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Systematic Review on Lean Manufacturing in the Productivity of the Food Industry

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Abstract*– The purpose of the following Research is to analyze the impact of Lean Manufacturing on the productivity of the food industry. A methodology related to the PICO and PRISMA methods was used with the purpose of searching for articles in academic databases and specifying the criteria for including and excluding research articles. The Results demonstrate that there is a positive impact when implementing Lean tools in companies in the food sector, which generates improvements in productivity, efficiency and minimizes waste and pro- duction costs. However, to obtain these improvements, a set of factors is required that organizations must have in order to continue growing in the sector. It is concluded that implementing Lean Manufacturing tools is decisive for this type of companies due to the increase in productivity and competitiveness in the food sector. Despite the multiple benefits, there are still companies that do not take full advantage of them, generating a clear opportunity for continuous improvement in this sector.

Keywords*-- Cycle time, food industry, lean manufacturing, product quality, supply chain management.

I. Introduction

Lean Manufacturing (LM) is a set of tools aimed at reducing costs, increasing sales, and optimizing processes. Some of the LM tools include Just in Time, Poka Yoke, 5S, Kaizen, Total Productive Maintenance (TPM), Heijunka, Value Stream Mapping (VSM), Kanban, among others. Its use provides a comprehensive framework for companies in the food sector to optimize their operations and achieve sustainable and competitive performance [1].

Currently, the food industry has managed to secure a stable position in the industrial market. However, this industry presents a significant gap due to the multiple changes in consumer demand today [2]. Additionally, small and medium sized enterprises (SMEs) in the food industry have outdated data processing systems that do not aid in making decisions in the current market and against the competition [3]. It is important to highlight that a large part of the companies in the food sector in Peru are micro and small enterprises (MSEs), representing 90% of the total, and are in a phase of sustained growth that demands the modernization not only of their supply systems, but also of their production processes [4]. These findings are not exclusive to Peru and can be applied to various regions and industries. In countries with emerging economies and developing industrial sectors, companies face similar challenges, such as the lack of technological resources and the need for specialized training. Despite the limitations, tools such as 5S, Kaizen and VSM have proven to be effective in different contexts, optimizing resources and improving productive efficiency in various sectors. Implementing LM tools is a complex task that involves significant economic investment, professional expertise, and non-productive times. This complexity has led to in- adequate use of these tools in the food industry [5]. In recent years, the food sector has started to monitor the use of LM to improve its efficiency. However, many SMEs lack information about the benefits of implementing LM, which limits its adoption. Additionally, in Peru, low productivity is a significant obstacle for the advancement of this sector, resulting in economic losses for companies. This context highlights the need for greater education and support for SMEs in the implementation of these tools, as well as efforts to improve overall productivity in the country's food industry [6].

In this regard, the purpose of this systematic literature review (SLR) is to conduct a theoretical analysis of the current state of LM in the food sector [5]. Companies in this sector face various difficulties, mainly due to inadequate materials management and lack of experience in the constant optimization of their operations. This lack of knowledge and effective practices prevents companies from fully optimizing their operations [7]. These tools have the potential to increase the country's Gross Domestic Product (GDP) by optimizing processes in these companies, which generates significant benefits. These benefits translate into increased productivity and product value, achieving a substantial reduction in losses. Effective implementation of these tools can, therefore, have a positive impact on the entire population [4]. The main objective of this SLR is to analyze how LM impacts productivity within the food industry, identifying the problems that can be solved in these types of companies and recognizing which tools improve productivity in the sector. Through this analysis, it aims to provide a clear vision of how to overcome these obstacles, improve the efficiency and competitiveness of the food sector in the current Peruvian context.

II. Methodology

This research was developed through the combined use of the PICO and PRISMA methods. The PICO method, which stands for "Population, Intervention, Comparison, and Outcomes," helped identify key questions and terms for the research [8]. Addition- ally, it was complemented by the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) methodology, which facilitates the search for information in the articles obtained in this research from the databases: Scopus, Scielo, and Web of Science [9]. One of the

main objectives is to analyze how LM tools increase productivity in organizations within the food industry. This type of company holds significant economic importance throughout Latin America. Therefore, LM was considered the most appropriate set of tools for this research.

Consequently, for the development of this SLR, the data established in Table 1 was considered, clearly defining the parameters considered for its preparation. To carry out the information gathering, academic documents, conference papers, and reviews published in academic journals in both English and Spanish were analyzed. For the reliability and precision of the articles, the information search engines Scopus, Scielo, and Web of Science were used. At the same time, articles published between the years 2019 and 2024 were selected, aiming to obtain current and high-quality information due to the increase in scientific research over the last seven years. Keywords were also considered to expand the number of results obtained, using this method of information gathering in the database. Logical operators such as AND and OR were manipulated, as well as other symbols like ("insert phrase"), which returned more favorable results. Considering these requirements, articles unrelated to the research topic and duplicate articles were discarded. Finally, the remaining documents were obtained for evaluation and development of the SLR.

TABLE I
SUMMARY OF THE METHODOLOGY USED FOR THE SEARCH

Search parameters	Parameters for searching for information.			
Research question	What Lean Manufacturing tools increase productivity in the food industry?			
Keywords used in the search	Lean Manufacturing. Technological tools. Food industry. Productivity.			
Data repository	Scopus	Web of science	Google academy	Scielo
Selection interval	2019-2024			
Language	Spanish		English	
Document type	Review	Conference Paper	Scientific article	
Accessibility	Open access			
Criterion of selection	Process elaborated by 3 main points, included in 7 Stages (Figure 1)			
General Equation	(TITLE-ABS-KEY (“Food industry companies” OR “Food manufacturers” OR “Food sector") AND TITLE-ABS-KEY (tools OR "Lean Manufacturing" OR lean OR "productivity improvement") AND TITLE-ABS-KEY (effectiveness OR evaluation OR comparative OR 5s OR Kaisen OR productivity) AND TITLE-ABS-KEY (results OR impact OR success OR performance))			

In search of collecting more accurate information, the PICO questions were developed. In this way, the documents are synthesized more precisely. The 4 questions developed are shown in table 2.

TABLE II
PICO SCHEME

PICO SCHEME	Parameters for searching for information.
P	What is the impact of Lean Manufacturing on the productivity of companies in the food industry?
I	What are the Lean Manufacturing tools that seek to increase productivity in the food industry?
C	What is the effectiveness of each Lean Manufacturing tool on productivity in the food industry?
O	What results have been obtained when applying the Lean Manufacturing tool in the food industry?

After performing the search, 158 results were found in Scopus, the set of keywords and the use of logistics operators returned 2 duplicate articles, which will not be considered for this RSL. In the same way, 9 articles were found in Scielo. At the end of the selection process, 105 articles were taken into consideration that are possible candidates for the development of this RSL. However, of the total records found, 27 articles were obtained that are directly related to the topic of this RSL. From that, they will be used for this research. Figure 1 shows the PRISMA process graph, which shows the choice of research documents.

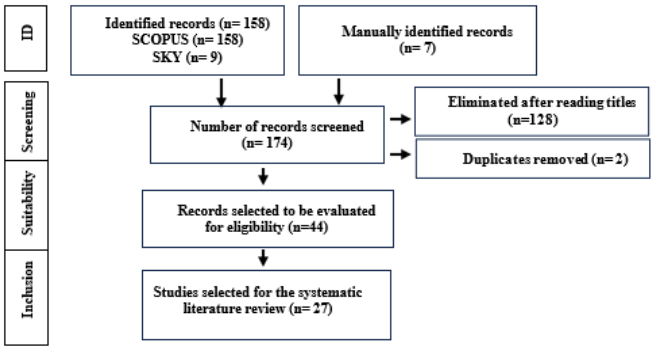

Fig. 1 PRISMA flowchart in four levels.

III. RESULTS

A. *Bibliometric results*

In the present investigation, the scientific documents were organized according to their place of origin and their year of issue. Figure 2 identifies how the application of LM has improved productivity in the food industry since 1998, where in 2022 interest in this topic increases.

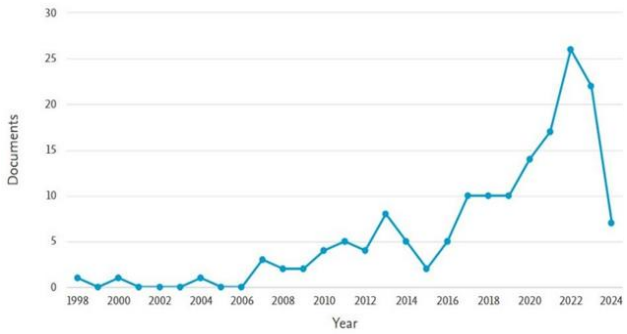

Fig. 2 Documents per year on Lean Manufacturing and the food industry.

On the other hand, Figure 3 shows that the country Italy is the one that has the greatest impact and dominance on the topic, with a total of 34 articles related to this RSL. At the same time, followed by the following countries: United Kingdom, Spain, Greece, India, Peru, United States, Germany, Netherlands, Ukraine, among others.

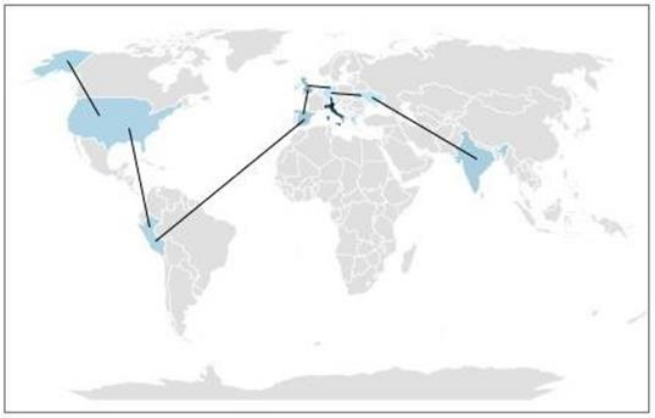

Fig. 3 Articles by country of origin.

Additionally, Figure 4 shows the frequency of the keywords used in the reviewed articles, highlighting that "food sector" is the most common term, followed by "sustainability", "food sector", and "human", among others.

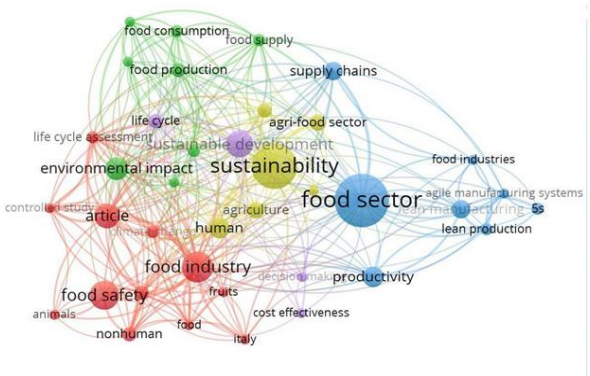

Fig. 4 Network Visualization.

In Figure 5, the age of the keywords used in this research related to the topic of LM in the productivity of the food industry can be observed.

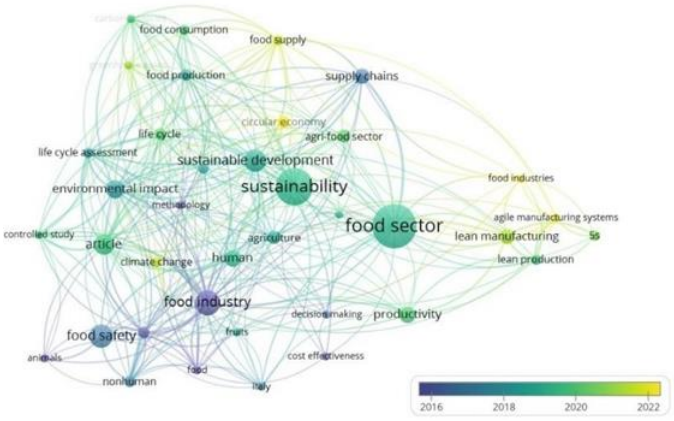

Fig. 5 Overlay visualization.

These results will be very useful to improve productivity in the food sector and respond to both the general and specific objectives of this RSL.

IV. Engineering Results

Initially, a compilation of the information obtained from the 27 documents chosen for this RSL was carried out based on the PICO questions.

P: What is the impact of Lean Manufacturing on the productivity of companies in the food industry?

Lean Manufacturing has a significant impact on operational efficiency in the food industry. By reducing inventory levels and optimizing resource utilization, both product quality and profitability are improved [10], [16]. Additionally, there is a 70% decrease in setup times, a 26.2% reduction in worker movements, and a 12% improvement in supply chain distribution and management [33]. Lean Manufacturing minimizes time and waste, increasing the sector's profitability [24], optimizing both resource use and productivity [28], [30]. These improvements also optimize cycle times and product quality [34], enhancing competitiveness [35].

In [13] highlight the improvement in efficiency, cost reduction, inventory, and waste. Similarly, [14] emphasize the optimization in production and customer and employee satisfaction. Additionally, [22], [23] emphasize waste reduction, downtime, and operating costs. [26] Underscores efficiency and profitability optimization.

[27] Mentions increased efficiency and profitability. [29] Points out a significant increase in productivity and cost reduction. [31] Highlights process optimization, cost reduction, waste reduction, and competitiveness improvement. [36]

Mentions performance improvement by reducing non-productive times and minimizing excess inventory.

Implementing LM in the food industry results in a significant increase in productivity. According to the authors, process improvement and waste reduction are key factors contributing to this increase [17], [25]. Additionally, by optimizing resources and reducing downtime, product quality is improved, which in turn increases customer sati faction and the company's competitiveness [32].

There are specific implementations of Lean tools that address needs within the food industry. For example, the 5S tool significantly improves process efficiency and work- place culture [18]. The integration of circular economy with LM through Circular Value Stream Mapping (C-VSM) enhances sustainability in agri-food operations [15]. In Uganda, the dairy value chain addresses losses and waste with LM practices [11]. Additionally, LM improves machinery availability in the production line, optimizing maintenance and resources [19]. In Ecuador, LM is integrated into bag sealing, evaluating its compatibility with the BRC standard [20]. Also, LM reduces unnecessary extra time in micro and small businesses, increasing their competitiveness [21].

Lean Manufacturing improves production flexibility and reduces waiting times in the food industry. According to the authors, the implementation of LM enables companies to better respond to market fluctuations and customer demands, thus optimizing processes and increasing competitiveness [12]. In figure 6, it can be observed that the authors leaned towards five sets of information in relation to question P.

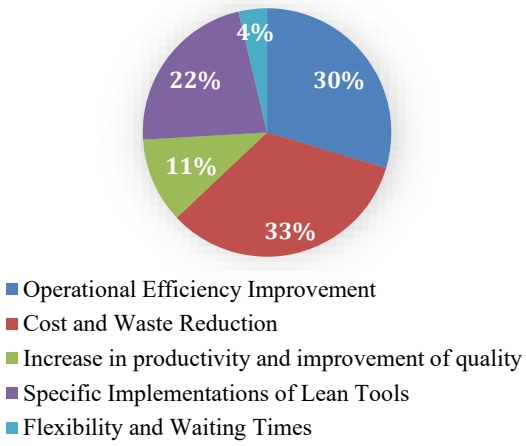

Fig. 6 Impact of LM on productivity in the food industry.

I: What are the Lean Manufacturing tools that seek to increase productivity in the food industry?

In this systematic review, [10] the Kaizen tool was investigated for its ability to eliminate waste and maximize efficiency. This tool optimizes continuous improvement and has proven effective in multiple industries, such as food, as it focuses on eliminating inefficiency and optimizing each step of the process. A milk processing plant, for example, achieved a significant increase in efficiency by decreasing downtime and improving raw material handling by applying Kaizen. Furthermore, there is a general consensus that Six Sigma parameters, VSM, and suppliers are critical factors for productivity improvement in the food industry [13]. In the case of Six Sigma, the decrease in quality variability is highlighted, while VSM allows for visual identification of bottlenecks within the production flow. For example, a case study carried out in a canning plant showed that the application of VSM reduced the cycle time of peanuts in syrup by 20% and customer orders were increased by 10%.

In addition, some tools utilized in Lean Manufacturing, such as 5S and Systematic Layout Planning achieve improvements on workspace optimization and improve on activities. For instance, the meat processing plant managed to rearrange its workstation through the adoption of 5S, achieving as high as a 30% reduction in changeover times and reduction in the workplace accident rate. Other studies have also cited the utilization of Kanban, Just-In-Time, and Value Stream Mapping in supporting Lean Manufacturing and enhancing food factories' efficiency on activities. Kanban and JIT, for example, have been utilized in a fruit processing plant to ensure that the factory produces the number of goods can be sold and minimize the inventory and waste levels.

Furthermore, the main objective of Lean Manufacturing tools, from the perspective presented here, is to minimize waste and, on the other hand, to continuously improve production activity. The positive impact of tools such as VSM, Kaizen, JIT and Kanban in the implementation of continuous improvement procedures has been demonstrated. In a fish processing company, JIT reduced raw material inventory by 15% and, as a consequence, workflow and customer satisfaction improved. Lean Manufacturing has also been taken into account in a cheese factory to improve waste management, reduce losses and maximize the use of resources. Sources identify VSM, 5S, Kanban, JIT and SMED among the tools that significantly support the improvement of food processes. SMED in this plant influenced the reduction of machine changeover times by 50%.

Also, implementing Kanban has been reported to optimize the supply chain and increase productivity. In one case of biscuit production, implementing Kanban has enabled a company to maintain adequate inventory levels for daily demand, eliminated unnecessary waiting times, and reduced lead times. Similarly, tools such as 5S, SMED, and Total Productive Maintenance contribute to eliminating failures, reducing inventories, and streamlining processes, which in turn enables the food industry to be more profitable. In one case study involving a sausage factory, TPM enabled the company to keep equipment in proper condition, an achievement that led to a 40% decrease in downtime and an overall improvement in capacity.

The use of a combination of tools such as 5S, Kaizen, Kanban and TPM in small and medium-sized companies in the management of SMEs is significantly observed in the management of resources, workflow and process management

[26]. On the other hand, the use of tools such as SMED and JIT in small and medium-sized companies is less common due to the complexity of the application [27]. A study carried out in a canning processing company revealed that with the use of VSM and 5S in small and medium-sized companies in the supply chain, the management of companies in the food sector was improved by 25% [34]. In summary, in a food processing sector, Lean Manufacturing tools such as VSM, JIT, TPM, 5S favor the company's activity and reduce the time cycle by 25% as well; in all three of them they favor productivity: VSM, [20], [30], [32]. Lean Manufacturing tools for food sodification Ponch Yoke and poka yoke or OEE suitable tools to optimize the use of resources [31].

While it is clear that the actual application of these tools will vary depending on the type of business and the specific situation, their impact on increasing efficiency and reducing waste is clear. As mentioned in studies on C-VSM implementation and employee training [15], [21], a detailed focus on training and resource management within a lean approach can be useful in the food sector. This is the key to maximizing profits. In short, correctly applying tools such as TPM, JIT, VSM, 5S, Kaizen, etc. will not only improve the efficiency of the production process, but will also optimize the supply chain, reduce waste, and increase the profitability of food companies. Evidence presented through case studies shows that lean manufacturing can transform the performance of this sector [35], [36].

In Figure 7, it can be appreciated that the authors focused on six datasets related to question I.

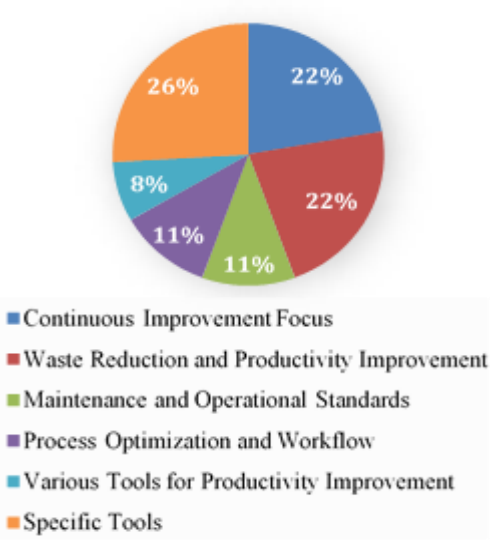

Fig. 7 LM tools that increase productivity in the food sector.

C: What is the effectiveness of each Lean Manufacturing tool on productivity in the food industry?

The implementation of Kaizen in the food industry has proven to be highly effective in waste reduction [10]. Six Sigma is recognized for improving quality and reducing waste [13]. Additionally, it is crucial to eliminate waste in the production process [21]. Research on Lean tools show their effectiveness in reducing waste and improving quality [28]. Finally, Lean tools are key to improving processes and making operations more efficient [30].

In the food industry, quality improvement is achieved through the implementation of various tools [13]. Six Sigma stands out for its ability to reduce waste and improve the quality of the final product. Additionally, the combination of [27] Just-in-Time (JIT) and Total Productive Maintenance (TPM) ensures consistent quality standards, while

[36] Jidoka allows for early detection and correction of issues, enhancing overall product quality.

In the study, the effectiveness of various Lean Manufacturing (LM) tools in the food industry is highlighted. The combination of pull system and Heijunka, along with 5S, optimizes the use of materials [12]. Additionally, Value Stream Mapping (VSM) and Single-Minute Exchange of Dies (SMED) reduce time and costs [14]. Kaizen, with 5S and Systematic Layout Planning (SLP), increases productivity [16]. Kanban improves internal communication [17], while TPM and SLP increase machine availability [22]. The integration of Kaizen, JIT, 5S, VSM, and Kanban enhances workflow [23]. Lean tools in general improve performance and quality [26]. Furthermore, JIT and TPM en- hance equipment quality and care [32]. Finally, 5S and SMED have optimized processes [33].

The implementation of 5S and Kanban has been shown to be effective in organizing and streamlining workflow in the food industry, according to [14], [17]. These tools contribute to creating a more orderly and efficient work environment, facilitating the identification and elimination of waste. Additionally, [18] highlights that 5S has significantly increased commitment and efficiency. On the other hand, [35] emphasizes that these tools improve communication, reduce variability, and increase profitability in the food industry.

The joint implementation of LM tools and the BRC standard has been extensively researched by [20]. These authors highlight that this combination has a significant impact on efficiency and production quality in the food industry. [22], [27], [34], [36] have addressed this integration, emphasizing how Total Productive Maintenance (TPM) and Systematic Layout Planning (SLP), along with Just-in-Time (JIT) and Value Stream Mapping (VSM), contribute to increased machine availability, improved work- flow, and process optimization. Additionally, these tools can be combined with Statis- tical Process Control (SPC) and Hazard Analysis and Critical Control Points (HACCP) to ensure rigorous quality control and more efficient operation.

According to the authors, [11] they assess the willingness of workers in the value chain to adopt measures against losses and waste in the food industry. Although specific Lean Manufacturing tools are not mentioned, this evaluation provides an overview of how companies are addressing waste management and process optimization. In Figure 8, it was identified that the authors' stance is related to six groupings that answer question C.

Fig. 8 LM tools that increase productivity in the food sector.

O: What results have been achieved by applying Lean Manufacturing in the food industry?

According to [12], implementing LM yielded favorable results for the food sector, such as reduced lead times and better process management. Implementing the Kanban tool resulted in increased profitability for the company [17]. Also, applying 5S over a period of 19 weeks led to cleaner and more organized work areas, increasing productivity and efficiency in the process [18]. Additionally, there was identified growth in productivity, cost reduction, and cycle time reduction in the food sector [22]. This is also attributed to inventory management improvement and meeting customer requirements [31]. At the same time, downtime was minimized, and the operators' performance level increased [33]. Therefore, downtime was reduced by 19%, inventory decreased by 40%, and performance increased by 25% [36].

In the food sector, there is high reliability when implementing the LM approach as a solution to resource loss and process waste [11]. By implementing this tool, waste has been reduced, improving productivity and increasing competitiveness in the sector [14]. Additionally, there has been an improvement in the quality of the end product through the reduction of production times and increased efficiency [23], [27]. The reduction of waste in the process has led to improvements in the company's capital and in the environment [30]. There has also been a reduction of 89.25% in product returns with defects, achieved through increased process efficiency and quality [34], [35].

According to [13], there was an increase in productivity, quality, reduction in delivery times, and costs. By implementing Kaizen, production space was adjusted to reduce process waste. Additionally, applying 5S increased performance by 31%, and implementing SLP streamlined resource management [16]. On the other hand, OEE increased by 93.14% with the reduction of incidents in the workflow [25]. The LM approach generated a reduction in expenses, streamlined the production process, and eliminated unnecessary tasks [26]. All of this resulted in improvements in quality, lower operational costs, increased competitiveness, optimization of activities, and improvement in the effectiveness of food companies [28], [29], [32].

According to [10], with the implementation of this tool, water usage in the process was reduced by 45%, and process efficiency increased by 20%. On the other hand, C- VSM simplified the detection of improvement opportunities focused on the circular economy, efficiently managing the company's resources [15]. Additionally, there was an increase in equipment availability, improving production efficiency [19]. By implementing LM tools in conjunction with the BCR approach, costs have been minimized, productivity and safety improved, purchasing times reduced, and waste reduced [20], [21], [24]. In Figure 9, four sets of information are shown that respond to question O, according to the researchers.

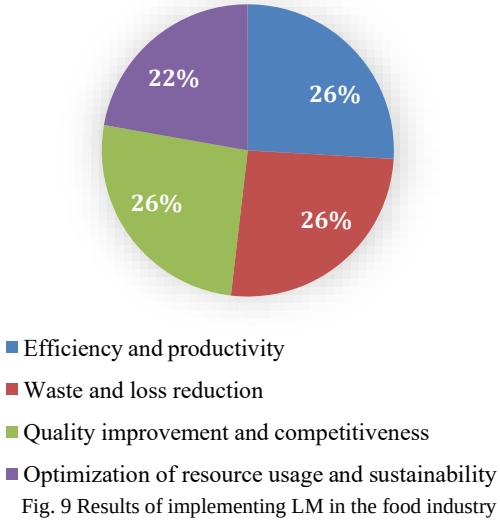

Fig. 9 Results of implementing LM in the food industry

V. Discussion

The implementation of Lean Manufacturing (LM) in the food industry has been the subject of numerous studies, highlighting its positive impact on operational efficiency, product quality, and profitability. Various authors agree that reducing inventory levels and optimizing resource utilization are crucial factors for these benefits. For example, [10] and [16] indicate that lowering inventory levels not only enhances product quality but also increases the profitability of companies. Additionally, [33] reports a 70% reduction in setup times and a 26.2% decrease in worker movements, contributing to a 12% improvement in supply chain management.

The use of specific LM tools, such as Kaizen, 5S, SMED, and OEE, has proven effective in waste elimination and continuous process improvement. [13] and [14] emphasize the importance of these tools in enhancing efficiency, reducing costs, and optimizing production, as well as in improving customer and employee satisfaction. Similarly, [22] and [23] highlight the reduction of downtime and operational costs, while [26] and [29] note significant increases in productivity and cost reductions. The effectiveness of these LM tools is

evident in multiple studies. For instance, [10] underscores the high efficacy of Kaizen in waste reduction, while [13] and [30] emphasize Six Sigma's ability to improve quality and reduce waste. Additionally, [27] and [36] mention that the combination of Just-in-Time (JIT) and Total Productive Maintenance (TPM) ensures consistent quality standards, and Jidoka enables early detection and correction of issues, enhancing the final product's quality.

Specific results of LM implementation in the food industry are varied and significant. [12] and [23] report improvements in production efficiency and greater machinery availability. [33] documents a 19% reduction in downtime and a 25% increase in operator performance. Moreover, [34] and [35] highlight an 89.25% reduction in returns of defective products, attributable to increased process efficiency and quality. Another important aspect is LM's ability to improve production flexibility and reduce waiting times, enabling companies to better respond to market fluctuations and customer demands. [12] and [17] emphasize how tools like Kanban and 5S facilitate a more orderly and efficient work environment, eliminating waste and enhancing internal communication.

Lean Manufacturing tools not only generate immediate benefits, but also have a positive impact on long-term sustainability and productivity in the food industry. According to [12] and [23], continuous improvements derived from practices such as Kaizen and TPM allow high levels of efficiency and quality to be maintained, even in changing contexts. Furthermore, [27] and [36] point out that sustained investments in training and process standardization, key characteristics of Lean, promote greater competitiveness over time. This long-term approach also facilitates greater adaptation to market demands and significantly reduces the risk of inefficiencies or overproduction throughout the production cycle.

Companies, especially SMEs, face considerable challenges when implementing Lean Manufacturing tools, mainly due to the complexity of advanced methodologies such as SMED, JIT and Heijunka [26], [27], [29]. These systems require high levels of standardization and control, which can be difficult to achieve without a solid foundation. To overcome these barriers, it is recommended to develop a continuous training strategy in resource and process management, prioritizing the adoption of more accessible tools, such as 5S and Kaizen, that allow a gradual and effective implementation [26].

Additionally, integrating LM with circular economy approaches, such as Circular Value Stream Mapping (C-VSM), has proven to enhance the sustainability of agri-food operations. [15] highlights how C-VSM aids in identifying improvement opportunities focused on the circular economy, efficiently managing company resources. In regions like Uganda and Ecuador, LM implementation has addressed losses and waste in specific value chains, optimizing maintenance and resources. Finally, it is important to note that despite the demonstrated benefits, there are unresolved gaps and problems in adopting LM, especially in SMEs, where the complexity of adapting certain tools can present a significant barrier. Training in resource management and integrating standards like BRC can be crucial for overcoming these obstacles and maximizing the benefits of LM.

VI. CONCLUSION

The implementation of Lean Manufacturing in the food industry brings substantial benefits in terms of productivity, efficiency, and product quality. Tools such as Kaizen, 5S, SMED, and OEE have proven effective in waste elimination and continuous process improvement. However, it is crucial to address certain gaps and unresolved problems, such as proficiency in these tools, adequate budgeting, and willingness to embrace change within companies. Additionally, although SMEs face various barriers to adopting these improvements, LM implementation results in short- and long-term enhancements that not only increase productivity but also strengthen the company's reputation and competitiveness in the food sector. It is essential to continue investigating specific problematic needs and gaps to further optimize the application of these tools and maximize their benefits in the food industry.

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