Applying Lean Manufacturing tools to minimize waste in a mass consumption food company

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Abstract*– The Bakery and Confectionery industry has expanded over the years and the products that make it up have taken an established place in people's diets. Many companies today seek to increase their market share while adding value to their products using fewer resources through process optimization, waste elimination, increased performance and productivity. Because of that the purpose of this research work is to provide the concepts of the Lean Manufacturing methodology and its Kaizen, Total Productive Maintenance (TPM) and Centerline tools, an example of its application in mass food consumption companies. Likewise, the application of the Lean methodology and its tools is carried out to a case study developed in a transnational cookie company with the purpose of guaranteeing the achievement of the internal objectives of the company, evaluating the processes and identifying the waste that is generated. in the production process to propose possible solutions.

Keywords*-- Lean Manufacturing, waste, Kaizen, Total Productive Maintenance, Centerline.

I. INTRODUCTION

The Bakery and Confectionery industry, BCI for its acronym in English, has expanded over the years and the products that make it up have taken an established place in people's diets. Currently, around the world, BCI has a wide variety of categories, which is why it is considered the largest subsector of the processed food industry [1].

In Peru, the bakery industry and its derivatives fell -4.15% in terms of production according to the INEI National Production Technical Report, during the first year of the Covid-19 pandemic [2]. However, according to a 2020 Euromonitor report, in economic terms, Salty Snacks reached a value of S/ 853 million in sales in Peru. Salty cookies or crackers had a percentage of 62% representation [3].

Most studies suggest using the Lean Manufacturing methodology when seeking to optimize processes, save costs and use fewer resources by eliminating waste in mass consumption companies. Lean manufacturing also has various diagnostic and problem-solving tools that have evolved over the years, and which have a single objective: the elimination of waste [4].

In Peru there are several studies on Lean Manufacturing applied to companies that are based on specific topics such as startups, implementation, continuous improvement, waste elimination, among others. However, this research focuses on the manufacturing area of the mass food consumption sector, providing the theory and concepts of Lean Manufacturing and the Kaizen, Total Productive Maintenance (TPM), Centerline and Value Stream Mapping (VSM) tools. Finally, a case study applied to a transnational cookie company using the methodology is developed.

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LEIRD2022.1.1.141
ISBN: 978-628-95207-3-6 ISSN: 2414-6390

II. LITERATURE REVIEW

A. *Lean Manufacturing*

1) Dead times: These are downtimes in production that are generated by waiting for materials, machinery, operations, personnel, among others. Likewise, these waiting times can be caused by work saturation.

2) Defective products: They are those finished products or products in process that do not meet the characteristics required by customers and by the operation. This may be due to operational errors, incorrect procedures, lack of training, machinery failure, among others.

B. *Kaizen*

It is a Japanese terminology that means "change for the better" or can also be understood as continuous improvement. This continuous improvement process is achieved through small increments, in which a process becomes more efficient, effective, controllable and adaptable [6]. Improvements are usually achieved with little or no expense, without sophisticated techniques or expensive equipment. This tool is originally from Japan and is based on the participation of all workers and their integration to solve problems and optimize processes [7].

Other authors carried out an investigation where they develop the Kaizen tools, process analysis, time taking, waste identification, standard documents of the workstation and Yamazumi graphics to increase the performance of a line of chocolates in an Italian confectionery company by reducing operating time by 3% [8].

C. *Total Productive Maintenance (TPM)*

Also called by the acronym in English TPM, which is a program where the maintenance indicators play an important role in streamlining the operation of maintenance services. Therefore, it is essential that they are calculated correctly and interpreted in a way that has a positive impact on the organization [10].

A study develops an integrated system of Overall Equipment Effectiveness (OEE) and Oil Based Maintenance (OBM) concepts. In addition, the author uses tools such as Scanning Electron Microscope (SEM), 5 Whys, Pareto and Fishbone charts to find the main causes of machinery failures and provide possible solutions. With the OEE analysis, the authors identified the most critical compared to the others. In addition, they carried out an analysis focused on the six assets that make up the Critical Line and showed that packaging machines 1 and 2 represent 58% of the losses due to failure of the production line [11].

Other study develops the TPM methodology based also on OEE measurement to improve operations management and increase the performance of a Croissant production line for a company in the European bakery sector. With the study, an OEE of the line of 75% was estimated and the main causes are the loss of speed and unproductive times. In addition, an inherent availability of the Croissant line of 93.67% was calculated. The availability is 91.29%, the real performance efficiency is 83.09% and the real quality index is 98.88%.

D. Centerlining

Centerlining is a post-SMED tool in the final stage that constitutes the reduction of adjustments and realignments of components to ensure the optimal functioning of the machines, reduce waste in rework and can also be easily integrated into the daily activities of workers and the machines. It allows to parameterize and monitor all the components of the machine prone to wear, as well as the parameters of the machinery programming that directly affect its operation. For Centerlining to be effective, the machinery must be in basic condition and the production process must be stable. That is, the company must maintain the machinery in its original state as when it was initially implemented without defects and having carried out all maintenance tasks [15].

It is essential that the manufacturing process is standardized and that all the variables are controlled. If this is not the case, the defined parameters will not be maintained over time, since neither the machinery nor the process will be stable [16].

III. METHODOLOGY

This section will present the proposed model to reduce waste using Lean Manufacturing tools that allow improving people's skills and generating a culture of continuous improvement that ensures reliable people, processes and products.

To develop the proposed model efficiently, the application of the methodology based on Lean Manufacturing is established as the core that integrates the other tools to be used, which in this case are Value Stream Mapping, Kaizen, TPM and Centerline. From the model, stages will be developed for the implementation that will be detailed in the following section.

The proposed model is made up of three fundamental components which are the Lean Manufacturing tools that will be implemented as part of the contribution of the research work for the company Galletas Perú SA

1) TPM: Likewise, for equipment failures and production outages in laminate, the TPM tool will be used. This tool allows to last the lifetime of the machines and also keep them in optimal operating conditions. Likewise, the TPM involves workers from leaders, management to operators since this methodology is focused on having zero equipment failures or breakdowns. Continuous improvement occurs because new skills are developed for workers and this allows a better organization of maintenance activities, which positively impacts maintenance costs.

2) Kaizen: The shrinkage generated by the cookie falling from the curved channels of the cooling bands will be attacked with the Kaizen tool. To do this, we rely on an article where the Kaizen methodology is used, applying the concepts of RCA analysis (Root Cause Analysis) and the Why-Why technique in a biscuit production line to improve the performance of the line and the quality of the products.

3) Centerline: For the cause of inefficient production starts, the Centerlining tool will be used since the operators of the rolling area in charge of the first stage of the production process indicate that the variation in the tenacity of the flour used for the dough is the that generates a problem in the laminate. In this area, the dough passes through a roller, cutting and pre-cut seals, which have parameters that are adjustable during the process. These parameters are not standardized depending on the texture of the dough, which is one of the measurement specifications that should be controlled in order to establish these parameters and thus not generate variation in the process that results in brittle or defective cookies. A successful investigation of the use of this tool was carried out in a cereal plant Reduce machine change times in a food industry, which are made up of four lines in the cereal packaging process. This research suggests initially implementing a methodology with the application of Centerlining, then implementing the SMED and demonstrating that it is possible to improve the changeover time of machinery.

IV. CASE STUDY

In order to validate the effectiveness of the improvement proposal, a pilot was carried out. After calculating the maintenance time index based on critical activities, a program that optimizes resources was implemented. Likewise, the design improvements implemented in the product channels generated less clogging, therefore less waste, as well as the placement of sensors and alarms in the oven for stops in the cooling bands. Finally, registers were implemented with the texture data of suitable doughs for laminating and training was given to the operators of the laminating area so that they can carry out this measurement and, in the future, adjust the values of the Centerline of dough textures. Before the implementation of the methodologies, training was given to the personnel who work in the bakery line, exposing in a general way and then in detail the implementation process of the improvement proposal.

A. Main Problem

For the case study, a line is chosen where 4 types of crackers or salty cookies are produced, which we will call cookies type A, type B, type C and type D. It is identified that there is an average economic impact of around S/84,000 per year due to the waste generated in the production of said to improve and increase the effectiveness of the team throughout

its life through the participation and motivation of the entire workforce. The TPM emerged as an outstanding competitive strategy both in the field of manufacturing and maintenance, with which it is possible to maximize the effectiveness of the equipment. Its main principle is to eliminate machinery breakdowns or defects caused by the production process [9].

The maintenance of machinery in production companies generates high costs. With ever-increasing competition in the marketplace and growing customer demands, companies must take more sophisticated steps to reduce costs. The material performance indicator reflects that the internal objective of 99% in production during 2021 was not achieved, having an average of 97% in the production of type D biscuits. Likewise, according to the OEE, the internal target of 86.9% having an average of 84%.

B. Model and tools

Landing the main causes of the problem of the waste generated in the production of type D biscuits, a Problem-evidence-impacts-causes and tools scheme was carried out so that the links to the success cases consulted will subsequently be developed, see Figure 1.

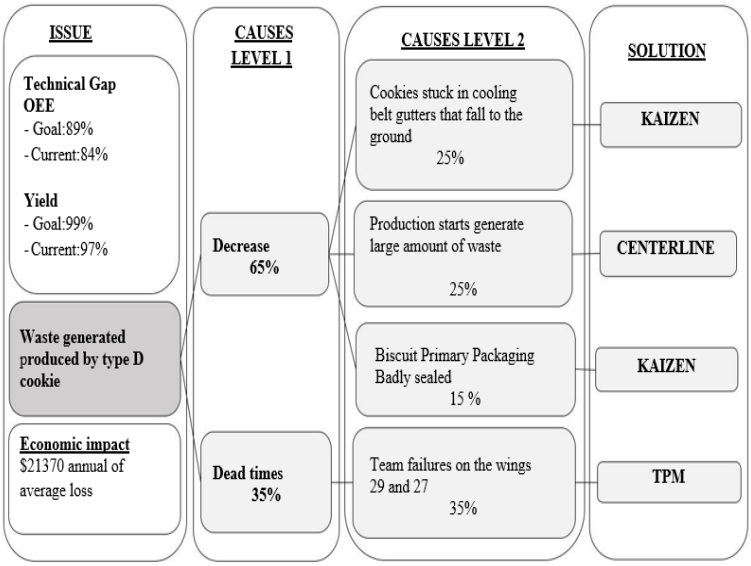

Fig. 1. Model and tools applied

For the problem of waste, which represents 65% of the waste generated, the Kaizen and Centerline tools will be used, since there are several studies which have been consulted and analyzed that show that these tools are beneficial for increasing the performance of production lines. crackers by up to 3% [7]

For the downtime that generates 35% of the waste in the production of type D biscuits, the TPM tool will be used since these downtimes are reflected in machine breakdowns, unplanned stops and minor stoppages. According to what was consulted in the investigations and case studies, the implementation of the TPM can increase the OEE of the machines by at least 3% and has even more beneficial results if it is implemented following the respective phases and having a multifunctional maintenance team [17].

The implementation of the proposal will be described in detail, developing the points described above, see Figure 2. Then the measurement of the results will be shown, functionally validating the project.

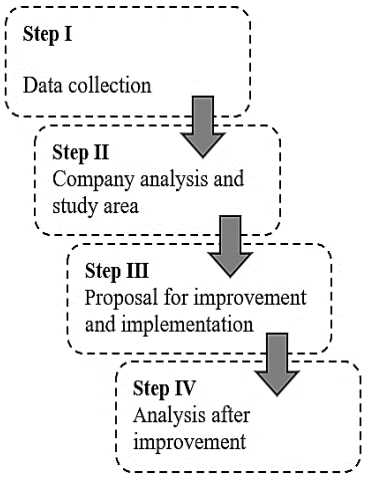

Fig. 2. Stages of the model

1) Stage I: Collection of information. For data collection, as mentioned above, various techniques are used in order to collect what is necessary for the respective analysis. The first step was the formation of the Lean Manufacturing team. The research team was formed, which must have one member per functional area in the company and is made up of the process engineer in charge of the line under study, the leader of the line, the maintenance technician in charge and the research team. The second step was initial diagnosis with management. It is necessary to capture the first impressions about what is affecting the line under study. This was done through the interviews and also by participating in the company's official meetings. The third step was to obtain the necessary access to the line and to the official databases.

2) Stage II: Analysis of the company and case study. The first step was to make a flow chart to better understand the production process of the line under study. From the information obtained, the following Figure 3 was developed.

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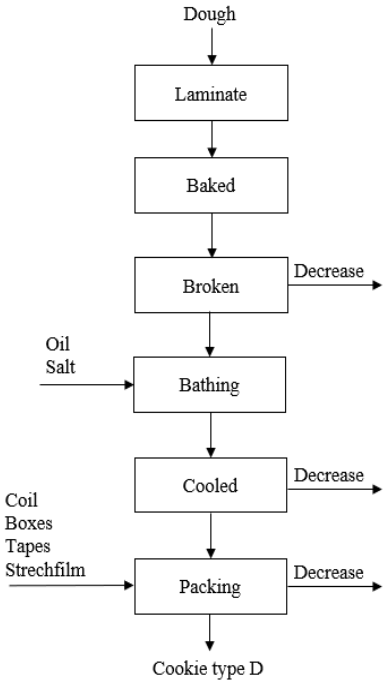

Fig. 3. Type D cookie production flow chart

As a second step, the initial Value Flow or VSM analysis was carried out to establish the Lead Time and the Cycle Time or LT and TC as handled by the authors of Lean Manufacturing. After developing the tool, a TL of 11.4 minutes and an operation TC of 457 minutes are obtained.

As a third step, a losses map was developed as an analysis of the indicators extracted from the official databases, see Table 1.

TABLE I
Losses Map

Loss Map	Trimester 1	Trimester 2	Trimester 3
Retentions (Kg)	4863	24499	6081
Minor Stoppages (Quantity)	38	31	19
Equipment Adjustment (Hours)	26	24	57
Decrease (Kg)	16581	6736	8480

3) Stage III: Proposal for improvement and implementation.

In Stage III of the pilot, Lean techniques were developed. It began by attacking the first main cause of the problem that represents 35% of waste. An RCA (Root Cause Analysis) was performed. This tool is widely used in organizations that manage integrated systems since a multifunctional team from various areas participates in it, in this case the maintenance area and the quality area participated to contribute to the analysis. To carry out the analysis, it was necessary to go to the line, understand the operation of the cooling bands through observation and explanation, since mechanical and electronic systems work on it. It was concluded that the biscuit or the dust from the biscuit entered through the lateral sides of the bands, falling on top of the synchronous belt, which performs mechanical work to give movement to the bands. This contamination clogged the synchronous belts to the point of wearing them down and breaking them, which stopped the belts, causing approximately 500 kg of waste for each stop.

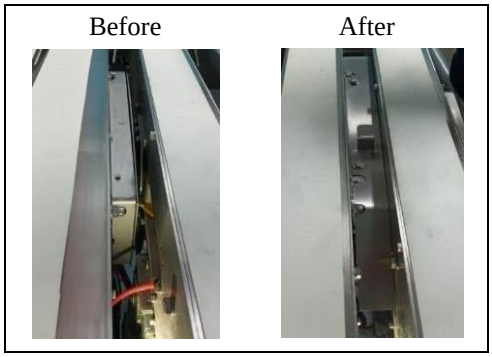

Fig. 4. Improvement in the structure of bands 27 and 29

Finally, this improvement was included in the autonomous maintenance formats for the cooling bands. These forms already existed on the line and are used to record and track key point inspections and lubrications on machines. What was included was the inspection of the synchronous belts on a weekly basis to anticipate any malfunction or wear.

The second main cause of waste is shrinkage, which represents 65% of losses. Within this, the clogging of cookies in the gutters at the entrance of the packers is a quality and performance problem that occurs in the production of type D cookies, as presented in the loss map developed in Stage II of the model. Through careful observation of the process with the team, it was determined that jams were caused by an issue related to the design of the gutter guides. The guides allow the orderly transport of the biscuit in a stacked manner and have not been modified since 2012, when the line began its operations. Therefore, a Kaizen event emerged as an action plan to prevent more bottlenecks from being generated and thereby eliminate the loss in that part of the process. This consisted of making a change in the design of the guides so that the biscuit has more space in the gutter and they are not generated. The guides that were implemented have a Y-shaped design so that the biscuit does not get stuck and can pass through the channel without any problem.

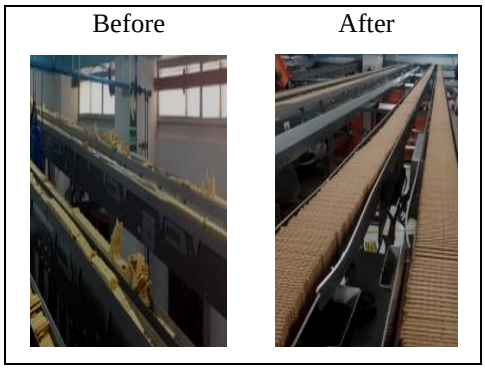

Fig. 5. Improvement in the structure of the product channels

Another Kaizen event was the brush design improvement on the primary packing machine. It was detected that the length of the brush was initially very short and did not provide stability to the sealing and cutting process, as a result there were poorly sealed packages, generating defective products, approximately 23% of the total loss in the production of type D biscuits.

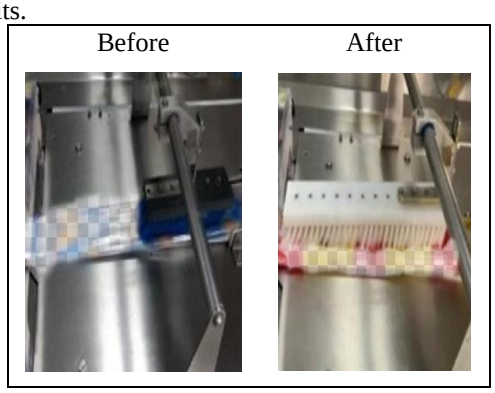

Fig. 6. Brush design improvement (packaging)

To attack the third cause of shrinkage, the Centerline tool was used. At the beginning of production, mainly the first batches became waste because there was no dough texture standard and the pressure parameters of the rollers in the laminating process and the temperature of the ovens had to be modified at the moment, which that generated brittle biscuit that could not be packed.

The improvement consisted first in training the operators of the laminating process in measuring the texture of the dough, for which a line texture meter was used. Then, the dough texture data of the type D biscuit were recorded for 3 months, and these were compared with the brittleness of the biscuit when it came out of the ovens. With the results obtained from the record, the dough texture parameter was adjusted, which was from 110 to 125 grams per second.

Finally, a standard procedure for this operation was developed and this was deployed to the rolling operators so that the dough texture measurement is carried out in each cookie production.

4) Stage IV: Analysis after improvement

This is stage 4 of the model. The two indicators with which we measure the impact of the waste generated in the production of the type D cookie will be reviewed, which are the percentage of material performance and the OEE. The improvement obtained with the TPM, which is obtained by specifying the action plans, directly attacked the problem of equipment adjustments due to pos 27 and pos 29 band regulations. they stopped being contaminated with biscuits and, in turn, unscheduled stops were eliminated all the time for this reason. From this, the OEE indicator was revised during the first quarter of 2022. The results indicate that the OEE of the type D cookie had an increase from 83.2 percent to 86.7 percent.

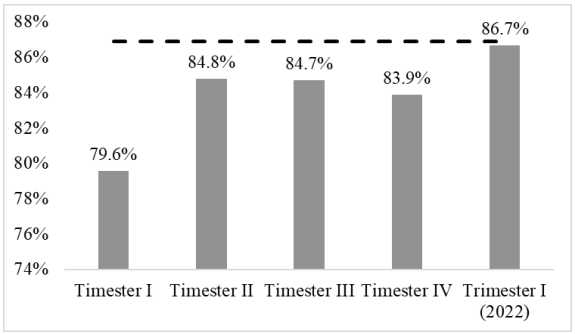

Fig. 7. OEE of Type D Biscuits after improvement

On the other hand, with the implementation of the Kaizen that is based on the modification of the guides of the curved channel of the cooling band where the cookies get stuck and fall in heaps to the floor generating the greatest amount of loss, it was possible to avoid said loss by recovering 150 kg of biscuit that in each production fell to the floor.

Finally, with the implementation of the Centerline, the record for 2 months of the textures of masses and temperature has been obtained. For this, it has been necessary to train the operators who prepare the dough to be able to use the measuring instruments. In the graph, the material yield of the type D biscuit had an increase from 96.7 percent to 98.9 percent. With the Kaizen and Centerline events, the losses generated by the decrease in the production of type D cookies were eliminated.

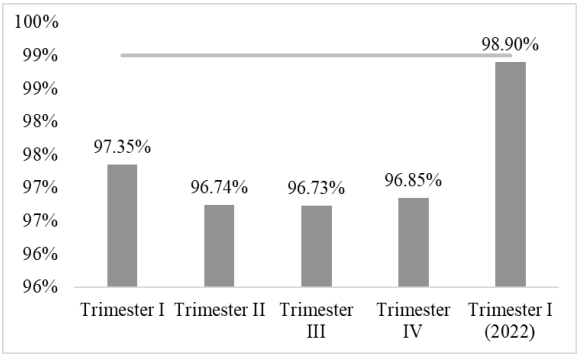

Fig. 8. Yield of Type D Biscuit materials after improvement

V. CONCLUSIONS

Based on the proposed model, which was created based on the Lean Manufacturing literature, the best tools to use are Kaizen, TPM and Centerline. To achieve these results, the context of the main problem and its respective causes must be considered, which in this case are the decrease (defective product) and downtime in the production process of a cookie.

Likewise, regarding the KPIs of the model, the OEE increased by 3.47% on average during the last quarter and the percentage of performance of materials increased by 1.9% on average.

On the other hand, this model also has a positive impact on the skill's development of the operators and on the environment.

Finally, the company benefited from savings in the production costs of the type D cookie of around $5,342.00 during the last quarter of that year.

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