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Sustainable Lean Manufacturing model to reduce waste in a dairy company in Peru

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***Abstract*– The application of lean-based sustainable approaches could address various challenges present in the food industry. A key tool that integrates lean principles and sustainability is value stream mapping (VSM), used to visualize the system and detect problems such as waste, bottlenecks, and overuse of resources. This paper presents an integrated model of lean practices and sustainability in a dairy company, with the objective of optimizing process efficiency, reducing waste, and improving environmental performance. Problems related to configuration, equipment maintenance, and process deficiencies were identified. Corrective actions were suggested including the use of SMED, Poka-yoke, and SW tools. In addition, in order to improve the sustainability of the model, all these elements were condensed into an A3 format, resulting in a 14% increase in efficiency and a 4% reduction in waste.**

***Keywords*-- Lean manufacturing, SMED, SW, Sustainability, A3, VSM.**

I. Introduction

Lean Manufacturing has been proposed as a solution to the various existing production chains in the market because each tool helps to eliminate one of the eight wastes: [7]. (1) defects, when something goes wrong; (2) overproduction, doing more than is required; (3) wait, wait for something to happen; (4) not using the talent of the staff; (5) transportation; (6) inventories, product without continuous flow; (7) movement, that the operator moves from his workstation; (8) extra-processing [13, 14]. On the other hand, the milk processing industry presents a series of difficulties, some such as surplus milk, inefficient production systems, reprocessing, food waste and contamination, acid, and pH measurement errors. All these aforementioned causes generate the existence of waste due to defects, which can be quantified in a deeper analysis of the processes [22, 15]. The LM philosophy is transforming the analysis of manufacturing processes and promoting business competitiveness [8, 9].

It is important to highlight the focus on sustainable development in manufacturing industries, and one of the best-known concepts in terms of sustainability is the Triple Bottom Line, which emphasizes the combination of economic, social and environmental responsibilities within business practices throughout of the supply chain [2]. This implies that all members of the chain come together with the aim of achieving specific goals related to economic performance, environmental protection, and social development [6]. Previous studies emphasize that LM practices play a crucial role in promoting business sustainability by reducing energy consumption, emissions, water consumption, and environmental waste [1]. These practices also contribute to improving the well-being of the workforce, as well as the financial and operational performance of companies. The objective is to identify Lean Manufacturing strategies in combination with sustainability to improve efficiency and reduce waste due to defects.

Secondly, present successful cases of implementation of tools and improvements as examples so that SMEs can learn and apply them in their own context. [19, 20]. The study is structured as follows: in the second section, topics such as the implementation of LM, waste management, sustainability and the relationship between sustainability and lean manufacturing are addressed. The third section presents the proposed model and the detailed steps for its application. The fourth section focuses on data collection and root cause analysis. The results are presented in the fifth section, and in the sixth and last section the conclusions of the investigation are presented.

II. Literature Review

A. Lean Manufacturing

It can be described as a management strategy that focuses on identifying and eliminating waste with the aim of reducing costs and improving productivity and excellence in operations [9]. It is essential to take this approach into account to differentiate between valuable activities, those that are unavoidable but do not add value, and those that do not add value and can be avoided [10]. Its approach is focused on the continuous improvement of processes with the aim of achieving perfection in the production chain, involving all the participants of the organization and seeking competitiveness in the market [3, 4]. The literature mentions that many of the operations are different for each LM implementation sector. For example, food processing industries may present various seasonal patterns or patterns of raw materials and processing equipment [20]. Currently, Lean practices have become essential in various manufacturing sectors, including electronics, plastics, textiles, food, dairy, foundry, and maintenance [5, 6]. Today, Lean practices have become essential.

B. Lean Manufacturing tools

Value Stream Mapping (VSM) is a widely used tool in lean practices due to its effectiveness in identifying losses and waste in the production chain. In addition, SW is to eliminate variability and waste in processes, while improving quality,

productivity, and safety at work [26]. The SMED method has as its main objective the reduction of setup and changeover time to less than 10 minutes [22, 25]. Finally, the Poka yoke approach's main goal is to achieve a unique solution: the elimination of defects completely. [31, 36].

C. A3

The A3 method originated at Toyota as part of its management approach known as the Toyota Production System (TPS) and has been widely disseminated in industry and other organizations [34]. The main objective of the A3 method is to encourage a disciplined and fact-based approach to problem solving, promoting critical thinking and team collaboration [29]. It is a problem-solving tool that allows the analysis and improvement steps to be documented and communicated in a standard format [35]. Condensing all these elements in an A3 format can facilitate the visualization and monitoring of the improvement processes in the dairy industry, as well as ensure the adequate documentation of the implemented changes [18]. The A3 format, which is based on A3 size paper, helps to summarize and present information in a visual and easy to follow way. All participants in the problem resolution can review and contribute to the A3 document, which facilitates communication and teamwork.

D. Sustainability

Sustainability has been widely addressed and studied in various industries globally [20]. This approach seeks to maintain a balance between economic, social and environmental aspects, promoting the responsible use of natural resources, environmental protection, social justice and sustainable economic development [21]. There is an increase in awareness and interest in the sustainability of the food supply chain, and this evolution is taking place in response to market demands and conditions [22]. Furthermore, supply chain sustainability in the food industry is an understandable concern, as food production contributes to more than one third of global greenhouse gas emissions [23,24]. The reduction of natural resources, emissions and climate change is driving companies to adopt environmentally sustainable practices and to reduce their dependence on non-renewable energy, such as fossil fuels, which can negatively affect the ecosystem [25]. To improve the performance of the food supply chain, the case study establishes the implementation of sustainability taking into account economic, social and environmental aspects [4].

E. Sustainability and Lean Manufacturing

It is well known that the world faces serious problems due to resource scarcity, capital constraints, deficiencies in energy capacity and the accumulation of waste [26]. Manufacturing processes carry various ecological, social and economic risks, as they are responsible for considerable consumption and waste of resources worldwide [27]. Therefore, sustainable performance is a crucial innovation to achieve organizations that are conscious of the environment, socially progressive and sensitive to current needs [28]. Establishing a practice of integrated approach between Lean and sustainability in SMEs has a positive effect. Sustainable production is defined as a method that reduces waste and reduces environmental impact [30].

By combining sustainability and lean manufacturing, it adopts a novel approach as an improvement strategy [8]. Within the framework of reviews, the growing importance of industries that are incorporating lean and sustainability strategies to achieve operational and ecological excellence with the objective of being competitive in the market [9] was highlighted. The contribution of sustainable manufacturing practices allows the efficiency of equipment and processes as it can save energy costs, reduce production time, reduce waste and use of resources [35].

F. Food Waste Managements

Food waste has received increased attention in recent years, with many companies accused of wasting enormous amounts of resources [12]. Addressing food waste is a significant challenge and requires a comprehensive approach at all stages of the food supply chain, from production to consumption. According to the FAO in its 2021 report, the dairy sector experiences losses in processing. As for the quantification of FLW in dairy processing worldwide, it aims to match or exceed the main industries [13,14].

Therefore, new approaches are needed for the management of food waste in its processing [5]. Waste management is sustainable when material resources are used efficiently to reduce the amount of waste produced and sustainable development goals are promoted [19]. Sustainable integration and lean practices are key approaches to achieving effective and sustainable integrated waste management in a food business. The results are presented in the fifth section, and in the sixth and last section the conclusions of the investigation are presented.

III. Methodology

A. Proposed model

This section presents the key steps in developing the proposed methodology for a production setting. The methodology is built by blending the LM approach with a focus on sustainability, as depicted in Figure 1.

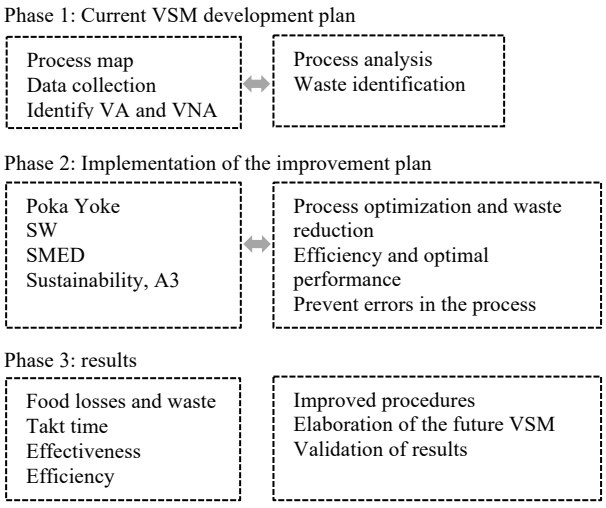


Fig. 1 Proposed model. Adapted Amrani and Duck 2021; Backar et al., 2022; Shirinkina et al., 2022.

B. *Step-by-step model*

At first, the data is rigorously collected at the plant and under strict supervision, with the purpose of obtaining reliable information for the analysis and development of the Value Stream Mapping in the dairy production chain. This will provide us with an accurate view of the current situation of the company. Thus, value stream mapping will be used to analyze and improve the production process of fruity yogurt. these actions will be carried out in order to reduce waste, improve quality and increase the efficiency of production processes. Next, we proceed to choose the appropriate Lean Manufacturing (LM) tools to address each critical situation identified in the current value stream mapping, which requires a solution measure.

In order to optimize the processes, the Standardized Work System is implemented in the milk reception process within the production chain for the production of fruit-flavored yogurt. First, we proceed to identify the time required to carry out work activities. Then, each of the activities is analyzed based on the established norms and quality standards. Subsequently, the activities are classified into correct and incorrect, with the aim of formulating the optimization of the process. Finally, the training and training of the operating personnel is carried out to guarantee the correct execution of the process.

In terms of efficiency, the SMED method is implemented in the incubation process, which implies identifying the equipment configuration times. Subsequently, the activities are separated into internal and external to analyze the corresponding times. It seeks to reduce these times by transforming several internal elements into external ones, which will reduce machine configuration times and, at the same time, reduce costs, thus generating significant savings for the company.

To improve accuracy and reduce errors, the Poka yoke tool is implemented in the shake process. It begins by observing the workstation, where three controls are used that generate a signal in case of detecting the following causes: omission of an ingredient, incorrect integration of ingredients, adjustment error, faulty operation, assembly error and omitting a thread. Consequently, the shake procedure at the station is halted until the identified error is corrected. In addition, the A3 method will be applied, which is based on a Lean system which will allow us to analyze and synthesize the problem.

This includes the identification, definition, and study of the current situation, followed by the analysis, proposal, and action plan, as well as the monitoring of the results. Once the Lean tools are implemented, the results will be validated using the selected metrics, which include: the percentage of frequency of machine failures, food losses and waste, effectiveness, and efficiency. In addition, the Takt Time, the production waiting time and the improved process time will be evaluated. An improved procedure for the milk reception process will also be obtained and the mapping of the future value stream will be carried out.

IV. Case Study

The present investigation was carried out in a dairy industry. The production of fruity yogurt is the product examined for the case study. If the efficiency of the processes is measured against the value of the industry, some efficiency problems become evident. The existence of activities without added value in the productive chain is a common problem that can affect the efficiency and profitability of a company.

A. *Data Collection*

We collect primary and secondary data using interviews as the main source of information. Semi-structured in-depth interviews turned out to be more appropriate for collecting data in SMEs. The key informants involved in the interviews were plant managers and operators. Then, the interviews were transcribed following the data protection guidelines.

B. *Data analysis*

Initially, data was collected using value stream mapping (VSM) to capture the current state of the yogurt production process, as shown in Figure 2. The results indicated several opportunities for improvement at the receiving, incubating, and processing stages. smoothie. Waste, long set-up times,

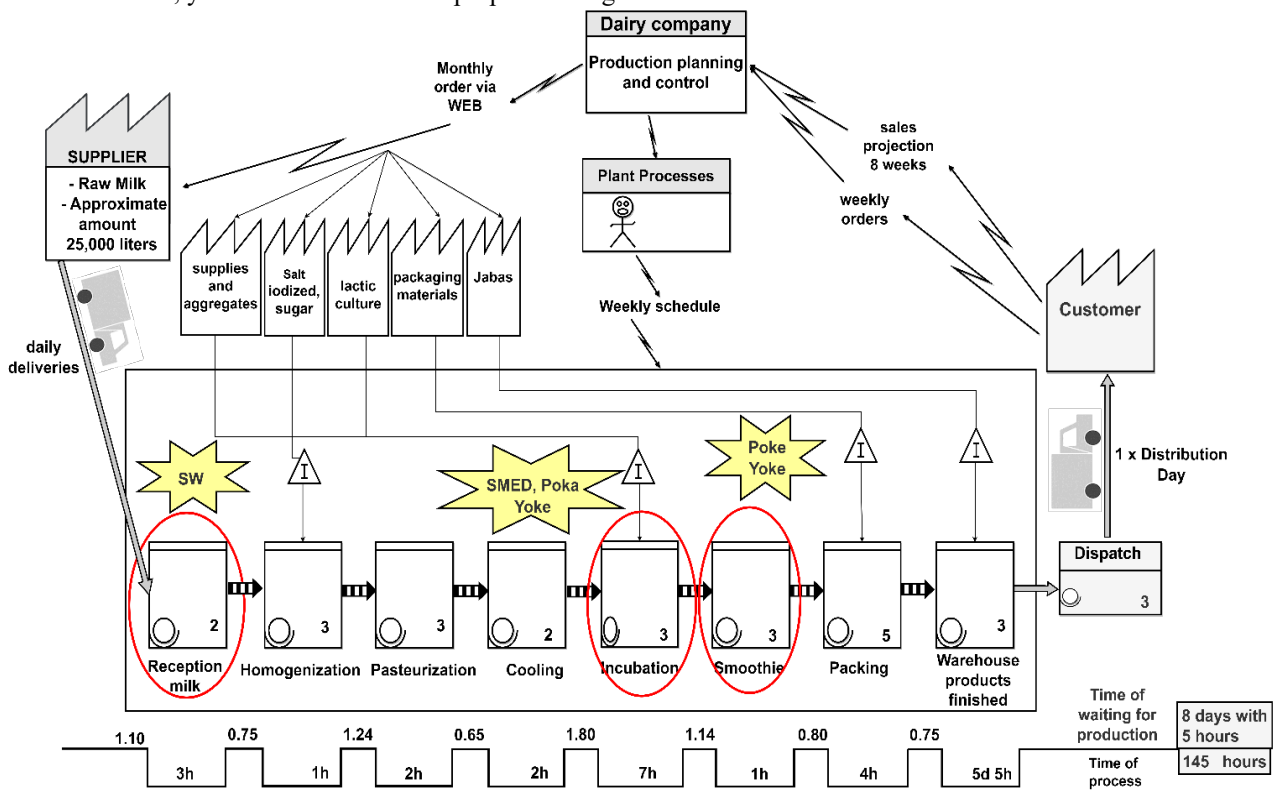
Lean Manufacturing tools was prepared. The use of SMED, SW and Poka yoke was prioritized, since they are tools that seek to standardize activities and implement continuous improvement within an organization. It was hoped that these efforts would be reflected in a future VSM, where the positive impact of the tools in terms of sustainability and efficiency in the yogurt production process would be evidenced.

C. *Model validation*

In this case study, a standard model will be developed to validate the use of the tools identified in the literature. The research method will be strengthened by process simulation modeling using Arena software. This simulation will make it possible to accurately assess the impact of the tools on the process and validate their effectiveness in improving efficiency. By using simulation modeling, it will be possible to analyze the performance of the system under different scenarios and optimize the implementation of the identified tools.

Also, sustainability metrics such as food losses and waste, consumption and use of energy are considered, which will allow quantifying the PDA in the processes and evaluating their energy efficiency to achieve sustainability in your research study. The model will take into account all the data recorded in the proposed design, once the simulation is run the software can generate visualizations, graphs and numerical data that can be used to analyze and validate the design. By

comparing the simulated results to the expected results or performance criteria, you can determine if the proposed design



meets the desired requirements.

Fig. 2 Current VSM of yogurt processing

V. Results

The main problem in the dairy industry is waste in the yogurt production process, so it is necessary to monitor the value chain to address it. In order to evaluate the effectiveness of the suggested tools, additional useful metrics can be used. By comparing present and future states, value stream mapping (VSM) in the context of Lean provides a visualization of improvements in cycle times and configuration. Sustainability metrics allow evaluating the environmental and economic performance of the dairy company in relation to waste in the yogurt production process. As indicated in Table 1, the following metrics are suggested in this case.

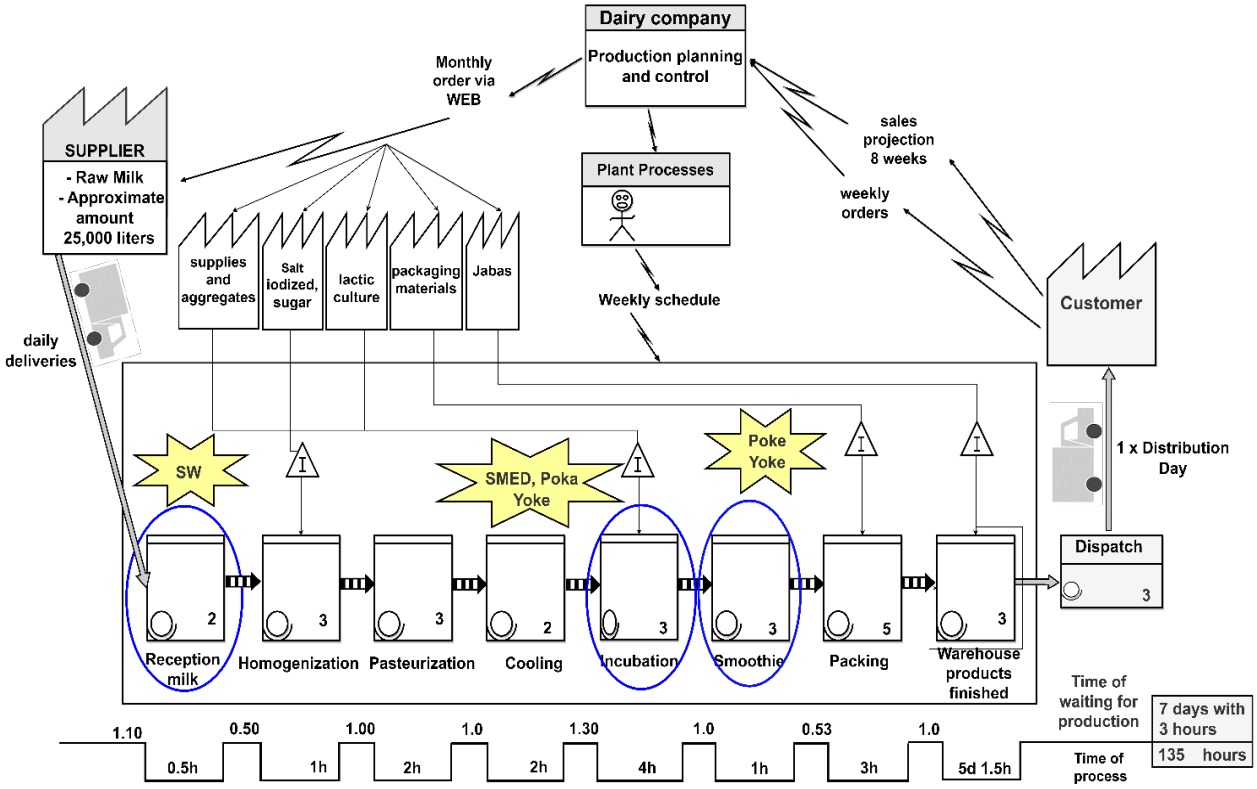
TABLE I
BEFORE AND AFTER THE IMPROVEMENT

	Metric	Before	After
Lean	Efficiency	69%	87%
	Effectiveness	61%	78%
	Takt Time	0.096 hours	0.088 hours
	Process time	145 hours	135 hours
	Waiting time	8 days 5 hours	7 days 3 hours
Sustainability	PDA	6.5 %	2.5%
	Energy Consumption (kW-h/960kg)	9	6.5
	Energy use (%)	95%	90%

Efficiency is considered an essential metric as it is the main challenge facing the plant and its level needs to be tracked. To measure the effectiveness of the proposed tools, there are additional metrics that are useful. By comparing current and future states, the application of VSM in the context of Lean allows visualizing improvements in cycle and adjustment times. In addition, cost analysis and decrease in energy consumption can be used as indicators to assess sustainability. The use of efficient tools allowed to reduce the configuration time to only 28.20 minutes. Efficiency increased significantly, from 69% to 78%. In addition, the effectiveness of the teams increased by 17%. The analysis of the future VSM revealed that the reception, incubation and shake processes are the main generators of waste. After the implementation of the lean tools integrated with sustainability, it was possible to reduce the total process time (LT) from 145 hours to 135 hours. Likewise, the production waiting time (NA) is reduced by 1 day and 2 hrs, while the Takt time decreases from 0.096 hours to 0.088 hrs. On the other hand, a

decrease in energy consumption was achieved from 95% to 90%, and food waste in yogurt production processes was reduced, going from 6.5% to 2.5%. These achievements have both economic and environmental benefits, as they contribute to conserving resources, reducing environmental impacts, and promoting more responsible practices in the dairy industry.

Fig. 3 VSM future of yogurt processing



VI. Conclusiones

The focus of this research project was the creation of a long-term model that combines Lean practices and sustainability principles in the dairy industry. The main problem of the case study is the waste that is produced throughout the yogurt production chain.

To increase the efficiency of productivity and guarantee the long-term viability of the model, lean techniques such as SMED, Poka yoke and SW were applied and to improve the sustainability of the model, all these elements were condensed in an A3 format.

These tools have been widely used in various industries to reduce waste, improve efficiency, and optimize processes. By improving the efficiency of processes and reducing waste, a more profitable and sustainable production is achieved. Continuing to use these tools and constantly looking for opportunities to improve will continue to optimize processes and ensure sustainable success in the yogurt production chain in the long term.

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