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## **ADOPTING PDCA TO LOSS REDUCTION: A CASE STUDY IN A FOOD INDUSTRY IN SOUTHERN BRAZIL**

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**Abstract:** *This study presented a case study about the application of the PDCA Cycle to analyze and solve the problem of excessive losses of sauce in a process that produces frozen meals in a food industry in Southern Brazil. Through a quantitative and qualitative approach, it was demonstrated the way of implantation of PDCA in the process and its performance as a tool for continuous improvement. The amount of lost sauce was weighed for the calculation of losses as well as a survey of the status of the process indicators prior to the application of the PDCA. Through the use of quality tools, the causes of the problem and their respective solutions were defined through a plan of action. The adoption of the PDCA Cycle reduced losses of sauce by 86.75% due to improvements in the design and operation of the sauce dispensing equipment, leading to an overall improvement of the process as well as evolution in the results of all process indicators.*

**Keywords:** *PDCA, Loss Reduction, Process Improvement, Food Industry*

### **1. Introduction**

With the growth of competition in markets, the smooth running of management programs has become essential for the survival of organizations (Todnem By, 2005). The speed with which companies develop and launch new products is increasingly faster, giving the consumer a wide range of products at their disposal (Cole, 2002). As competition gets more intense, consumers are demanding higher quality products, and companies are looking for ways to improve their operational performance (Jones et al., 2010).

In this sense, the continuous search for the improvement of quality and innovation has become a strategy for organizations to defend their position of competitiveness (Pekovic & Galia, 2009; Dahlgard et al., 2013). The Total Quality Management

(TQM) stands out, which has become one of the most important strategies adopted by organizations of all sizes and sectors (Marchiori & Mendes, 2018). According to Singh et al. (2018), the organization's leadership, customer satisfaction and strategic plans play an important role in ensuring quality and improving process performance.

According to Xiaorong (2013), TQM has four distinct stages: Plan, Do, Check, Act, known as the PDCA cycle. Although it has been developed for many years, it has a very current concept and its application is adequate for the management of several organizations.

The PDCA Cycle assists in the analysis of problems, using tools and studies to define causes and solutions that are prioritized to solve them. Its use is carried out in phases, in order to plan the execution, guarantee this

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execution in an appropriate way, evaluate the results obtained and establish means to maintain the good results. Its use presents a great use in solving problems, having a very widespread use (Yu, 2017).

Improvement processes, even if they show relatively low results, provide a great advance in the market dispute. Improvements that require large changes in the production process tend to present greater resistance on the part of organizations in their implementation. For these situations it is necessary that the gains are demonstrated by the managers of the change, being the processes well directed in all their stages of production, and that the opportunities for improvement are by all desired.

For these reasons, it is necessary to intensify the development of activities that provide the reduction or elimination of losses, be they of any nature. The PDCA Cycle is a methodology of great effectiveness in continuous improvement, being the tool defined as a management method to be used by the companies to solve these questions (Rosa & Broday, 2018).

This study describes the process of manufacturing frozen meals in a food industry in Southern Brazil, analyzing losses of sauce placed in frozen meals during the packaging stage. Thus, this study will demonstrate the adoption of the PDCA Cycle in the aid of sauce losses reduction, as well as propose measures of control for process continuous improvement.

## 2. Literature Review

### 2.1. The Importance of Quality in Organizations

It is necessary to go back to the past to understand the evolution of quality, as well as its perception and need for humanity. The understanding of quality is present since the figure of the first artisans, where due to the low productivity it was possible to obtain

quality control over the entire process. In this manufacturing method, one manufactured product was not the same as the other, so that it became impossible to standardize components. At this point the quality of production had its vision only in the final product, not in the process (Carpinetti, 2012).

During the Industrial Revolution, the need to maximize production has made the standardization more important than customization. Craft works were losing space for serial production lines. Later, through the division of labor and standardization of manufacturing production volumes grew even more (Daniel & Murback, 2014). With the increase of the demands, it was possible that the products were cheapened due to the great availability. As at this time the goal of the industries was to increase the volumes produced, they concluded that there was no time to be lost with quality controls (Gomes, 2004).

New advances were obtained through the use of statistical concepts, developed by Shewhart, for use in the area of quality (Carvalho & Paladini, 2012). Shewhart was also responsible for creating a very popular problem-solving tool these days, the PDCA Cycle. The development of these practices characterized this period as the era of Statistical Control. These techniques allowed the beginning of the analysis of causes of the defects in the processes, so that they were prevented and not only detected through the segregation of defective finished products (Montgomery, 2009).

Later, new quality systems were proposed by other specialists. Feigenbaum proposed the Total Quality Control (TQC) system, where quality was treated systemically, based on the model proposed by the International Organization for Standardization (ISO), the 9000 series (Carvalho & Paladini, 2012). The focus of quality then becomes the productive system, characterizing the era as that of the Quality Assurance (Daniel & Murback, 2014). However, during product

development at this time, factors such as customer needs were not considered. These factors did not imply a reduction of sales by the industries, since there was no competition for the western factories.

After World War II, Japanese industry was undergoing a process of reconstruction. These industries saw in the quality a way of being competitive in front of the western factories. With the help of scholars such as Shewhart and Deming, Japanese industries have developed their own production systems, aimed at reducing waste and meeting customer needs (Carpinetti, 2012).

A model that had great influence in the evolution of the Japanese quality was the Toyota System of production, idealized by Taiichi Ohno. Toyota System or Lean production is based basically on waste reduction (Carvalho & Paladini, 2012). Through the development of these systems, Japanese products placed on the US market presented higher quality and customer identification at a lower price. (Daniel & Murback, 2014). Currently, one of the main concerns of Quality is to satisfy the needs of the consumer. Total Quality Management is an efficient philosophy that was created in order to provide customer satisfaction, no matter the size of the company (Ebrahimi et al., 2014).

Therefore, the history of quality continues to be written by the organizations, in the competition for the market, evolving through the organization of strategies and by the greater systematization in the process management (Maximiano, 2014). Managers also have the role of seeking better forms of production, and be attentive to the news that can make a difference in the management of processes and people.

## 2.2. PDCA Cycle

The PDCA Cycle (Plan - Do - Check - Act) is a tool developed by Shewhart and disseminated by Deming for analysis and problem solving, with great application in

studies of improvements (Johnson, 2002). Shewhart is considered the father of statistical control for being the pioneer in the use of these tools aimed at quality. It presented numerical data collected in visual form, through control charts, so as to make it easy for all the organization's employees to understand (Montgomery, 2009). Each step of the PDCA cycle will be explained below.

In *Plan*, the problem is defined as a goal or objective of interest in which the method is to be applied, and actions are also defined to achieve it (Aguiar, 2002). It can be considered a good goal, one that comes from strategies to improve the process, which seeks to meet the demands of the market and the maintenance of the company's competitiveness. A bad goal is one that comes from process problems and is used as a way of correcting deviations (Werkema, 2012).

Following the cycle, one must locate the focus of the problem, define the root causes, the deficiencies of the process and analyze the best solutions for them. The quality tools are of great use in these steps, both for data collection and visualization, and in the search for root causes and prioritization of actions. A plan of action is elaborated where all the actions prioritized must be executed. This first phase tends to be the most laborious and time consuming. However, the more and better the data entered in the PDCA in this phase, greater are the chances of success of the cycle (Cunha, 2013).

The planning phase consists generally in the phase of greater commitment and work employed in a PDCA Cycle. The other phases are facilitated by good planning. According to Aguiar (2002), the division of phase P can be adapted as follows:

- a) Definition of the problem;
- b) Study of the phenomenon and identification of the causes;
- c) Study of the process and prioritization of the causes;
- d) Elaboration of the action plan.

In *Do* the execution of the action plan elaborated is performed. It must be provided at this stage the acceptance of the action by the team, and the accomplishment of the necessary training for its correct execution. With the consent of all concerned, and after the elimination of all impediments, the actions are executed. A follow-up to the execution can also be performed when this is necessary to ensure that actions are carried out as planned (Aguiar, 2002).

In *Check* the verification of the results obtained after the execution of the actions, as well as the evaluation of their effectiveness, are verified. A comparison is made with before and after the process, through the information collected in the planning phase and after the execution of the action plan. In the case of an unsatisfactory result, the phase *P* should be returned to identify the reasons for non-attendance. The return to the planning phase tends to have a faster execution, once all the analyzes of the problem and of the process have been carried out, being able to skip some stages of this phase (Werkema, 2012).

The final phase, *Act*, consists in the adoption of good practices implemented as routines in the process. The standardization of actions guarantees the correct execution of the activities, through established procedures, and the training and training of employees. After the actions to maintain the results are guaranteed, it is possible to complete the PDCA. A new cycle can be rotated whenever there is a need for corrections or improvements in the process. This possibility facilitates the continuous improvement of the process (Cunha, 2013).

### 3. Methods

#### 3.1. Company and Process Description

The company in which the present study was conducted is a food industry located in Southern Brazil. It currently has more than 105 thousand employees, distributed in 35 sites in Brazil and 13 sites abroad. It also

exports its products to more than 120 countries in 5 continents. It works in the manufacture of frozen processed products, with production lines for pizzas, lasagnas, salted pies, sweets, desserts and ready-made dishes.

The process where the study was carried out, works in the production of frozen ready meals, through the production in 5 different lines. Lines 1 and 5 present the highest production capacities (70 plates per minute). The other lines have significantly lower volumes (60 plates per minute) due to the fact of using less modern equipment. In the same way as with lines 1 and 5, lines 2 and 3 are also identical. Line 4 differs slightly from other lines, and has a lower production capacity due mainly to the lower degree of automation present in this line.

Due to this higher speed and the ability to produce higher volume dishes, the production of lines 1 and 5 together corresponds to 64.5% of the total production in tons of the factory. Due to the greater volume produced in these lines, these were the ones selected for the application of the PDCA for loss reduction, since to act in the reduction of waste of these lines, there would already be a significant reduction in the whole process. As a matter of greater ease of making available the line for the study, the work was initially performed on line 5. After completing the work on line 5, the actions could be easily replicated on line 1.

At the beginning of the line, some inputs are supplied manually. The main materials supplied manually are the trays, where the product will be packed, and the cheese that is deposited in a specific equipment for the dosage. Depending on the product being produced, other inputs are also available. The sauce for packaging arrives to the production line by pipes connected to the machines of the preparation stage of sauce. There are five devices responsible for the dosage, all of which are the same, and distributed along the line. They have two

dosing sets each, and their actuation is performed by presence sensors that indicate the correct moment of the release of the sauce in the tray.

The dosers are constituted of an electro-pneumatic system, that makes the drive of a piston and piston assembly. Through this drive the dosage of the correct amount of sauce defined for the product is made. Between the dosages of sauce, the other inputs (pasta, ham, cheese) are inserted according to the recipe of the product produced. The completion of the packaging is done after verifying if the product is in compliance with the established tolerance limit. After that, the trays with fresh product is sealed.

### 3.2. Description of Productivity Indicators

With the application of the PDCA Cycle it was intended to obtain a reduction in the losses of sauce in the packaging lines. There was no indicator dedicated specifically to measuring the wastes of sauce until this study was conducted. The verification of the opportunity for improvement in the losses of sauce was mainly observed visually on the production lines and through disorders caused by these wastes.

There are, however, other indicators used by the company, of which the loss of sauce has a direct impact. Unplanned Production Stops are all production line interruptions, without prior scheduling with the planning industry. This indicator is measured in hours and characterizes the period of time that a production was stopped by the need for some intervention or lack of available raw material. For these occurrences' notes are opened, where the stop time and its respective cause are inserted.

The Number of Accident Risk Conditions indicator refers to all possible factors that could lead to an accident if they are not eliminated. They assess, in addition to the number of accident risk points, the total time and resources to eliminate this condition. All

these indicators, together with the quantification of the loss values of the sauce, will be used in the development of the PDCA Cycle. They will be of great importance in the planning and verification phases of the results, being made through their results the comparison of the effectiveness of the actions carried out.

### 3.3 Adopting PDCA

For the application of the PDCA Cycle in solving the problem, it was necessary to initially quantify the amount of sauce that was lost in the packaging stage. The execution of the PDCA Cycle in the study can be visualized in figure 1.



Figure 1. PDCA Cycle

The *Plan* phase was initiated through the collection of process data. To measure the wasted quantities, plastic bags were inserted at the points of accumulation of the sauce, in order to collect these volumes. Figure 2 illustrates the method of collecting the lost sauce.

The collections on the production lines were carried out on different days, for periods of one hour. Several types of sauce were collected for three days in all lines. After the collection, the samples were weighed in order to discover the total weight of the inputs that were lost. During this stage a total of 20 samples of each line were collected.

Knowing the values of losses, a verification of the occurrence of the problem was started,

in order to make a survey of the possible hypotheses of the causes. A conversation with operators and experts was made, in order to add a greater knowledge to the

survey of possible causes. Using the Ishikawa diagram, it was possible to confirm and define some fundamental causes for the occurrence of the problem.



**Figure 2.** Loss of sauce in the packaging line

Having defined the root causes of the hypotheses already tested and confirmed, it was then started to survey and elaborate strategic actions that would solve the problem raised. Discussions and process inspections were carried out, as well as consultations with process specialists and specialized suppliers in the application of solutions to similar problems, in order to confirm the feasibility of actions.

The *Do* phase was to carry out the proposed actions. In the execution of the action plan, we also counted on the suppliers, working together the internal workforce of the company. For this phase several tests of materials and equipment were used, so that the ones that would present a better performance in the process improvement were evaluated and defined.

After completing the action plan, the *Check* phase began, where new measurements were taken to verify the current situation of the problem raised. In this phase, the results obtained in the production indicators used by the company after the improvements in the process were also compared. These values

were again obtained through consulting the company's scorecards.

In the *Act* phase all the effective actions were replicated to production line 1, which had the same specifications, and consequently presented the same problems as similar values of losses. The Act phase was completed, along with the implementation of the PDCA Cycle in the process.

### 3.4 Validation of Improvements

Through the application of the PDCA Cycle it was intended to obtain several improvements in the production process, having as main focus the reduction of the losses of sauce in the packaging lines. In order to verify the fulfillment of the main objective, a new data collection was necessary after the actions were carried out. The new survey was carried out in the same way as it was done when the objective was to measure the amount of sauce that was lost before the execution of the action plan.

Plastic bags were then placed again on the gutters of the container line in order to collect the sauce that fell on them. For this stage 20 samples were also collected for the line where the work was performed, the measurement being performed on different days for periods of 1 hour. The collections in this stage also took 3 days to complete. In the same way as initially done, the bags were weighed to quantify the average amount of sauce lost after performing the actions.

A new data collection of process indicators was also necessary to analyze its evolution. Its purpose is to confirm or not possible relationships of losses with the results of these indicators. With all the data at hand, it was possible to compare the initial data of the work with the current situation of the problem.

#### 4. Data Analysis and Discussion

The losses of sauce in the filling lines occurred by the dripping of the dosers during the filling of one tray and another. These lost quantities of sauce were accumulated in gutters under the container line and also on the floor, according to figure 3.



Figure 3. Loss of sauce on the floor

The *Plan* phase began to be executed through the collections made to quantify the losses. The volumes collected through the bags were weighed, and the values obtained were recorded. Through the results, a calculation was made of the mean value of losses among all the different variables in

which the samples were collected. Figure 4 shows an example of a sample after being weighed.

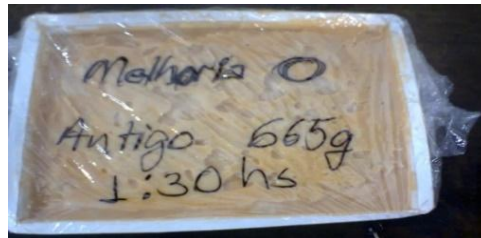


Figure 4. Weighed sample

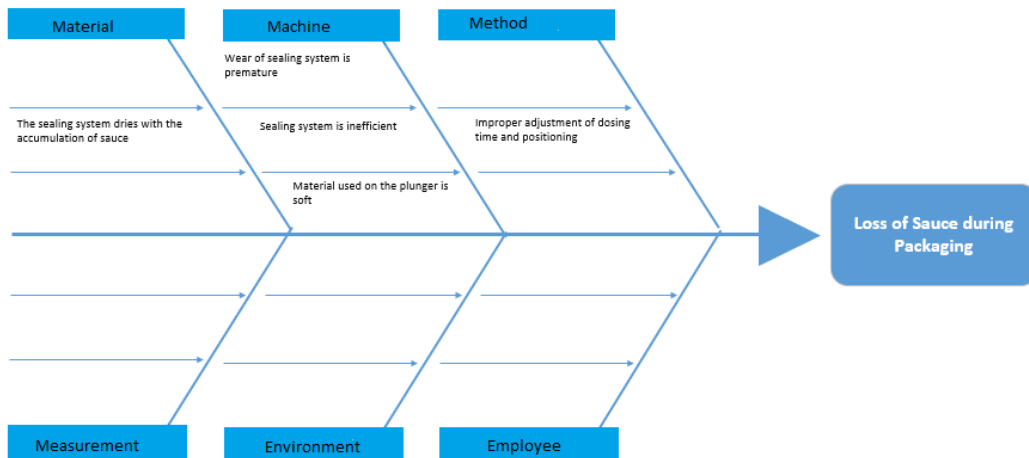
Through data collection, an average of all measurements showed the amount of 0.4343 kg of lost sauce per hour in each doser. The Unplanned Stops had an average occurrence of 21.13 hours in the months prior to the completion of the work. In the specific case of the loss of sauce, there were reports of line stops because the trays had the edges soiled with sauce, and in many cases interfering with their sealing. At certain periods of production there is also the need for unplanned shutdown of the line so that hygiene can be performed and removal of the excesses of sauce on equipment and on the floor. The presence of sauce on the floor also has a frequent risk of accidents, and despite having a relatively simple action, it became a recurrence since there was no elimination of its fundamental cause.

After measuring the quantities of the losses of the sauce, a verification was carried out in the production line, in order to raise the causes of the loss of the sauce. It was found that the sauce dispensers remained dripping onto the conveyor chains even after they were closed. It was also verified that besides the problem of the loss of sauce, as the edges of the trays were dirty, some trays did not seal correctly and they ended up dirtying the equipment of sealing of plates generating the necessity to stop the line to also make its cleaning. The occurrences of the sauce drips can be visualized in figure 5.



**Figure 5.** Drip of sauce in the dispensers

A detailed analysis was also performed on the dosing set of these equipments. Through information obtained from operators and suppliers it was possible to raise more possible causes of the dosers to continue dripping after closed, causing the losses of sauce studied. Through the use of the Ishikawa Diagram or Fishbone Diagram, it was possible to relate the causes raised with the effect occurring in the process, as showed in figure 6.



**Figure 6.** The Ishikawa Diagram

Based on Ishikawa Diagram, tests of the causes were performed for each of the hypotheses, in order to confirm their relation

with the problem. These tests can be visualized in table 1.

**Table 1. Testing the causes**

| Probable Cause of the Problem                           | Test performed  | Result   |
|---|---|--|
| The sealing system dries with the accumulation of sauce | Checking the conditions of sealing systems which are more used                  | Sealing system materials was dried, leading the sauce to pass          |
| Wear of sealing system is premature                     | Replace the sealing system for a new one if loss of sauce continues             | Even with a new sealing system, dosers keep the drip                   |
| Sealing system is inefficient                           | Checking if the measures of sealing system is the correct for the doser plunger | Sealing system doesn't fit perfectly at plungers                       |
| Material used on the plunger is soft                    | Checking if the material of plungers wears quickly                              | Some of plungers was   |
| Improper adjustment of dosing time and positioning      | Checking if the plungers are being adjusted and its influence in process        | It was verified that not all the operators made the correct adjustment |



It was verified that not all the operators made the correct adjustment but there wasn't standard for adjustments of the dosing equipment, according to the different products that are produced in the process. Based on the fundamental causes found, the following actions were prioritized:

In phase *Do* the execution of the actions proposed began. The first two actions (a and b) were performed in parallel, as they involved the realization of project modifications and tests of new materials applied in the sauce dispensers. Both actions

- a) Develop material for the sealing system that is process resistant;
- b) Develop efficient and suitable cut-drops for the process;
- c) Create new standards for adjustments of dosers.

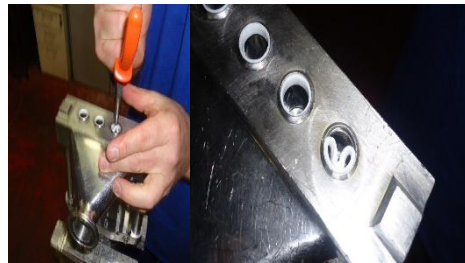
were carried out through the partnership between the company and a supplier specialized in industrial sealing system. Figure 7 shows the assembly of test materials for the development of the new cut-drops system.



**Figure 7.** Cut-drops system

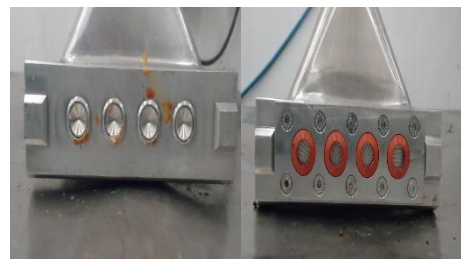
It was observed during the development of the new dropper system that it would also be necessary to make modifications to the doser rods to accommodate the new system. The new seals were also mounted in the dosers for the tests to be performed. Figure 8 shows the assembly of some seals in the dosers.

After the modifications in the dosers, assemblies with different configurations were set up in the production line for the tests to be carried out.



**Figure 8.** Sealing System

The choice of the ideal system was performed by comparing the leaks caused by the original doser with the modified ones. For this comparison the plastic bags were inserted again to collect the volumes of wasted sauce. Through a single collection, the set that presented the lowest average amount of waste, in the different measurements made with several types of sauces, was selected so that its characteristics were replicated to the other dosers. Figure 9 demonstrates how it was and how it is now after replacing the parts:



**Figure 9.** Sealing System before (left) and after (right)

It was also carried out the replacement of the dosing system of the assemblies, by those with the installation of the new complete cut-drops system. After completing the substitution of the dosers in the production line, the last action of plan (c) was performed. Dosers configuration standards were established, taking into account the original parameters of the equipment, since the equipment now had functioning and functionality of the system very similar to the ideal characteristics defined by the manufacturer. In the execution of this action,

the goal was mainly to correct the time and amount of dosage within the dishes, in order to avoid spattering on the edges of the trays.

For all actions, a detailed follow-up of their executions was carried out to eliminate any doubts that appeared during the work, thus guaranteeing a perfect alignment between what was foreseen and what had been delivered. This monitoring also provided greater agility in the execution of the actions, resulting in the complete completion of the action plan well in advance of the dates that had been initially proposed.

After finishing the work on the actions proposed in the plan, new measurements were made of the quantities of the losses of the sauce in the dosers. The collection method was the same used in the planning phase of this PDCA Cycle. Plastic bags were installed on the line gutters, and 20 samples of the line were collected on different days and shifts. Samples were weighed and a new mean was calculated. At this stage the average waste was 58.7 grams per hour in each doser. Figure 10 shows a comparative in the losses of the dressing per doser before and after the modification of the dosing system.

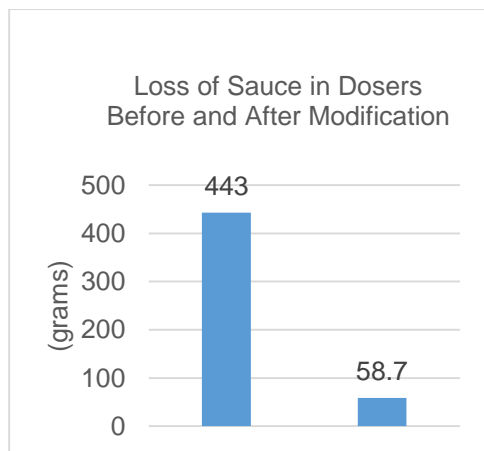


Figure 10. Comparative Analysis

The reduction of the losses of the sauce also caused a general reduction in the quantity of Unplanned Stops in the production line. In

the three months after the modification, an average of 16.95 hours of stopping occurred, compared to 21.13 hours in the months prior to work. In the month after the completion of the modifications of the sauce dispensers no Accident Risk Condition was also reported on line 5.

The last phase of the PDCA Cycle, Act, was due to the standardization and training of the improvements made in order to seek a maintenance of the good results obtained. The seals and repairs of the dispensers, as well as the dropper system became manufacturing items of the supplier who assisted in the modifications. Work instructions were elaborated both for the exchange of the sealing system and repairs, and for the operational adjustment of the dosers based on the ideal parameters defined in the execution of the action plan. All the actions that referred to the dosers were replicated to the dosers of line 1. This, because it was an identical line, and presented very similar loss values, did not require the elaboration of a new PDCA Cycle to reduce your sauce losses.

With the modifications made, a reduction of 86.75% of loss of the sauce in the packaging lines was obtained. It can be stated that the problem defined in the PDCA Cycle to reduce the losses of the sauce in the packaging line was solved. The reduction, even if discreet, of the number of Unplanned Production Stops results in greater line availability for production. The number of Accident Risk Conditions, caused mainly by the presence of sauce on the floor, were eliminated in the month following the execution of the modifications.

Other studies also confirm the efficiency of the PDCA cycle in optimizing the results of an activity. Prashar (2017) developed in an Indian paper mill industry an energy management system to save energy adopting the PDCA cycle. The results showed a 35% reduction in energy consumption, improving the results of the company.

Silva et al. (2017), implemented a Cleaner Production method based on PDCA cycle in order to reduce cans loss in a beverage industry. As a result, a decrease of 35% in costs was observed from one semester to the other. The application of PDCA provided for the company improvements in quality and productivity. Sugiyama et al. (2015) presented a method for reducing losses in sterile drug products in manufacturing processes. It was observed that the Annual Cost of Losses was reduced, where multiple scenarios were applied in order to verify which one is better for the process improvement.

Sangpikul (2017) improved the relation of teaching and learning by applying an academic service project and the PDCA in a graduate marketing course. The goal of the study was promoting opportunities to students learn and the PDCA cycle generated teaching improvements.

Based on the values obtained in the process indicators after the execution of the PDCA Cycle, it can be affirmed that, once there are reductions in the loss, there will be also improvements in the results of all the other indicators presented that relate to this type of loss.

## 5. Final Considerations

The challenge of reducing losses in production processes is now a basic need of companies that want to achieve a higher quality in the processes, as well as maximize their profits in order to remain competitive in the market. The processes of continuous improvement are important for the evolution of a company, having the use of several quality tools in its idealization.

The PDCA Cycle was a very efficient tool in the search for these improvements. This statement can be reinforced through the use of the cycle in the present study. The characteristics of this tool provided the fulfillment of the general objective that was proposed in this study. The significant

reduction in the losses of sauce that was had in the lines of packaging provided a better brainstorming of ideas on what the causes of the losses, as well as it optimized the survey of the actions and through its executions of correct form. The selection of the work team was important both in the planning phase and in the execution phase of the plan. Through the application of the specialties and knowledge of each team member, it was possible to plan and execute the PDCA Cycle more effectively.

The philosophy for continuous process improvement was also better disseminated and visualized by all employees in the industry. This phenomenon occurred mainly through the perception of the quality of the actions to all those who did not have access to the numerical data of the improvement. This was achieved through improvements in safety and environmental aspects related to the waste reduction that was achieved.

The use of basic quality tools, such as Ishikawa Diagram, provided the best survey, testing and prioritization of the causes for the occurrence of the problem. These helped to locate the root causes, as well as structuring and selecting actions with a greater chance of solving the problem. The PDCA Cycle also allowed the establishment of actions for standardization and maintenance of the good results achieved, an activity that was not included in the objectives initially in this study. This activity was essential for the results to be established over the periods that followed the study.

Through the good practices adopted, all those involved in the process for the development of similar work in the future were finally encouraged, using the methodology of the PDCA Cycle. This lack of adherence to changes was until then the greatest difficulty to carry out work of this type. Through this, the way in which this method ends up always being related as a tool of continuous improvement of the process is strengthened.

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