Filling Process Yield Improvements

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Abstract - *Misus Winery is a wine making and distribution plant. Its main product is Cherry Blossom which is a pink wine. The high demand for its product has created the need to make improvements in their processes. As part of this research project, it was focused on the improvements in the process yield results in the filling in Misus Winery. The process yield is the metric use to measure a process performance. Currently, there was reported a variability in the process yield obtained per production lot. By the end of this project, the process yield will be improved and sustained above the target goal. In order to improve the process yield, a DMAIC (Define-Measure-Analyze-Improve-Control) methodology was conducted to achieve the project goal. DMAIC is conducted in well-defined steps that helps to understand a problem and solve it in a systematic way. The process yield will be improved by the standardization and optimization of the filling process.*

Key Terms*: DMAIC, Process Yield, Standardization, DOE.*

INTRODUCTION

The wine industry in the United States is one of the more consistent and profitable achieving a total revenue of around $62.7 billion by 2017. The wine making process is divided in five stages: harvesting, crushing and pressing, the fermentation, the clarification and the aging and botting.

The wine industry, as most industries, have innumerous challenges due to the constant changes in the market, customer needs, regulations, competitors, among others. To keep up in the business, most of the industries are implementing initiatives to improve their processes that reduce production costs and increment profits. In addition, maintaining the product quality and achieve the customer satisfaction.

The bottling is performed by a filler machine that automatically fills the bottles at a specific target fill. This research project will be focused in the improvement of the process yield for the filling process at the bottling stage.

PROJECT STATEMENT

Misus Winery is a family wine making, packaging and distribution plant that have been operating for at least thirty years. Its main product which it is distribute worldwide is named Cherry Blossom. The high demand for this product in recent years has created the need to make continuous improvement in their processes.

The filling process in Misus Winery is performed by a Filler Machine which uses a volumetric technology. Six empty bottles are tare by calibrated scales. Then the bottles are filled simultaneously by the machine nozzles at the target fill established. After been filled, the bottles are weight by calibrated scales to obtain the gross weight. The machine is programmed to determine the net weight based on the subtraction of the gross weight and the tare weight of each bottle. A high limit and low limit for the net weight are programmed in the machine. All bottles out of the allowable range are automatically rejected by the filler machine. These bottles are return to the plant for reprocessing.

To measure the filling performance of the machine, yield is used as a metric. Production yield refers to the ratio of non-defective units against the number of manufactured units. In the filling process the non-defective units are the bottles filled at the allowable range. A target yield is established by the manufacturing area that is used a guideline of performance and financial metric. Any variability denoted in the production yield possibly impacts the product delivery to customers and the financial expectations. The production yield obtained had shown a Variability in the filling process that affect the quantities of good bottles produce. The objective of this project is to determine the root cause of this variability in the filling process in order to improve and maintain the yield to achieve the business projections and supply the high demand of the product to the market.

PROBLEM STATEMENT

During the first two (2) quarters of 2018, it was reported a Yield to Date (YTD) of 2.588 for the filling process Misus Winery main product. This yield reported represents a 0.15% below the goal of 2.592 established by the manufacturing area in order to achieve the business metrics. The goal of this project is to increase and maintain a consistent yield of 2.600 for the filling process of the company main product by the second quarter of 2019. In order to achieve this goal, a DMAIC methodology will be developed.

RESEARCH DESCRIPTION

The importance of this project is to achieve a consistent yield above the target goal established by the manufacturing area. If the yield is consistently above the target, it can be reach the management expectations and the good product availability to the customer.

RESEARCH OBJECTIVES

The objective for this project will be addressed to:

- Improve the production yield of the filling process of the company main product.

RESEARCH CONTRIBUTIONS

The main contribution of this project is to improve the filling process yield which results in more non-defective units that can be deliver on time to the external customers. The improvements would benefit financially the business since more product can be schedule to produce and deliver to the customer on-time. This improvement can benefit the business in general from keeping a good relationship with its customers. In addition, this project will benefit since the purpose is determine possible root causes for the yield variability under the target and implement permanent solutions that can result in budget savings to the area.

LITERATURE REVIEW

Lean Manufacturing is defined as a set of management practices to improve efficiency and effectiveness [1]. The Lean concepts were introduced by Henry Ford with the purpose to increase the production of units at the shortest time possible. After the contributions made by Henry Ford to the businesses, Taiichi Ohno developed the Toyota Production System (TPS). The TPS combined line efficiency with variety.

Six Sigma is a management system for driving, achieving and sustaining breakthrough improvements in every part of an organization [2].

The industries around the World are constantly performing improvements to keep up with the market changes, reduce production costs and increase profits. Most of the companies invests lots quantities of money in develop projects related to process improvements. Improvements related to new production lines, equipment, modification of existing processes, among others. The Winery industry is not the exception.

The wine market biggest competitor is the beer and spirit markets, but most of it, the wine industry suffers the consumption trends changes. Which make it challengers. With time, the wine industry had incorporated innovative technology in order to maintain a consistent, effective and reliable process. Lean Six Sigma is conducted in the industries to performed process improvements in a systematic way.

Concepts of DMAIC Methodology

In a business environment, the only constant is change. Changes are conducted to improve the processes or solve a problem. Define, Measure, Analyze, Improve and Control (DMAIC) is defined as a structured problem-solving driven methodology. DMAIC methodology leads through a process of defined phases which conducts to the implementation of permanent solutions of an existing problem. The DMAIC methodology is widely used in business to improve speed, quality and speed in the processes. In addition, DMAIC is well employed when performance problem are complex and their possible root causes are not known (Figure 1).

- Define: In this phase are detailed the customer requirements, project scope, goals, boundaries and performance targets. The problem is stated and it is validated reviewing existing data or other sources of information. Financial benefits can be validated using existing data and estimate financial impact if the project goal is achieved. Process maps and scope can be developed to document the main steps and evaluate the project scope. In addition, a communication plan, schedules and milestones can be established during the Define phase.
- Measure: In this phase, reliable data is collected to understand the current process state. The data collected can be used to expose the underlying causes of the problem. As part of the Measure phase, are determine the outputs and inputs of the process, articulate the process, validate the measurement system, create and execute the data collection plan and assess the process capability and performance.
- Analyze: In this phase are pinpoint and evaluate the causes that affect the inputs and outputs of the process identified in the Measure phase. As part of the Analyze phase, the critical inputs are determined, the data and process analysis is performed, the root causes are determined and prioritize.
- Improve: In this phase, the implementation of the selected solutions is full-scale executed. The work analysis conducted is review and consolidate. The solutions are generated, selected and prioritize, Lean Six Sigma practice are applied, risk assessments can be conducted and pilot the solution to the problem.
- Control: The process is not completed until mechanisms are developing for maintaining the changes made. In this phase are institute metrics and control charts, document procedures, create process control plans, create project storyboard and concludes with the transition of the process ownership.

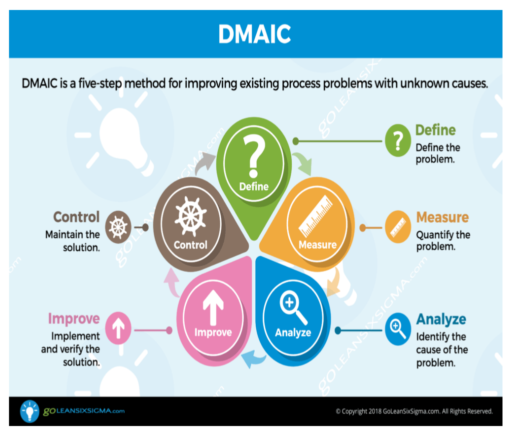

Figure 1
DMAIC

Project Methodology

A systematic approach needs to be used as a methodology to achieve the goals of the project to be conducted. Since the purpose of this project is to improve and maintain the yield of the filling process of the Misus Winery main product, the DMAIC methodology tools to use will be determined as more convenient.

The Define Phase will be conduct by completing the project charter (Figure 2). Project Charter, is a document that defines and align the fundamental information about a project. In a Project Charter, can be outline the problem, scope, team roles/responsibilities and objectives. In addition, the project charter detailed the project goals and identified the main stakeholders. The project charter is used as a guideline for the future of the project. It will be created a communication plan with the project participants and stakeholders. The Voice of Customer (VOC), Critical to Quality Parameters (CTQs), and SIPOC map will be performed during the Define Phase [3].

The Measure Phase will be conduct using the more convenient tools to gather the data necessary to understand the process. During this phase the tool to be considered are Process Flow map that describes visually the flow of work [3]. In addition, Value Stream Map (VSM), and Failure Modes and Effects Analysis (FMEA), among others. As part of this phase, data of yield per lot in the filling process was collected. The data obtained showed the need of improvement in yield in the filling process.

The Analyze stage focuses on the analysis of the data gathered in the Measure phase of DMAIC to identify the cause. In this phase, it cannot be a conjecture or assumption to obtain the best results. The analysis should be performed on the data gathered. Therefore, for this phase, Six Sigma provides the following tools to identify the root cause(s): Cause and Effect Diagram, Statistical Analyses, and Process Map Analysis, among others [3].

Based on the root cause(s) identified during the Analyze phase, the identification of possible solutions or improvements to the process can be developed. The selected solution(s) will be implemented and, in addition, can be prioritize. As part of this phase, the project tools used can be ANOVA, cause-and-effect analysis, Fish Bone, among others.

The last phase of the DMAIC methodology is the Control. This phase helps to monitor how the solutions implemented are working. In addition, the project documentation is completed including recommendations for further action or opportunities [3].

Results and Discussion

In this section are summarized the results obtained through the DMAIC phases made for this project. Each phase details the tools used, the results obtained and a brief discussion.

Define

During the Define phase, it was developed the project charter (Figure 2). This tool helped in the definition of the Problem Statement, Project Scope, and Business Case. Also, it can be used to organize the different phases of DMAIC methodology in the project.

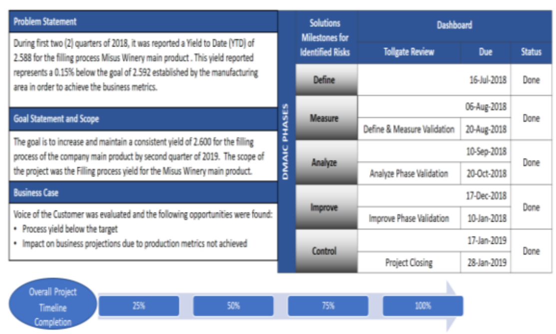

Figure 2
Project Charter

A SIPOC diagram (Figure 3) was developed to identify all elements of a process improvement project before work begins. It helps define a complex project that may not be well scoped by defining the boundaries of the process.

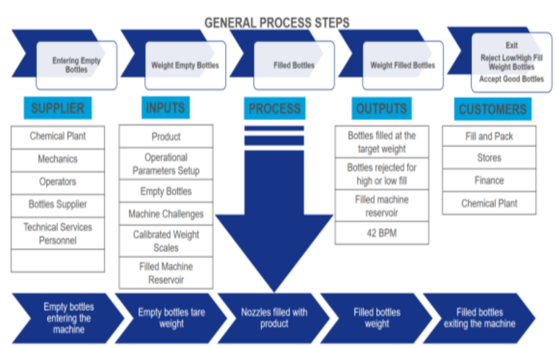

Figure 3
SIPOC Diagram

A Voice of the Customer (VOC) was performed to define what are the customers' needs and what of these needs can be achieved. The voice of customer was collected by interviews and point-of-use observation.

The following is a summary of the results of the VOC:

- The process yields calculated from the lots manufactured were below the target goal.
- High incidence of High/Low fill bottles which are automatically rejected by the machine. The high/low fill bottles are flush into a carboy. This product is returned to the chemical plant for reprocessing.
- Filler machine setup variability between mechanics.
- High incidence of nozzles tips ruptures.
- Operational parameters uploaded by a validated recipe. There are fixed operational parameters and recommended operational parameters. To optimize the filling process, there is an operational parameter that requires the constant operator intervention in the machine. Each operator modified the operational parameter according to his experience.
    - The Fill and Pack area operated in two shifts. In both shifts are new operators conducting filling process.

MEASURE

The purpose of the measure phase is collecting the data needed to evaluate the current process the process yield of filling. In order to evaluate the current process, it was necessary to understand each process step. A high-level process flow (Figure 4) was created.

The overall filling process consists of product that is transfer from the chemical plants to the Fill and Pack vessels. This product is then transfer into the filler reservoir. The product is then conducting into the nozzles pumps to fill the empty bottles at a specific target fill. Before the filling, the bottles are tare weight and after the filling are gross weight. The machine is programmed to reject all the bottles out of the filling weight range established. All the bottles rejected are returned to the chemical plant. The bottles classified as good units continue the process to reach the customer.

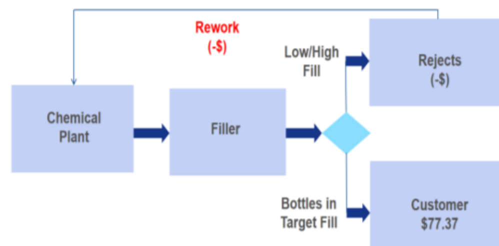

Figure 4
High Level Process Flow

The process yield data was collected from the plan attainment of the production line. From the data obtained, it was summarized into the product bulk produce per month, the quantity of bottles produced, the bottles rejected, the bottles that reach the customer and the average yield per month (Table 1). The process yield per month was graphically shown (Figure 5). It is shown that even there are months that the process yield was reported above the target goal, the results obtained are not consistent and varied within months.

Table 1
Summary Results per Month

Monthly Results	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Average
Bulk (KG)	17,972	37,589.0	35,570.20	37,600	41,303.70	41,139.8	23,508.5	35,109	33,724
Bottles Produced	46,518	85,124	92,274	97,615	107,116	97,995	60,880	74,057	82,697
Quantity of Bottles Rejected	294	328	370	370	417	316	263	603	370
Total Bottles Customer	46,326	97,236	91,854	97,158	106,662	106,128	60,648	90,378	87,049
Yield	2.585	2.594	2.591	2.593	2.59	2.592	2.587	2.581	2.5902
Yield Goal	2.592	2.592	2.592	2.592	2.592	2.592	2.592	2.592	N/A

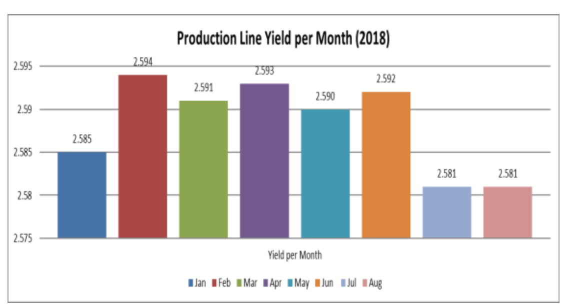

Figure 5
Production Line Yield per Month

ANALYZE

The purpose of the Analyze phase is identifying the root cause of the situation detailed in the problem statement. After the evaluation of the data obtained, it was decided to perform the 5Why's Analysis. According to the results obtained for the 5Why's analysis (Figure 6), a high incidence of high/low fill bottles that are rejected per production lot was affecting the process yield. The results of the high/low fill bottles were collected (Figure 7) and it was observed that within 263 to 603 bottles are rejected in average monthly. The production lots for this product are of 5,500 bottles.

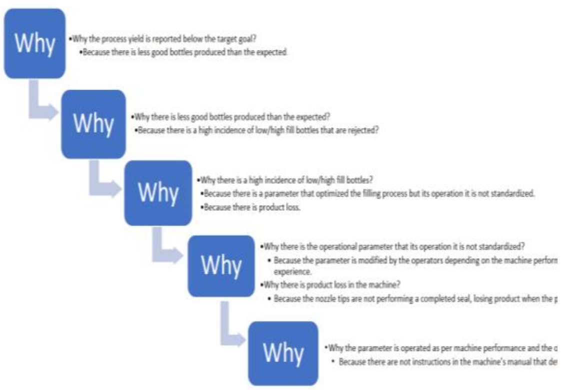

Figure 6
5Why's Analysis

Observing the process and interviewing the operators, it was noticed that the instructions to operate the machine are detailed in the operating manual for the fixed parameters. The fixed parameters were validated and are uploaded to the machine through the product recipe. However, there was another parameter that affected directly the filling process for which every operator had its own procedure to operate it. The pump stroke parameter was not validated since it was affected by the machine performance making very difficult to established and validate a set point. Instead, it was defined an operational range that it was used to modified the parameter according to the machine performance and the operator's experience. The pump stroke parameter operation, which it can optimize the machine performance, was not standardized in an operating manual and training.

In addition, it was identified that the nozzles tips of the filler machine did not performed a correct seal causing product loss when the pumps are filled. The product loss was noticed by the operators since a drops were observed after the filling process was performed. The nozzles tips, called nozzles type A, used for the filling process performed the sealing in the outside part of the tip. The tip was made of teflon which wear with used causing product loss.

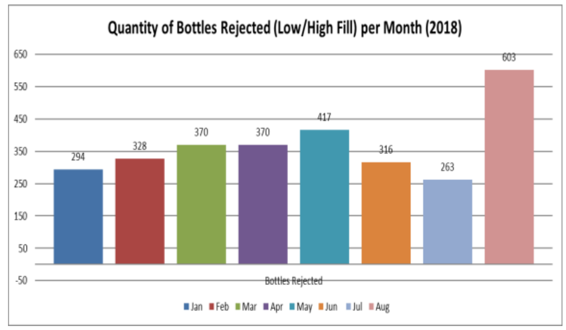

Figure 7
Bottles Rejected per Month

After concluding the Analyze phase, it was found that there were two root causes for the variation in the process yield.

- Pump Stroke parameter operating instructions were not standardized causing process variations.
- Nozzles tips not properly sealed due to wear causing product loss.

IMPROVE

During the Improve phase, the possible solutions to the root causes identified during the Analyze phase were developed.

For the standardization of the operation of the Pump Stroke parameter, it was conducted interviews with the operators to understand the process. With the interviews, it was developed instructions to standardize the pump stroke operation during the filling process. The instructions developed incorporated each operator's methodology to operate the pump stroke parameter. The instructions were developed using pictures as guidelines for the operators. In addition, the instructions were developed in English and Spanish since it was noticed that some operators were not bilingual.

A new nozzle tip design was proposed for the product loss cause. The design included a sealing in the inside of the nozzle. The new sealing avoided the product loss since the tip was more adjusted with every use. For the implementation of the new nozzle tip a Design of Experiment (DOE) was developed since new operational parameters were required. In a DOE, we have a response variable and we connect it mathematically to various predictions [4]. Four factors with two were evaluated for the DOE analysis (Table 2) for a Factorial Experiment [5]. A total of 33 runs were performed to examine every possible combination of factors [6]. The responses evaluated were according to the requirements of the manufacturing area: fill weight, bottles per minute (BPM), No Product Splash and Low/High Rejects.

After the completion of the verification, it was determined the factors combinations by a Pareto Chart and Main Effects Plots. According to the results obtained, a suggested operational parameters range was tested and the responses obtained were satisfactory.

Table 2
DOE Factors

Factors Evaluated in DOE	
1	Pump Load Speed
2	Pump Fill Speed
3	Nozzle Bar Fill Speed
4	Feedscrew Speed

The Nozzle Bar Fill Speed and Feedscrew Speed were the operational parameters that affect directly the responses evaluated. The remaining operational parameters analyzed did not affect the responses evaluated. As determined by the verification, the Nozzle Fill Speed and Feedscrew Speed operational parameters can be considered critical for the outcome of the responses evaluated. The operational parameters range suggested were detailed in Table 3.

A confirmation run, as an Operational Qualification, was performed to evaluate the machine performance. During the filling process, it was observed the responses of Bottles per Minute filled (BPM), Product Splash, Low/High Fill Weight Rejects and Fill Weight. A total of 316 bottles were filled. The results obtained were satisfactory. The results obtained for the Fill Weight response were satisfactory (within the acceptable range of 380.50g to 392.70g). The fill weight depends mostly on the Pump Stroke operational parameter. This operation was standardized by the new instructions detailed in the machine operating manual.

Table 3
Operational Setting

Operational Parameter	Suggested Operational Setting
Pump Load Speed	15.00% - 25.00%
Pump Fill Speed	20.00% - 25.00%
Nozzle Fill Speed	1.50% - 2.50%
Feedscrew Speed	8.00% - 10.00%

After the completion of the confirmation run evaluation, a Performance Qualification exercise was conducted to validate the new filler nozzles and the operational parameters. Three production lots were monitored during the exercise and the results obtained were satisfactory. The operational parameters were varied within the range for each production lot. The machine performance was monitored for a period of ten (10) minutes during the beginning, middle and last of each lot. The monitoring consisted on observed the Bottles per Minute (BPM) filled, the Product Splash and the Low/High Fill Weight Rejects. Table 4 shows the results obtained.

In addition, to evaluate the fill weight of the bottles a total of fifty (50) bottles per lot were randomly sampled in order to verify its volume with a graduated cylinder. According to the analysis of variable data pre-established the results obtained complied with $L + Ks \leq \bar{x}$ in which L is the lower limit (250.0mL), K is the factor determined by (WinSSD) Software Version 1.6.1 for a sample size of fifty (50) bottles, s is the standard deviation and $\bar{x}$ is the average of the measurements obtained. The results obtained were detailed in Table 5.

Table 4
Performance Qualification Results

Bulk Lot Number	Period	Bottle per Minute Filled (BPM)	Quantity of Bottles Accepted*	Bottles Rejected (Low)	Bottles Rejected (High)	Product Splash	Bottles Rejected Unknown
S-18-035	Beginning	27	167	0	0	0	0
	Middle	27	2,900	0	0	0	0
	Last	27	1,720	0	0	0	0
S-18-036	Beginning	33	482	0	0	0	0
	Middle	33	2,768	0	0	0	0
	Last	33	5,000	0	0	0	0
S-18-037	Beginning	38	500	8	0	0	0
	Middle	38	3,080	0	0	0	2
	Last	38	5,405	0	0	0	0

*These quantities are the values shown in the machine HMI at the end of the monitoring period

After the completion of the filling process of the bulk lot numbers, the yield was calculated since the purpose of the evaluation was to improve and maintain a process yield above the target goal. Table 6 summarized the results obtained.

CONTROL

The Control phase ensures that the modifications performed are sustained for a full-scale implementation [3]. During the control phase of this project the following actions were performed:

- Modification of the machine operating manual. Various modifications were performed for the operating manual.
    - It was incorporated detailed instructions to operate the Pump Stroke parameter which is directly related with the filling performance. The instructions were developed in conjunction with the operators to incorporate the actual steps to operate the machine.
    - For the instructions, it was incorporated pictures as guidelines for the operators.
    - The instructions were included in English and Spanish for easy understanding.
- It was established only the more capable operators in the filling operations. These operators were trained with the new instructions as in the field training.
- The machine operating manual was modified to incorporate the new operational parameters.
- The machine job plan and spare parts list was incorporated the new filler nozzles. The old filler nozzles were decommissioned.
- The Failure Mode and Effect Analysis (FMEA) of the filler machine was updated including the modifications performed during this project.

Table 5
Volume Measurements Analysis

Bulk Lot Number	Quantity of Bottle Sampled	Average Volume Filled ($\overline{X}$)	Standard Deviation (s)	Lower Limit (mL)	K	L + Ks	L + Ks ≤ $\overline{X}$	Pass / Fail
S-18-035	50	252.12mL	0.350mL	250mL	2.609	250.91mL	250.91mL ≤ 252.12mL	Pass
S-18-036	50	252.54mL	0.503mL			251.31mL	251.31mL ≤ 252.54mL	Pass
S-18-037	50	252.26mL	0.443mL			251.15mL	251.15mL ≤ 252.26mL	Pass

Table 6
Production Yield in the Filler Machine

Bulk Lot Number	Bulk Size (kg)	Total Accepted Unit in the Filler Machine	Yield	Manufacturing Yield Target
	A	B	C = B/A	
S-18-035	2,250 kg	5,833	2.592	2.592
S-18-036	2,193 kg	5,710	2.604	
S-18-037	2,295 kg	5,973	2.603	

CONCLUSION

The main objective for this project was: improve the production yield of the filling process of the company main product.

To improve the production yield of the filling process, a DMAIC methodology exercise was conducted. During the exercise the following opportunities areas were found:

- Pump Stroke parameter not standardized in the filling process.
- Product loss through the filler nozzles tips.

For the standardization of the operation of the Pump Stroke parameter, it was developed detailed instructions in conjunction with the filling area operators. The instruction included pictures as a visual guideline for the operations and it were included in English and Spanish. In addition, the training process was reinforced to the filling operators. These actions helped to standardized the filling process and optimized the machine performance.

For the product loss, it was validated a new design of filler nozzles that prevent the product loss. A DOE analysis was conducted to determine the operational parameters range that optimized the responses evaluated. After the determination of the operating range, the new parameters were validated obtaining satisfactory results.

After the modifications performed, it was obtained a process yield above the target goal of 2.592. These modifications improved the filling manufacturing process guarantying a standardized process that it is optimized complying with the manufacturing requirements and the customer requirements.

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