S&G 18 (2023), pp. 243-261

S&G Journal

S&G JOURNAL
ISSN: 1980-5160

PÓS-GRADUAÇÃO DINÂMICA DOS OCEANOS E DA TERRA UFF

PROPOSING IMPROVEMENTS IN THE AÇAÍ PULP PROCESSING PROCESS: AN APPLICATION OF LEAN SIX SIGMA

Marian Carneiro
mariana_karneiro@yahoo.com.br
Pará State University - UEPA,
Belém, PA, Brazil.

Tassy Alves
tassyalves1996@gmail.com
Pará State University - UEPA,
Belém, PA, Brazil.

Mariana da Silva Monteiro
marihmont@gmail.com
Pará State University - UEPA,
Belém, PA, Brazil.

Nyna Arisa Ueoka
nynaueoka0707@gmail.com
Pará State University - UEPA,
Belém, PA, Brazil.

Giovanna Moreira Silva
g21moreirasilva@gmail.com
Pará State University - UEPA,
Belém, PA, Brazil.

ABSTRACT

The commercialization of the açaí fruit has increased considerably since the 1990s, boosting demand and the price of the fruit as well as attracting new investments in the açaí pulp processing industries to the northeastern region of the State of Pará. Therefore, this study aims to use the principles and methods of Lean Six Sigma to propose improvements to the açaí pulp processing process. These improvements aim to reduce machine downtime to provide the company with greater profitability and the development of continuous flow. First, a literature study was carried out to understand the methodologies of Lean Manufacturing and Six Sigma and how they complement each other. Then we used the Six Sigma method, DMAIC, with the Define, Measure, and Analyze phases. In this phase, the main reasons were identified and the percentage of stoppages that each one represents on the line, such as lack of product in the process area (33.75%), lack of production order (23.91%), change of laminates and coils (12.7%), cleaning before production (7.49%), and mechanical breakdown or failure (7.35%), which together account for 85.2% of the line's total stoppages. Therefore, an action plan was proposed for each reason identified to reduce or eliminate it. The main limitations of the research were the lack of a qualified team and a centralized organizational culture that would allow faster data analysis. Some of the main practical implications include statistical methods for decision-making in the açaí agro-industry, a sector that has sought to professionalize its management and improve the supply of its products.

Keywords: Açaí industry; Lean Six Sigma application; Downtime reduction; Flow.

PROPPI / DOT
DOI: 10.20985/1980-5160.2023.v18n3.1863

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

INTRODUCTION

In an increasingly competitive environment, organizations in various sectors constantly seek to improve their processes, making them more efficient. This continuous search for improvement has forced companies to find methods capable of managing and guaranteeing the quality of their products and/or services. This scenario is no different for the food industry. According to Costa et al. (2018), the global food industry faces several challenges that force companies in this sector to improve their productivity and quality strategies to remain competitive. In this context, açaí fruit is one of the most relevant products of national extractivism and one of the main contributors to highlighting the biodiversity of the Amazon rainforest. In terms of the national market, the country's northern region concentrates most of the açaí production, with Pará and Amazonas accounting for 87.5% of the total, with the state of Pará being the world's largest producer, having doubled its production in the last ten years, and Brazil's largest exporter, followed by Amazonas (Conab, 2019). Researchers and operators in the sector point to critical factors for the competitiveness of the Amazon in açaí production and processing, especially considering the emergence of plantations in other tropical areas. According to Fernandes and Almeida (2022), balanced production combined with sustainable planning is the key to açaí becoming one of the most commercialized fruits in the country. Therefore, companies in the segment need to invest in verticalization and crop expansion strategies.

Lean Manufacturing, also known as the Toyota Production System, aims to reduce waste in the production process, thus improving quality and reducing production time and, consequently, production costs. Lean uses several tools such as 5S, Bottleneck Analysis, Kaizen (Continuous Improvement), PDCA, Poka-Yoke, Root Cause Analysis, SMART objectives, Just-in-time, and Takt Time. The tools can be combined according to business type, such as lean startup, lean healthcare, and lean Six Sigma (Ferreira, 2018).

In this way, lean provides a relevant framework for improving efficiency by reducing waste, i.e., operations that are unnecessary, excessive setup times, unreliable machines that can be made more reliable, rework that can be eliminated, and others (Costa et al., 2018). Six Sigma is a statistical approach that seeks to identify and eliminate defects, reduce process variability, reduce production costs, improve product quality, and reduce defects (Cruz, 2021) using the DMAIC methodology. This methodology can be improved and structured as a diagnostic model for problem solving (Bugor and Lucca Filho, 2021). Lean Six Sigma combines the speed strategy and cultural and organizational processes of Lean aligned with Six Sigma statistical tools. The consequence of this fusion is that processes have higher quality and speed, avoiding waste and resulting in lower cost production (Silva and Gonzalez Junior, 2022). For Costa et al. (2018), the main studies encompassing the two philosophies, L and SSi, in the context of the food industry are mainly driven by six different factors: reducing process variation, reducing waste, improving competitiveness, reducing cost, reducing inventory, and increasing process efficiency.

This study aims to propose improvements in the açaí pulp processing process using Lean Six Sigma principles and methods.

RESEARCH METHOD

The project was carried out in an açaí pulp processing company located in Brazil, in the municipality of Castanhal, PA. Its name or any information that could compromise it will not be mentioned during the work.

To conduct the study, information was initially sought from primary sources through unstructured interviews with the company's board of directors and management, as well as on-site observations. The aim was to define the study's context and purpose, focusing on the characteristics of this type of industry. By analyzing the processes and identifying the relationships with customers (as they are the crucial link in the business), the aim was to identify the main flaws that occur in the process and provide solutions.

The work in question was carried out using the DMAIC cycle, executing the Define, Measure, and *Analyze* steps with the construction of the entire action plan. This can be implemented later, as well as a brief description of what needs to be done to control the process.

A bibliographic survey was carried out to identify the set of activities that make up the DMAIC method using theoretical references. This provided the basis for the work, from how its structure to using the main tools to conduct it.

To achieve the proposed objective, the following stages were followed:

a) Define: An analysis of the seven losses of lean was responsible for developing the project contract, aligned with the company's strategies. It defined the scope, justification, analysis of the chances of success, timetable, and targets. In addition, a SIPOC diagram and process mapping were drawn up to understand how the process works from start to finish.

b) Measure: The variables of interest to be measured were defined to identify the sectors and lines that had the most influence on the problem. Data was then collected from the company's downtime recording system and through timekeeping. Subsequently, the appropriate tools were used to process the data for a better understanding of the current state of the process;

c) Analyze: The problems found were prioritized, and solutions were generated by drawing up action plans to eliminate or minimize them. The analysis was carried out using different quality tools, such as the Pareto Diagram, the Ishikawa Diagram, and regression analysis. In addition, an in-depth analysis of the line process identified in the previous stages was carried out using the VSM, pointing out possible improvements to the process. Finally, an action plan was created to solve the main problems identified.

RESULTS AND DISCUSSION

Define stage

It was found that the main problem is related to the downtime of labor, parts, equipment, products, and information throughout the process, resulting in an inefficient flow. Specifically, the project scope is centered on the machine stoppages that prevent the factory from reaching its daily production targets. Currently, production occurs without rhythm and in a pushy manner, with no standard setup time or maximum machine downtime. As a result, many stoppages occur during production, preventing the main process—filling—from taking place on time.

The project aims to raise the level of utilization of the factory's production capacity, identify the activities that do not add value to the product, and, with this, draw up an action plan to minimize machine downtime, increasing productivity, providing the shop floor with a continuous production flow, and reducing costs.

Thus, the Project Initiation Agreement (PIA) was initially developed, establishing the commitment of the implementation team to the company and vice versa, as shown in **Chart 1**.

It is worth noting that the TAP has undergone some changes during the project: due to difficulties in accessing certain information, some variables could not be quantified more precisely, and the contract was realigned as the Measure phase was carried out.

Next, to better understand the process, the SIPOC Diagram (**Figure 1**), which outlines the basic process elements, was drawn up.

As the company's estimates reflect an increase in its production and sales volumes over time, it is necessary to analyze and understand the general flow of the process to subsequently establish the flow of the value chain and eliminate and/or reduce activities that do not add value to the product. A process flowchart (**Figure 2**) was drawn up for a better understanding of the stages following the process.

If the product is to be reprocessed in the off-season, it is removed from the packaging and crushed in the ice breaker to restart the pasteurization process.

During this process, many problems influence the operation's low efficiency, especially concerning machine downtime. To quantify this problem, we analyzed data on machine downtime from April 2018 to October 2019.

Measuring Stage

Upon realizing that the factory cannot meet its daily targets due to the large number of stoppages during the process, the company has collected data to discover the reason. However, the data is not transformed into information to visualize and understand what is happening during the production process. Using statistics, we hope to understand the behavior of the variables that impact the high rates of machine downtime.

The graph in **Figure 3** was plotted to better visualize the downtime behavior over the period analyzed.

As you can see, the graph shows a peak in August in both years compared to the previous months, showing a significant rise in 2019. In the period in question (the start of the harvest), the machines should be working at full capacity, as this is when demand is highest and the raw material price falls. A total of 2,582,227 minutes of downtime were recorded.

This data refers to specific machines in certain sectors, listed in the steering diagram illustrated in **Figure 4**. A relevant factor to take into account is that the machines that produce mix and the icebreaker were considered separately because they do not have a specific sector.

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

Chart 1. Project Charter

PROJECT CHARTER			
PROJECT NAME:	Proposal to reduce machine downtime in an açaí pulp processing company		
REQUESTING AREA:	Production Sector		
RESPONSIBLE/SPONSOR:	Strategic Manager		
PROJECT MANAGER:	Process Supervisor		
START DATE:	May 2019	END DATE:	November 2019
PROJECT DATA			
AIM			
Proposing improvements to reduce machine downtime in the açaí pulp manufacturing process through the Lean Six Sigma approach			
CURRENT SITUATION			
- On average, it takes two hours or more after the start of working hours for production to start steadily, causing machines to remain idle;			
- Production cannot start with two or more products on a line at the same time;			
- The factory has no criteria for sequencing the day's Production Orders (quantity, delivery forecast, preparation time, etc.);			
- The current layout does not favor continuous flow and generates more activities that do not add value to the product;			
- The company is moving towards adopting lean practices;			
- The process of implementing the practices needs to be aligned/structured.			

PROJECT SCOPE	
The data obtained from the machine downtime records will be analyzed, interpreted, and treated statistically, and then the production process will be mapped to obtain the cycle time, rhythm, and lead time of the process. After this stage, an action plan will be drawn up to address the variables that directly influence shop floor productivity based on the process constraints. Actions that can be implemented by the organization in the short, medium, and long term will also be defined.	
BENEFITS	
QUANTITIES	QUALITATIVE
Reduce overtime during the harvest;	Less bureaucratic activities;
Reduce variation in downtime;	More engaged employees; Achieving the daily production target
Reduce cycle time and process lead time.	Continuous flow in the process; Motivated working environment.
GOALS	
Reduce total machine downtime by at least 20%; Increase the availability of the single 100 g filling line by 30%; Finalize the project by delivering the action plan by the end of the 2019 harvest.	
THE PROJECT'S MAIN STAKEHOLDERS	
- The board of directors (Strategic and Operational);	- Project team;
- Plant manager;	- Advisor;
- Sectors (Production, Production Planning, and Control - PCP, Maintenance and Sales).	- University.
PREMISES	RESTRICTIONS
- The team conducting the work will have access to information; - The entire operator team will take part in the project; - The research will identify the value stream;	- Data collection can only begin in July (harvest); - Analyses can only be carried out during the morning shift; - Tests can only be carried out when there is no production; - The project must be completed by the end of the 2019 harvest; - The company's name cannot be mentioned in the project.
- The proposals for improvement will be presented to the company's board of directors.	

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

WORK TEAM			
	NAME	**DUTIES**	**AREA/MANAGEMENT**
LEADER:	Process Supervisor	Project management	Production/Supervision
TEAM MEMBERS:	Process Analyst	Analyze and process data, propose improvements	Production
	Industrial Manager	Guide project and make data available	Production/Management
	Process Analyst	Collect data, analyze and implement improvements	Production

PROJECT SCHEDULE

FASE	ATIVIDADES	2019 JUN	JUL	AGO	SET	OUT	NOV	DEZ
Define	Termo de Abertura do Projeto	X						
	Criação do Diagrama SIPOC	X						
	Mapeamento do Processo	X						
Measure	Criação de um plano de coleta de dados		X	X				
	Coleta de dados			X	X	X		
	Tratamento estatístico de dados				X	X	X	
Analyse	Análise dos dados					X	X	
	Análise das causas do problema					X	X	
	Elaboração do vsm						X	
	Criar plano de ação						X	X

Source: The authors (2023)

Legend: PHASE: Define; Measure; Analyze. ACTIVITIES: Project Opening Statement; Creation of the SIPO C Diagram; Process Mapping; Creation of a Data Collection Plan; Data Collection; Data Statistical Treatment; Data Analysis; Analysis of the causes of the problem; Elaboration of the VSM; Create an Action Plan. 2019: JUN; JUL; AUG; SEPT; OCT; NOV; DEC.

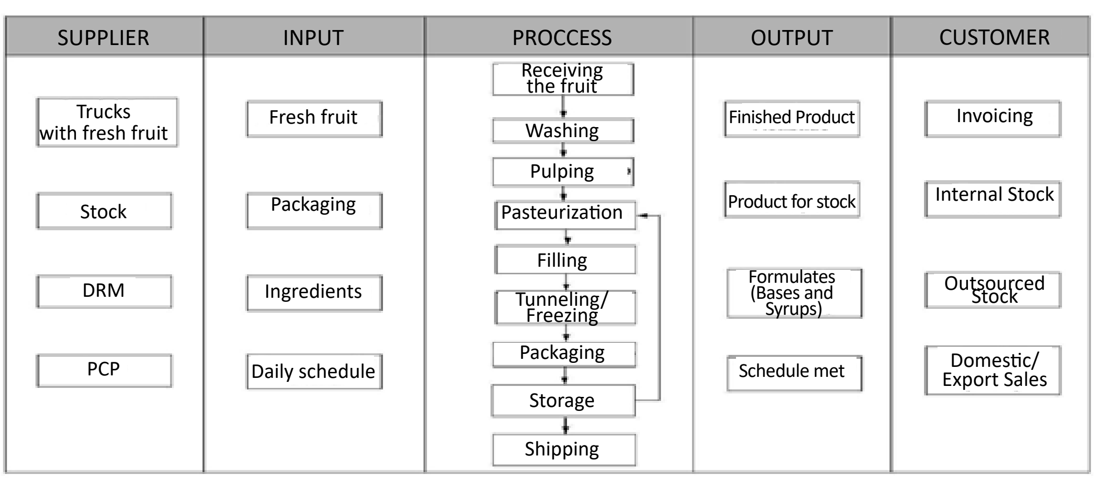


Figure 1. SIPOC Diagram

Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

Fruit recep- tion BEGINNING Fruit Wei- ghing Will the fruit be blanched?	Fruit Washing Washing with Bleaching YES Washing Without Bleaching NO	Pulping Fruit Pulping Has the fruit been blanched?	Pasteuriza- tion Pasteurize Product NO	Standardiza- tion Standardize Product YES	Filling Filling Pro- duct	Grinding Grind product for reproces- sing Remove packaging / Cutting	Freezing Freeze product until it reaches -180C Is there secondary packaging?	Packaging Pack products YES NO	Storage Storing products in chambers Will it be re- processed? YES	Shipping END NO

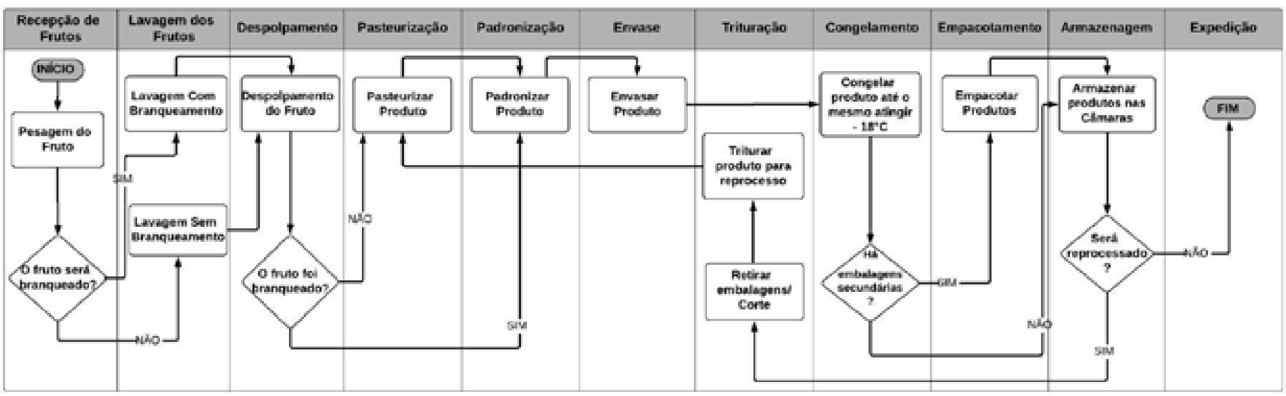


Figure 2. Cross-functional process flowchart
Source: The authors (2023)

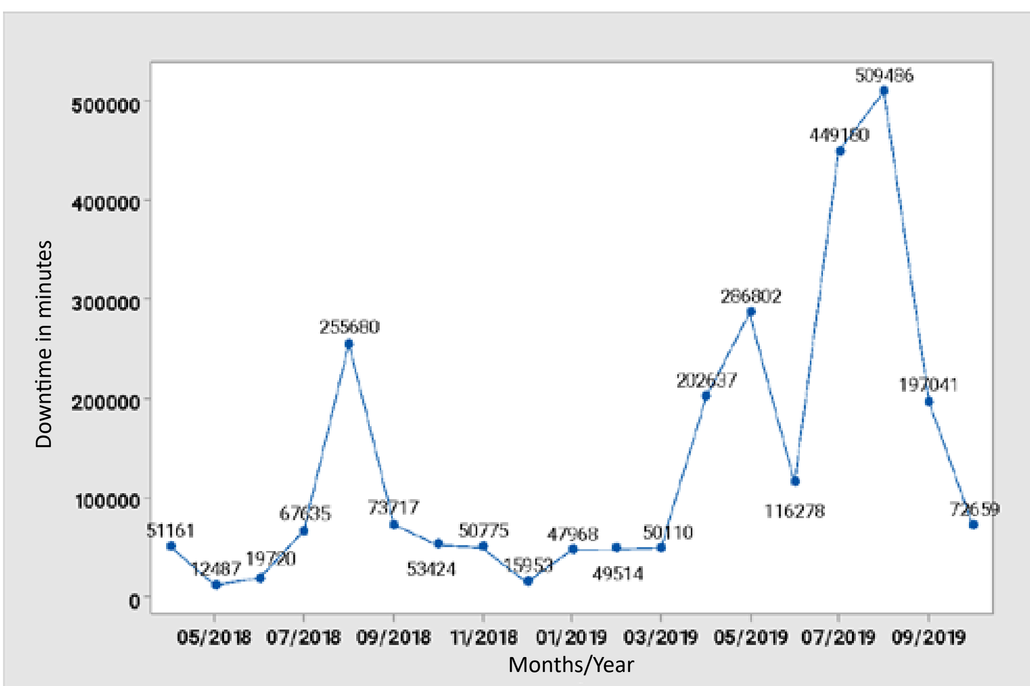


Figure 3. Time series graph of machine downtime
Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

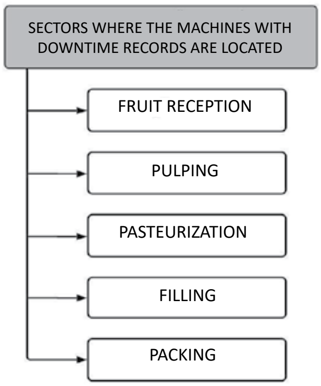


Figure 4. Sector driver diagram
Source: The authors (2023)

The downtime survey is presented by sector in the Pareto Diagram in **Figure 5**, allowing us to identify where the most machine downtime occurs.

Figure 5 shows the following main lines, arranged according to the diagram in **Figure 6**.

A Pareto Diagram (**Figure 7**) was then drawn up to prioritize the line that will be the focus of the work, i.e., the one with the most downtime records.

The graph shows that the 100 g single line is the one with the longest downtime, accounting for 36.5% of the sector's total. In a general analysis, this means that this line accounts for 24.06% of the total downtime recorded in the period, as shown in **Figure 8**.

The single 100g line consists of seven machines in the filling sector, as seen in **Figure 9**.

For the analysis, the ideal would be to identify whether the machines show variations in downtime between them. However, as the line analyzed already corresponds to the

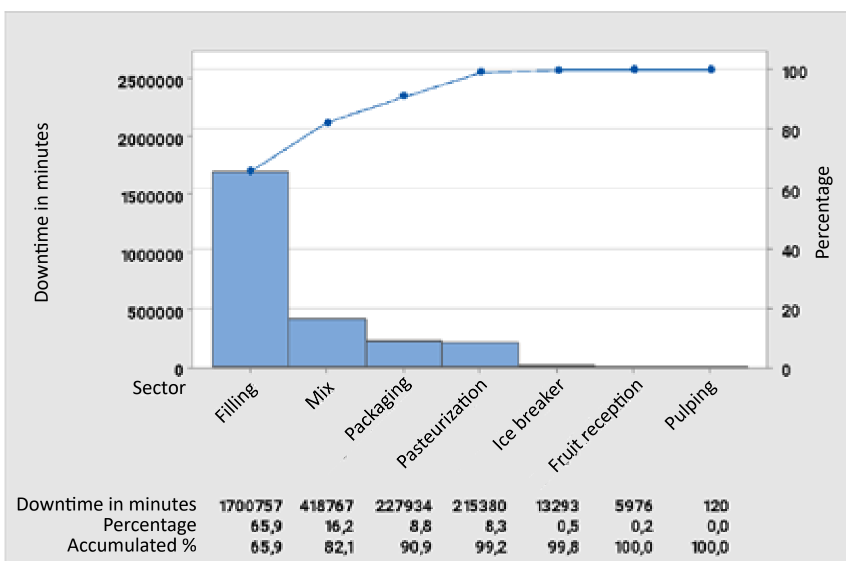


Figure 5. Pareto diagram for sectors
Source: The authors (2023)

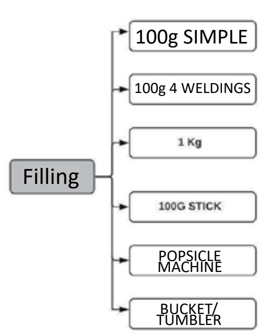
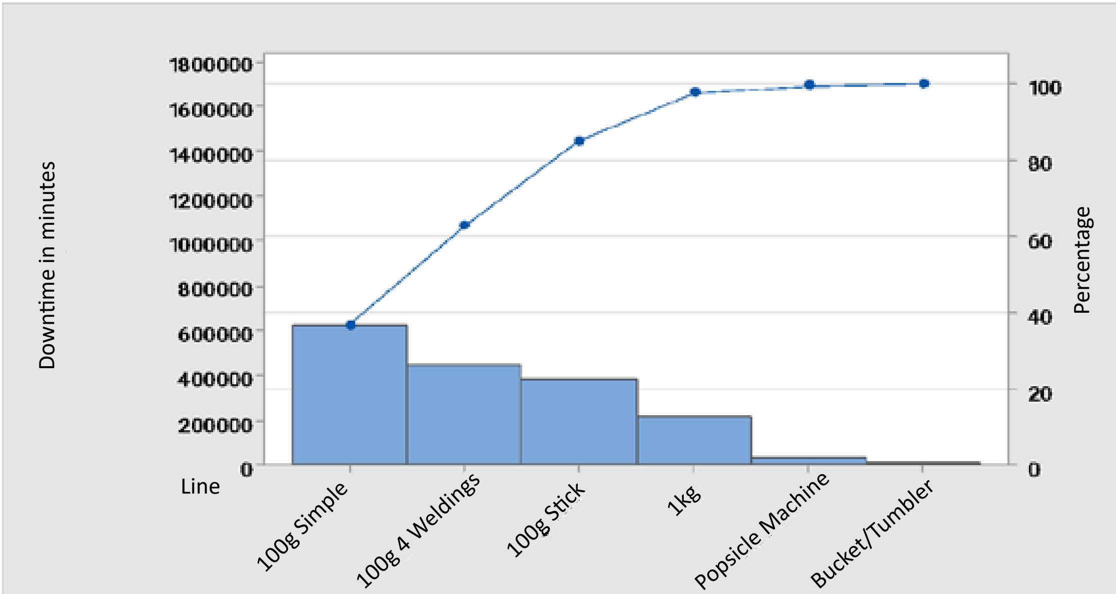


Figure 6. Filling line routing diagram
Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890



	100g Simple	100g 4 Weldings	100g Stick	1kg	Popsicle Machine	Bucket/Tumbler
Downtime in minutes	621339	445248	378457	216223	30564	8926
Percentage	36,5	26,2	22,3	12,7	1,8	0,5
Accumulated %	36,5	62,7	85,0	97,7	99,5	100,0

Figure 7. Pareto Diagram for lines
Source: The authors (2023)

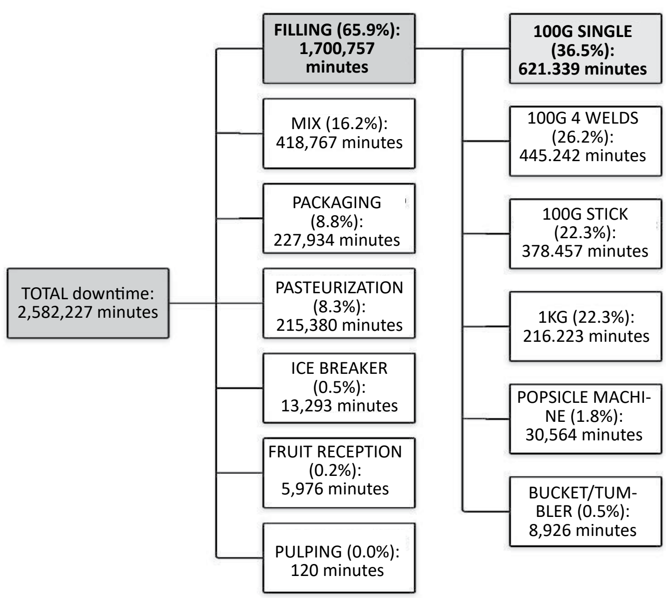


Figure 8. Summary of times by sector and line
Source: The authors (2023)

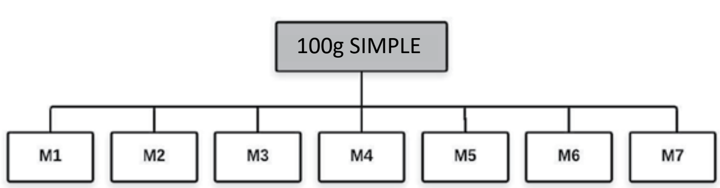


Figure 9. Machine guidance diagram for the 100 g single line
Source: The authors (2023)

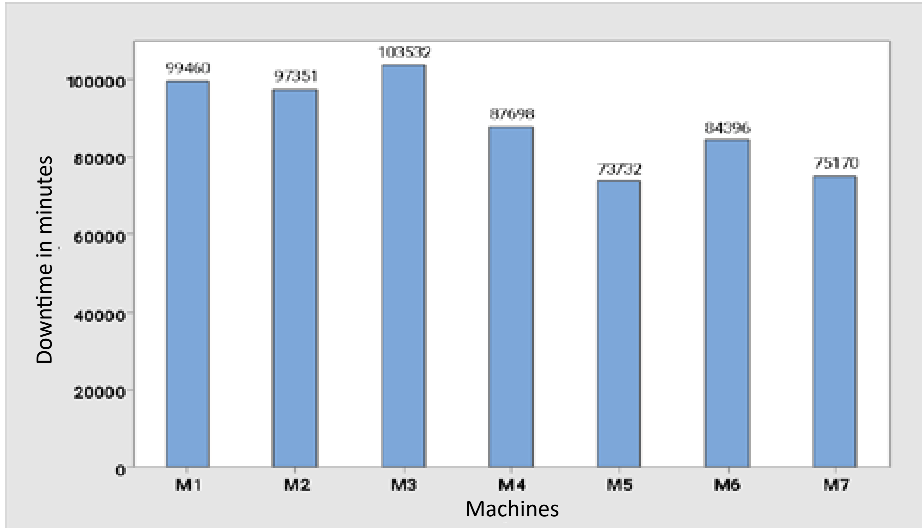


Figure 10. Minutes of downtime per machine
Source: The authors (2023)

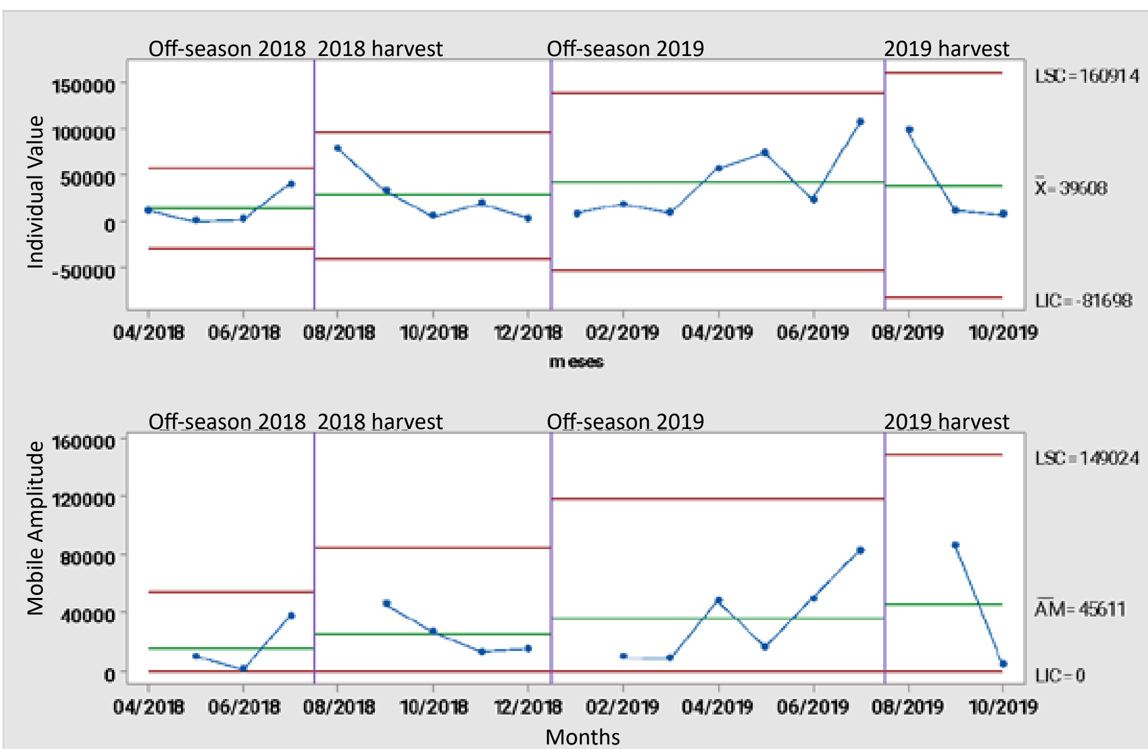


Figure 11. Control chart for machine downtime
Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

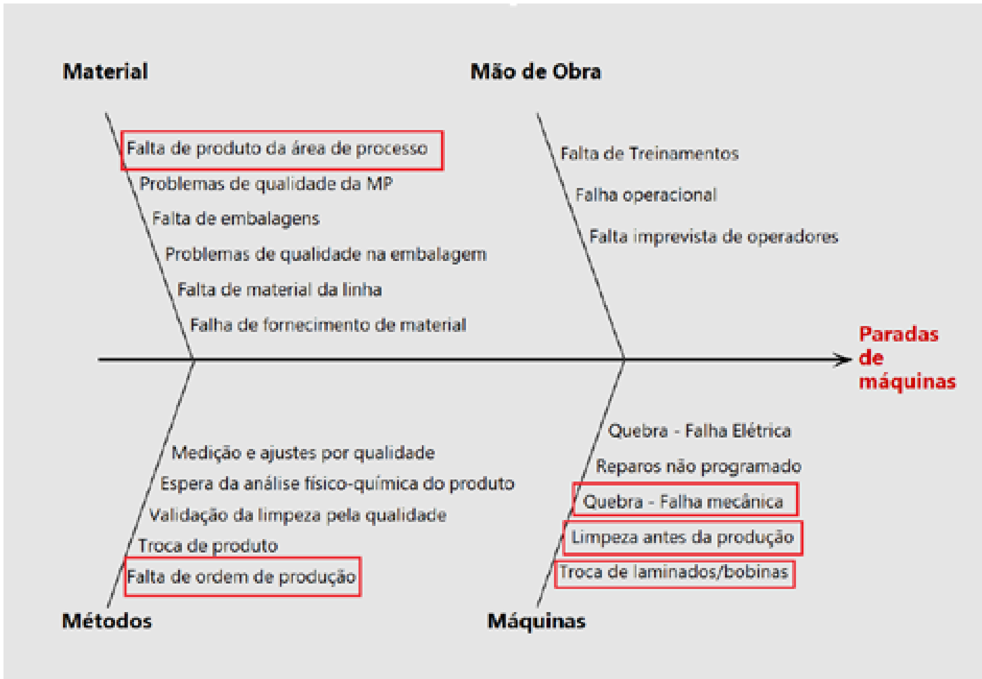


Figure 12. Cause and Effect Diagram for Machine Downtime

Source: The authors (2023)

Legend: Material: Shortage of product from the process area; MP quality problems; Shortage of packaging; Packaging quality problems; Material shortage on the line; Material supply failure. Labor: Lack of training; Operational failure; Unforeseen shortage of operators. MACHINE BREAKDOWNS. Methods: Measurement and quality adjustments; Waiting for the physical-chemical analysis of the product; Validation of cleaning by quality; Product changeover; Lack of production order. Machines: Breakage - Electrical failure; Unscheduled repairs; Breakdown - Mechanical failure; Cleaning before production; Change of laminates/coils.

percentage of improvement aimed by the study, all the machines in the sector were analyzed, regardless of their behavior. The graph in **Figure 10** shows the distribution of total downtime in minutes by machine.

In this case, it can be seen that machine 3 has the highest downtime, and machines 1 and 2 have close values. On average, each machine has a total of 88,762.72 minutes of downtime. Considering the number of days each machine is down, this means an average of 3 hours and 42 minutes per day.

The data collected over the period was grouped by month and plotted on a control chart (**Figure 11**) to analyze the stability of the downtime.

The graph considered the harvest and off-season periods in 2018 and 2019.

Analyzing the two harvests and the two off-seasons separately, the average downtime per month is 32,831.63 and 32,607.82 minutes, respectively. These figures are very close, given that they are completely different periods in terms of the number of orders and production volume. This creates the false impression that the machines are being used more during the harvest period when, in fact, the average idle time is close to that of the off-season.

Analyzing Stage

First, brainstorming was carried out to identify the possible causes, according to material, method, machine, and workforce.

When a machine stops, the employee records the downtime and specifies the reason. It is worth noting that a stoppage may not only be related to mechanical and/or electrical faults or defects. Various factors can influence this interruption, especially those related to the process. The various reasons recorded were grouped and/or consolidated for better analysis and are shown in the Ishikawa Diagram in **Figure 12**.

Figures 13, **15**, and **17** show the Pareto Charts for prioritizing the reasons for downtime in general, in the harvest, and in the off-season, respectively.

A multiple regression analysis was carried out to validate the data and check whether the variables really do affect the

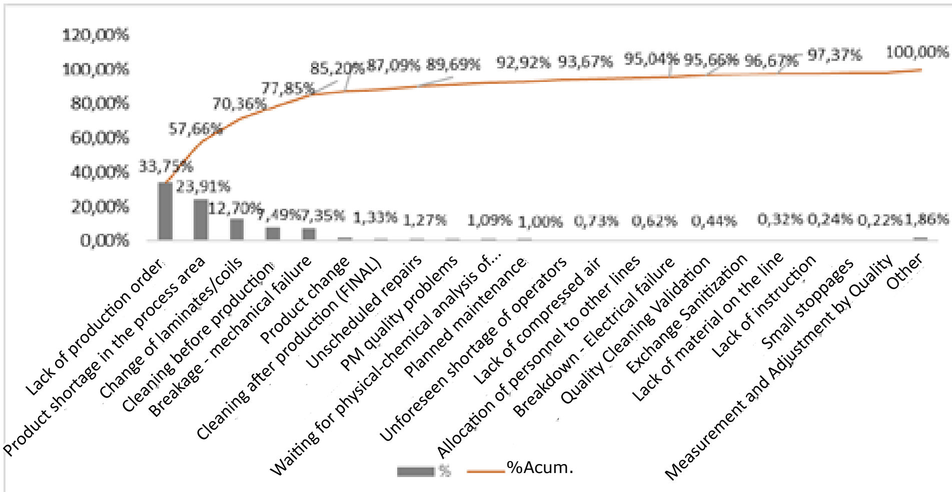


Figure 13. Pareto diagram for reasons for total downtime
Source: The authors (2023)

ANOVA			
	gl	F	F for meaning
Regression Residual Total	5 13 18	927.9965957	4.06022E-16
	Coefficients	P-value	95% lower
Intersection	191.8408067	0.807466679	-1474.506652
Missing production order	0.969986641	1.77301E-13	0.901232446
Product missing from process area	1.117057364	9.18894E-09	0.929202566
Change of laminates/coils	1.287245381	1.21233E-08	1.065752606
Cleaning before production	2.30649643	2.14026E-05	1.534885669
Breakage - Mechanical failure	0.862848494	0.000593794	0.448905636

Figure 14. Multiple regression analysis for the total period
Source: The authors (2023)

problem. According to **Figures 14**, **16**, and **18**, the analysis was carried out for the five priority causes found in **Figures 13**, **15**, and **17**, and the —H0 (there is no relationship) — and alternative — H1 (there is a relationship) — hypotheses were defined.

The reasons that have an influence on the periods analyzed are those highlighted in gray since the F significance value and the P value are lower than 0.05. Therefore, the null hypothesis (that no relationship exists) should be rejected with a 95% confidence level.

The same analysis will be made for the harvest and off-season graphs in **Figures 15** to **18**.

When only the harvest period is analyzed (**Figure 15**), the graph shows that the five main causes of downtime are lack of product in the process area (31.39%), change of laminates and coils (24.11%), breakage due to mechanical failure (12.07%), lack of production order (7.87%), and cleaning before production (7.75%). Together, they accounted for 83.19% of the downtime in the period.

The regression analysis shows that only the lack of product in the process area, the change of laminates and coils, and breakage due to mechanical failure have an influence.

When the off season period is examined separately (**Figure 17**), the graph shows that the five main causes of downtime are lack of a production order (52.70%), lack of product in the process area (18.44%), cleaning before production (7.30), changing laminates and coils (4.35%), and breakage due to mechanical failure (3.89%). Together they account for 86.68% of the downtime in the period.

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

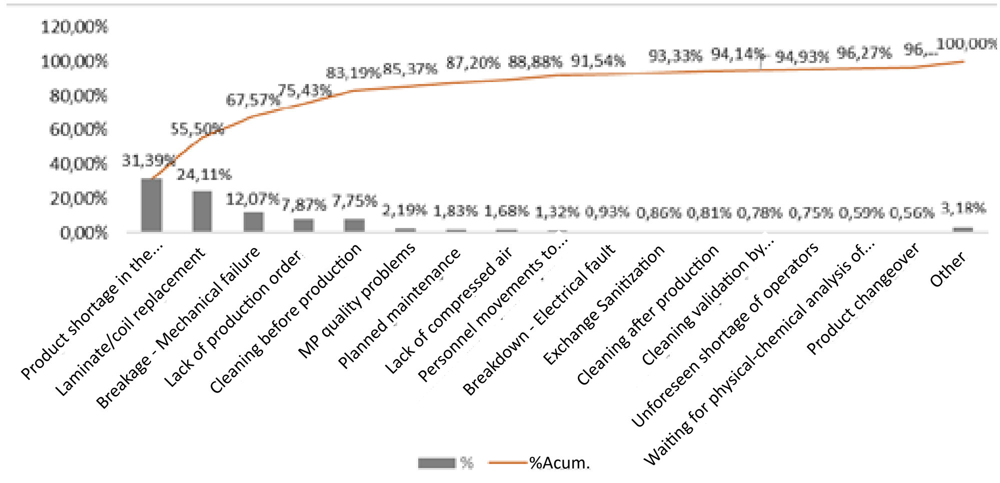


Figure 15. Pareto diagram for reasons for harvest stoppages
Source: The authors (2023)

ANOVA			
	gl	F	F for meaning
Regression Residual Total	5 2 7	695.8847705	0.001435575
	Coefficients	P-value	95% lower
Intersection	-1391.367266	0.365756368	-6551.505225
Missing production order	1.074286158	0.109445362	-0.595166101
Product missing from process area	0.893224314	0.000120108	-0.574366844
Change of laminates/coils	1.692588441	0.003054377	-0.097422988
Cleaning before production	0.609655651	0.804246568	-8.682402975
Breakage - Mechanical failure	1.840465714	0.005125882	-4.075543918

Figure 16. Multiple regression analysis for harvest
Source: The authors (2023)

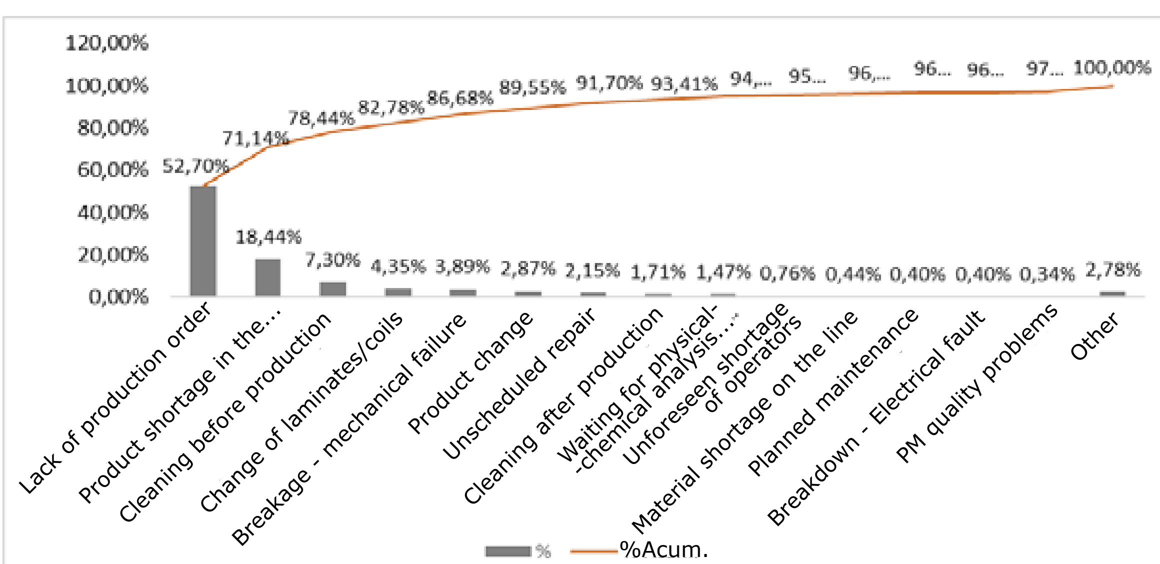


Figure 17. Pareto Diagram for reasons for downtime in the off-season
Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

ANOVA			
	gl	F	F for meaning
Regression Residual Total	5 5 10	625.926	5.51081E-07
	Coefficients	P-value	95% lower
Intersection Missing production order Product missing from process area Change of laminates/coils Cleaning before production Breakage - Mechanical failure	1545.15152 0.983851407 1.06389043 1.179591508 2.304875529 0.474084419	0.19309 3.37E-06 0.006158 0.324033 0.001637 0.507748	-1097.040165 0.870402958 0.461749047 -1.593356622 1.343484021 -1.235211101

Figure 18. Multiple regression analysis for off-season
Source: The authors (2023)

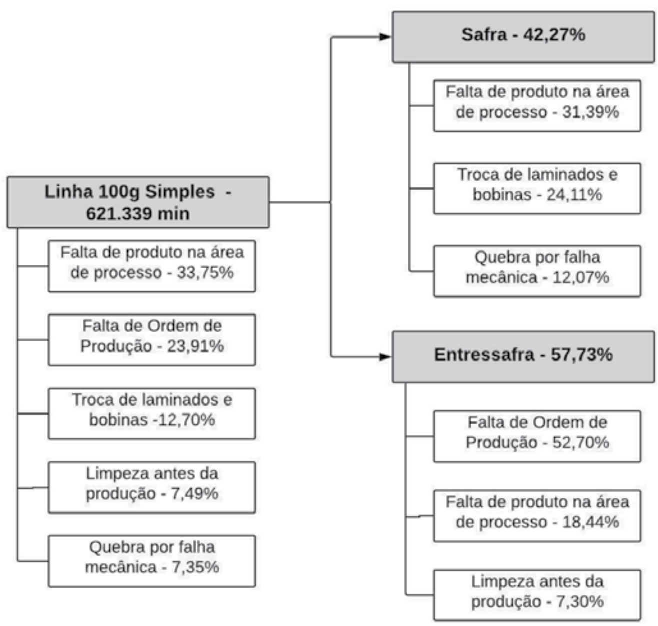


Figure 19. Driver diagram for reasons by period
Source: The authors (2023)
Legend: 100g Single Line - 621,339 min: Lack of product in the process area - 33.75%; Lack of production order - 23.91%; Change of laminates and coils - 12.70%; Cleaning before production - 7.49%; Breakage due to mechanical failure - 7.35%. Harvest - 42.27%: Product shortage in the process area - 31.39%; Change of laminates and coils - 24.11%; Breakage due to mechanical failure - 12.07%. Off-season - 57.73%: Lack of production order - 52.70%; Lack of product in the process area - 18.44%; Cleaning before production - 7.30%

In summary, the diagram in **Figure 19** shows the analysis discussed above, in which the single 100 g line is responsible for 24.06% of the total downtime. Of this, 42.27% (262,640 min) corresponds to the harvest period, and 57.73% (358,699 min) corresponds to the off-season.

To minimize and/or eliminate the five problems highlighted, action plans were drawn up for each one.

ACTION PLAN

Given the data collected and the identification of the problems highlighted, action plans were developed for lack of production order (**Chart 2**), change of laminates and coils (**Chart 3**), cleaning before production (**Chart 4**), breakage due to mechanical failure (**Chart 5**), and lack of product in the process area (**Chart 6**). Current and future VSMs were also made for this problem, as shown in **Figures 20** and **21**.

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

Chart 2. Action Plan for Missing Production Orders

Objective: To reduce 23% of the downtime on the 100 g line for this reason, for the harvest and the off-season.						
	WHAT?	HOW?	WHERE?	WHEN?	WHO?	WHY?
1	Develop new products	Through customer research, monitor products on the market that meet customer needs and are profitable for the company.	In the quality sector	Continuously/until the stipulated factory occupancy levels are reached	Marketing Director, Quality Manager, Sales Manager, and R&D Assistant	For better line use in the off-season
2	Allocate or outsource the line to fill other products	Seek partnerships with companies interested in producing or using the line to fill outsourced products	Production	Until the beginning of the next off-season	Strategic and operational director, industrial manager, and production and PCP managers	Keeping the line in operation, even when there is no production in-house or from its signed clients
3	Expand the market and develop new clients to increase demand (commercial sector)	Through a plan to increase the client portfolio and, consequently, demand. Seek out new partners at trade fairs; Develop current customers so that they increase their orders	Commercial and Marketing Sectors	Continuously/until the stipulated factory occupancy levels are reached	Sales manager and coordinator and marketing team	Increasing demand for products that use this line in the off-season

Source: The authors (2023)

Chart 3. Action Plan for Changing Laminates and Coils

Objective: Reduce downtime by 12% on the 100 g line for this reason for the harvest and the off-season.						
	WHAT?	HOW?	WHERE?	WHEN?	WHO?	WHY?
1	Draw up standard operating procedures for changing laminates and coils	On site, observe how the procedure is carried out, talk to those involved to gather information, break it down into stages and time the individual execution times, as well as the order and frequency in which they should occur.	In production	Until the end of the harvest	Process management team	Establish standard changeover times to reduce the time consumed
2	Train operators according to the Packaging Manual	According to standard procedure	In the training room and the shop floor	In the off-season	Process management team	Ensure that operators carry out the established procedure correctly and that cleaning is carried out in less time
3	Analyze the feasibility of working with rolls of film (packaging) by modifying the compartment where the reels are placed in the fillers	The maintenance team must conduct this analysis and carry out the tests needed to make this action feasible or not	In maintenance	Until the end of January	Maintenance team and process and quality management	Reduce the amount and time spent changing packaging

Source: The authors (2023)

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

Chart 4. Action plan for cleaning before production

	Objective: To establish a standard cleaning time of one hour for the harvest and the off-season.					
	WHAT?	HOW?	WHERE?	WHEN?	WHO?	WHY?
1	Draw up a Standard Operating Procedure for the cleaning process	In loco, observe how the procedure is carried out, talk to those involved to gather information, divide it into stages, time the individual execution times, and the organize and frequency in which they should occur. Analyze which activities add value and eliminate those that do not.	In production	January/2020	Process management team and quality sector	Establish a standard cleaning time (1 hour) to reduce the time this activity consumes
2	Train operators according to the established Cleaning Manual	According to standard procedure	In the training room and on the shop floor	At the end of the harvest	Process management team	Ensure that operators carry out the established procedure correctly, cleaning in less time

Source: The authors (2023)

Chart 5. Mechanical Breakdown Action Plan

	Objective: To establish a standard cleaning time of 1 hour for the harvest and the off-season.					
	WHAT?	HOW?	WHERE?	WHEN?	WHO?	WHY?
1	Apply the preventive maintenance plan	As established by the PCM team and manufacturer's guidelines	At the factory	In the off--season (January to June)	Process management team	Ensure that the downtime rate due to mechanical breakdowns or failures decreases, avoiding corrective maintenance
2	Create an inspection routine/ checklist for the Preventive Maintenance Plan	With the plant's leadership, draw up a checklist that includes the preventive maintenance schedule, the people responsible for carrying it out in each sector, and the plan's implementation according to the established schedule.	In the factory and in maintenance	At the end of the harvest	Process management team	Ensure that the preventive maintenance plan is carried out
3	Carry out machine breakdown analysis	Apply a PDCA to specifically investigate machine breakdowns	Maintenance, operators, and process team	At the end of the harvest	Process management team	Identify, correct, and control downtime for this reason
4	Train operators to carry out Autonomous Maintenance	Provide the team with practical and theoretical courses on inspection, lubrication, changes, and adjustments according to the instruction and operation manual drawn up by the manufacturer or the process management team.	At the factory	Between harvests (January to June)	Maintenance and production managers and foremen, machine operators, and process management staff	Train operators directly linked to the process to carry out quick maintenance on their own machines
5	Bring in the manufacturer to train the team	Schedule a technical visit with the machine manufacturer to train operators and maintainers on how to operate and maintain the equipment.	At the factory	In the off--season (January to June)	Maintenance and production managers and foremen, machine operators, and process management staff	Train operators and maintainers in fast maintenance on their own machines

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

6	List the parts that break down the most and ensure that they are in stock	Via the system, filter the most requested parts, classify their priority, and organize them by sector and machine. Analyze the number of times they are requested to establish the minimum quantity of each in stock. Link the list to the financial loss that their absence could bring to the company.	In maintenance		Maintenance manager and process management team	Ensure the supply of the most consumed parts and avoid machine downtime due to routine breakdowns; Enable the operator to return the machine to operation in the time needed just to change the part.

Source: The authors (2023)

Chart 6. Action Plan for Product Shortages in the Process Area

Objective: 33% reduction in downtime for this reason for the harvest and off-season.						
	WHAT?	HOW?	WHERE?	WHEN?	WHO?	WHY?
	SHORTAGE OF PRODUCT IN THE PROCESS AREA					
1	Transfer the standardization process to the 10,000 kg tank after the pasteurization stage	Via the system, filter the most requested parts, classify their priority, and organize them by sector and machine. Analyze the number of times they are requested to establish the minimum quantity of each in stock. Link the list to the financial loss that their absence could bring to the company.	In production	At the end of the harvest	Industrial manager, production foremen, maintenance manager and foreman, and process and quality management team	Eliminate stock stages during the process and reduce the waiting time between the standardization and pasteurization stages, where the solid analysis procedure can occur after pasteurization.
2	Review procedure that validates the inputs available for the production of a given product to take place	Meeting with a representative from each sector, who must fill in the checklist and update the information in the event of problems already detected; Drawing up a new version	With all sectors directly involved in production	Until the end of December	Process management team	Eliminate process errors that cause downtime on the analyzed line in the filling sector
3	Analyzing the feasibility of changing the layout between the filling and packaging sectors	Design a project that considers the costs involved in changing the layout versus the productivity gains that could be achieved by reducing downtime due to lack of product caused by the current layout (long transport distances); Analyze the feasibility and actions that could make the project feasible.	In production (filling and packaging sectors)	Before the start of the 2020 harvest	Strategic management, maintenance team, and process and quality management team	Reduce the time spent on non-value-added activities, such as transportation (pipelines and manuals), stocks, and cross-flows between sectors.
4	Analyze the feasibility of scheduling production considering products that have the same standard (pure or with guarana).	Meeting with those responsible for production (manager and foremen) to discuss the possibility of scheduling the production of products with the same standard that can be filled on several lines.	Production planning and control sector (PCP)	Until the end of the harvest	PCP team	Reduce the variety of products produced during the day, avoiding waiting for a product due to the need to clean it because of a change in product type (açaí with guaraná vs. pure açaí).

Source: The authors (2023)

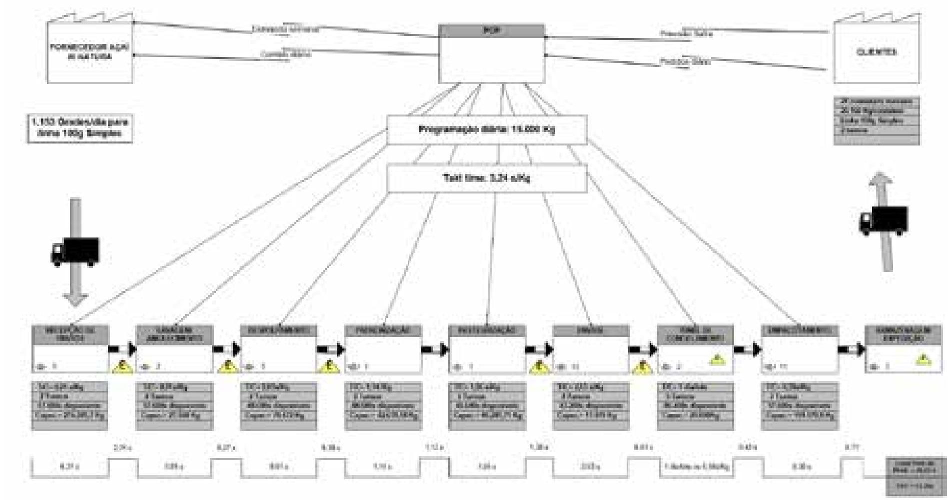


Figure 20. Value Stream Map of the current state of the 100 g single line

Source: The authors (2023)

Legend: SUPPLIER AÇAI IN NATURA; 1,153 Grids/day for 100g Simple line. Weekly demand; Daily contact. PCP. Daily schedule: 15,000 Kg; Takt time: 3.24 s/Kg. Harvest forecast; Daily orders. CUSTOMERS; 21 monthly containers; 20,160 Kg/container; Single 100g line; 2 shifts. FRUIT RECEPTION – 5; WASHING/SOFTENING – 2; PEELING – 3; STANDARDIZATION – 1; PASTEURIZATION – 1; ENVASING – 12; FROZENING TUNNEL – 2; EMPACOTING – 11; WAREHOUSING/SHIPPING – 2. T/C= 0.21 s/Kg; 2 shifts; 57,600s available; Capacity = 274,285.7 Kg. T/C= 0.81 s/Kg; 2 Shifts; 57,600s available; Capacity = 27,560 Kg. T/C= 0.61 s/Kg; 2 Shifts; 48,600s available; Capacity = 79,672 Kg. T/C= 1.14 s/Kg; 2 Shifts; 48,600s available; Capacity = 42,631.58 Kg. T/C= 1.05 s/Kg; 2 Shifts; 48,600s available; Capacity = 46,285.71 Kg. T/C= 2.53 s/Kg; 2 Shifts; 43,200s available; Capacity = 17,075 Kg. T/C= 1 day/batch; 3 Shifts; 86,400s available; Capacity = 20,000 Kg. T/C= 0.38 s/Kg; 2 Shifts; 57,600s available; Capacity = 151,578.9 Kg. 0.21 s; 2.31 s; 0.81 s; 0.27 s; 0.61 s; 0.38 s; 1.14 s; 1.12 s; 1.05 s; 1.38 s; 2.53 s; 0.61 s; 1 day/batch or 6.58 s/Kg; 0.42 s; 0.38 s; 0.71 s; Production lead time = 20.52 s; Tav=13.30 s.

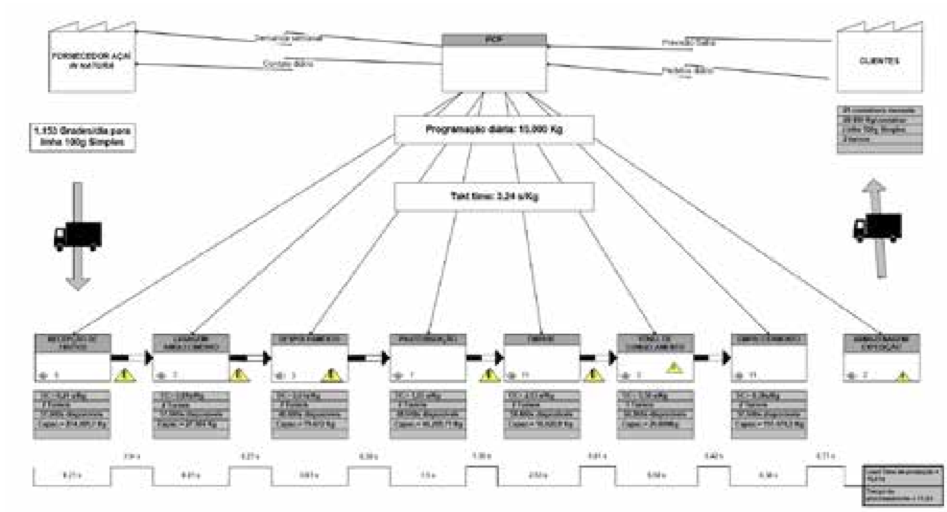


Figure 21. Value Stream Map of the future state of the 100 g single line

Source: The authors (2023)

Legend: SUPPLIER AÇAI IN NATURA. 1,153 Grids/day for 100g Simple line; Weekly demand; Daily contact. PCP; Daily schedule: 15,000 Kg; Takt time: 3.24 s/Kg. Harvest forecast; Daily orders. CUSTOMERS: 21 monthly containers; 20,160 Kg/container; Single 100g line; 2 shifts. FRUIT RECEPTION - 5; WASHING/SOFTENING - 2; PULPING - 3; STANDARDIZATION - 1; PASTEURIZATION - 1; FILLING - 11; FREEZING TUNNEL - 2; PACKAGING - 11; STORAGE/SHIPPING – 2. T/C= 0.21 s/Kg; 2 shifts; 57,600s available; Capacity = 274,285.7 Kg. T/C= 0.81 s/Kg; 2 Shifts; 57,600s available; Capacity = 27,560 Kg. T/C= 0.61 s/Kg; 2 Shifts; 48,600s available; Capacity = 79,672 Kg. T/C= 1.05 s/Kg; 2 Shifts; 48,600s available; Capacity = 46,285.71 Kg. T/C= 2.53 s/Kg; 2 Shifts; 50,400s available; Capacity = 19,920.9 Kg. T/C= 5.50 s/Kg; 3 Shifts; 64,800s available; Capacity = 20,000 Kg. T/C= 0.38 s/Kg; 2 Shifts; 57,600s available; Capacity = 151,578.9 Kg. 0.21 s; 2.31 s; 0.81 s; 0.27 s; 0.61 s; 0.38 s; 1.5 s; 1.38 s; 2.53 s; 0.61 s; 5.50 s; 0.42 s; 0.38 s; 0.71 s. Production lead time= 16.91 s; Processing time= 11.53 s.

S&G Journal
Volume 18, Number 3, 2023, pp. 243-261
DOI: 10.20985/1980-5160.2023.v18n3.1890

FINAL CONSIDERATIONS

This study's overall goal was to propose improvements in the açaí pulp beneficiation process using Lean Six Sigma principles and methods. The main reasons for downtime were identified, and an action plan drawn up, considering its application in the short, medium, and long term, with a view to implementing it for the following harvest. Therefore, the work's objective was achieved. Thus, knowledge was gained not only of the reasons that most influence stoppages on the line analyzed, which are possibly the same as those that affect other lines, but also of the time that each one represents in the total number of stoppages recorded over the months analyzed.

This was the company's first project focused on improvement using statistical tools. It should be noted that it was only possible to carry it out on the basis of the records collected and after implementing a system of indicators that allows information to be entered in real time on both productivity and machine and equipment idleness.

However, although the company records information daily, it does not use data control and management methods such as statistical processing, but rather uses forms. On the other hand, major factors limited the research: the lack of incentive from top management to carry out projects to improve processes in line with customer requirements, the lack of a qualified team to process the information, the application of tests to prove improvements and the organizational culture of centralized decision-making.

It is thus worth highlighting the importance of carrying out work that statistically proves the real effectiveness of the proposed actions. As a suggestion for future work, the real impact on reducing downtime could be demonstrated quantitatively through experimental tests. Another suggestion is a project aimed at implementing a data control or measurement system that provides the company with plausible results from its processes, serving as a basis for decision-making.

A culture of quality and process improvement should be encouraged and seen as a key to success, making the company more professional and competitive. By using the lean method combined with the Six Sigma tools, it can develop projects that add value to it and its stakeholders, in addition to identifying points of inefficiency in the process and eliminating them.

REFERENCES

Andreosi, C.A.C. (2018), Aplicação do mapeamento de fluxo de valor (MFV) no processo de liberação de leitos: um estudo de caso em um nosocômio com atendimento de urgência e emergência, Monografia em Engenharia de Produção, Universidade Federal de Ouro Preto, João Monlevade, Ouro Preto, disponível em: http://www.monografias.ufop.br/handle/35400000/1018 (acesso em: 4 jan. 2023).

Balardim, E. (2019), Lean manufacturing: o que é objetivos e princípios, FIA - Fundação Instituto de Administração, disponível em: https://fia.com.br/blog/lean-manufacturing/ (acesso em: 2 jan. 2023).

Bugor, F., Lucca Filho, J. (2021), "Utilização da metodologia DMAIC para promover melhorias na qualidade em indústrias alimentícias: uma revisão de literatura", *Interface Tecnológica*, Vol. 18, No. 2, pp. 724-733, disponível em: https://doi.org/10.31510/infa.v18i2.1280

Cabral, W., Geraldi, L.M.A. (2022), "Lean manufacturing aplicado à indústria de produção: um estudo na empresa WEG equipamentos elétricos S.A", *Revista Científica Multidisciplinar Núcleo do Conhecimento*, Vol. 01, Ano 7, pp. 65–83, disponível em: https://www.nucleodoconhecimento.com.br/engenharia-de--producao/lean-manufacturing (acesso em: 4 jan. 2023).

Cae Treinamentos (2021), *SIPOC*, Frons, disponível em: https://caetreinamentos.com.br/blog/processos/mapeamento-processos/attachment/sipoc/ (acesso em: 4 jan. 2023).

Conab - Companhia Nacional de Abastecimento (2019), *Açaí - Análise Mensal – Maio/2019*, Conab, Brasília, disponível em: https://www.conab.gov.br/info-agro/analises-do-mercado--agropecuario-e-extrativista/analises-do-mercado/historico--mensal-de-acai/item/11564-acai-analia-mensal-maio-2019 (acesso em: 04 jun. 2019).

Costa, L.B.M., Godinho Filho, M., Fredendall, L.D., Paredes, F.J.G. (2018), "Lean, Six Sigma and Lean Six Sigma in the food industry: a systematic literature review", *Trends in Food, Science & Technology*, Vol. 82, pp. 122-133, disponível em: https://doi.org/10.1016/j.tifs.2018.10.002

Cruz, J.M.L.M. (2021), Melhoria de processo com recurso ao Lean Seis Sigma: caso de estudo, Dissertação de Mestrado em Engenharia e Gestão Industrial, Universidade Beira Interior, Covilhã, Portugal, disponível em: http://hdl.handle.net/10400.6/11599 (acesso em: 3 jan. 2023).

Fernandes, A.P., Almeida, W.A.P. (2022), "Tecnologia e sustentabilidade: um estudo sobre a transformação da cadeia produtiva do açaí através da verticalização e alongamento de safra", artigo apresentado na XXIV ENGEMA: Encontro Internacional sobre Gestão Empresarial e Meio Ambiente da FEA/USP, São Paulo, 29-30 de nov. 2022, disponível em: https://engemausp.submissao.com.br/24/anais/arquivos/569.pdf?v=1674592420 (acesso em: 5 jan. 2023).

Ferreira, D.C. (2018), Otimização em processos hospitalares: metodologia Lean Six Sigma, Dissertação de Mestrado em Gestão e Inovação em Saúde, Universidade Federal do Rio Grande do Sul, Natal, Rio Grande do Sul, disponível em: https://repositorio.ufrn.br/handle/123456789/26363. (acesso em: 5 jan. 2023).

Ferreira, G.L., Morgado, T.S.V. (2019), "Melhoria dos processos produtivos através da aplicação das ferramentas de gestão de produção: estudo de caso em uma empresa do ramo de navegação", *The Brazilian Journal of Development*, Vol. 5, No.

6, pp. 5700-5713, disponível em: https://doi.org/10.34117/bjdv5n6-094

Franco, M.S. (2021), Aplicação de ferramentas da qualidade na identificação de problemas relacionados à segurança dos alimentos em usina de beneficiamento de leite, Trabalho de Conclusão de Curso em Engenharia de Alimentos, Instituto Federal de Educação, Ciência e Tecnologia Goiano, Rio Verde, GO, disponível em: https://repositorio.ifgoiano.edu.br/handle/prefix/2044 (acesso em: 4 jan. 2023).

Godoy, L.P., Stefano, N.M., Bueno, W.P., Godoy, T.P., Wegner, R. da S. (2018), "O impacto do Lean Manufacturing como fator de melhoria no desempenho produtivo", *Revista Gestão da Produção, Operações e Sistemas*, Vol. 13, No. 2, pp. 69, disponível em: https://doi.org/10.15675/gepros.v13i2.1844

Grandchamp, L. (2020), Seis Sigma: 5 benefícios que traz para a sua empresa, Rede Jornal Contábil, disponível em: https://www.jornalcontabil.com.br/seis-sigma-5-beneficios-que-traz-para-a-sua-empresa/ (acesso em: 3 jan. 2023).

Marcondes, J.S. (2020), *Diagrama ou Gráfico de Pareto: ferramenta da gestão da qualidade*, Blog Gestão de Segurança Privada, disponível: https://gestaodesegurancaprivada.com.br/diagrama-ou-grafico-de-pareto-conceito/ (acesso em: 4 jan. 2023).

Pinho, F.C., Vilela, A.S., Barros, J.G.M., Almeida, M.G.D., Sampaio, N.A.S., Silva, J.W.J. (2020), "Proposta de melhoria da qualidade com a implantação da metodologia Seis Sigma", *Research, Society and Development*, Vol. 9, No. 10, e5969108445, disponível em: http://dx.doi.org/10.33448/rsd-v9i10.8445

Pinho, L. (2023), *Diagrama de Ishikawa ou Diagrama Espinha de Peixe: o que é e como fazer*, Siteware, disponível em: https://www.siteware.com.br/metodologias/diagrama-de-ishikawa/ (acesso em: 15 jan. 2023).

Santos, T.P., Kawakame, M.S. (2019), "Utilização do diagrama de pareto e outras ferramentas da qualidade para análise de não conformidade de uma indústria metalúrgica do Sul de Minas Gerais", artigo apresentado no XXXIX Encontro Nacional de Engenharia de Produção, Santos, SP, 15-18 de out. 2019, disponível em: https://www.google.com/url?sa=t,source=web,rct=j,url=https://abepro.org.br/biblioteca/TNSTP293165638514.pdf,ved=2ahUKEwiFj7KLxuj8AhWoHrkGHQrhAQsQFnoECAkQAQ,usg=AOvVaw3774VMxN1cK8jFG5ZefcJe (acesso em: 4 jan. 2023).

Silva, A.E., Santos, A.G., Fonseca, L.A., Lima, M.L. (2018), "Aplicação de ferramentas do controle estatístico de processo em uma empresa do setor de bebidas", artigo apresentado no II SIENPRO: Simpósio de Engenharia de Produção, Catalão, GO, 28-30 de ago. 2018, disponível em: https://files.cercomp.ufg.br/weby/up/1012/o/APLICA%C3%87%C3%83ODEFERRAMENTASDOCONTROLEESTAT%C3%8DSTICODEPROCESSOEMUMAEMPRESADOSETORDEBEBIDAS.pdf?1536010816 (acesso em: 4 jan. 2023).

Silva, E.M., Gonzalez Junior, I.P. (2022), "A importância do Lean Seis Sigma: um estudo de caso na Nestlé Brasil Ltda - unidade Feira de Santana/BA", *Revista Formadores: Vivências e Estudos*, Vol. 15, No. 1, pp. 43–57, disponível em: https://doi.org/10.25194/rf.v15i1

Silva, M.C. (2021), Proposta de aplicação da metodologia DMAIC para melhoria de um processo no setor de transporte de uma instituição federal de ensino superior, Mestrado em Engenharia de Produção, Universidade Federal do Amazonas, Manaus, AM, disponível em: https://tede.ufam.edu.br/handle/tede/8606 (acesso em: 4 jan. 2023).

Silveira, S. (2022), *Diagrama SIPOC como ferramenta de descoberta de processos*, iprocess, disponível em: https://blog.iprocess.com.br/2022/10/diagrama-sipoc-como-ferramenta-de-descoberta-de-processos/ (acesso em: 4 jan. 2023).

Soluce (2020), O que é o *Lean Six Sigma*?, Soluce, disponível em: https://www.soluce.com.br/post/o-que-e-lean-six-sigma (acesso em: 4 jan. 2023).

Stephani, I. S. (2020), Mapeamento do fluxo de valor aplicado à logística industrial: um estudo de caso, Trabalho de Conclusão de Curso em Engenharia Química, Universidade Federal de Uberlândia, Uberlândia, SP, disponível em: https://repositorio.ufu.br/handle/123456789/28570 (acesso em: 4 jan. 2023).

Torres, G.J.S., Coba, F.P.R. (2018), Aplicación de la metodología Lean Six Sigma en una empresa de lácteos: caso de estudio en la fabricación de quesos frescos, queso mozzarella y mantequilla, Mestrado em Engenharia Industrial, Menção Qualidade e Produtividade, Universidade São Francisco de Quito, Quito, Equador, disponível em: https://repositorio.usfq.edu.ec/handle/23000/7820

Vidal, B.P., Soler, V.G., Molina, A.I.P. (2018), "Metodología Six Sigma: comparación entre ciclo PDCA y DMAIC", *Cuadernos de Investigación Aplicada*, pp. 27-34, 2018, disponível em: http://dx.doi.org/10.17993/EcoOrgyCso.2018.47

Zendesk (2022), *Guia completo: Diagrama de Causa e Efeito de A a Z*, Zendesk, disponível em: https://www.zendesk.com.br/blog/diagrama-de-causa-e-efeito/ (acesso em: 4 jan. 2023).

Received: July 14, 2023

Approved: November 20, 2023

DOI: 10.20985/1980-5160.2023.v18n3.1890

How to cite: Carneiro, M., Alves, T., Monteiro, M.S., Ueoka, N.A., Silva, G.M. (2023). Proposing improvements in the açaí pulp processing process: an application of Lean Six Sigma. Revista S&G 18, 3. https://revistasg.emnuvens.com.br/sg/article/view/1890