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IMPLEMENTATION OF LEAN AND JIT PRACTICES FOR WASTE REDUCTION IN THE FOOD MANUFACTURING INDUSTRY: A CASE STUDY

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Abstract
The food manufacturing systems, especially dairy processing facilities, consist of constant challenges regarding the waste production, the uneven production flow, and the large inventory because of the perishability and strict quality standards. The adoption of lean manufacturing and Just-in-Time (JIT) practices have been quite well known to enhance the efficiency of the operations; but the amalgamation of these models in the ongoing food processing settings is not highly prevalent. The paper examines how Lean and JIT can be applied to reduce waste and improve the flow of production and a milk pasteurization and packaging system. Value Stream Mapping (VSM) was also used as the case study to examine the current condition of material and information flow and to determine the key areas of waste, such as the waiting time and work-in-process inventory. The future state was also conceptually developed based on the current state analysis; it involved combining the principles of Lean and JIT, which included production that works in a pull manner, synchronization of the flow, and control of inventory. Production Flow Efficiency (PFE) and waste reduction indicators were used to determine the effectiveness of the proposed implementation. This was done through the analysis based on assumed yet realistic operational data, as had been done in previous methodologies of Lean manufacturing case studies. The outputs reveal that there were significant decreases in waiting time, intermediary inventory, and overall lead time, which resulted to a tremendous enhancement in the Production Flow Efficiency. The results prove the thesis that the combined use of the Lean and JIT practices can be effective to improve Production Flow Efficiency and waste reduction on the dairy manufacturing systems. The work is significant to the literature because it offers a systematic use of the example-based approach to the implementation of Lean-JIT in the food processing companies and offers useful information on enhancing operational sustainability in large dairy processing plants.

Keywords: Lean manufacturing; Just-In-Time (JIT); Value Stream Mapping; Production Flow Efficiency; Waste reduction; Dairy manufacturing; Food processing systems

Introduction

The food manufacturing business is becoming increasingly challenged to enhance its operations effectiveness, and concurrently comply with the strict quality, safety, and sustainability standards. The dairy processing systems are most likely the most sensitive to inefficiencies because of the products perishable nature, hygiene limitations, and change of demand. These features tend to cause too much waiting, production flow that is not balanced and a build up of in between inventory hence lengthening lead time and operational expenses.

Lean manufacturing has received much appreciation as a successful method to remove non-value-added processes and enhance the process flow by ensuring a systemic identification and elimination of wastes. Complementary to this, Just-in-Time (JIT) aims focus on a pull-based production, minimization of inventory and process synchronization to achieve responsiveness and efficiency of flows. Despite the widespread application of the Lean and JIT principles in the discrete manufacturing industries, its combined implementation in the food processing industries, especially dairy manufacturing, is scarcely felt.

Value Stream Mapping (VSM) has become an effective Lean diagnostic system that allows visualizing the material flow, information flow, and identifying waste and bottlenecks in the complex production systems. In this respect, this paper will research to explore the combination of Lean and JIT in a milk pasteurization and packaging system to minimize wastes and enhance Production Flow Efficiency (PFE).

Review of Literature

The concept of Lean manufacturing has been receiving more attention over the past few years as a solution to enhancing operational efficiency and minimizing waste in food manufacturing systems. Food processing industries are mostly susceptible to inefficiency like excessive waiting time, lass iteration in production flow, and high work in process (WIP) inventory due to perishable nature of food products and strict quality considerations. Recent and groundbreaking research focuses on the fact that Lean manufacturing offers systematic ways of detecting and removing non-value-added processes and, thus, improving the overall performance and sustainability of processes in the food manufacturing setting (Antony et al., 2021; Dora et al., 2021).

Value Stream Mapping (VSM) is one of the most popular tools of analysing the flow of materials and information throughout the production systems that have appeared among other Lean tools. The recent cases of the VSM use within the food and dairy processing industries prove its efficiency in revealing the issue of bottlenecks, waiting time, and inventory accumulation in various processing levels (Lopes et al., 2015; Mazelan et al., 2021; Garcia-Garcia et al., 2022). According to these studies, VSM allows visualizing the current state fully and makes it possible to create better state configurations in the future. Nevertheless, the recent and underlying studies mainly use VSM as a qualitative or diagnostic instrument and there is a dearth of quantitative analysis of flow performance benefits.

Just-in-time (JIT) techniques have not been neglected in the research, as well, especially in terms of inventory minimization and production optimization. Modern literature suggests that JIT principles including pull-based manufacturing, decreased batch quantities, and inventory management have a substantial effect of lowering overproduction and WIP inventory in the production process (Porras et al., 2023; Mendoza-Sotomayor et al., 2024). Recent studies in the food manufacturing setting note that JIT is particularly valuable in waste reduction based on inventory and enhanced responsiveness to variation in demand and the presence of a perishable environment (Garcia-Garcia et al., 2022). However, a number of studies do not use JIT in systematic connection with Lean flow-analysis tools, like VSM.

Production Flow Efficiency (PFE) or other related flow-based efficiency indicators have become significant in recent Lean research as an indicator of the efficiency with which value-added time is used in total production lead time. The previous research highlights that flow-based metrics are a more relevant measure of Lean performance than the traditional productivity metrics, especially in continuous and semi-continuous production processes (Buer et al., 2018; Akanmu and Nordin, 2022). Despite the fact that the application of PFE in food manufacturing research is infrequent, similar flow-based efficiency metrics are increasingly used in recent research to have an idea of reductions in non-value-added time and process synchronization (Antunes et al., 2022). This shows an increased appreciation of flow efficiency as an important performance measure in Lean implementation.

One of the key results of Lean and JIT implementation that is still observed in recent literature is the waste reduction. The literature about the studies carried out in the past five years are consistent, indicating a decrease in waiting time, WIP inventory, and overall lead time after Lean-based interventions in food manufacturing systems (Dora et al., 2021; Garza-Reyes et al., 2022; Sahoo and Yadav, 2023). Through such

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studies, it is noted that food processing waste minimization not only enhances efficiency of the operations, but also minimizes quality risks and losses incurred by handling overstocks and delays. Nevertheless, most of the previous research is based on qualitative evaluation or a general performance index, providing scanty understanding of the waste reduction at the process level.

In general, the recent literature proves that VSM and JIT practices are the tools of Lean that can be successfully implemented in food manufacturing industries to eliminate waste and enhance the performance of operations. Nonetheless, studies that have been conducted in the past five years indicate that there are a number of gaps. First, there are few studies which combine VSM and JIT in a single framework as a way of enhancing the system level production flow. Second, flow-based performance indicators used empirically in a dairy processing system (like Production Flow Efficiency) have limited empirical usage. Third, not many studies compare quantitatively the current and future state scenarios regarding the waiting time, WIP inventory, and lead time. To fill these gaps, the current paper combines Lean (VSM) and JIT practices and their influence on the Production Flow Efficiency and waste minimization in a dairy manufacturing system and thus adds a new flow-based case-based approach to the current literature.

Research Gap

Although the concept of Lean manufacturing has been widely researched on food industries, there is little literature on the combined use of Lean and Just-in-Time (JIT) practices in the dairy processing systems. Specifically, not many studies explore continuous/semi-continuous food production set-ups through flow-driven measures of performance including Production Flow Efficiency (PFE). Moreover, the quantitative case studies involving the use of Value Stream Mapping (VSM) to compare the present state with the future state regarding the waiting time, work-in-process inventory, and lead time are underrepresented. These restrictions suggest the necessity of a systematic, flow-based case-based analysis combining Lean and JIT practices to measure waste minimisation and Production Flow Efficiency of the dairy manufacturing systems.

Objectives

- To conduct analysis of a milk pasteurization and packaging system in the present state through Value Stream Mapping.
- To determine the key sources of waste especially waiting time and work-in-process inventory.
- To plan forthcoming condition production process by the imaginary application of Lean and Just-in-Time activities.
- To test how the implementation of Lean-JIT affects Production Flow Efficiency.
- To evaluate the reduction of waste in regards to the waiting time, inventory levels and total lead time.

Conceptual Framework

The variables chosen in the study were to ensure that there is a high concentration on manufacturing systems and process-engineering. Value Stream Mapping (VSM) was selected as the main Lean practice due to the ability to visualize material and information flows end to end, allowing to systematically identify waste at the level of the whole production systems, as well as at a complex food production environment with perishability and batch processing restrictions (Rother and Shook, 2003; Lopes et al., 2015; Mazelan et al., 2021; Garcia-Garcia et al., 2022). The 5S and SMED other Lean tools were not included because they are more local in their effect. Just-in-Time (JIT) practices were chosen because they assist in demand-based manufacturing, inventory reduction, and harmonizing material movement, eliminating overproduction and wastes in food systems (Mendoza-Sotomayor et al., 2024; Porras et al., 2023; Garcia-Garcia et al., 2022). Production Flow Efficiency was also incorporated as a mediating variable, which refers to a rise in flow and a decrease in waiting time and synchronization under the Lean-JIT practices (Rother and Harris, 2001; Buer et al., 2018; Akanmu and Nordin, 2022). The dependent variable was the waste reduction, which was selected as the most direct and measurable result of the Lean-JIT implementation emphasizing on the material losses, inventory, and process inefficiencies without considering financial or customer-related outputs to maintain a clear engineering focus (Kennedy et al., 2013; Steur et al., 2016; Bonamigo et al., 2023; Porras et al., 2023).

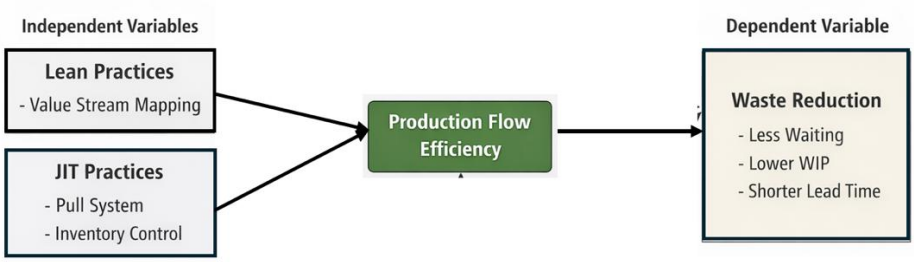

Fig.1 Conceptual Framework

The conceptual framework demonstrates how Lean practices (VSM) and JIT practices (pull system, inventory control) serve as independent variables, which enhance Production Flow Efficiency (PFE), which subsequently decreases waste such as shortening of waiting time, WIP reduction and shortening of lead time. The model focuses on the improvements in the flow at the system level and underlines the causal line of flow between Lean-JIT implementation and increased operational efficiency of the dairy manufacturing systems (Rother and Shook, 2003; Mendoza-Sotomayor et al., 2024; Kennedy et al., 2013).

Case Description

The paper analyzes one of the milk pasteurization and packaging lines in a medium size dairy processing unit, which was chosen because of its continuous material flow and high vulnerability to waiting, inventory and flow wastes. Unbalanced operation and intermediate storage are frequent causes of inefficiencies in dairy processing systems, which can be the right targets of Lean manufacturing interventions (Dora et al., 2021). The flow of production involves the reception of milk, its filtration, pasteurization, cooling and packaging, which represents a common dairy processing arrangement. Value Stream Mapping (VSM) is also used to visualize the present state of material and information flow and reveal non-value-added activities, which is suggested in recent food manufacturing research (Antony et al., 2021; Sahoo and Yadav, 2023). According to the knowledge gained during the analysis of the current state, Just-in-Time (JIT) concepts are developed conceptually to achieve better process alignment and minimize the excessive waiting and inventory, which have been proven to promote flow efficiency in the food processing setting (Garza-Reyes et al., 2022). Production Flow Efficiency (PFE) is another key performance indicator that is used to measure the effectiveness of the proposed Lean-JIT implementation, and waste reduction is measured by the changes in waiting time and in middle inventory levels. The analysis is informed by a series of earlier Lean case studies in which access to industrial information was

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constrained, which is concordant with the current methodological practices that have been adopted in Lean manufacturing research wherein direct access to industrial information is restricted (Sahoo and Yadav, 2023).

Process Flow

The milk pasteurization and packaging line of the chosen dairy processing facility is a structured process of operations that begins with the reception of raw milk, then filtration, pasteurization, cooling, and final packaging, which is typical in the dairy products industry (Bhattacharya et al., 2022; Rosa et al., 2024). The stages contribute to the quality and safety of the product, yet the delays between stages and the inter-stage inventory levels cause the lead time and flow interruptions that are known to be major contributors to inefficiencies in the food manufacturing systems (de Farias et al., 2023; Singh and Kumar, 2021). To fully describe and measure these flow properties, the whole process was modelled with the help of Value Stream Mapping (VSM) that is broadly recognised as a potent lean diagnostic instrument of identifying both value-adding and non-value-adding operations in process industries (Liu et al., 2023; Antunes et al., 2022). This discovery of waiting and idle periods during the stages of the process with the help of VSM offers the prerequisites of specific application of Just-in-Time (JIT) principles, which would aim to align production flow with inevitable inventory reduction, which is in line with recent applications of Lean production in food industries (Garza-Reyes et al., 2022).

Production Flow Efficiency

Production Flow Efficiency determines the ratio of active time used to add value to a product to the total lead time (active time + waiting time). It influences the ease of work passing through a process, where high efficiency implies there are few bottlenecks and, consequently, idle time and, consequently, output is maximized, and waste is minimal (Rother and Harris, 2001; Akanmu and Nordin, 2022). It is assessed by comparing the performance of the present and the future state of the milk pasteurization and packaging line with four supporting tables. Table 1 displays the data on the current state operations, which point out a high waiting time and work-in-process inventory leading to low flow efficiency even with moderate value-added processing time. Table 2 represents the statement of the future state made with the implementation of the principles of Lean and Just-in-Time with the emphasis on the enhanced synchronization of the processes and the decrease in the non-value-added time. Resting on these datasets, Table 3 will compare values of Production Flow Efficiency in the present and future state, whereas Table 4 will provide an overview of the respective decrease in the critical waste parameters. These tables, together, offer a systematic foundation on which flow efficiency gains, achieved by the implementation of Lean-JIT, can be evaluated.

Table1. Current state operational data of milk pasteurization and packaging line

Process Stage	*Cycle Time (min)*	*Waiting Time (min)*	*WIP Inventory (litres)*
Milk Reception	*10*	*30*	*2,000*
Filtration	*8*	*25*	*1,800*
Pasteurization	*15*	*40*	*2,500*
Cooling	*12*	*35*	*2,200*
Packaging	*20*	*60*	*3,000*
Total	***65***	***190***	***11,500***

Table 1 replies the current state operational performance of the milk pasteurization and packaging line in terms of Value Stream Mapping (VSM). The findings show that the individual processing cycle times are moderate but there is a lot of waiting time and much work-in-process inventory at the various stages, which translate to long lead times and low Production Flow Efficiency. These inefficiencies are the common features of push-based and inadequately synchronized manufacturing systems of food (Antony et al., 2021; Dora et al., 2021; Liu et al., 2023).

Table 2. Future state operational data after Lean and JIT implementation

Process Stage	*Cycle Time (min)*	*Waiting Time (min)*	*WIP Inventory (litres)*
Milk Reception	*10*	*10*	*1,200*
Filtration	*8*	*8*	*1,000*
Pasteurization	*15*	*12*	*1,500*
Cooling	*12*	*10*	*1,300*
Packaging	*20*	*15*	*1,600*
Total	***65***	***55***	***6,600***

Table 2 shows the operational data of the state in the future after the conceptual implementation of the Lean and Just-in-Time (JIT) practice. The findings indicate the significant decrease in waiting time and intermediate inventory in all stages of the process and the same value-added cycle time. Those additions indicate the higher level of process synchronization and pull-oriented flow which was used in the previous Lean-JIT applications in the food processing sectors (Garza-Reyes et al., 2022; Sahoo and Yadav, 2023).

Current State

Value Added Time = 65 mins; Waiting Time = 190 mins;
Total Lead Time = Value Added Time + Waiting Time = 65 + 190 = 255 mins

PFE % of Current State = (65/255)*100 = **25.49%**

Future State

Value Added Time = 65 mins; Waiting Time = 55 mins;
Total Lead Time = Value Added Time + Waiting Time = 65 + 55 = 120 mins

PFE % of Future State = (65/120)*100 =**54.17%**

Table 3. Production Flow Efficiency comparison between current and future states

State	*Value-Added Time (min)*	*Total Lead Time (min)*	*PFE (%)*
Current State	*65*	*255*	*25.49*
Future State	*65*	*120*	*54.17*

Table 3 is a comparison between Production Flow Efficiency (PFE) in the present and future. The results indicate that there is a significant level of PFE between the current and future states, with the level of PFE incrementing and meaning that the flow efficiency is enhanced, and non-value-added time is decreased due to the implementation of Lean-JIT. The same enhancement of PFE has also been observed in recent case studies of food manufacturing with the application of Lean-based flow optimization methods (Antunes et al., 2022). The growth in Production Flow Efficiency **25.49 %** to **54.17 %** shows that there was a significant decrease of the non-value-added time through the application of Lean and JIT-based flow improvements.

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Waste Reduction Analysis

Table 4. Comparison of waste parameters before and after Lean–JIT implementation

Parameter	*Current State*	*Future State*	*Reduction (%)*
Waiting Time (min)	*190*	*55*	*71*
WIP Inventory (litres)	*11,500*	*6,600*	*43*
Total Lead Time (min)	*255*	*120*	*53*

The summary of the comparative reduction in key waste parameters after the implementation of Lean and Just-in-Time (JIT) is traced in Table 4. It has been shown that the waiting time, work-in-process inventory as well as the total lead time reduced significantly, which proves the efficiency of flow-oriented Lean interventions. The results align with the previous literature of food manufacturing systems that indicate that the incorporation of Lean and JIT practices can greatly increase the efficiency of the operation by reducing the number of non-value-added processes and making processes more responsive (Dora et al., 2021; Garza-Reyes et al., 2022; Sahoo and Yadav, 2023).

Results & Discussion

The study findings prove the efficiency of Lean and Just-in-Time (JIT) practices in the milk pasteurization and packaging system to reduce wastes and enhance Production Flow Efficiency. The analysis of the current state, using Value Stream Mapping (VSM), has shown that the cumulative value added cycle time was relatively low, but the total production lead time was modified, dramatically, because of the excessive waiting time and the high ratio of work-in-process (WIP) inventory. These results prove that the existence of significant non-value-adding processes (waiting and inventory waste) is typical of food manufacturing systems where the production is organized on the principles of push (Antony et al., 2021; Dora et al., 2021).

In the future state, the results of the operational performance are significantly better after the implementation of the concepts of Lean and JIT. Table 2 shows that the waiting time and the level of intermediate inventories were significantly decreased at all the processing stages and the same value-added cycle time was kept. This is because the upstream and downstream operations are synchronized better, batch sizes are reduced and there is the introduction of pull-based flow control. The same results have been obtained in previous Lean-JIT implementation in food processing facilities, where inventory management and flow alignment were found to be the main factors in efficiency gain (Garza-Reyes et al., 2022; Sahoo and Yadav, 2023). The measure of the performance improvement is a key indicator which is Production Flow Efficiency (PFE) and it has significantly risen between the present state to the future one as depicted in Table 3. The decrease in PFE is an indicator of a major decrease in time (non-value-added) compared to the lead time, meaning more continuity in the flows and less interruptions in the processes. This result is consistent with other research works, which have highlighted PFE as a valid indicator to measure the Lean efficacy in the continuous and semi-continuous food production system (Antunes et al., 2022). The waste cut list shown in Table 4 further supports the effects of implementation of Lean-JIT. The fact that the waiting time, WIP inventory, and the total lead time decreased significantly proves that flow-related improvements are more efficient than process-level optimizations. The shortening of the lead time with the help of reduced inventory levels also helps to minimize the handling requirements and possible quality risks that are important factors of consideration in dairy processing operations (Bhattacharya et al., 2022; Rosa et al., 2024). Generally, the findings suggest that a combination of Lean and JIT systems can considerably optimize the efficiency of operations in dairy production systems with medium-scale operations. The results complement the current body of knowledge by showing that even conceptual Lean-JIT implementation, backed by realistic operational data may be used to offer useful insights into the opportunities of waste reduction and flow improvement in food manufacturing settings. These findings affirm the fact that flow-based Lean interventions are more successful compared to isolated process improvements.

Conclusion

This paper tested how Lean and Just-in-Time (JIT) concepts could be applied to a milk pasteurization and packaging process and the aim was to minimize wastage and enhance Production Flow Efficiency. As the main diagnostic tool, Value Stream Mapping (VSM) was used, which has shown that the present condition of the production line had very serious non-value-added activities, mostly waiting time and high work-in-process inventory. The futuristic state proposed after the implementation of the Lean-JIT principles showed significant gains in the performance at the operational level. This resulted in a significant decrease in the total lead time as the decrease in waiting time and intermediate inventory, whereas Production Flow Efficiency (PFE) improved significantly. The results support the conclusiveness of this paper that flow-oriented Lean interventions, even assessed by assumed but realistic operational data, can be effectively utilized to improve efficiency and responsiveness in food manufacturing systems. Findings add to the literature of the emerging research on Lean application to the food processing industry and offer operative information to medium-scale dairy processors aiming at enhancing their sustainability in operations. An evaluation of a flow based analysis of Lean-JIT integration with Production Flow Efficiency in a dairy processing setting is added in this study.

Future Scope

Although the current research offers good information, its weaknesses are the assumption of operations data and one-case scenario. The work can be expanded on by future research that can confirm the suggested Lean-JIT framework through real time data of the industrial environment and through longitudinal evaluations of the performance. Additional research possibilities can be also connected to combining Lean and JIT activities with digital technologies like real-time monitoring systems, Internet of Things (IoT), and Industry 4.0 tools to make the production more visible and decision-making.

Also, the study on the synergetic effects of Lean-JIT application on quality performance, energy consumption, and environmental sustainability of dairy processing systems could be considered in future studies. Comparison of various food manufacturing units would also aid in generalizing the results and consolidating the empirical results regarding the effectiveness of Lean-JIT in the context of the food industry at large.