Analysis of the Implementation of the SMED Methodology to Reduce Machine Setup Times and Die Change in the Food Industry: A Literature Review

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Abstract

This research seeks to spread the use of the Single minute exchange of die (SMED) tool. According to the literature reviewed, there are few investigations where this tool is applied in companies in the food sector. The objective of the study is to conduct an analysis of the research carried out on the implementation of the SMED tool in the food industry. A systematic review of the literature was implemented, 3 categories and 7 study subcategories were formed to analyze 30 articles published between 2015 and 2021. It was found that 64% of the articles were concentrated between 2017 and 2019, and that 43% were made in Latin America. Also, it was found that work methods are the main cause that affects the changeover time and 67% of the articles reviewed mention the increase in productivity as the main benefit. The principal obstacle to the implementation of this methodology is the lack of staff training. The major limitation found in this research is that the cost reduction calculations mentioned are not detailed. For future research, it is recommended to detail the quantification of cost reduction after SMED implementation.

Keywords
Lean Manufacturing, Food Industry, Productivity, SMED, and Systematic Literature Review.

1. Introduction
The food industry has a large share in the manufacturing sector, since it produces basic necessities. In Peru, according to the Ministry of Production (2020), the food industry represents 32.8% of the manufacturing sector; likewise, the Banco Central del Perú (2021) mentions that this sector represents 12% of the country's GDP; therefore, its contribution to the economy is significant. As a result, it was decided to investigate what management problems the companies in this area had in common, resulting in the food industry presenting problems of excessive time losses in die changes in machines due to factors such as lack of work methodology (Lozano et al. 2017). According to previous studies, every factory in Europe loses at least 5% of its productivity due to downtime, and some lose up to 20% in Latin America (Reyna, 2020).

In order to improve the productivity of manufacturing companies, several management tools are being used, among them Lean manufacturing. Specifically, to reduce machine setup times, the SMED methodology is used, which seeks to reduce changeover times and achieve to perform each activity in the shortest possible time (Pantoja and Castrillón 2017). However, lean tools are not widely used in food industries due to the unique characteristics of this sector, i.e., short shelf life, heterogeneous raw materials, and seasonality. In addition, barriers such as large and inflexible machinery, long installation time, and resource complexity, has limited the implementation and impact of lean practices in Process Industries in general (Maalouf and Zaduminska 2019).

1.1 Objectives
The purpose of this study is to conduct a literature review to determine the benefits of the SMED methodology, the main causes that affect production time in the food sector industries, the countries that have conducted more studies on the subject, the main contributions found by the authors, the characteristics of SMED implementation and how to apply it in industrial companies in the food sector, with the purpose of spread this information among the sector's entrepreneurs.

2. Literature Review

To follow a correct path in research it is necessary to clarify some theoretical concepts, such as SMED. Around, 1950, Shigeo Shingo, a Japanese engineer developed this methodology that in its extended name would be "single minute exchange of die". According to Shingo (1985) any machine change or process readiness should take no more than 10 minutes, hence the phrase single minute, making setup operations faster and simpler, SMED helps the company to produce in small batches (Arboleda and Rubiano 2017). On the other hand, Morales and Silva (2016) mention that SMED can be defined as a methodology to reduce setup times that require innovation, which allows companies to respond quickly and effectively to variations in demand, as well as, eliminate waste and reduce batch sizes.

It is also essential to define "lean manufacturing", Pérez Rave (2011) points out that lean manufacturing is a set of principles and tools for production management that seeks continuous improvement through minimizing waste considered, the latter as any activity that does not add value (Sarria et al. 2017). There are other similar definitions, such as that of Hernández and Vizán (2013) who state that it consists of a philosophy of work and optimization of production systems aimed at determining what are the wastes and eliminate them, these are defined as processes that use more resources than are needed.

According to the literature reviewed, the application of the SMED technique generates many benefits, in such sense Pantoja and Castrillón (2017) mention that with the application of the SMED technique it was possible to reduce the ink color change time by up to 49.43%. On the other hand, Keyser (2021) indicates that with the implementation of SMED a reduction of about 42% of the average setup time of a 66" Koppers rotary die cutter was obtained. Also, Gálová (2018) concluded that, with the implementation of this methodology, the average changeover time was reduced by 21% in a food industry in Czech Republic and with the increase in productivity to 21 ton/year savings of 130 thousand CZK were obtained. In addition, Morales and Silva (2016) point out that with the application of the SMED technique an increase in OEE (Overall Equipment Effectiveness) from 77% to 85% was achieved. Similarly, Borges et al. (2015) express that in the two companies where the tool was applied, it was possible to reduce changeover times in the packaging and packing lines, in the first one, they decreased between 21% and 37% and in the second one between 23% and 45%. Likewise, in their article they advise for future work, specifically with regard to SMED, to focus on quantifying more precisely the impact of changes in machine design and the impact on inventory reduction (Borges et al. 2015).

The food sector is of utmost importance to society because of the contributions it makes. Technological innovations always have a positive impact because they allow companies to adapt to the requirements of the community and remain in a competitive market that allows them to continuously improve. According to Vázquez (2011), one of the effects of the application of SMED is the reduction of risks at work, as well as greater safety for workers.

The literature review will have a contribution in the economic field, given that according to the Banco Central del Perú (2021) the manufacturing sector has a weight of 12% of Peru's GDP. Where the food sector represents 32.8% of the manufacturing industries in Peru according to the Ministry of Production (2020). This shows that promoting productivity improvements in this sector will economically benefit both the country and the companies in this area. The SMED methodology also helps to reduce companies' production costs. In the article "Proposed model for the implementation of the SMED methodology in a food company in Santiago de Cali", it was found that with the implementation of the SMED tool, the time of the chosen process was reduced by 66.77% this produced an increase in the efficiency of the production line of 5.94% and a cost reduction of approximately $3,041,000 per year (Arboleda and Rubiano 2017).

The practical contribution of this research is that it with information on the implementation of the SMED methodology in companies of the food industry. Morales and Silva (2016) confirmed in their research an increase in productivity, before the study they had a productivity of 8 pieces/hour, after the application of the methodology they obtained 8.8 pieces/hour.

3. Methods

In this research, a systematic literature review was used as a methodological design which, according to Kitchenham (2004), "is a way of evaluating and interpreting all available research that is relevant to a particular research question in a thematic area or phenomenon of interest" (Benet, et al. 2015).

The design of this research is basic, since the objective is to extend the knowledge about the chosen topic. The paradigm is interpretative, since the researchers are in a position to influence the research process, which is carried out in a social context defined as the manufacturing companies of the food sector. The research has a qualitative approach, since the objective is to study a phenomenon in order to describe, understand and interpret it. Finally, the scope is exploratory because a topic is investigated in order to obtain more complete and concise information.

In addition, the variables "die change time" and "SMED methodology implementation" will be analyzed, with the results obtained by the indicator "percentage reduction in die changeover time", under the dimension "machinery utilization time".

The questions on which the study was based were the following: Which are the countries that have carried out the most studies on the use of the SMED tool in the food industry; What are the main causes that affect production time in the food industry; What is the impact of the reduction of machine preparation time on productivity; What are the characteristics of the implementation of the SMED methodology in the food industry; What benefits has the use of the SMED methodology generated in the food industry; What are the benefits of the SMED methodology in the food industry?

The following inclusion criteria were taken into account in the selection of the study articles:

- Studies that mention the use of the SMED methodology in the title, abstract or keywords.
- Studies developed in the context of the food industry that applied the SMED methodology.
- Articles written in English and Spanish.
- Articles from globally indexed journals.
- Articles published between 2015 and 2021.

In the search for articles, the following databases were used: Proquest, Springer, Scopus, Google Scholar, Scielo, Redalyc and Dialnet. The keywords used were SMED, lean manufacturing, die change time, food industry, manufacturing and productivity. The word SMED was considered to be present in the title, abstract or keywords of the article.

According to these descriptors, a first list of 60 papers was obtained. After reading each article, we discarded those that did not meet all the inclusion criteria and some cases of duplicity where the same article was found published in different journals. Of the duplicates, the one in the journal with the highest impact factor was chosen. Finally, 30 articles were selected from this first list.

For the analysis of the articles, Excel pivot tables and bibliographic sheets were used. These instruments made it possible to organize the articles found and classify them according to the methodology used, variables, scope and main results. In addition, this helped to complete the study categories shown in Table 1.

Table 1. Study Categories

Categories	**Subcategory**
Countries with more studies on the use of SMED methodology in the food industry.	Number of publications per year
	Magazines where published
	Country where the study was conducted
Causes affecting production time in the food industry and characteristics of the SMED implementation procedure.	Causes affecting production time
Effects of SMED implementation.	Characteristics of the implementation procedure
	Benefits of implementation

	Implementation limitations

4. Results and Discussion

Regarding the first category of study: countries with more studies on the use of SMED methodology in the food industry, the following was observed:

In recent years, research about the use and implementation of the SMED methodology has gained more attention in the scientific community, since in the first months of 2018 there were already 3 articles published (Bento Da Silva and Godinho 2018). And in this research, a total of 5 articles were found in that year. However, in 2020 and 2021, a considerable reduction in the number of research on the use of SMED has been observed, especially in the food industry.

In the present research, 30 articles referring to the topic under study were found, between the years 2015 and 2021, Figure 1 shows that the concentration of articles is between the years 2017 and 2019 with 64% of the total.

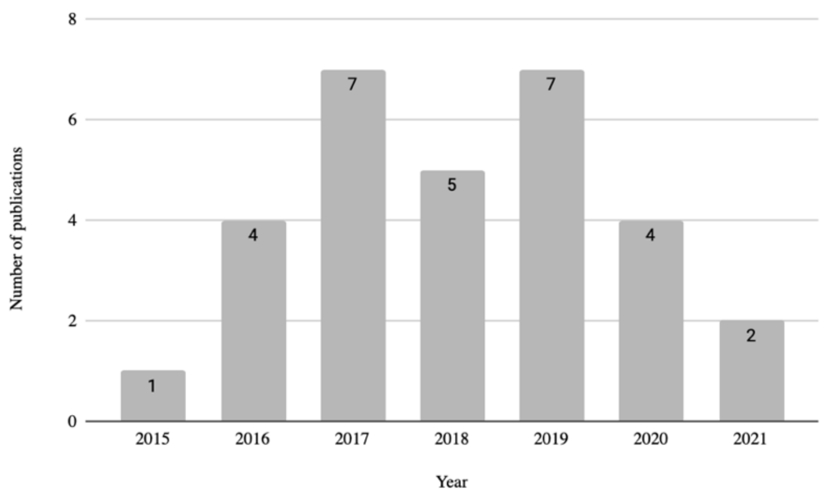

Figure 1. Number of publications per year

The articles were published in 17 academic journals, mostly Colombian. Also, 6 university repositories were reviewed, of which 2 theses were published in Peruvian repositories. In addition, articles published in 4 international conferences were taken into consideration. On the other hand, most of the articles are published in journals specialized in engineering, technology and manufacturing, where the journal "The International Journal of Advanced Manufacturing Technology" stands out with 3 publications and the journal "Procedia manufacturing" with 2 publications.

Regarding the country where the study was conducted, it was identified that 23% of the total number of articles were conducted in Colombia, this could be due to the fact that according to Arrieta et al (2011) the food industry is one of the sectors with the highest number of studies on the implementation of lean manufacturing in its processes (Quesada and Arrieta 2019). On the other hand, the number of articles found in Latin America, Europe, United States and Asia is 43%, 33% and 7% and 17% respectively.

With respect to the second category of study: Causes affecting production time in the food industry and characteristics of the implementation process, Figure 2 shows a cause-effect matrix about causes affecting production time as found in the study articles.

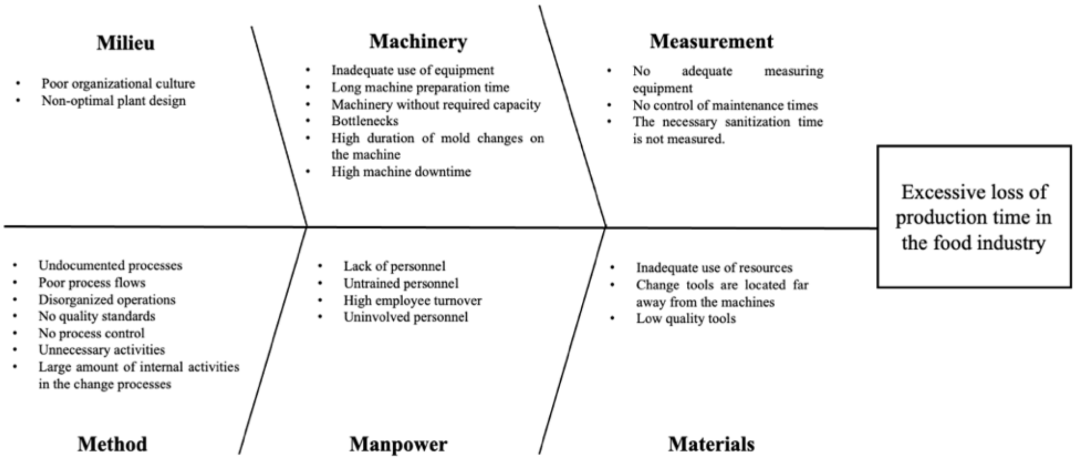

Figure 2. Cause - Effect Matrix

The main causes that affect production time in the food industry according to the authors are related to the company's methods, machinery, manpower and measurement. Making changes in production lines and not updating documentation causes the process to be performed under inadequate instructions (Arciniegas et al. 2017). Also, other causes that affect production time are that personnel are not involved in the processes, untrained operators and high employee turnover (Morales and Silva 2016). On the other hand, Stapelbroek (2018) mentions that the condition of the facilities, tools and machine equipment used to set up a production line influences the amount of time needed to replace or adjust the equipment. In addition, Olaya (2020) indicates that the downtime that occurs in the production line is due to bad procedures, failures in some activities due to misuse of resources and bad handling that causes over processes. Cruz et al. (2018) describes in their study that food industry companies apply SMED in sanitization processes and it has given very good results, decreasing the time lost due to sanitization from 7.5 to 2.5 points of monthly efficiency.

Table 2 shows the number of items according to each "M" of the Cause-Effect diagram, it should be noted that some items indicate more than 1 cause for the problem:

Table 2. Number of items for each "M" in the cause-effect diagram

6 Ms	Number of items
Method	14
Machinery	12
Manpower	8
Measurement	5
Materials	4
Milieu	1

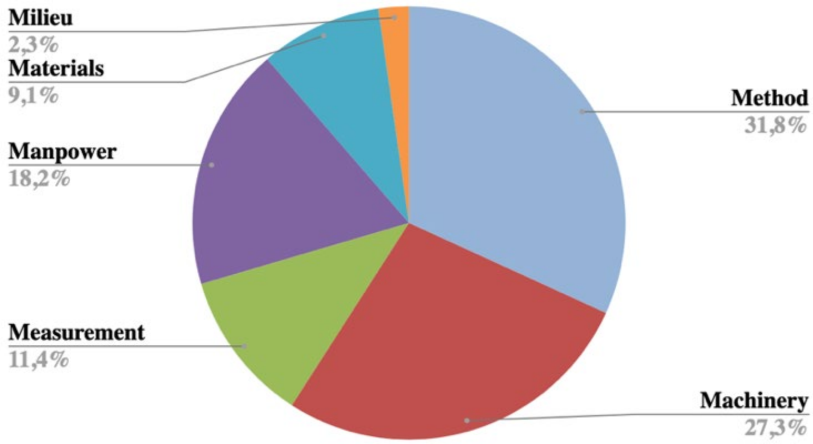

Figure 3. Percentage of items for each "M" in cause-effect diagram

From the causes found in the different articles and their classification according to the matrix, it can be observed in the Figure 3 that most of the authors indicate that working methods and machinery are the main causes that affect production time. Working methods represent 31.8% of the total, in this category, Arboleda and Rubiano (2017) indicate that there is a bad order in work operations, Maalouf and Zaduminska (2019) point out that there are unbalanced process flows and Lozano et al. (2017) highlight that there is a lack of optimization in the managements. On the machinery side, 27.3% of the total was obtained, Gálová (2018) mentions in his study that the production line of a food industry has the second largest loss in scheduled times, with up to 1500 machine hours per year losses. Also, Stapelbroek (2018) states that machine changeovers are time consuming and often accompanied by significant losses in product quantity and quality. Pantoja and Castrillón (2017) mention in their article that ink color changes for each packaging reference, occupy 20% of the programmed machine time and up to 35 changes can be performed per month, which involve significant downtime and as a consequence low productivity.

In relation to the subcategory implementation characteristics, the fwas found: According to Shingo (1989), in his book "The TOYOTA Production System from an engineering point of view" describes that the SMED methodology consists of 4 stages, as shown in Table 3.

Table 3. SMED Stages

Preliminary Stage	Study of the change operation
First Stage	Separate internal and external tasks
Second Stage	Transform internal tasks into external ones
Third Stage	Improve internal and external tasks

Note. Adapted from "The TOYOTA Production System from an Engineering Point of View," by Shigeo Shingo, 1989, 3rd ed, p. 90-107.

In the literature review, it was found that of the 30 articles reviewed, only 22 describe the stages of SMED implementation, where 14 agree with the stages mentioned by Shingo. Figure 4 illustrates the number of articles versus the number of implementation stages.

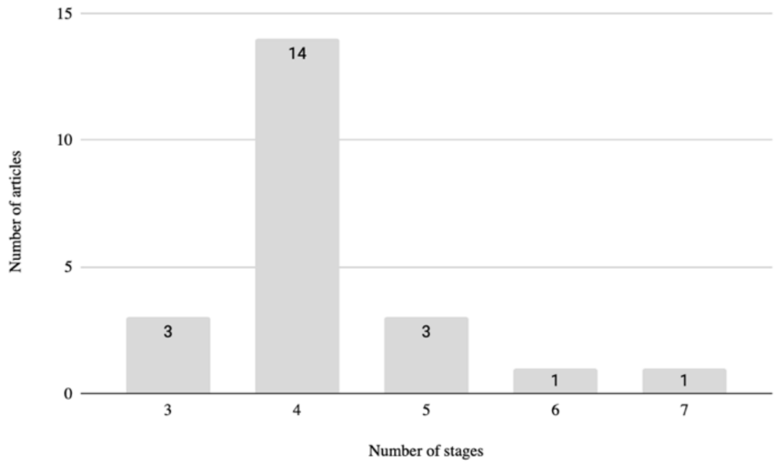

Figure 4. Number of articles vs. Number of Implementation Stages.

According to the articles reviewed, each stage of SMED was described:

1. Preliminary stage: Villaseñor and Galindo (2007) mention that in this stage, internal and external activities are not differentiated, i.e., what can be performed externally is performed internally (Arboleda and Rubiano 2017). Therefore, a study of the change operation must be carried out, the procedure described, time measurements made and the data obtained analyzed (Pantoja and Castrillón, 2017).
2. Stage One: Maalou and Zaduminska (2019) describe that in this phase all activities should be separated as external (the setup activities that can be performed when the machine is running) or internal (the actual setup operations to be performed while the machine is off). According to Shingo (1985), this is often the most important step in SMED implementation, since many activities can be performed with the machine running, however, operators wait for the machine to stop to perform them (Borges et al. 2015).
3. Second Stage: Also called transformation stage, it consists of re-evaluating the operations to see if any activity is wrongly assumed to be internal (Diaz et al. 2016). In this stage, unnecessary activities are eliminated and the internal preparation is transformed to external (Salwin et al., 2019).
4. Third Stage: The last stage is based on perfecting the activities, for this it is necessary to make a detailed follow-up from tests to verify if the changes made are optimal (Barrientos and Gamboa 2019). Ahmad and Soberi (2018) mention that the final stage focuses on streamlining all internal and external activities. This stage serves to standardize the timing of activities and improve all operations.

In contrast, 3 articles do not mention the preliminary stage in their studies, however, they agree on the following 3 stages described by Shingo.

On the other hand, there are 5 articles that describe more than 4 stages for the implementation of the SMED methodology. Morales and Silva (2016), describe 6 stages to implement SMED: Select the process where SMED will be applied, Analysis of the initial configuration, classification of internal and external activities, standardize, validate and training. Another article mentions 5 steps, observation and recording, separation of internal and external tasks, conversion of internal to external, optimization of all possible tasks and documentation (Godinaa et al. 2018). Similarly, Parwani and Hu (2021) mention that it is 5 steps, however, it has some differences: observation, analysis, separation of activities, eliminating external activities and ensuring that processes are simplified. Keyser (2021) details 7 steps for implementation, identification of the machine to be studied, defining the configuration, analyzing and separating internal and external activities, recording a video, brainstorming, applying the activities to future configurations and team discussion.

In relation to the third category of study: Effects of the implementation of the SMED methodology in the food industry and with respect to the subcategory benefits of SMED implementation, 24 of the 30 articles reviewed highlight that by applying this methodology to reduce machine setup times, other positive results are also obtained for the company. Figure 5 shows the benefits found; it should be noted that some articles mention more than one benefit.

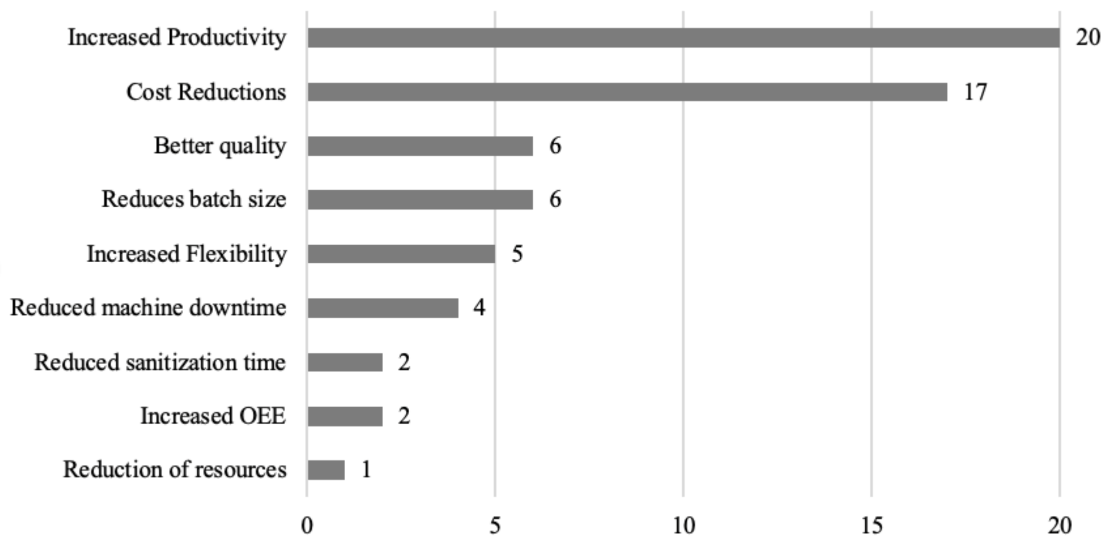

Figure 5. Number of articles for each benefit found

Most of the articles describe benefits related to increased productivity. According to the literature reviewed, 20 out of 30 articles state that the reduction of machine setup time has a positive impact on productivity. With the application of the SMED methodology, it was possible to minimize the squaring times by 20%, this is equivalent to 25% of the monthly scheduled machine time, obtaining an increase in productivity of 10% converted into units of packaging manufactured in 200,000 units (Pantoja and Castrillón 2017). Also, Morales and Silva (2016) describe that SMED allows the reduction of setup and adjustment time that has a direct impact on productivity and production efficiency. In their study they managed to increase productivity from 8 to 8.8 parts/man-hour. According to Borges et al. (2015), reducing changeover times allowed productivity gains with negligible investment, estimating that manufacturing cost savings would amount to €35,000/year just by reducing changeover times. Likewise, Gálová (2018) indicates that with the reduction of changeover times an increase in productivity by 21 tons per year was obtained, Henriques (2019) mentions in his study that with the SMED methodology he achieved a 21% increase in productivity and Salwin (2019) obtained in his case study an increase in annual production by 2.54%.

However, the authors highlighted other benefits such as increased flexibility, quality, lower costs and lot size reduction. Table 4 describes the authors' results according to the main benefits found.

Table 4. Other benefits found to be provided by the implementation of SMED

Batch size reduction	- Sarria et al. (2017) indicate that the implementation of SMED reduces the lot size which avoids overproduction. - Olaya Herrera (2020) points out that it derives in the possible reduction of production lots allowing on-time delivery place and stock control in uses. - Maalouf and Zaduminska (2019) mention that the reduction of changeover time allows a small batch size, which reduces the delivery cycle time. - Sousam et al. (2018) state that the results of SMED application are based on [...] smaller batch sizes. - Rosa et al. (2017) emphasized that SMED allows batch size reduction (Abdul et al. 2020). - Henriques (2019) indicates that the results of SMED application can be found in: [...] smaller batch sizes.
Increased flexibility	- Arboleda and Zuñiga (2017) mention that implementing SMED to all machines could generate to the company greater flexibility without the need to maintain large inventories. - Morales and Silva (2016) point out that productivity increased while times were reduced and organizational flexibility increased. - Sousa et al. (2018) state that the results of SMED implementation are based on [...] increased flexibility. - Bento and Godinho (2019) indicate that the use of SMED together with other lean tools such as 5S provides greater flexibility. - Pereira (2016) mentions that one of the indirect benefits of SMED implementation is an increase in productive flexibility (Henriques 2019).
Cost reduction	- Implementing the improvement in the machine, the company would obtain a savings of \$3 041 00 per year and its production cost would drop \$1 per unit (Arboleda and Zuñiga 2017). - Sembiring (2017) points out that one achievement in using SMED implementation in the company to be analyzed is a 30% cost reduction. - SMED implementation reduces both setup times and changeover costs (Diaz et al. 2016). - Barrientos and Gamboa (2019) indicate that by making the proposed SMED methodology changes, the company would generate a cost reduction of approximately \$670,000 annually. - Gálova (2018) mentions that SMED can achieve significant annual cost savings through the selected industrial engineering tools.
Quality improvement	- Godinaa et al. (2018) point out that companies around the world can use the SMED tool to achieve better product quality. - Maalouf and Zaduminska (2019) mention that tools such as VSM, SMED and 5S help to improve quality in manufacturing processes. - Sousa et al. (2018) indicate that the application of SMED results in [...] quality improvement. - Díaz et al. (2016) state that SMED provides as a benefit the improvement of product quality. - Ahmad. and Soberi (2018) emphasize that it is able to shorten production lead times and help achieve higher quality standards. - Henriques (2019) mentions that as a result of SMED implementation better product quality can be found.

In reference to the subcategory implementation limitations, only 10 articles were found to detail them, i.e. 30% of the total, as shown in Table 5:

Table 5. Authors and implementation limitations

Authors	Limitations
Sarria et al. (2017)	Management gaps and difficult to hire highly qualified personnel due to budget constraints.
Bento Da Silva and Godinho (2019).	Tool selection is one of the main management challenges that can determine the success of the smed technique.
Borges et al. (2015).	Most of the time-consuming tasks were related to calibration and adjustments on the machine (start-up period), which could not be reduced to ensure quality.
Lozano et al. (2017)	To apply this study, it is not possible to use just any Lean Manufacturing tool, since the point is to properly define the tasks, organize them and then optimize them. Therefore, one of the main limitations of the study is the impossibility of using any tool that cannot be adapted to optimize the supply chain.
Maalouf and Zaduminska (2019)	The relatively limited application of lean in food processing industries has been attributed to the unique characteristics of the food sector, i.e., short shelf life, heterogeneous raw materials, and seasonality.
Gálová (2018)	The most critical phase is phase one, in which it is necessary to divide all the activities, if it is not done correctly, the expected results will not be obtained.
Parwani and Hu (2021)	There may be other influencing factors, such as safety procedures in a manufacturing environment, that could increase changeover time. This case study does not take such influences into account.
Sousa et al. (2018)	It is important to emphasize that a good working environment, trust in employees and cooperation among all are fundamental to the success of any project; this fact is even clearer in a project of this type that requires the participation of everyone and the prospect of a change in the way work is done.
Ahmad and Soberi (2018)	Although SMED is promoted as one of the methods for changeover time reduction, it is not a generic method that applies in all cases, it was stated that conventional SMED is only suitable in systems consisting of a single machine and a worker.
Filla (2016)	Distribution and synchronization of activities.

5. Conclusion

The purpose of this study was to conduct a literature review to determine the main benefit, characteristics, and contributions found by the authors about the SMED methodology.

It was found that the main benefit of implementing the SMED methodology, mentioned by 67% of the articles reviewed, is the increase in productivity, reducing die change time by up to 49.43%. Also, the authors describe other benefits such as increased flexibility, quality, lower costs and lot size reduction. Likewise, it was found that the principal cause affecting die change time is inadequate work methods and that the main obstacle for the implementation of this methodology is the lack of personnel training.

On the other hand, of the 30 articles reviewed, it was found that 64% were published between 2017 and 2019, and 43% of the studies were conducted in Latin America.

The main limitation of the research is that the articles reviewed do not detail the quantification of the reduction of costs after the implementation of SMED, so it is recommended that for future studies a more detailed explanation of the calculation be made, since some articles only mention the value of savings or the percentage reduction.

Finally, the main contribution of this research from a business point of view is that it will promote the implementation of SMED in food industries in order to reduce production times and increase productivity.

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