Nigerian Journal of Engineering Science Research (NIJESR).
Copyright@ Department of Mechanical Engineering,
Gen. Abdusalami Abubakar College of Engineering, Igbinedion University, Okada, Edo State, Nigeria.
ISSN: 2636-7114
Journal Homepage: https://nijesr.iuokada.edu.ng/

Evaluation of Thermal Oil Heating in Double-Jacketed Mild Steel Pasteurization Equipment

[1*]Sunday Reagan Ogblechi, [2]Gerard Obinna Ekoh, & [3]Philip Osezele Unabor

[1]Director & Head, Mechanization and Post-harvest Technology Department, Nigerian Institute for Oil Palm Research.
reaganogblechi@gmail.com

[2]Research Officer 1, Mechanization and Post-harvest Technology Department,
Nigerian Institute for Oil Palm Research.
gekoh45@gmail.com

[3]Senior Research Officer, Mechanization and Post-harvest Technology Department,
Nigerian Institute for Oil Palm Research.
philipunabor@nifor.org.ng

[*]**Corresponding Author: Sunday Reagan Ogblechi**, reaganogblechi@gmail.com

Manuscript History
Received: 19/03/2026
Revised: 28/04/2026
Accepted: 05/05/2026
Published: 14/05/2026
https://doi.org/10.5281/zenodo.20191182

Abstract: *Efficient heat transfer is key in achieving safe and energy-efficient industrial pasteurization process. This study evaluates the thermal performance of a heated 500 liter double- jacketed mild steel pasteurization vessel using thermal oil filled industrial pressure burners. This process involved the experimental investigation of two burner configurations under controlled laboratory conditions, with both water (500 L) and thermal oil (25L) temperature profiles closely monitored at 30 – 60 minutes intervals. Initially, the system operated a three burner configuration (baseline), showing slow heating rate, limited thermal efficiency, and extended pasteurization time; requiring 300 minutes to achieve a water temperature of 81°C, while oil temperature peaked at 71°C. To improve performance, a fourth burner configuration (modified) was introduced, and the system's heating profile reassessed. In contrast, the four-burner configuration achieved 82°C water temperature in 210 minutes, while the oil temperature stabilized around 99–100°C, representing approximately a 30-35% reduction in processing time and a near 40% increase in maximum oil temperature. The findings indicate that increasing the number of burners significantly enhances conductive heat transfer and thermal responsiveness, reduces processing time, and stabilizes the system for continuous pasteurization cycles. This study evaluates pasteurization systems by demonstrating a practical approach to increasing thermal efficiency through burner configuration adjustments. The outcomes provide a benchmark for industrial scale double-jacketed pasteurization equipment design, enabling faster processing, lower energy consumption, and improved operational reliability. Future work will focus on integrating remote monitoring and automated control for High Temperature Short-Time (HTST) pasteurization to further improve process safety, efficiency, and scalability.*

Keywords: *Pasteurization, Thermal, Double-jacketed, Industrial, efficiency.*

INTRODUCTION

Pasteurization remains one of the key thermal processes employed in the dairy and food processing industries, to preserve both sensory and nutritional quality, while ensuring microbial safety. Being able to reduce product degradation and deactivate microbial activities, the HTST pasteurization is mostly deployed (Grant *et al*., 2002). Nevertheless, uniform heat distribution and precision in thermal control largely determine effective pasteurization in industrial settings. The relationship between heating profile and pasteurization efficacy have been carefully examined in previous studies. To ensure delivery of stable and uniform heat transfer at high temperatures, double-jacketed pasteurization containers are mostly deployed for thermal oil heating equipment. These containers unlike their direct steam injection counterparts, offers conductive heating across the wall jacket in a controlled manner, thus minimizing localized, overheating while increasing energy efficiency. However, operational throughput can be compromised with heating cycles prolonged due to insufficient heat flux or limited burner capacity.

Past research has emphasized that temperature profile optimization has effectively helped in ensuring microbial inactivation. Grant *et al.* (2002) demonstrated that increased pasteurization temperatures with proper holding time, significantly lowers pathogen survival rates. Calahorrano-Moreno *et al.* (2022) noted that although pasteurization reduces microbial load, contaminants may still survive if heating remains uneven. Narayanan Mallick *et al.* (2022) explored automatic pasteurization systems and concluded that multiple heat sources improve thermal uniformity and process control. Sobharnadakani (2018) noted that improperly heated milk may retain trace contaminants, emphasizing the importance of adequate heating in pasteurization design. Also, Vahedi *et al.* (2013) emphasized that inappropriate thermal regulation may cause residual microbial infection in pasteurized milk. Recent trends in remote-controlled and automated HTST systems further highlights the advantages of precise heat management (Muthu & Jayakumar, 2023). Additionally, Proportional-Integral-Derivative (PID) systems as an advanced control technique have been proven to enhance energy efficiency while optimizing temperature profiles in milk pasteurizers (Amole *et* al., 2022). Together, these literatures emphasize the need for heat input optimization, as well as maintaining a stable temperature in pasteurizer equipment to improve both microbial inactivation and energy efficiency. Regardless of this progress, research gap still exists in the area of experimental investigation on burner configuration and its effect on thermal oil-based double-jacketed systems. This study aims at evaluating the thermal efficiency of a 500L double-jacketed mild-steel pasteurization system, using thermal oil heating, by comparing different burner configurations and determining their effect on heat transfer rate, temperature uniformity, and processing time.

MATERIALS AND METHODS

2.1 Equipment Description:

The double-jacketed pasteurizer is used for indirect heating of product (water) through thermal oil to achieve uniform heat distribution. It comprises the following:

i. ***Heating Medium***: Thermal oil in closed-loop circulation.
ii. ***Test Fluids***: Water (inner chamber) and thermal oil (jacket)
iii. ***Volume***: Water – 500 L, Thermal Oil – 25 L (both setups)
iv. Thermometers for measuring oil and water temperatures at intervals
v. Mild steel vessel: Houses the set-up and offers conductive heat transfer surface
vi. ***Burners***: Industrial pressure burners (Three-burner configuration, and Four-burner configuration), supplies the required heat energy for raising the temperature of thermal oil.
vii. ***Initial Conditions***: Water: 26–30°C, Oil: 20–30°C, Ambient: ~30°C

2.2 Experimental Procedure

The conductive and convective heat transfer principles guides the system operation. Oil temperature is increased by heat emanating from the burner, which transfers heat through the jacket wall based on Fourier's law of heat conduction at a rate proportional to the surface area and temperature gradient. Thermal efficiency is achieved by increase in heat flux, resulting from increasing the number of burners. Two experimental setups were used, and to ensure reliability, environmental condition were kept constant. The thermometers used were all calibrated before experimentation.

1. *Three-burner configuration (control)*: Operated for 300minutes (5hours); temperature readings of water and thermal oil were recorded every 30–60 minutes as shown in Table-1.

Ogblechi *et al.* (2026). *Evaluation of Thermal Oil Heating in Double-Jacketed Mild Steel Pasteurization Equipment. Nigeria Journal of Engineering Science Research (NIJESR), 9(1), 84-89.* https://doi.org/10.5281/zenodo.20191182

Table-1 Water and Oil temperature readings at an interval of 30 – 60 minutes (3-burner)

Time (minutes)	Water Temperature(°C)	Oil Temperature(°C)
30	35	35
60	38	40
120	49	46
180	60	53
210	74	64
300	81	71

Fig. 1 Three-burner configuration of a double-jacketed mild steel pasteurizer

2. *Four-burner configuration (Modified setup)*: Operated for 210minutes (3.5 hours); temperature readings recorded every 30–60 minutes.

Table-2 Water and Oil temperature readings at an interval of 30-60 minutes (4-burner)

Time (minutes)	Water Temperature (°C)	Oil Temperature (°C)
30	26	85
60	42	99
120	58	99
180	78	99
210	82	99

Fig. 2 Four burner configuration of a double-jacketed mild steel pasteurizer

Ogblechi *et al.* (2026). *Evaluation of Thermal Oil Heating in Double-Jacketed Mild Steel Pasteurization Equipment. Nigeria Journal of Engineering Science Research (NIJESR), 9(1), 84-89. https://doi.org/10.5281/zenodo.20191182*

RESULTS AND DISCUSSION

The three-burner setup displayed slow water heating, reaching a maximum temperature of 81°C in 300 minutes (5 hours), while the oil temperature peaked at 71^{0}C. The limited heat energy input is reflected by the gradual rise in temperature as displayed in the heating curve in fig. 3 below. In contrast, the four-burner setup reached a temperature of 82^{0}C in 210 minutes (3.5 hours), indicating a 30-35% decline in processing time. Oil temperature speedily raised to and normalized around 99-100^{0}C, representing approximately 40% above what is obtainable with the three-burner arrangement.

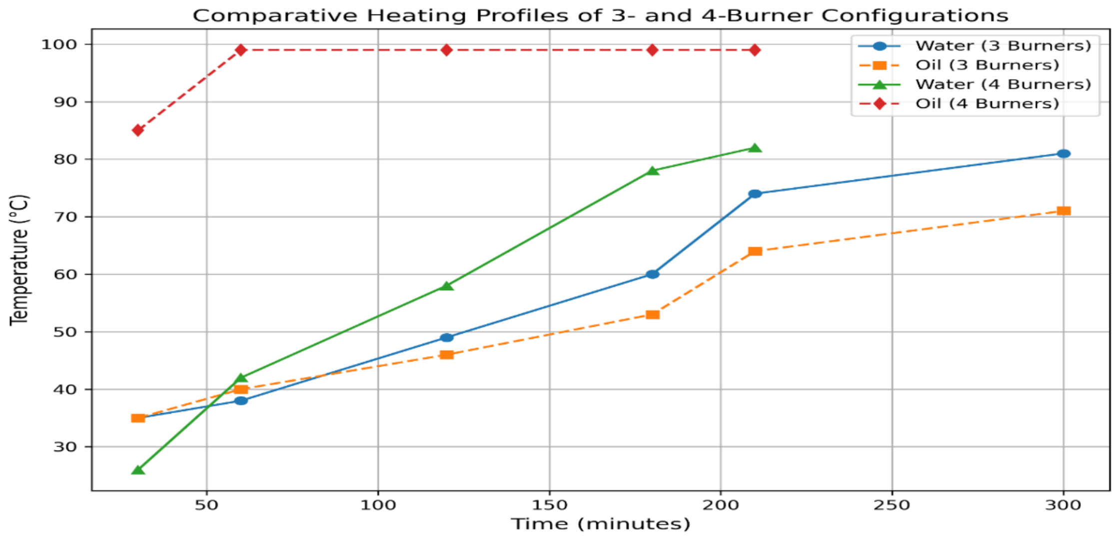

Fig. 3 Graphical Representation of Table 3

Table-3 Combined temperature profiles for water and oil using 3 and 4 burner-configurations

Time (minutes)	Water Temperature (°C) – 3 Burners	Oil Temperature (°C) – 3 Burners	Water Temperature (°C) – 4 Burners	Oil Temperature (°C) – 4 Burners
30	35	35	26	85
60	38	40	42	99
120	49	46	58	99
180	60	53	78	99
210	74	64	82	99
300	81	71	86	99

The fourth burner increased thermal energy input, significantly improving the heat transfer rate from the oil jacket to the water inside the vessel. Comparative analysis of both burner configurations reveals some key metrics as shown in Table-4.

Table-4 Comparative analysis of both burner configurations showing key metrics

Parameters	3 Burners	4 Burners	Improvements
Maximum Water Temperature (°C)	81	82	+1°C
Time to reach 60°C Water	180 min	120 min	33% faster
Max Oil Temp (°C)	71	99	40% higher
Total Operation Duration	5 hrs.	3.5 hrs.	Reduced by 30%

From Table-4, using the *descriptive comparative analysis,* we can deduce the following:

i. *Maximum Water Temperature*

3 Burners: 81^{0}C, 4 Burners: 82^{0}C. Absolute Difference: 1.00^{0}C. Percentage Improvement: 1.23%

ii. *Time to Reach 60^{0}C Water Temperature*

3 Burners: 180minutes, 4 Burners: 120minutes, Time Reduction: 60.00minutes. Percentage Reduction: 33.33%

iii. Maximum Oil Temperature

3 Burners: 71^{0}C, 4 Burners: 99^{0}C. Absolute Increase: 28.00^{0}C. Percentage Increase: 39.40%.

iv. Total Operation Duration

3 Burners: 5hours, 4 Burners: 3.5hours. Duration Reduction: 1.5hours. Percentage Reduction: 30.00%. The addition of a fourth burner meaningfully improved system performance. Water heating time reduced by 33.33%, while oil temperature increased by 39.4%; and total operating time reduced by 30.00%; all pointing to improved thermal efficiency, accelerated heat transfer, and increased process throughput when using the modified 4 burner configuration. Experimental test results, shows enhanced oil heating with four burners accelerated pasteurization cycles. Conductive heat transfer across the jacket wall was enhanced by improved oil temperature which invariably increased the water heating rate. Additionally, the faster heating rate demonstrated through the attainment of 60^{0}C in 120 minutes against 180minutes in the three-burner configuration confirms thermal responsiveness of the modified setup, reduces energy consumption, and improves production throughput.

CONCLUSION

This project aims at improving the energy flux into the thermal oil of a 500l double-jacketed mild steel pasteurizer for oil palm processing in order to reduce cycle time while maintaining system stability. This was achieved by increasing the burner configuration. Adding a fourth industrial burner significantly improves the thermal performance of 500l double-jacketed pasteurizer. Water heating time was reduced by 30–35%, enhancing throughput. Oil temperature reached an almost stable 99-100°C levels improving by nearly 40%, thereby ensuring consistent pasteurization. These findings reveals burner configuration as major driver of efficient heat transfer and operational throughput in thermal oil-based pasteurization equipment. Future work will focus on the development of a fully automated and cloud-based system for real-time control of heating cycles. Investigate burner placement optimization using computational fluid dynamics (CFD); Integration of PID-based automatic control systems, and evaluation of energy consumption and cost savings associated with multi-burner configurations.

ACKNOWLEDGEMENT

The authors acknowledge the executive director and chief executive officer of the Nigerian Institute for Oil Palm Research (NIFOR) for approving and providing the needed funding, laboratory facilities, and technical support for this study.

CONFLICT OF INTEREST

There is no conflict of interest in this study

REFERENCES

Grant, I.R., Ball, H.J., Rowe, M.T. (1999). Effect of Higher Pasteurization Temperatures and Longer Holding Times at 72^{0}C on the Inactivation of Mycobacterium paratuberculosis in Milk. *Letters in Applied Microbiology*, *28*(6), 461-465.

Grant, I.R., Hitchings, E.I., McCartney, A., Ferguson, F., Rowe, M.T. (2002). Effect of Commercial-Scale High-Temperature, Short-Time Pasteurization on the Viability of Mycobacterium paratuberculosis, in Naturally Infected Cow's Milk. *Applied and Environmental Microbiology*, *68*(2), 148-153.

Calahorrano-Moreno, M.B., Ordoñez-Bailon, J.J., Baquerizo-Crespo, R.J., Dueñas-Rivadeneira, A.A., B S M Montenegro, M.C., Rodríguez-Daíz, J.M. (2022). Contaminants in the cow's milk we consume? Pasteurization, and other Technologies in the Elimination of Contaminants. *National Library of Medicine*, *11*(1), P. 91.

Mallick, A.N., Kumar, M., Chander, A., Kumar, R., Arora, K., Sahani A. (2022). Automatic Pasteurized Formula Milk Preparation Machine with Automatic Sterilized Containers. *IEEE EMBC*, pp. 5–8.

Sobhanardakani, S. (2018). Human Health Risk Assessment of Cd, Cu, Pd & Zn through Consumption of Raw and Pasteurized Cow's Milk. *Iran Public Health, 47*(8), 1172-1180.

Vahedi, M., Nasrolahei, M., Sharif, M., Mirabi, AM. (2011). Bacteriological Study of Raw and Unexpired Pasteurized Cow's Milk Collected at the Daily Farms and Super Markets in Sari City. *J. Prev. Med*. Hyg., *54*(2), 120-123.

Muthu, M., Jayakumar J. (2023). Design and Implementation of Remote-Controlled High Temperature Short Time (HTST) Pasteurization System for Healthy Milk Production. doi: 10.20944/preprints202308.0020.v2

Amole, A.O., Olabode, O.E., Akinyele, D.O., Akinjobi, S.G. (2022). Optimal Temperature Control Scheme for Milk Pasteurization Process Using Different Turning Techniques for a Proportional Integral Derivative Controller. Iranian Journal of Electrical and Electronic Engineering, *18*(3), 1-6.