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Production process improvement model to increase productivity by applying Lean Six Sigma methodologies and Lean tools in a Peruvian pastry MSE

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Abstract–In Peru there were 2,608,343 micro-enterprises, which represents 95.3%, 3.8% correspond to small companies and 0.6% to large and medium-sized companies and 0.3% to the administration public. During the Covid-19 pandemic, several companies were affected, causing them to declare bankruptcy or change their business model to continue operating. Peru's GDP decreased by -61.4% in the accommodation and restaurant sector and by -9.9% in the manufacturing sector, due to the fact that people had to enter a state of quarantine or isolation to avoid contagion . Therefore, currently the economy of Peru continues on the path of recovery, in the different economic activities. For this reason, in order to help microenterprises continue to produce and improve their processes, this research is focused on productivity within the cake production process of a microenterprise and its purpose is to propose a management model that allows increasing productivity using the Six Sigma and making use of various lean tools such as 5S, VSM, Poka Yoke, KPIs and techniques such as the 5 whys. On the other hand, some of the problems that a microenterprise currently faces are unsatisfied demand, lack of documentation in the production process, waste of inputs and poor distribution of work areas.

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I. INTRODUCTION

The manufacturing sector is one of the most important economic activities, because it is linked to other economic activities. The importance of the manufacturing sector is that they provide goods and/or services that improve the quality of life not only in Peru, but also in other countries. In addition, this sector must be in constant change, because it must adapt to the needs of the market and it is a great generator of employment that helps to reduce poverty. Therefore, during the Covid-19 pandemic, these were strongly affected, the INEI [1] maintains that 67.4% of the companies that are operating decreased their sales and 11.7% of them did not make sales. due to the health crisis, which led many Peruvians to seek other alternatives to generate income. In addition, 64% of microenterprises were strongly affected by the pandemic.

A study carried out by ComexPeru, the private sector in Peru is made up mainly of micro and small companies, representing 95% of all companies, which represented 4% growth in employment.

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On the other hand, the Peruvian MSEs is reflected in that they remain in the market according to their sales, since it is the main generator of income for thousands of Peruvian families and its productive performance [2].

Due to the health crisis that was experienced at the beginning of 2020, and that we are currently recovering from, national production in 2020 decreased by

-11.12%, which represented the lowest rate in the last 3 decades. According to the Ministry of Production (PRODUCE), at the end of 2020, production in the manufacturing sector obtained a growth of 9.21%, this figure was reflected after nine months of negative behavior [3]. In 2021 this sector registered an increase of 17.9% compared to the previous year, this result was driven by the growth of the non-primary subsector, which was influenced by a higher production of consumption by 17.3% and intermediate goods 30 .7% [4].

This article will be carried out in the pastry subsector, which belongs to the manufacturing sector and uses a traditional channel. Likewise, the bakery and pastry sector that belongs to the food industry was also affected during the Covid-19 pandemic in 2020 and, consequently, the reduction of pastry sales by 50% [5].

On the other hand, [6] indicates that some of the problems faced by a pastry microenterprise are unsatisfied demand, inadequate distribution of work areas and non-standardized processes. In addition, there is currently great competition among micro-enterprises. For this reason, they seek to compete in terms of quality, costs and expedited fulfillment of their orders. The authors [7] argue that companies are constantly influenced by changes in the environment, customers change and are more demanding. Therefore, organizations have the need to improve or modify their methods in terms of their processes and quality. On the other hand, the authors [8] mention that currently the economic environment is constantly changing and thus leads to a significant growth in competitiveness in companies for the development of their products, which must be of high quality and low cost. . Companies must seek new strategies that respond to the new challenges of the competition, increase their productivity and the continuous evolution of customer demand [9]. For this reason, with the proposed improvement, we seek to increase productivity in the production process in

the pastry shop and not only that, but also the tools that can be implemented in any type and size of company, obtaining favorable results and at low cost. being beneficial especially to micro-enterprises. For the improvement that will be carried out, the Lean Six Sigma methodology will be used, which is an improvement model and lean tools such as 5S, Poka Yoke, VSM and KPIs.

The model that is proposed will be carried out initially with the analysis of the company, in order to reflect its current state, which will show the current processes through diagrams and graphs, in order to identify the activities that do not generate value and lead to failures in the production process, thus generating low productivity, economic losses and loss of raw material. After carrying out the analysis and the root causes found, the proposal to the problem is generated, with the objective of increasing productivity in the area of cake manufacturing. To validate our improvement proposal, it will be simulated to compare its initial state, before and after the improvements made.

The authors [10] implemented the 5s technique in a plastic machinery company in India. It was possible to improve productivity from 75% to 101% and also, the search and waiting time for materials was reduced by 7 months. Likewise, the authors [11] applied Lean techniques in order to reduce the time in the process of selecting raw materials in a microenterprise. They managed to obtain a productivity increase of more than 22% as well as a saving of 83% in picking time.

II. STATE OF THE ART

A. *Lean Six Sigma*

Lean Six Sigma is a process improvement methodology that consists of five stages (Define-Measure-Analyze-Improve-Control). It was developed in the 80's by the engineer Bill Smith, based on the concepts of Shewart, Deming, Juran and Taguchi [12]. On the other hand, the LSS is seen as a method of improvement in companies, because it works well for processes where the causes of their problems are not known, helping to provide a set of tools to improve product quality by reducing or reducing waste and process variability [13]. Six Sigma is a business process, which allows organizations to drastically improve their results, through designs and monitoring their activities in order to minimize waste and increase customer satisfaction, also guides the company to not make mistakes in your processes, eliminating quality failures, the tool not only corrects the errors, but also provides methods to recreate the process and improve it. In addition, it is a method to execute process improvement projects, since it eliminates defects and helps the development of corrective actions through DMAIC (Define, Measure, Analyze, Implement and Control) [14] [15].

Such is the case of [16] who carried out a study implementing lean tools, the authors maintain that companies in the clothing industry is one of the most demanding and includes several critical operations. Companies in this sector must keep up with changing market trends. It should be noted that the clothing industry is always exposed to an unconscious supply of raw materials (fabrics, threads, etc.) in its production processes [17]. In addition, productivity is one of the parameters that any industry has, whether small or medium, and these generate value with lean manufacturing tools such as VSM. On the other hand, companies from different process industries face the challenge of low productivity due to poor standardization of work. In addition, these companies must define, measure, analyze, improve and control their production systems to meet their customers and stay in the market. For this reason, all the companies of the different production sectors must use an adequate combination or selection of different tools in their processes, in order to eliminate the possible causes that may arise in the production process of any product, to avoid quantities massive inventories [18][19]. Likewise, they implemented lean Six sigma tools such as VSM, process efficiency, Kaizen, 5S and Pareto chart, in order to evaluate these processes and improve productivity, reduce waste and increase customer satisfaction. As a result, they managed to increase the efficiency of the process from 23% to 40%. Likewise, a reduction in the level of downtime was obtained from 32.6% to 11% and the excess of personnel that was 33 went down to only 16.

On the other hand, the authors [20] mention that improvement activities at the operational level result in an increase in the competitiveness of the company, improve the quality of products and processes, and also manage to reduce operating costs. Improvement projects are carried out with a specific methodology such as PDCA and DMAIC. Likewise, the authors [21] argue that a young company presents different problems such as standardization of the flow of information and materials, unlike a developed company, so processes must be prioritized.

The authors [22] adopted the DMAIC and Lean Six Sigma approach in a study carried out with the objective of improving the process capacity in an aluminum industry and the extrusion process, where a better sigma level was obtained that went from 2.84 to 3.65 and the process yield was improved to 98.43%. A study was also carried out where Six Sigma was used with the aim of increasing the quality of a company's manufacturing process and, in addition, the research is helpful for companies to have an approach regarding intelligent manufacturing and sustainability. It is worth mentioning that the study was prepared on the basis of the process capability index and the quality control method [23].

B. *5S Methodology*

SMEs must be in constant updating and continuous improvement. Rodriguez maintains that the 5S is a work methodology that improves the quality and productivity of companies, thus promoting a culture of continuous improvement through the commitment and participation of the people that integrate it. Likewise, the five-stage cost tool that is used in all types of companies such as clinics, organizations, schools, restaurants, etc. In addition, it focuses on promoting

employee learning because it is a simple and agile tool to make small changes [24] [25]. Its components are the following: Organization (Seiri), Order (Seiton), Cleanliness (Seiso), Standardization (Seiketsu) and Discipline (Shitsuke).

- Seiri: It consists of classifying what is useful and what is not useful in the work area, for this we select only the necessary materials and eliminate everything that we consider does not help in the process.
- Seiton: "A place for each thing and each thing in its place", for this S a place must be assigned for each object for this it is classified if it is frequently used it must be kept, infrequently keep it in a distant place or if not used remove it. This will allow us to reduce the search time and quickly find the materials
- Seiso: This S helps us create a clean work area, where the people involved in the area can work comfortably and increase their efficiency.
- Seiketsu: Create or convert the attitude in order and cleanliness into a habit, that what is implemented is a "normal" way of carrying out the activities, for this, inspections must be carried out and verify that the implemented standard is being followed correctly
- Shitsuke: This S is completed when the people involved in the area acquire cleaning as a discipline, the agreed procedures become a habit or routine.

The authors [26] argue that implementing lean tools or models guarantees the competitiveness of a company, so lean manufacturing contains methods and tools to produce large volumes of products in less time and effort. The author carried out a study with different lean tools in order to monitor their effectiveness in different companies, where the result was to apply more of the 5S and KPI technique. Likewise, the application of the 5S method increases efficiency, improves employee productivity, reduces the number of defects, and saves time and money for the company. In addition, the authors [27] recommend implementing an improvement plan, through the use of SIPOC, Ishikawa, Pareto, 5S tools to improve efficiency and productivity not only in the tire manufacturing, but also in other industries. First, the tire manufacturing process map was made, in order to understand the process. After monitoring and analyzing the process, improvement opportunities were identified to organize the work space. The next step was to carry out the improvement plan, where they implemented the 5S methodology, in order to organize the work area for the preparation of molds. After implementing the tools, a 39% increase in mold production was obtained. Likewise, there was a reduction in the time of the activities by 25%.

C. Poka yoke

It is an error-proof tool, in order to prevent defects or non-conformities from arising in the production process. Likewise, it focuses on identifying and eliminating the causes that generate variations in the production processes, which lead to product defects [28]. The Poka Yoke system is profitable and also easy to understand and apply for any type of company, regardless of its category or size. It is a continuous improvement strategy that can generate higher performance in production processes. In order to stay in the market and become a competitor, companies must generate new strategies and technology hand in hand with zero defect practices. On the other hand, [29] indicate that the tool helps us to avoid these errors even when they are made unintentionally and helps to incorporate quality in their processes, as well as the operators when taking charge of repetitive tasks or actions that depend on their memory, the poka yoke it can help free up the worker's time and mind to focus on more value-added activities. The authors [30] implemented a poka yoke system in a welding production line, because the cycle time was fast and repetitive, human errors were constant. Obtaining problems from 34.7% of customer complaints, after applying its poka yoke system with IoT in the production line, satisfactory results were obtained with a reduction in customer complaints of 5.3%.

D. Kanban

"It is a production management technique based on a pull system (pull) that is based on the self-management of processes, eliminating centralized programming." [31]. Also, the kanban tool is based on six rules, so it is common to see task cards in specific places like a board or a wall which are known as “kanban tasks”. The kanban card is the beginning of a task, in which information is detailed such as the name, time, who is assigned to it, among others [32].

The authors [33] tested a method to optimize logistics flows using the Kanban system. The kanban tool was used within the company to move products from the warehouse to the next production process. Likewise, kanban signals were implemented for the process, on the other hand, the kanban card contained basic information about the origin of the product, whether the supplier was external or internal, where it had been originally stored, the quantity, identification number, name and place Where should the product be delivered? As a result, an increase in production of 13% and an increase in value-added processes of 13.5% and a 70% decrease in interoperative stocks and increases in production times of up to 12% were obtained.

E. Key Performance Indicator (KPI)

The measurement of key performance indicators is a widely used instrument in the detection of changes in the performance of the production system in order to coordinate and take appropriate countermeasures. On the other hand, KPIs have become increasingly important in maintenance management [36][37]. Key Performance Indicators (KPIs) are often used to measure performance. Comprehensible measurement of multidimensional system performance with time, cost and quality objectives can only be achieved with multiple KPIs. The authors [38] identified problems in a hospital outpatient pharmacy such as product shortages,

incomplete drug routes, and medical personnel not knowing methods to deal with logistical problems. So, they created KPIs in order to quantify their problems and analyze solutions for storage. To do this, they considered inventory management policies for existing and future resources. Then, with the help of the LHU IT team, the inventory management module of the information system was parameterized so that restocking could be done electronically. As results from the creation of KPIs (patients attended, new patients, stockouts, Kanbans sent to order, updated Kanbans and departure time from the OA to the APh) to the implementation of the new Inventory Management System, the results of the change were remarkable, if achieved a 30% reduction in stockouts. The authors maintain that the creation of management KPIs made the problem quantitatively analyzed from the beginning, helping process management and ensuring continuous improvement in the planning and evaluation of the implemented solutions, as well as allowing them to generate follow-up on their solution.

III. CONTRIBUTION

In the present research work, it is proposed to carry out the Six Sigma model in the production process in the pastry MYPES located in the district of La Molina, with the objective of increasing the productivity of the company. A study carried out by the INEI in 2018, there were a total of 2 million 270 thousand 423 micro-enterprises, which represented an increase of 4.0% compared to the previous year. In addition, this figure concentrated 94.9% of the total number of companies at the national level, which is extremely important, since it generates employment and increases participation in the socioeconomic development of the country.

Taking into account that the pastry company emerged during the year 2020, we are interested in providing a solution proposal to the problem that we identified, which is low productivity in the pastry production process. We seek to increase its level of competitiveness and satisfy its customers. In this case, it seeks to improve productivity, reducing its cake preparation times and fulfilling the orders requested by customers, since by improving times and organization in the area production waste that does not add value in the work area can be eliminated.

The design and structure of the proposed model arose based on the identification and analysis of the main problems that the bakery presented. The methodology that will be applied is based on Lean Six Sigma and different lean tools such as 5S, Poka Yoke, Kanban, Standardization and KPIs. The proposed model is presented in Figure 1.

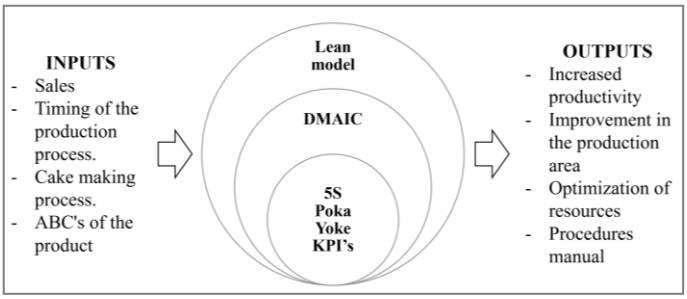

Fig. 1 Proposal for improvement of the production process.

Subsequently, an analysis of the relationship of the problems presented by the pastry company with each of the components and phases of the proposed model will be carried out.

A. *Little order in the work area*

To solve this root cause, it has been proposed to implement the 5S tool, which aims to promote changes in the work area; that is to say, to improve its production process, allowing a better performance in the elaboration of cakes, reducing errors in the cakes and search times for materials or supplies, which consequently will positively impact its productivity in the elaboration of desserts. The flow of the implementation of the 5S tool is shown below, which consists of 6 phases:

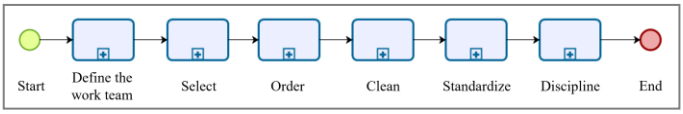

Fig. 2 Implementation flowchart of the 5S tool.

In the Seiri phase, it is proposed to establish the criteria for classifying objects in order to maintain adequate control, in addition to the designation of two types of cards that are yellow and red. Then, in the Seiton phase, the pastry work area must be organized in order to avoid wasting time and unnecessary movements to search for supplies and/or utensils. Later, in the Seiso phase, an analysis format and action plan is proposed to be able to identify and record the generators of dirt, determine the causes that originate it and possible prevention solutions. In the Seiketsu phase, the proposed changes must be maintained and the area must be kept in optimal conditions, and an evaluation must be carried out to verify that the changes are being maintained. Finally, in the Shitsuke phase, it is proposed to carry out a 5S audit once a month in order to determine if the 5S principles are being followed correctly and, in addition, a meeting must be held to propose corrective actions.

B. *Production of cakes with faults*

To solve this root cause, it is proposed to implement a Poka Yoke system (Figure 3) that will allow us to identify errors (cakes with faults). First, it begins with the identification of errors in the cake production process, the

defects and the area where they originate. It was identified that the most significant error is the mismeasurement of the ingredients and for this, the proposal is of a preventive type because it wants to avoid errors and defects in the preparation of cakes. Therefore, the proposal is the use of a movable storage shelf and a table where the meters are organized with their respective conversion.

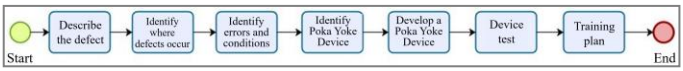

Fig. 3 Implementation flowchart of the Poka Yoke tool.

Likewise, it is proposed to use a Kanban system, making use of the cards that allow a quick understanding of the details of the order received by the sales manager. In addition, the card serves as a source of information to have knowledge about the products to be produced, the size and quantities. Below is the production Kanban card that will be attached to a Kanban board, located in a visible place for the production manager.

Product	
Flavor	☐ Classic chocolate cake ☐ Carrot cake ☐ Lemon and blueberry cake ☐ Red velvet cake ☐ Banana Cake ☐ Orange cake ☐ Alfajor cake ☐ Three milk cake ☐ Lemon pie
Amount	
Order date	
Date of delivery	

Fig. 4 Kanban card.

C. Waste of inputs

For the solution of the last root cause, the elaboration of a procedures manual is proposed in order to capture the activities of the process of making cakes; that is, it must contain the method and way of carrying out the process, it must also be written clearly and specifically. Below is the recipe format where the product, size, time, equipment and/or utensils, the ingredients with their quantity and the preparation procedure are specified.

Product			**Procedures**
Size			
Time			
Equipment and utensils			
Ingredients	**Amount**	**Unit**	

Fig. 5 Recipe format.

Likewise, the use of a KPI (quality indicator) is proposed in order to maintain a follow-up and control of the improvements in the production area of the company, which are the following:

1) % waste of raw material i in period j

% waste of raw material i in period j		
Objective	Measure the amount of waste in certain period of time	
formula		**Unit of measurement**
(Amount of raw material and wasted in period j / Amount of raw material i used in period j) *100		Percentage
DEFICIENT	**IN PROGRESS**	**OPTIMUM**
> 10%	5% - 9%	< 5%

Fig. 6 Waste indicator.

2) Indicator of non-conforming products

Non-compliant units indicator		
Objective	Measure the percentage of products that they presented faults	
Formula		**Unit of measurement**
(Non-compliant units /Units total produced) *100		Percentage
DEFICIENT	**IN PROGRESS**	**OPTIMUM**
35% - 45%	46% - 70%	71% - 100%

Fig. 7 Indicator of non-conforming products.

3) Customer satisfaction

Customer satisfaction indicator		
Objective	Measure if the service provided by the bakery meets the expectations of the customers	
Formula		**Unit of measurement**
(Number of customers satisfied with the sale/ Total customers served) *100		Percentage
DEFICIENT	**IN PROGRESS**	**OPTIMUM**
<= 70%	71% a 90%	91% a 100%

Fig. 8 Customer satisfaction indicator.

4) Profitability Indicator

Profitability Indicator		
Objective	Measure the effectiveness of the company's administration	
Formula		**Unit of measurement**
(Profit obtained / Sales)		Percentage
DEFICIENT	**IN PROGRESS**	**OPTIMUM**
<= 10%	11% - 15%	>= 16%

Fig. 9 Profitability Indicator.

5) Productivity Indicator

Productivity Indicator		
Objective	Measure the performance of the company's production process	
Formula		**Unit of measurement**
(Total goods and services/total Resources used)		Porcentaje
DEFICIENTE	**IN PROGRESS**	**OPTIMUM**
<= 40%	41% - 60%	61% - 100%

Fig.10 Productivity Indicator.

IV. Validation

To validate the proposed model, the experimental method was used, in which a new time was taken after the proposed tools. After taking the time in the month of September, it was possible to identify that the average production time of the most requested product in the company decreased by 14.14 minutes.

TABLE I
PRODUCTION PROCESS TIME BEFORE AND AFTER IMPLEMENTATION

Cake production time		
Previous time (min)	Current time (min)	Reduction
174.11	159.96	8.127%

For the new taking of times, the activities of the production process were modified, due to the fact that in the proposal it was proposed to carry out the weighing before beginning the elaboration process and that these are stored.

TABLE II
AMOUNT OF PRODUCTION OF DAILY CAKES

Before	After
8	9

Compared to the daily production before the improvement, it can be seen that by reducing the time of the production process, it was possible to produce one more cake.

Finally, other results that were considered for validation is the indicator of non-conforming products, because in this it is possible to know if the requested orders are correctly fulfilled and there are no failures in the production process.

Non-compliant units indicator		
non-conforming orders	1	**Unit of measurement**
		%
Orders requested in the month	24	**Calculation**
		(1/24)*100 = 4.2%
DEFICIENT	**IN PROGRESS**	**OPTIMUM**
>15%	6% a 14%	<=5

Fig. 11 Indicator compliance

The indicator of non-conforming products shows the level of production that does not comply with the requested orders, which is 4.2%, which shows an improved result, since at the beginning it had a value of 15%, so it can be affirmed that the implementation of the proposed model is valid.

The results obtained in the month of September are shown below, due to the fact that time was taken with the proposed tools and the orders requested in said month.

The following figure shows the efficiency indicator in the production process of the data obtained in the month of September, in this indicator it shows an improvement of 9,470%, for which it was possible to improve the efficiency of the process.

TABLE III
EFFICIENCY VARIATION BEFORE AND AFTER IMPLEMENTATION

Efficiency Indicator in the month of September (Production Process)		
Before	After	Improvement
86%	96%	9.470%

Regarding the performance indicator, it was taken into account regarding the number of orders fulfilled in the month of September, in which there was a greater number of orders compared to the month of September of the year 2021, of which the majority could be fulfilled. of those requested, obtaining an improvement of 14.015%.

TABLE IV
PERFORMANCE INDICATOR

Performance indicator in the month of September (fulfilled orders)		
2021	2022	Improvement
82%	96%	14.015%

Finally, the comparison of the productivity indicator in the month of September is shown, the company managed to be

more productive compared to the previous year, obtaining an improvement of 6.897%, which if a correct monitoring of the tools continues, a best annual comparison.

TABLE V
PRODUCTIVITY INDICATOR

Productivity indicator in the month of September		
2021	2022	Improvement
0.327586207	0.396551724	6.897%

V. CONCLUSIONS

One of the conclusions that can be mentioned from the present investigation was whether the hypothesis of the proposal to improve production processes to increase productivity by applying Lean Six Sigma methodologies and Lean tools in a Peruvian pastry MYPE was also validated. the viability of the proposal, for which it was possible to contribute to the improvement of the production process of the pastry microenterprise where the study was carried out, in addition to the fact that it was possible to increase and improve its process.

To carry out the proposal, different methodologies and tools were taken into account, one of them is Lean Six Sigma and tools that are easy to implement and do not require a high cost for a microenterprise that has not been created for a short time. Therefore, the following improvements were developed:

- 5S Tool: This allowed the company's production area to be better organized, separating and discarding the materials that were not necessary and those that, if they were useful, finally placed the materials in appropriate places according to their use.

- Poka yoke: Together with the 5s, this tool allowed us to reduce the weighing time in the production process because it took into account having a shadow board and a shelf with already weighed supplies.

- Kanban: With the Kanban cards implemented, it was possible to improve the communication of orders from the sales and production area, in order to avoid confusion regarding the receipt of orders according to the delivery date.

- Standardization: A manual of procedures, so that the person in charge of the production area and future workers follow the appropriate procedure for each type of dessert, likewise, avoid waste of raw material and avoid monetary losses generating reprocessing.

- KPI's: The last tool helps the company to have control according to the proposed indicators, establishing ranges of deficient, in progress and optimal, so that the organization can correctly manage its processes and ensure continuous improvement of the solutions that were implemented.

With the aforementioned lean tools, an improvement model was developed to apply in the pastry production area, the 5s were carried out, Kanban, a poka yoke prototype, a procedures manual and kpi's were developed to help company future.

It was possible to measure the productivity of the company before and after the proposal for improvement in the production area, which was through the taking of times in which it was possible to reduce 14.13 minutes in the production process and increase the production of daily cakes, which could be increased from 8 to 9, likewise, the number of orders requested in the month where the time was taken was fulfilled, which allows us to have greater customer satisfaction.

With what is supported in previous lines, it can be exemplified that the model presented contributes to manufacturing MYPES in the pastry industry, with tools that are considered low-cost, but can generate great benefit and impact, making the company more competitive and profitable. In addition, it makes the people in charge of the area more productive and able to fulfill orders, and customers can receive their orders at the established times and with good quality.

Economic evaluations were carried out in 3 scenarios, taking into account the VPN, IRR and PAYBACK, with which an investment of S/3,006.00 is required, which is considered viable because an internal rate of return (IRR) of 18%, likewise, a NPV of S/1,841.17 and PAYBACK of 5.3 months.

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