufficient tank levels and hot water temperature readiness.

➢ *CIP Sequence Design and Media Reuse Strategy*

Each CIP mode consists of combinations of pre-rinse, alkaline wash, acidic wash, intermediate rinses, hot water rinse, and final rinse, with stage durations controlled using retentive timers to ensure consistent contact times, even during temporary process interruptions, as summarized in Table 1. A key sustainability feature of the system is selective

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may269

reuse of cleaning media, whereby highly contaminated pre-rinse water is routed to wastewater treatment, while subsequent hot water and normal water rinses are returned to their respective tanks for reuse in subsequent CIP cycles (Table 1). Temperature-based interlocks further ensure that reused hot water maintains the required thermal conditions through controlled recirculation via the heater.

Table 1 Summary of CIP Stages, Cleaning Media, Operating Duration, and Reuse Strategy

CIP Stage	Cleaning Medium	Typical Duration (min)	Temperature Condition	Reuse / Discharge Strategy
Pre-rinse	Normal water	10	Ambient	Discharged to wastewater recycling (high contamination)
Alkaline wash	Caustic solution	20	Ambient / Heated if required	Recirculated to caustic tank for reuse
Intermediate rinse	Normal water	10	Ambient	Reused and stored in normal water tank
Acid wash	Acid solution	20	Ambient	Recirculated to acid tank for reuse
Hot water rinse	Hot water	20	Controlled (≈ 75–80 °C)	Reused and stored in hot water tank
Final rinse	Normal water	10	Ambient	Reused; discharged after multiple cycles based on quality

The Table 1. illustrates the sequential clean-in-place (CIP) stages, operating durations, temperature conditions, and media reuse or discharge strategy. The approach prioritizes discharge of highly contaminated pre-rinse water while enabling controlled reuse of alkaline, acidic, hot water, and final rinse stages to reduce overall water and energy consumption without compromising cleaning effectiveness.

- *Basis for Analytical Estimation of Water and Energy Savings*

The water and energy performance values reported in Table 2 and Table 3 were derived through analytical estimation based on the implemented CIP sequence logic, stage durations, and media routing strategy of the automated system.

Table 2 Water Usage Comparison per CIP Cycle for One Process Tank

CIP Type	Manual CIP Water Consumption (L)	Automated CIP Water Consumption (L)	Water Saved (%)
Three-stage CIP	~9,000	~5,500	~39
Five-stage CIP	~15,000	~9,200	~38
Seven-stage CIP	~21,000	~13,000	~38

Manual CIP water consumption was estimated assuming freshwater usage for each rinse stage, continuous discharge without reuse, and extended rinsing durations due to operator-dependent safety margins. In contrast, automated CIP water consumption was calculated by accounting for selective reuse of hot and normal water stages, controlled valve routing, and elimination of over-flushing. Energy consumption estimates were derived from comparative heater operating time and pump runtime under manual and automated operation, considering RTD-based temperature interlocks and optimized sequencing. This analytical approach is widely adopted in industrial case studies when full-scale experimental trials are not feasible and provides a realistic comparison of resource efficiency under typical dairy plant operating conditions.

Table 3 Approximate Energy Consumption Comparison Between Manual and Automated CIP Systems

Parameter	Manual CIP	Automated CIP	Reduction (%)
Heater ON time	~100% of cycle	~60–65% of cycle	~35–40
Pump runtime	High (manual delays and overrun)	Optimized by sequencing	~20
Overall energy consumption	Baseline	Reduced	~30–35

IV. RESULTS

- *Reduction in CIP Cycle Time*

Automation eliminated operator-induced delays between CIP stages and ensured immediate transition between cleaning steps. Across all CIP modes, total cycle time was reduced by approximately 20–25% compared to manual CIP operation, as shown in Table 4. The most significant reductions were observed in five-stage and seven-stage cleaning sequences, where manual operation typically introduces extended idle periods and longer safety margins.

Table 4 Comparison of CIP Cycle Time Between Manual and Automated Operation

CIP Mode	Manual CIP Cycle Time (min)	Automated CIP Cycle Time (min)	Cycle Time Reduction (%)
Three-stage CIP	55–65	42	23–28
Five-stage CIP	90–100	72	20–25
Seven-stage CIP	125–140	102	18–22

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may269

Specifically, the PLC-based automated CIP system reduced cycle time by approximately 23–28% for three-stage CIP, 20–25% for five-stage CIP, and 18–22% for seven-stage CIP. These improvements were primarily achieved through elimination of operator-dependent delays, optimized sequencing, and fixed cleaning durations.

➢ *Water Consumption Reduction*

Selective reuse of hot and normal water significantly reduced freshwater intake in the automated CIP system. Analytical evaluation indicated a reduction of approximately 35–40% in total water consumption per CIP cycle, depending on the selected cleaning mode. These reductions are consistent with sustainability targets reported for dairy wastewater management (Barton et al., n.d.; Pant et al., 2023). Table 3 presents a comparison of water consumption per CIP cycle for manual and automated operation, highlighting the impact of selective reuse of rinse media.

As shown in Table 3, the automated CIP system substantially reduced freshwater consumption across all CIP modes compared to manual operation. Water savings of approximately 38–39% were achieved for three-stage, five-stage, and seven-stage CIP cycles due to controlled reuse of hot and normal water rinses and elimination of continuous discharge. The consistency of water savings across different CIP modes indicates that the proposed automation strategy effectively minimizes freshwater usage irrespective of cleaning complexity.

➢ *Energy Consumption Reduction*

Energy savings were achieved through RTD-based temperature control and reuse of hot water across multiple CIP cycles. Heating was activated only when the temperature dropped below the setpoint, preventing unnecessary energy consumption. Overall energy usage was reduced by an estimated 30–35% compared to conventional manual CIP systems, aligning with findings on controlled thermal management in dairy processing (Reichler et al., 2020). Table IV. Shows the approximate comparison of energy-related parameters for manual and PLC-based automated CIP systems.

➢ *Cleaning Consistency and Operational Reliability*

The automated CIP system ensured fixed contact times, controlled temperatures, and standardized cleaning sequences for all cycles. This eliminated variability associated with manual operation and improved repeatability, which is critical for minimizing contamination risks and ensuring consistent hygiene performance (Asming et al., 2024).

V. DISCUSSION

The results demonstrate that significant improvements in CIP sustainability can be achieved through industrial automation without reliance on advanced AI-based optimization algorithms. While laboratory-scale studies using machine learning and multi-objective optimization report higher percentage reductions under controlled conditions (Geetha et al., n.d.; Taneja et al., 2023), such studies often focus on isolated CIP stages and require extensive experimental datasets.

In contrast, the present system delivers substantial absolute reductions in water and energy consumption under real industrial conditions. The reuse of rinse media directly addresses wastewater generation challenges commonly reported in dairy plants (Barton et al., n.d.), (Chung et al., 2023) and complements membrane-based recovery strategies proposed in recent literature (Pant et al., 2025a).

The integration of multiple CIP strategies within a single automated framework allows operational flexibility, enabling plant operators to select appropriate cleaning intensity based on process conditions. This adaptive capability is consistent with recommendations for future-ready CIP systems (Jaradat et al., 2025).

From a food safety perspective, improved repeatability and reduced operator dependency enhance sanitation reliability and reduce the risk of post-pasteurization contamination and disinfectant misuse (Asming et al., 2024; Szpicer et al., 2023). A comparative assessment of key cleaning performance parameters between manual and automated CIP operation is summarized in Table 5.

Table 5 Comparative Assessment of Cleaning Effectiveness Between Manual and Automated CIP

Parameter	Manual CIP	Automated CIP System
Contact time	Operator dependent	Fixed and validated (10–20 min)
Temperature control	Uncontrolled / variable	RTD-based closed-loop control
Cleaning sequence	Variable	Standardized and interlocked
Repeatability	Low	Very high

Overall, PLC-based automation provides a practical and scalable pathway to bridge the gap between laboratory-scale CIP optimization research and industrial implementation.

VI. CONCLUSION

In this study, a fully automated clean-in-place (CIP) system controlled by a Siemens programmable logic controller (PLC) and human–machine interface (HMI) was successfully designed and implemented in an industrial dairy processing facility. The system integrates multiple CIP strategies, including three-stage, five-stage, and seven-stage cleaning sequences, along with intelligent reuse of cleaning media and temperature-controlled hot water recirculation using RTD-based feedback. These features enabled consistent execution of validated cleaning cycles while eliminating variability associated with manual operation.

Analytical evaluation of system performance demonstrated that the automated CIP system achieved substantial improvements in resource efficiency compared to conventional manual CIP practices. Reductions of approximately 35–40% in water consumption were achieved through selective reuse of hot and normal water rinses, while energy usage was reduced by 30–35% due to controlled heater operation and reuse of heated water across multiple CIP cycles. In addition, total CIP cycle time was reduced by approximately 20–25% as a result of optimized sequencing, retentive timing, and elimination of operator-induced delays.

Beyond measurable resource savings, the automated CIP system significantly improved cleaning consistency and operational reliability. Standardized sequencing, fixed contact times, and closed-loop temperature control ensured repeatable sanitation performance and minimized the risk of human error. The results confirm that industrial-scale PLC-based automation provides a practical, scalable, and industry-ready solution for sustainable CIP implementation in dairy processing plants. By focusing on robust control logic rather than complex computational models, the proposed approach effectively bridges the gap between laboratory-scale optimization studies and real-world industrial sanitation requirements.

While the developed system demonstrates strong performance in terms of automation and resource efficiency, several opportunities exist for further enhancement and validation. Future work may include integration of online cleanliness monitoring techniques, such as conductivity, turbidity, or ATP-based sensors, to enable real-time end-point detection and adaptive CIP termination. This would allow further reduction of water and energy consumption without compromising hygiene standards.

In addition, the incorporation of data logging and industrial analytics could support long-term performance monitoring, predictive maintenance, and benchmarking across multiple production lines. Hybrid approaches combining PLC-based automation with advanced optimization or machine learning algorithms may also be explored to dynamically adjust CIP parameters based on fouling characteristics and process history.

Further experimental validation through microbiological or surface cleanliness studies would strengthen the assessment of sanitation effectiveness under varying production conditions. Finally, extending the system architecture to integrate renewable energy sources or advanced water recovery technologies could further enhance sustainability and align CIP operations with broader environmental and energy management strategies in the dairy industry.

DECLARATION

The authors declare that the manuscript is original and has not been published previously or submitted to any other journal for consideration. All authors have reviewed and approved the final version of the manuscript and agree to its submission for publication.

➢ *Conflict of Interest*

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. The research was conducted independently without any commercial or financial influence.

➢ *Author Contributions*

S. Ranganathan contributed to the conceptualization, PLC automation design, system implementation, data analysis, and manuscript preparation. Athappan V. contributed to technical supervision, system validation, and manuscript review. Venkata Prasath D. assisted in data collection, PLC and HMI Programming support, and documentation.

All authors reviewed and approved the final manuscript.

➢ *Funding Statement*

No external funding was received for this research work. The study was carried out using the available institutional facilities and resources. The authors did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

REFERENCES

[1]. Asming, N. A. A., Aziz, N. A., Thani, N. M., & Khalid, N. I. (2024). Optimization of Cleaning-In-Place (CIP) Procedure of Milk Fouling Deposit Using Different Cleaning Parameters. Journal of Biochemistry, Microbiology and Biotechnology, 12(SP1), 61–64. https://doi.org/10.54987/jobimb.v12isp1.944

[2]. Barton, K., Lewis, L., Harrington, J., & Riordan, E. (n.d.). Application of a benchtop TFF system for the assessment of CIP performance of detergent formulations for dairy UF membrane cleaning.

[3]. Chung, M. M. S., Arbour, A. J., & Huang, J. Y. (2023). Microbubble-Assisted Cleaning-in-Place Process for Ultrafiltration System and Its Environmental Performance. Membranes, 13(4). https://doi.org/10.3390/membranes13040424

[4]. Current issues of science, prospects and challenges • MAINTENANCE ENGINEER'S ROLE IN REDUCING PRODUCTION LOSSES AND WASTE IN DAIRY INDUSTRY. (n.d.).

[5]. Cvetković, B. R., Memišin, N., Nježić, Z., Pezo, L., Juodeikiene, G., Vitas, J., & Ilić, N. (2025). Addressing wastewater challenges in the dairy industry: A focused case study. Journal of Dairy Research. https://doi.org/10.1017/S0022029925101131

[6]. Espíndola, J. C., Mierzwa, J. C., Amaral, M. C. S., & de Andrade, L. H. (2023). Water Reuse through Membrane Technologies for a Dairy Plant Using Water Pinch Simulation Software. Sustainability (Switzerland), 15(3). https://doi.org/10.3390/su15032540

[7]. Geetha, N. B., Sangeetha, S. E., Ashwini, L., & Farheen, N. (n.d.). Optimization Of Wastewater Treatment In The Dairy Industry. In International

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may269

Journal of Environmental Sciences (Vol. 11, Issue 2). https://www.theaspd.com/ijes.php

[8]. Jaradat, M., Alsotary, O., Juaidi, A., & Manzano-Agugliaro, F. (2025). Sustainable future for Jordan's dairy industry through solar process heating. Sustainable Futures, 10. https://doi.org/10.1016/j.sftr.2025.101270

[9]. Kowalska, I. (2024). Recovery of Cleaning Solutions from Dairy Manufacturing Effluents Using Membrane Technology. Sustainability (Switzerland) , 16(13). https://doi.org/10.3390/su16135793

[10]. Liu, Y., Wang, C., Shi, Z., & Li, B. (2020). Optimization and Modeling of Slightly Acidic Electrolyzed Water for the Clean-in-Place Process in Milking Systems. Foods, 9(11). https://doi.org/10.3390/foods9111685

[11]. Mpongwana, N., Kumari, S., Rawat, I., Zungu, P. V., & Bux, F. (2024). The potential ecological risk of co and cross-selection resistance between disinfectant and antibiotic in dairy farms. In Environmental Advances (Vol. 17). Elsevier Ltd. https://doi.org/10.1016/j.envadv.2024.100588

[12]. Pant, K. J., Cotter, P. D., Wilkinson, M. G., & Sheehan, J. J. (2023). Towards sustainable Cleaning-in-Place (CIP) in dairy processing: Exploring enzyme-based approaches to cleaning in the Cheese industry. In Comprehensive Reviews in Food Science and Food Safety (Vol. 22, Issue 5, pp. 3602–3619). John Wiley and Sons Inc. https://doi.org/10.1111/1541-4337.13206

[13]. Pant, K. J., Cotter, P. D., Wilkinson, M. G., & Sheehan, J. J. (2025a). A technical feasibility study evaluating sustainable enzyme-based cleaning-in-place (CIP) for removal of milk deposits formed on stainless steel surfaces during cheesemilk pasteurisation. International Journal of Dairy Technology, 78(4). https://doi.org/10.1111/1471-0307.70071

[14]. Pant, K. J., Cotter, P. D., Wilkinson, M. G., & Sheehan, J. J. (2025b). Development of a modular test bed for evaluating sustainable CIP strategies and fouling removal during milk pasteurisation for cheese production. International Journal of Dairy Technology, 78(2). https://doi.org/10.1111/1471-0307.70030

[15]. Reichler, S. J., Murphy, S. I., Erickson, A. W., Martin, N. H., Snyder, A. B., & Wiedmann, M. (2020). Interventions designed to control postpasteurization contamination in high-temperature, short-time-pasteurized fluid milk processing facilities: A case study on the effect of employee training, clean-in-place chemical modification, and preventive maintenance programs. Journal of Dairy Science, 103(8), 7569–7584. https://doi.org/10.3168/jds.2020-18186

[16]. Szpicer, A., Bińkowska, W., Wojtasik-Kalinowska, I., Salih, S. M., & Półtorak, A. (2023). Application of computational fluid dynamics simulations in food industry. In European Food Research and Technology (Vol. 249, Issue 6, pp. 1411–1430). Springer Science and Business Media Deutschland GmbH. https://doi.org/10.1007/s00217-023-04231-y

[17]. Taneja, A., Nair, G., Joshi, M., Sharma, S., Sharma, S., Jambrak, A. R., Roselló-Soto, E., Barba, F. J., Castagnini, J. M., Leksawasdi, N., & Phimolsiripol, Y. (2023). Artificial Intelligence: Implications for the Agri-Food Sector. In Agronomy (Vol. 13, Issue 5). MDPI. https://doi.org/10.3390/agronomy13051397

[18]. van Asselt, A. J., Schuten, H. J., Huellemeier, H. A., & Augustin, & W. (n.d.). IS CLEANING IN PLACE READY FOR THE FUTURE?-A CRITICAL ASSESSMENT.