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REDUCTION OF SUGAR LOSS USING LEAN SIX SIGMA TOOLS AND DMAIC METHOD TO INCREASE COMPETITIVENESS AND REDUCE COSTS IN A SOFT DRINK COMPANY

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ABSTRACT

Introduction: The Lean Six Sigma method is the integration between Lean Manufacturing and Six Sigma, two methods that have been adding value to the productive processes, generating the best results, because they provide tools to assist in the management of the indicators of the companies that use them. The use of this method in the manufacturing process is a strategic factor for the competitive companies, whose focus seeks to meet the customers with an appropriate cost to the market requirements, considering that the existing processes related to the manufacture of a finished product have their variability. **Objective:** This study aimed to present the application of Lean Six Sigma tools, describe the use of the DMAIC model and demonstrate its application in the process of syrup and filling of beverage in one of the companies of Simões Group, as well as demonstrate the results obtained with the reduction of production cost by reducing the loss of sugar. **Methodology:** The technique applied in this study followed the steps of DMAIC methodology, where statistical tools were used to DEFINE the objective, the scope and the main steps of the project and to delimit the problem, to MEASURE the current performance of the process and to reduce the problem area, to ANALYZE the potential root causes and confirm them with data to determine the opportunities for improvement, to IMPLEMENT the process improvements by developing and testing solutions that address the root causes and finally to CONTROL the processes to maintain the gains and the transition to full implementation. **Result/Discussion:** This project had a team that applying VOC methodologies - Voice of Customer, identification of the Critical Attributes for the Quality of the customer - CTQs (Critical to Quality), Serpent Diagram and SIPOC, were able to collect with the internal customers information about the processes of manufacturing of simple syrup, final syrup and filling of drinks in PET bottles, as well as others related to the theme. **Conclusion:** It was possible to determine and quantify the main process wastes after the total implementation of the actions proposed by the six sigma team, having reached the objective of this project. By comparing the sugar loss with the previous period measured, the analyzed process reduced the average percentage of losses from 2.02% to 0.07% after the implemented actions. Thus, there was a financial contribution of the project to the company with the average annual production cost reduction on sugar waste from $26,056 to $862, resulting in a loss reduction of $25,194 for the company.

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INTRODUCTION

In the current scenario of constant changes, the beverage industry must adapt continuously to maintain a competitive pace. In this context, factors such as quality, cost and deadline play a key role in the success of organizations (RABECHIN et al, 2002). In Brazil, the beverage sector according to (BNDES, 2017) was characterized in the recent past by a strong growth and, in relation to the near future, by issues that go beyond the most traditional variables, going through segmentations of high added value and reaching what has been called "experience economy", which is characterized in the Brazilian market by strong competitiveness factors. The beverage sector has been showing great dynamism and according to (IBGE, 2014) which presents information from the Monthly Industrial Survey (PIM-PF), the accumulated growth of the physical production of beverages in Brazil reached 50% in the period 2004-2013. In this period, the average growth rate of the volume produced was 4.2% p.a. Given that in that time interval the Brazilian Gross Domestic Product (GDP) grew at an average real rate of 3.7% p.a. This type of industry worldwide is characterized by fierce competition for greater market share. In view of this factor, the market no longer has room for inefficiency, competition already exceeds the price criterion, the focus is now turned to the value linked to quality standards, low production costs, effectiveness of services and fair price (TERNER, 2008). To improve the efficiency in their processes, several companies work with problem solving methodologies, in this scenario, several strategies are developed by these companies that seek the adequacy of the production system to the current market reality, such as Lean Manufacturing and Six Sigma methodologies, which when interacted with each other, Lean Six Sigma, which has been used with great representativeness (DIAS, 2011). Two approaches have been used in most projects of improvement of processes and management, underpinning the Lean Six Sigma, the first being: Lean Manufacturing (Lean Manufacturing), focused on the exhaustive thinking, whose focus is the elimination of steps and activities in a process that do not generate value to the product, and the second: Six Sigma (Six Sigma), based on the continuous reduction of process variability, focused on continuous improvement of processes (YADAV; DESAI, 2016). It is of great value to increase interest in studies and development of projects that make use of methodologies and tools for problem analysis based on data analysis so that decision making is assertive and sustainable. For this, the implementation of the mentioned method can be done through the application of several tools, such as the improvement approach DMAIC (Define, Measure, Analyse, Improve and Control). The beverage companies also benefit from the principles and tools of DMAIC methodology, therefore the present work, a case study applied in a beverage company of the Industrial Pole of Manaus, aims to demonstrate the causes of sugar loss through the use of structured methods, being able to analyze the problem and propose improvement actions to solve it and control this indicator monthly in order to guarantee its conformity in the production process.

BIBLIOGRAPHIC REVIEW

Lean Six Sigma Methodology: Originally the known Lean Thinking has its roots in the Toyota Production System, whose revolutionary drivers were Sakiichi Toyoda, his sons, Kiichiri and Eiji and also Taiichi Ohno, a production engineer (Dekier, 2012). And it was from the need and difficulty faced by the Toyota company after the period of World War II that this system is born and developed (LANDER, 2007). Lean Manufacturing, Six Sigma and TQM (Total Quality Management), are some of the tools implemented from then on to generate process improvement, quality assurance that is offered to the end customer. In the face of major developments that the industry has undergone, the current scenario allows mixing and synchronising different tools that can make the company even more competitive. An example is the combination of the Lean philosophy with the Six Sigma systematic method (ANTONY et al, 2018). The method resulting from the integration of Lean and Six Sigma is a powerful strategy for any company seeking increased competitiveness with reduced production cost. Lean is based on the philosophy that eliminates waste, assisting in increasing productivity, transforming the way organisations work, generating a faster return on financial investments. While Six Sigma focuses on optimizing products, services and processes to satisfy customers and consumers (WERKEMA, 2006). The definition of Lean Six Sigma involves a strategic and methodological organizational approach that increases process performance resulting in improved customer satisfaction and actually maximizing the value offered to the customer (SNEE, 2002). For most companies focused on improving themselves, working with Lean Six Sigma involves adopting a systematic, structured and statistical set of tools, because lean tools and a continuous improvement cycle help in eliminating activities that do not add value to the product, improving product quality by eliminating process variation, generating production cost reduction.

It can be stated that there are many reasons for the implementation of Lean Six Sigma in industry, for example: to improve operational efficiency, production capacity and to reach global markets ((JOHNSON, 2003). It is possible to say that the Lean Six Sigma methodology can be explained by encompassing a group of techniques and tools that together enable organisations to identify and eliminate eight different types of waste, formulating what has been called The 8 Industry Wastes (Figure 1) (PETENATE, 2018): - Overproduction, - Waiting, - Under-utilisation of potential, - Transportation, - Stock, - Handling ,- Unnecessary processes and Defect.

Source: Authors, (2022).

Figure 1. The eight Lean Six Sigma wastes

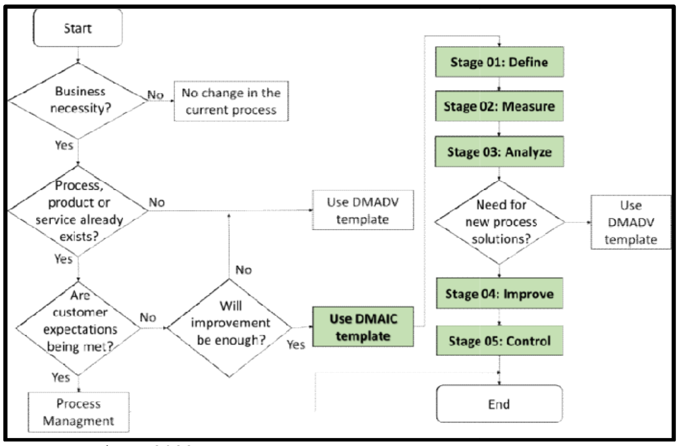
It is understood as waste all activities that do not add value to the service or product, according to Alódio (2019), so it is important to know each of the categories of waste and how Lean Six Sigma can support the company in the resolution of each one, according to the relationship described in Table 1.

Table 1. Relationship of Types of Waste and Lean Six Sigma

Number	8 Waste	Methods of Lean Manufacturing
#1	Over-production	Kanban, Heijunka, VSM
#2	Waiting	TPM, SMED
#3	Under-utilization of potential	Kaizen
#4	Unnecessary transport	Kanban
#5	Excessive stocks	Kanban, Heijunka, VSM
#6	Unnecessary movements	5S, Standardized work
#7	Excessive processing	Standardized work, Kanban
#8	Product quality errors and defects	Poka-Yoke, Jidoka, Kamishibai

Source: Adapted (REWERS, 2016).

DMAIC Methodology: The DMAIC methodology originally also had its roots in Motorola as part of the Six Sigma method and currently one of the most used method to assist the conduct of project management in a company, since this method enables the organization in the implementation, development and completion of Six Sigma projects (CLETO, 2011). DMAIC is also known as the evolution of the Six Sigma program due to its approach focused on process improvements. The stages of the DMAIC methodology identify deviations and define opportunities for improvement through the data collected and analyzed (SCHROEDER, 2007). The initiative to implement the DMAIC methodology in the production process can be done through a diagnosis to identify opportunities for improvement using the decision tree tool to decide to start a project with this approach. For the analysis of the decision tree, as shown in Figure 2, the flowchart is used to choose the type of project.



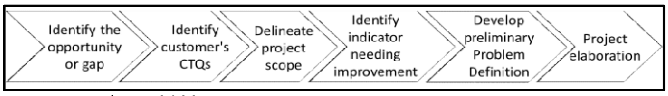
Source: Authors, 2022.

Figure 2. Flowchart of the decision tree for DMAIC

The DMAIC improvement approach helps to deal with complex or recurring problems, with a rigorous methodology, possible to quantify, measure the data efficiently to analyze and eliminate problems. This approach has the definition Define, Measure, Analyse, Improve and Control.

The unfolding of each stage can be described as follows:

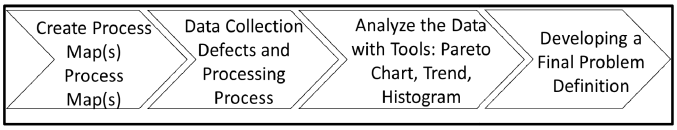
Define - In this phase, the proposal and scope of the project are defined. Among the tools in this phase are the project planning form, CTQ analysis and "snakes and ladders" diagrams. It is possible to describe a map of this phase according to Figure 3.



Source: Authors, 2022.

Figure 3. DMAIC Map - 1 Define.

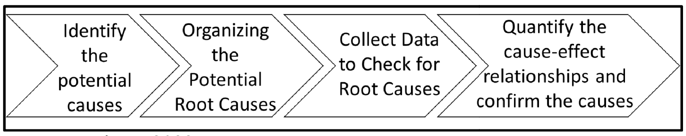
Measure - This phase focuses improvement efforts by gathering information of the current situation. Tools include flowcharts, operational definitions, data collection tools, sampling, control charts, stratification and Pareto charts. It is possible to describe a map of this phase according to Figure 4.



Source: Authors, 2022.

Figure 4. DMAIC Map - 2. Measure

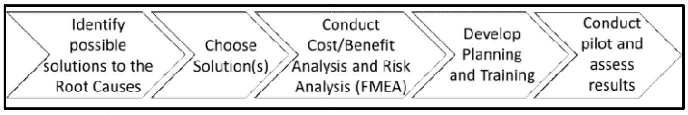
Analyse - Here, root causes are identified and confirmed with data. Relevant tools include data collection tools, cause and effect diagrams, hypothesis testing, scatterplots, regression analysis and design of experiments. It is possible to describe a map of this phase according to Figure 5.



Source: Authors, 2022.

Figure 5. DMAIC Map - 3. Analyse

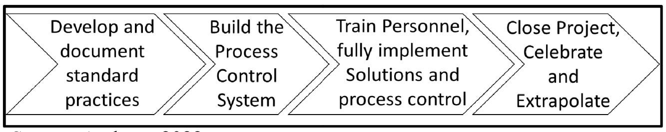
Improve - In the fourth phase, pilot, review and implement the solutions that address the root causes. Data is used to evaluate both the solutions and the plans used to finalized them. Tools in this stage include check forms, prioritization matrix, cost-benefit analysis, FMEA, design of experiments, planning tools, change management tools, Pareto charts, control charts and frequency charts. It is possible to describe a map of this phase according to Figure 6.



Source: Authors, 2022.

Figure 6. DMAIC Map - 4 Improve

Control - Finally, gains are maintained through standardization of working methods, processes and transition to full implementation. Future improvements are anticipated and the lessons of this effort are preserved. In this phase, the following tools are common: check form, trend charts, control charts and Process Management Control System charts. A map of this phase can be described in Figure 7.



Source: Authors, 2022.

Figure 7. DMAIC Map - 5. Control

CTQ - Critical To Quality: The metrics used in the DMAIC method measure defects more effectively than those commonly used in quality programs. These metrics and terms are Critical to Quality (CTQ), a product or process attribute that affects customer acceptance, that is, it is an attribute specified by the customer (WHEELER, 2002). Critical Characteristic for Quality (CTQ) is the description of a product or service attribute that influences the customer's purchase decision.

CTQs exist at various levels of processes and must be defined so that indicators can be created to measure them.

Some examples of CTQs are:

- Timeliness of delivery;
- Accuracy of definitions;
- Conformity of the product;
- Product and service knowledge.

To help in the definition of CTQs we can ask two questions, the first being: What is critical to the market? And second, what are the critical processes? (FOUQUET, 2012). Once it is known to the company what is critical to quality, DMAIC projects can be carried out to ensure increase without their performance by systematically reducing variability in their processes (STONE, 2012). We can list ten key characteristics for quality, possible CTQs, which the customer looks for in a service as shown in Table 2.

Table 2. Possible CTQs of the Customer: Service

CTQs	Key features
Reliability	Consistency of performance and reliability;
Receptivity	Willingness and readiness to provide services;
Competence	Skills and knowledge required to perform the service;
Accessibility	Easeofcontact;
Courtesy	Politeness and respect, and a neat and tidy appearance;
Communication	Keeping customers informed using language they can understand; paying attention to the customer; responding to customer inquiries;
Credibility	Always have the customer's interest in mind; honesty;
Security	No dangers, risks or doubts;
Understanding	Make an effort to understand the customers' needs;
Tangibility	Physicalevidenceofservisse.

Source: Authors, (2022).

We can list nine key Quality Characteristics, possible CTQs, which the customer looks for in a product as per Table 3.

Table 3. Possible CTQs of the Customer: Product

CTQs	Key features
Performance	Basic ProductFeatures
Characteristics	Additionaltouches.
Conformity	Precisionor meeting expectations
Availability	Available as needed
Reliability	Constant performance over time
Utility	Adaptability, responsiveness
Durability	Longservicelife
Aesthetics	Sound, texture, appearance
Reputation	Perceived quality and intangible factors

Source: Authors, (2022).

Whys Tool: The 5 Whys method was also originally created by Toyota and aims to help find the origin of the problem through five questions followed by why certain occurrences happen (OHNO, 1997).This method starts by defining the problem and asking why it occurred. After the major causes of the problem have been identified, the question about the reasons for these causes is asked again. Normally the root cause is found after the fifth question, but if it is necessary, the questions of why must be continued until what originated the problem is found (JOHNSON, 2003). In the 5 Whys method, the reason for that problem is questioned, always questioning the previous cause. The number of five questions is variable, because in practice the root cause of the problem can be identified through more than five questions or less than five questions (SERRAT, 2017).When you get to the deeper Whys, it is time to organise the ideas, using the Cause and Effect Diagram tool or another tool, so by analysing what has been raised it will be possible to say "this causes this which causes that", which works as another check on your reasoning. The real root cause will always be the lowest "why" that is answered and to apply this tool Table 4 can be used.

Table 4. Tool Model 5 Why

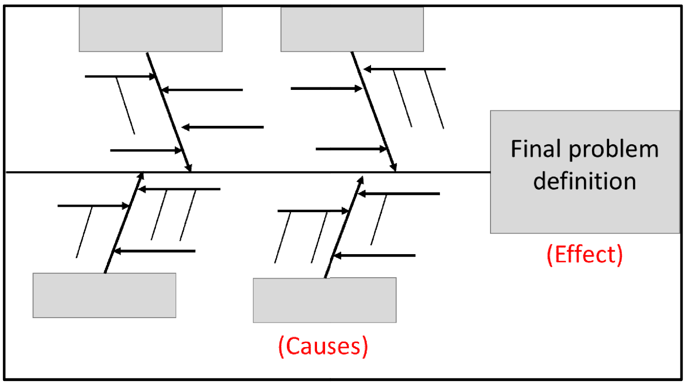
Potential Cause	1st Why	2st Why	3st Why	4st Why	5st Why

Source: Authors, (2022).

Ishikawa Diagram: The Cause and Effect Diagram, or also known as Fishbone Diagram or Ishikawa Diagram, is a graphical tool used in the management and control of quality in different processes. It was suggested by the Japanese chemical engineer Kaoru Ishikawa in the 1940s and improved over the years. With its use it is possible to identify the probable causes of a specific problem, highlighting the interaction between the effect, a quality characteristic, and its causes (FERNANDES et al, 2011). According to Peinado & Graemi (2007), the Ishikawa Diagram illustrates only the possible causes of a specific occurrence. These possible causes correspond to hypotheses that need to be analysed and validated individually, in order to attest their veracity and determine the degree of influence or impact on the situation under analysis. In this methodology, every problem has specific causes, and these in turn must be analysed one by one in order to ensure which of them is the real cause of the effect. The diagram of Ishikawa helps to simplify complex processes dividing them in simpler processes and, therefore, more controllable (TUBINO, 2004). For Oliveira; Allora; Sakamoto, 2006 this quality tool aims through the attack to the cause (process), extinguish and restrain the appearance of problems (effects). It is possible to have a graphic representation of the unfolding and survey of possible causes that generate effects in the process according to Figure 8.

MATERIALS AND METHODS

To construct this work the research method used was a qualitative and quantitative case study, carried out through field research and documentary research. With this method, it was possible to carry out the description of the characteristics of an organization of the segment of beverages a, before and after deploying Lean Six Sigma and DMAIC method aimed at obtaining the defined objects.



Source: Authors, (2022).

Figure 8. Ishikawa Diagram

Description of the object of study: The research unit of study of this work was in one of the companies of Simões Group, operating in the beverage segments for over 70 years in the Industrial Pole of Manaus. The object of study was in the sector of syrup and bottling of soft drinks, more specifically in the PET production line.

Main stages of the work: This study was divided into some main stages for the development of the case study with focus on the survey of opportunities for reducing sugar loss in the production process.

Step 1 - Survey of current data

In the data survey stage, information was obtained through sources made available by the company, such as reports of consumption of inputs for the period January 2021 to October 2021, detailing the amount of sugar consumed during the period analyzed.Also in the same period of analysis, the reports of sugar losses in the processes of simple syrup manufacturing, final syrup manufacturing, bottling of beverage in the PET line were consulted, thus it was possible to identify the business opportunity or financial GAP existing in the mentioned processes where the sugar loss has its relevance within the production cost.

Stage 2 - Process Mapping

In this stage it was possible to map the high level processes and to establish limits through the use of some tools such as the Serpent or Ladder Diagram that helped in the mapping of the sub-processes, besides the creation of the flowcharts of the syrup and bottling processes. This helped the team to gain perspective of the business and to focus the project scope through a series of process levels.

Step 3 - Measuring Losses

In this stage a data collection plan was created with sampling of the sugar loss, besides using some graphics that helped in the stratification and analysis such as control chart, trend chart, histogram and pareto chart. All this measurement of loss occurred in the processes of dosages of syrup and filling PET bottles, so it was possible to stratify and delimit the final focus of the project. As a metric for calculating the percentage of loss the following concepts from equation 1 were used.

$$\text{Sugar Loss}(\%) = \frac{\text{Qtd.Real (Kg)} - \text{Qtd.Teórica (Kg)}}{\text{Qtd.Teórica (Kg)}} x\ 100 \quad (1)$$

Stage 4: Cause Analysis

In this stage it was possible to analyse the data and the process map to determine the root causes and the opportunities for improvement, each cause being identified and validated through well-known tools such as the Cause and Effect Diagram and the 5 Whys method.

Step 5: Action Proposals

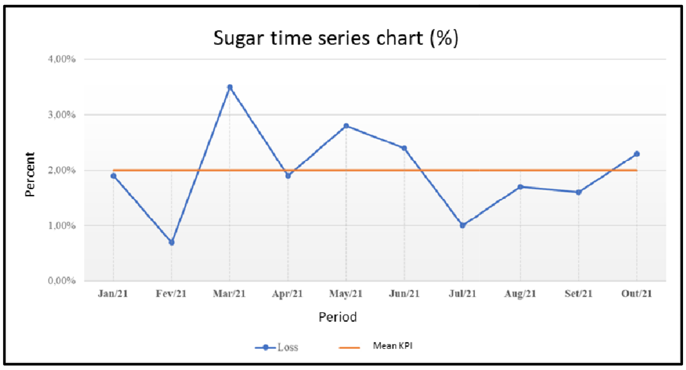
Once the root causes were known through the use of the tools for the investigation of causes, a structured action plan was developed for the follow-up and monitoring of the actions to reverse the loss. For this plan, the 5W2H tool was used, where deadlines were attributed, as well as the respective responsible persons and the costs applied to the improvement actions.

Step 6: Results Obtained

The evaluation of the results obtained after all the previous phases that goes from the survey of the opportunity, data collection, analysis of the causes until the conclusion of the improvement actions, it was possible to compare the results of sugar loss before and after the implementation of the applied methodology. The results were satisfactory for the company in both levels of indicators, both in percentage and financial.

RESULTS AND DISCUSSIONS

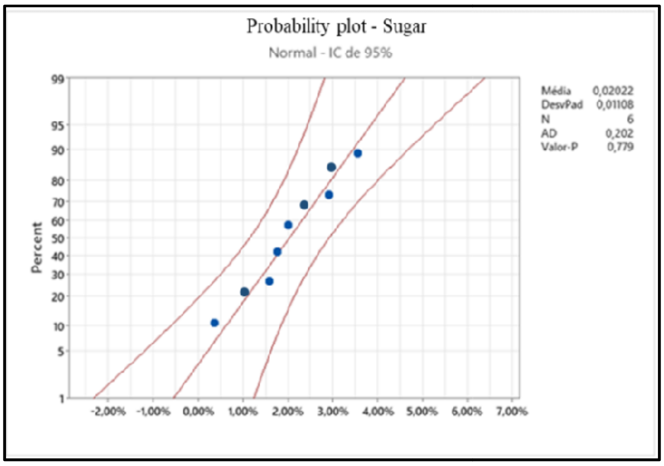
By applying the DMAIC methodology to capture a better business opportunity in face of the variation in sugar consumption existing in the company under study, we applied the step Define which was possible to observe through internal performance meters in the processes of syrup dosing and filling of beverage in the PET production line a loss of this highly relevant input in the composition of the Production Cost. In the graph of Figure 9 we can observe the statistical analysis of the data which shows the high variability in the process and the non-compliance with the internal targets set for the sugar indicator, with an average KPI of 2.02%, and the established target of 0.46%.



Source: Authors, (2022).

Figure 9. Average monthly sugar loss

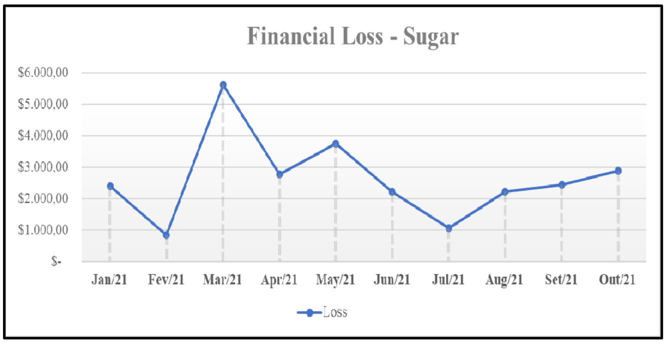
A data normality test was applied and proved that the data used in this study is normal with a 95% reliability index as shown in Figure 10.



Source: Authors, (2022).

Figure 10. Graph of normality of sugar loss

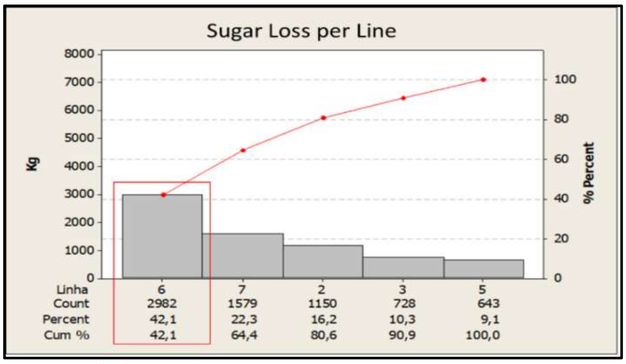
The soft drink manufacturing process does not allow the recovery of sugar along the existing sub-processes, since the sugar goes through a process of transformation from the solid state, crystal sugar, for simple syrup (composition of water and sugar) this waste along the process generates a financial impact for the company that can be seen in the graph of Figure 11, and considering the accumulated losses in the analyzed period, the company had a loss of approximately $ 26,082.00.



Source: Authors, (2022).

Figure 11. Monthly expenditure on sugar loss

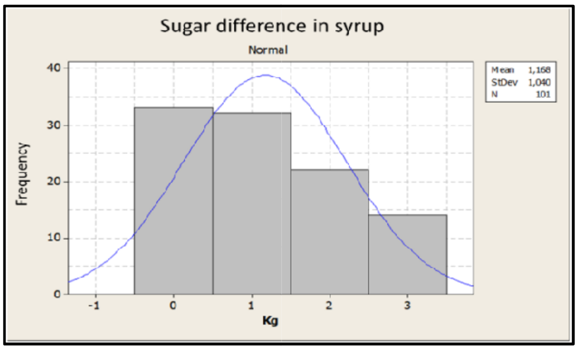
For the beverage filling process in the production lines, all product losses were surveyed, either by rejection in the electronic inspection equipment due to irregular level of drink, or by product out of standard, or by sampling of product for quality testing. During the measurements it was observed that line 06, which corresponds to the PET line, accounted for 42% of sugar losses compared to the other production lines, as shown in the pareto chart in Figure 12.



Source: Authors, (2022).

Figure 12. Sugar loss per production line

For the syrup manufacturing process, data of the dosages performed were collected by comparing the actual sugar consumption with the theoretical consumption expected in each recipe or mixing procedure. This mixing procedure contains the amount of simple syrup, composed of water and sugar, to be used for a production kit. During the measurements it was found that the operator, when performing the dosage of the kit, sometimes used up to 3 kg more sugar, as illustrated in the histogram of Figure 13.



Source: Authors, (2022).

Figure 13. Histogram of sugar loss in syrup manufacturing

Table 5. VOC Methodology - Voice of the Customer

VOC - Voice of Customer				
Client	**Need**	**CTQ (Critical to Quality)**	**Valid Requirement**	**Indicator**
Client 01	Brix within specification range	Sugar loss	Brix Specification Chart	Brix Specification
Client 02	Actual loss against budgeted loss	Sugar loss	<=0,46%	% of sugar loss
Client 03	Actual loss on target attendance	Sugar loss	<=0,46%	% of sugar loss
Client 04	Low organic load	Organic Load	<2400	Limit of DQO (Chemical Oxygen Demand)

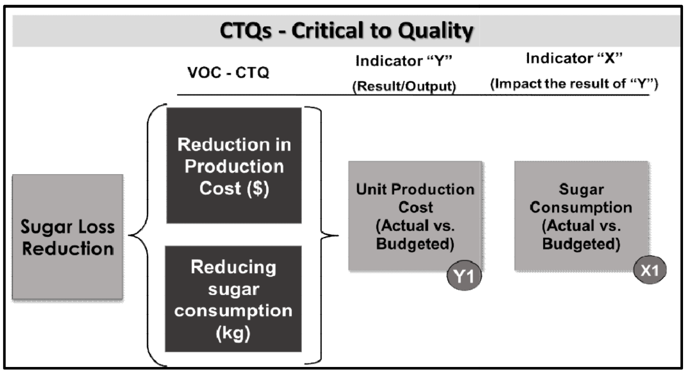
Source: Authors, (2022).

Table 6. Data collection plan for sugar loss

Measurement Point	Description of Variables	Measuring Form	Measurement Frequency
M1 - Loss of sugar in the final syrup tank	Quantity of simple syrup in final syrup production	Supervisory recording of the final syrup shop	Once per shift
M2 - Sugar loss in the filling machine PETLine	Quantity of beverage discarded by tailings	Register in the equipment's IHM	Hour by hour
M3 - Sugar loss in the Proportioner PET Line	Quantity of drink provided in the equipment	Proportioning tank volume recording	Hour by hour

Source: Authors, (2022).

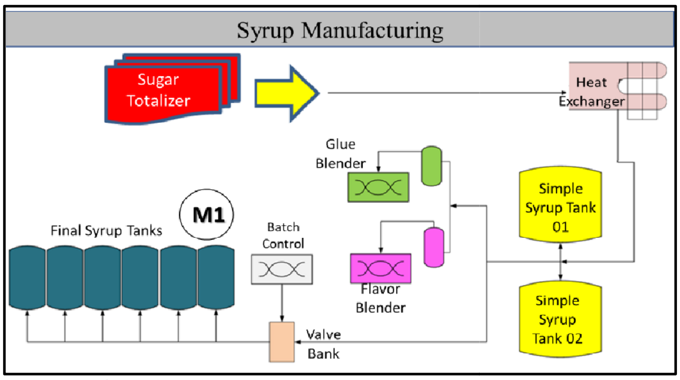
During the unfolding of the Define phase, the VOC (Voice of the Customer) tool was used to raise the expectations of stakeholders and then define the target and deadline for meeting the sugar loss indicator.The VOC from the use of direct interviews with customers, it was possible to identify that the main need is to meet the sugar loss indicator, and it was also possible to define valid requirements, which serve as the target of the project as well as which indicators will be used to monitor the achievement of the goal, as shown in Table 5. The definition of the CTQs (Critical to Quality) is of extra importance for the progress of the case study. It was possible to develop them through interviews with customers as shown in Figure 14, specifying the process attributes that guarantee customer acceptance.



Source: Authors, (2022).

Figure 14. Critical to Quality for reducing sugar loss

After defining the customer's expectations it was possible to start the stage of measuring sugar losses, a survey of information was structured to ensure the mapping of the measurement points and one of the points is located in the syrup process as shown in Figure 15.

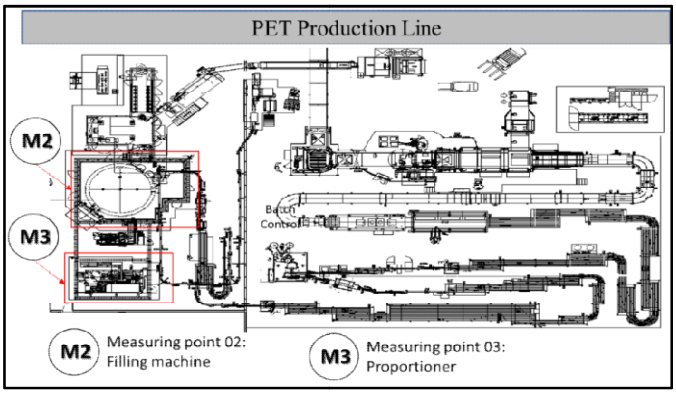


Source: Authors, (2022).

Figure 15. Mapping of losses in the syrup process

Another point of mapping and data survey is located in the filling process of the PET line as shown in Figure 16.

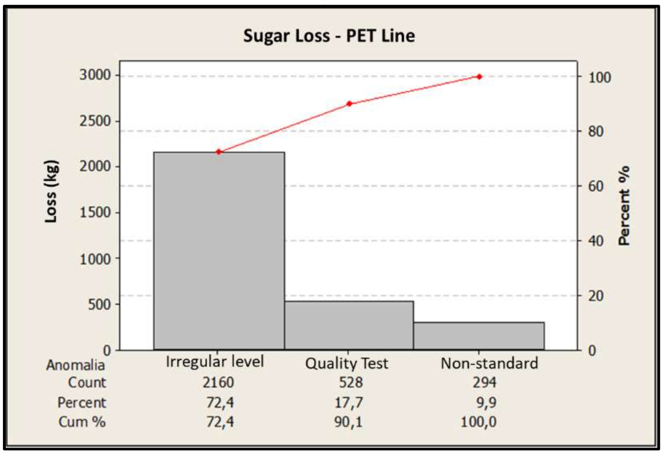
A data collection plan was developed using the model detailed in Table 6, which provides information about the measurement points, description of the indicators and the way the team will collect each collection and its respective frequency of realization.



Source: Authors, (2022).

Figure 16. Mapping of losses in the PET Line process

A pareto chart was assembled after the planned period for data collection, so it was possible to identify the main causes of sugar losses in the analyzed processes. As can be seen in the resulting graph in Figure 17, three different causes were identified for sugar losses where one of them stands out from the others as being the most representative with 72.4%, irregular level, i.e., level of beverage filled below the specified volume for each package.



Source: Authors, (2022).

Figure 17. Pareto Graph of the main sugar losses

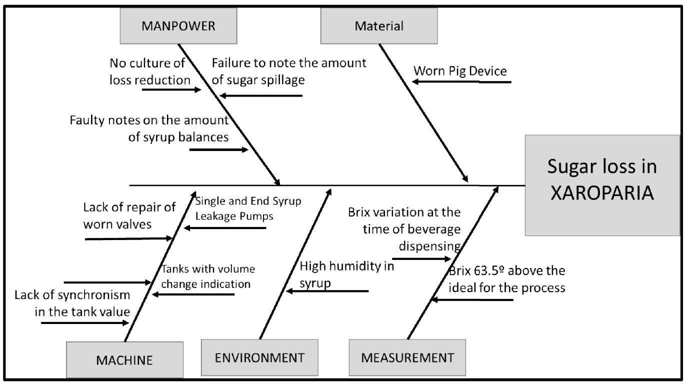
Analysis: After the identification of the main variations of sugar loss in the production process, some tools were used to help raise the root causes by analysing all the factors that involve the execution of the processes. The tools applied were Branstorming, Cause and Effect Diagram and the 5 Whys, as described in Table 7.

Table 7 - 5 Whys tool applied to sugar loss

Potential Cause	1st Why	2st Why	3st Why	4st Why	5st Why
Variation in the filling valve generating irregular level	Faulty operation of the electronic level control boards of the filling valves	Lack of preventive maintenance on valve components	Lack of dedicated people to create and review existing maintenance scripts	N/A	N/A
bottles tipping over at the filler exit	Lack of available parts in stock	Inadequate collection of spare parts	N/A	N/A	N/A
Error when changing the worm shaft	Difficulty in adjusting the worm shaft change of the filler inlet	Lack of standard for adjusting the change of the worm shaft of the filler inlet	N/A	N/A	N/A
AntonPaarmalfunction	No shut-off ball valve in the CO2 inlet tubing	No pressurecontrolvalve	No standard procedure to perform the CO2 Brix analysis of the beverage	Lack of preventive maintenance on components	N/A
Thread trimmingerror	Method used has no up-to-date standard available	Loss of patterns that were used	No suitable location for operational standards	N/A	N/A
Excessive breakage of the bottle ring	Wear of the brake-star clamps	Lack of synchronism of the stele	Servo motor wasfaulty	Equipment does not have an inspection script	N/A

Source: Authors, (2022).

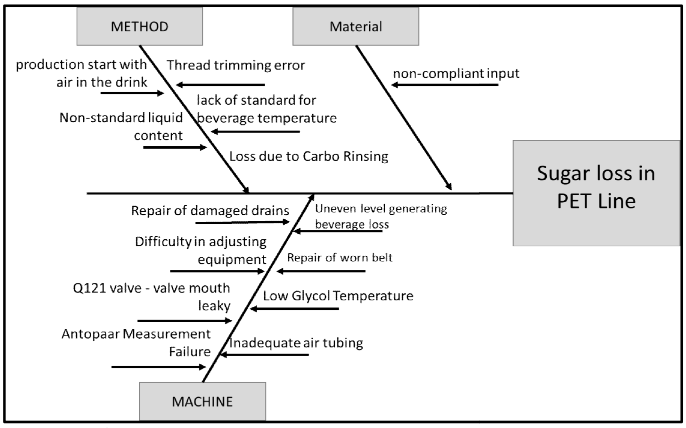
After investigating the root causes, the Cause and Effect Diagram was used as shown in Figure 18 for the sugar loss problem in the syrupy process.



Source: Authors, (2022).

Figure 18. Ishikawa Diagram tool of the Xaroparia process

As can be seen in the Ishikawa Diagram, some causes were identified in the beverage filling process on the PET Line as shown in Figure 19.



Source: Authors, (2022).

Figure 19. Ishikawa Diagram tool of the filling process

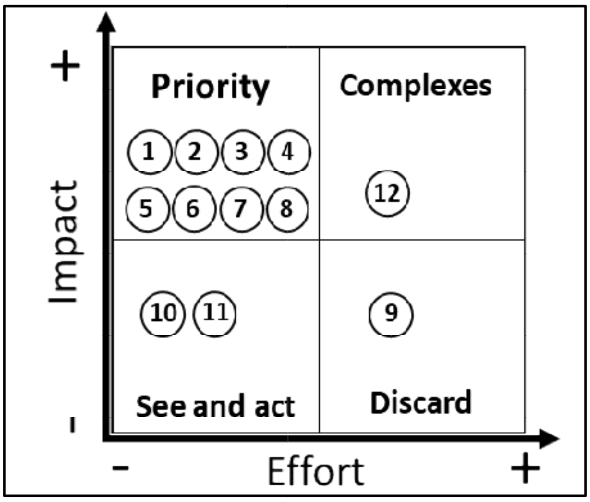
By analyzing the Ishikawa Diagrams applied to both study areas, syrup shop and bottling, it is possible to observe that the causes are concentrated in the machine category, where problems such as leaky simple and final syrup pumps, tanks presenting variations in the reading of syrup levels, Antopaar equipment generating failures in the readings regarding the sugar rate of the bottled drink, appear in the analysis as shown in Figures 18 and 19.

Once the causes were identified, they were listed in Table 8 for application of the 2x2 Matrix tool or also known as the Effort X Impact Matrix (Figure 20) which assists in prioritizing actions to address the causes identified. With this tool it was possible to divide the causes raised into 4 groups, according to the classification of the impact generated and the effort expended.

Table 8. List of root causes

#	Root Cause
1	Single and End Syrup Leakage Pumps
2	Tanks with volume change indication
3	Lack of repair of worn valves
4	Information about the tank levels with variations
5	Lack of synchronism in the tank value
6	Repair of damaged drains
7	Difficulty in adjusting equipment
8	Q121 valve - valve mouth leaky
9	Antopaar Measurement Failure
10	Uneven level generating beverage loss
11	Repair of worn belt
12	Low Glycol Temperature
13	Inadequate air tubing

Source: Authors, (2022).



Source: Authors, (2022).

Figure 20. Effort X Impact matrix for sugar loss

The team of this work applied scores for the causes raised taking into account notes for low and high level and of effort to apply the corrective actions, so it was also scored the two level of impact for the result of the company. It was possible to observe that eight causes that have a low effort level low and high impact (- Effort, + Impact), two of the causes have a low effort level and also a low (- Effort, + Impact), for this classification can be performed immediate actions to reverse the loss of sugar. One of the causes had a high level of effort and high level of impact (+ Effort, + Impact), this cause was taken to the level of further investigation to decide if it is worth the investment in the improvement action. One of the causes was left with low effort and low impact (- Effort, - Impact) being this cause discarded and not contemplated in the action plan.

Actions: In Tables 9 and 10 we can analyze the unfolding of action plans created to address the causes mapped in the quadrant See and Agile and Priority, these plans were developed through the tool 5W2H with focus on reversing the loss of sugar in the syrup process and bottling of beverage.

With the actions executed according to the previous planning, it was possible to follow up the result of the sugar loss indicator and compare it with the period before the implementation of the improvement actions, according to the graph of the sugar loss index shown in Figure 21. As can be seen, the history of the sugar loss index from January 2021 to June 2022 suffered oscillation after the implemented actions. When comparing the loss averages it is possible to observe that in the period from January 2021 to October 2021 the average loss was 2.02%, however, with the corrective actions the average loss was reduced to 0.07% in the period from November 2021 to July 2022. The project aimed to reduce the sugar loss rate to 0.46%, which is the strategic target set by the company. This reduction in the sugar loss ratio would represent a saving of $25,194 in production costs, however the positive impact exceeded expectations generating a gain of $46,554 for the company.

Table 9. Action plan of the quadrant See and Act (- Effort, - Impact)

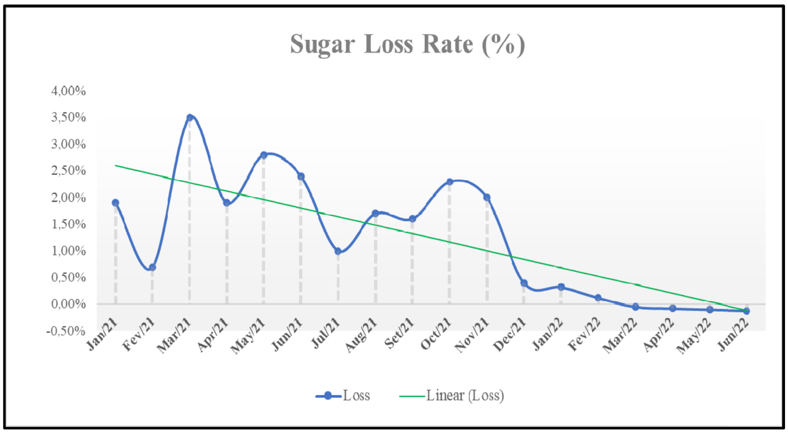
Actions	Responsible	Deadline	Local	Argument	Procedure
What?	Who?	When?	Where?	Why?	How?
Open Service Order for inclusion of the parts search routing in the process expert checklist	Colaborator 1	15/10/2021	Filler Machine	Ensure revision of belt maintenance schedules	Including activity in the process experts' checklist
Carry out replacement of the filling valves	Colaborator 2	30/09/2021	Filler Machine	To correct the irregular level problem	Installing valve identification module

Source: Authors, (2022).

Table 10. Action plan in 5W2H format for the causes identified.

Actions	Responsible	Deadline	Local	Argument	Procedure
What?	**Who?**	**When?**	**Where?**	**Why?**	**How?**
Open Service Order for inclusion of the roadmap revision in the Process Specialist and Mechanical Maintenance checklist	Colaborator 1	15/09/2021	Filler Machine	Ensure revision of belt maintenance schedules	Including activity in the process experts' checklist
Registering items in the warehouse to perform periodic maintenance	Colaborator 4	10/10/2021	Proportioner	Eliminate drain valve leakage	Replace damaged seals
Create Process Sheet for Filler Kit Adjustment	Colaborator 3	30/09/2021	Filler machine	Ensure proper adjustment of the filler kit	Develop standards needed for the activity and train employees
Perform training of the developed standard	Colaborator 3	10/10/2021	Filler machine	Ensure proper adjustment of the filler kit	Develop standards needed for the activity and train employees
Create a cleaning and internal and external lubrication script for the valves and actuators	Colaborator 5	10/08/2021	Syrup tank	Ensure efficient maintenance of Xaroparia's automatic valves	Creating and updating standars and supplying the spare parts
Perform calibration of the tanks according to the availability of syrup	Colaborator 5	15/09/2021	Syrup tank	Ensure the correct reading of the dosed volumes in the Syrup tanks	Perform calibration of the tanks
Open monthly Service Order for periodic review of the loss calculation spreadsheet	Colaborator 2	30/08/2021	Syrup tank	Ensure the update of the calculation basis of the loss control spreadsheet	Review the Production Analyst checklist
Create and apply training focused on losses in the Syrup process	Colaborator 4	20/09/2021	Every company	Disseminate loss culture to Xarope's operational team	Developing training with coverage of loss points

Source: Authors, (2022).



Source: Authors, (2022).

Figure 21. Historical sugar loss index after implementation of actions

CONCLUSIONS

This work focused on the technical aspects of implementing the Lean Six Sigma methodology together with the DMAIC method in a beverage industry installed in the city of Manaus, aiming to reduce production costs by reducing the loss of sugar in the processes of syrup manufacturing and filling of soft drink in the PET line. With the choice of applying the usual tools of DMAIC and Lean Six Sigma, it was possible to determine and quantify the main points of loss and in which processes there was greater loss of sugar, as well as analyze the root causes for the establishment of improvement actions and reversal of the scenario in which the company was facing the chosen indicator. With this case study, it was possible to apply the tools and certify the contributions of each one to meet the objective of the study: Statistical analysis of normality of data, VOC - Voice of the Customer, CTQs - Critical to Quality, Pareto Chart, Histogram, 5 Whys, Ishikawa Diagram, Effort x Impact Matrix and 5W2H. In addition, one can observe the importance of the participation and engagement of the sectors involved with the indicator studied, a crucial factor for the implementation to occur successfully. The two methodologies implemented bring great benefits to the company, this study is proof that by following and respecting the concepts and principles of each of them, great results are achieved. The objective of this work was achieved, generating satisfactory results, proven with evidence of reduction of the sugar loss index of approximately 1.95% equivalent to the comparison of the average losses in the periods before and after the execution of the study. With the reduction in the loss rate of one of the most consumed inputs in the company studied, it was possible to meet customer expectations by providing a positive impact on production costs, enabling an increase in the company's competitiveness. The financial gains were approximately U$ 46.554 per year, as a result of the effectiveness of the improvement actions implemented after investigating the real causes of losses for the organization.

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