Application of quality tools in the potato *chip* packaging process: A case study

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ABSTRACT
This article addresses the variations in the weights of 45-gram potato chip packages at Company X, identifying financial problems due to the disposal of out-of-bounds packaging. Using the PDCA Cycle and Quality Tools, the methodology reveals lack of preventive maintenance and inadequate planning as the main causes. An action plan is proposed, involving maintenance contracting, training, and scheduling. The goal is to reduce non-compliant samples by 80%, optimizing the process and minimizing financial waste. Post-implementation follow-up is highlighted as essential.

Keywords: Potato chips, Training, Schedule.

1 INTRODUCTION

The main problem of this work is about the variations in the weights of the packages of 45 (forty-five) grams of potato *chips* from company X, a local company that supplies its product to large distribution centers in the city and region.

In May 2022 (two thousand and twenty-two), samples of the production of the 6 (six) packaging machines were analyzed and there was a great variability in the weights of the packages. Packages that have weights outside the pre-established limits need to be discarded and the raw material returned to the packaging process.

According to information from the financial sector, the cost of packaging is high and its waste generates a large financial expense, so when verifying that the weights are above the ideal, they are allowed to be sent to customers, but if the weight is below the ideal, rework is necessary to correct the situation.

In view of the scenario presented, it was verified the need to apply quality tools in order to identify problems, observe them, analyze them and create an action plan proposing improvements in the process to minimize waste and rework.

This paper presents an analysis of how quality management can help the manager to elaborate the diagnosis of the problem-situation faced, through the correct use of management tools (DA SILVA MELO C. A. et. Al, 2016).

2 THEORETICAL FRAMEWORK

2.1 PDCA CYCLE

The PDCA cycle is a tool applied in the improvement of management processes (ANDRADE, 2010), characterized by being a method of quality improvement through a continuous cycle system, where quality will rise a new level from the conclusion of each cycle (NING, 2010). PDCA is so named due to the combination of the initials of each stage that composes it, in its source language: *Plan*, *Do*, *Check and* Act *(ANDRADE, 2003), which in Portuguese means to plan, execute, verify and act (LOPES B, ALVES J, 2020).*

The method of continuous improvement is applied in organizations in order to manage internal processes to achieve pre-established goals, with information as a factor for directing decisions, also used to maintain a result achieved or seek a better result (MARIANI, 2005).

Figure 1 – PDCA Cycle

Fonte: Sebrae, 2021.

2.2 QUALITY TOOLS

Quality tools are seen as means capable of leading through their data to the identification and understanding of the reason for problems and generating solutions to eliminate them, seeking to optimize the company's operational processes (DANIEL, E. A., & MURBACK, F. G. R., 2014).

> The use of the PDCA cycle involves several possibilities, it can be counted on quickly and easily in the search for the necessary inputs for the defined activity, because one of the great advantages is that it is a method that allows greater reliability and effectiveness in the execution of a company's activities; agility in processes, since the cycle proposes an optimized and continuous form of analysis and control of all stages of the production process; control of the use of equipment and required documents; stimulation of creativity; and ease of communication, useful for solving problems (DANIEL, E. A., & MURBACK, F. G. R., 2014).

2.2.1 Stratification

According to *Ishikawa* (1986, p. 197) "without stratification, one cannot conduct an analysis or control".

Stratification divides the sample population into subgroups for certain characteristics, aiding the analysis and control over a given event. Each of these subdivisions is called stratum (FERRAZ, PICCHIAI, SARAIVA, 2015).

2.2.2 Check Sheet

Checksheets are tables or spreadsheets used to facilitate the collection of data in the systematic format for compilation and analysis. The use of this tool saves time, as it eliminates the work of drawing figures or writing repetitive numbers, avoiding compromising data analysis (AYRES, M. A. C., 2019).

2.2.3 Brainstorming

Brainstorming is a tool that helps people produce ideas to solve a problem (VIEIRA J. A. et. al, 2015).

2.2.4 Affinity Diagram

It is a tool that seeks to divide into relationship groups, allowing you to structure ideas or other types of information in them. It should be used when dealing with complex problems or organizing a set of information (GOMES F. et. al, 2017).

3 PROBLEM DESCRIPTION

Company X, located in the city of São João del-Rei, Minas Gerais, produces potato *chips*, packages them and distributes its products to the large distribution centers in the city and region. The company works with packages with pre-defined net weights: 45 (forty-five), 76 (seventy-six) and 200 (two hundred) grams, in this case study we will deal with packages of 45 (forty-five) grams.

The wrapper model used is the Maqinox SPK 250 - vertical wrapper, as shown in Figure 2.

Figure 2 – Maqinox SPK 250 Packaging Machine

Cast iron: Maquinox.

The potato chip production process begins with the receipt of the raw material, inspection, weighing, separation, washing, cutting, passes through the fryer and salter and then are taken by the vertical elevator that takes the potatoes to a large chute called *revertrek*, which forwards the potatoes to the packaging machines, the latter is the process that we will deal with in our case study. When passing through the conveyor, the ready-made potatoes, fried and seasoned, are distributed in the 6 (six) packers, which are composed of 18 (eighteen) buckets, controlled by *specific software*, which combines the weights so that they are deposited in the package, the portions are weighed until they accumulate 45g, when they are released into the package. After receiving the potatoes, the packages are sealed, and collected by a professional who stores them in cardboard boxes, then stacked on pallets and directed to the company's stock for later delivery to customers.

As reported, the process analyzed is the production of 45 (forty five) *gram potato chips*, the weight of each empty package is approximately 6 (six) grams, so the ideal total weight is 51 (fifty-one) grams.

In order to verify that the weights of the packages are correct, after the sealing of the packages, samples are taken to verify the weight, when a difference in the pre-defined values is noticed, the process is interrupted for the process of tare of the equipment, calibration of the buckets of the packers and, if necessary, a maintenance request is opened. In this scenario, all packages that have errors are opened and discarded, the potato returns to the conveyor belt and starts the process again. In addition to rework, packaging waste is also observed.

The company's financial sector informed that the value of the packaging is very high, being higher than the cost of the potato, so when verifying that the weight of the final packaging is above the defined limits, it is allowed to send them to customers. The opposite happens when the weight is below the limits, requiring the process of opening the packages and discarding them, returning the potatoes to the conveyor belt and repackaging the product. These activities cause production stoppages, rework, packaging waste, and consequently, an increase in production costs.

Therefore, it was necessary to carry out a study in order to reduce waste and minimize rework, using quality tools. For this, data were collected from the weights of 5 (five) packaging samples per hour, from each of the 6 (six) packers at 20 (twenty) times during the production shifts on days in May of this year.

4 METHODOLOGY

To carry out the case study, all the steps related to the Planning phase of the PDCA Cycle were executed: Problem Identification, Observation, Analysis and Action Plan.

In the Problem Identification phase, it is necessary to collect data and proceed with their analysis, and establish the result indicator.

First, there is a need to establish the lower and upper limits of specification for packages of 45 (forty-five) grams of potato chips, for which Inmetro Ordinance No. 248 of July 17, 2008 was used:

The ordinance provides a table with calculations for acceptance of the average given a batch of products, for this we need some data:

- Qn - Nominal Content, in our case 45gr
- S - Standard deviation of means

K – factor that depends on the sample size obtained in Table 1.

Table 1 – Sample for Control

Tamanho do lote	Tamanho de amostra	Critério para Aceitação da média	Critério para Aceitação individual (c) (máximo de defeituosos abaixo de Qn-T)
9 a 25	5	X ≥ Qn - 2,059.S	0
26 a 50	13	X ≥ Qn - 0,847.S	1
51 a 149	20	X ≥ Qn - 0,640.S	1
150 a 4000	32	X ≥ Qn - 0,485.S	2
4001 a 10000	80	X ≥ Qn - 0,295.S	5

Source: INMETRO, 2008.

To calculate the standard deviation, the means of the samples from each machine were used and S=1.05457 was obtained.

Based on the sample and lot size of our company, it was used to obtain the lower limit of specification from the first row of the previous table, so k=2.059

X> 45 – 2,059. (1,05457)

X> 43 gr

When considering the weight of the packages, we must consider the Lower Limit of specification as 49 (forty-nine) grams.

In view of the calculations presented, it was defined that the control limits are between 50 (fifty) and 52 (fifty-two) grams of potato *chips* for the final packages.

With the limits calculated and the data collected, Verification Sheets were created for the packaging machines:

Table 2 – Machine Check Sheet 1

Foha de Verificação																				
Máquina 01																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	51,5	50,7	51,3	53,3	53,7	50,6	50,2	51,7	51,8	52	50	51,1	50,7	52,5	52,1	49,6	51,6	52,1	52	50,3
Amostra x2	50,8	51	52,4	52,5	52,6	51,3	51,2	51	52,2	52	50	51,9	50,8	52,5	52,1	50	51,4	53,4	51,7	50,9
Amostra x3	51	50,2	50,6	52,8	52,8	50,4	51,8	51,1	52,2	52	50	50,3	51,8	52,9	51,3	49	51,2	52,1	51,9	51,1
Amostra x4	52,1	51,1	51,7	54,7	52,7	51,4	51,6	51,3	51,6	52	50	51,1	51	52,8	51,9	50,8	52,2	51	52,7	51
Amostra x5	51,6	50,4	51,8	58,3	53,3	51	51,5	51,1	51	52	50	51,1	51,3	52,3	51,2	46,9	51	51,8	51	51
Média das amostras	51,4	50,7	51,6	54,3	53	50,9	51,3	51,2	51,8	52	50	51,1	51,1	52,6	51,7	49,3	51,5	52,1	51,9	50,9
Nº de amostras não conformes				4	5									2		3		1		
Necessidade de tara do equipamento				tarou	tarou											tarou				

Source: The authors.

Table 3 – Machine Check Sheet 2

Foha de Verificação																				
Máquina 02																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	48,4	51,8	51	51,4	48,2	51,2	51,2	52	52	52,3	53,3	51,2	53	50,9	49,1	52	49,6	51	53,1	50,6
Amostra x2	49,7	51,6	50	51,4	49,3	51,1	51,1	54	50	51,4	51,1	50,6	51,2	50	50,3	51,3	52	49,7	52,4	50,3
Amostra x3	49	51,8	51,8	51,5	49,5	51,6	51,6	50	50	52,6	50,9	53	53,5	49,7	49,8	52,6	51,3	51,4	51,8	50,5
Amostra x4	48,7	50,6	50,3	51,4	49,7	51,2	51,2	52	50	52,8	53,3	51,1	51	49,7	50,8	51	50,8	50,2	52	50,8
Amostra x5	48,1	50,6	51	51,1	49,9	51,2	51,2	54	50	52,5	53,2	50	51,8	51,4	50	51,6	51	51	51	51,8
Média das amostras	48,8	51,3	50,8	51,4	49,3	51,3	51,3	52,4	50,4	52,3	52,4	51,2	52,1	50,3	50	51,7	50,9	50,7	52,1	50,8
Nº de amostras não conformes	5				5			2		2	3	1	2	2	2	1	1	1	1	
Necessidade de tara do equipamento	tarou				tarou															

Source: The authors.

Table 4 – Machine Check Sheet 3

Foha de Verificação																				
Máquina 03																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	52,1	51,5	54,3	53,3	54,2	51	51	52	52	50,9	50,6	50,3	50,7	51,7	49,8	50,9	51,3	51,7	58,9	51,2
Amostra x2	51,3	51,5	51,6	52,2	53,6	51	51	52	52	51,4	51,2	51,8	50,7	51,8	57,5	50,4	51,3	50	51,4	51,3
Amostra x3	51,1	50,4	52,7	53,1	54,6	50	50	50	54	52,3	50,7	50,4	51,4	52,8	51,3	49,6	51	51,1	57,2	50,9
Amostra x4	49,6	50,4	50,6	52,7	52,8	52,4	52,4	52	52	52,1	51	51	51,7	50	52,8	53,8	51,8	52	51,1	51,4
Amostra x5	50,3	51,6	50,9	52,9	51,3	50	50	51	52	51,4	51	51,2	71,9	50,4	51,4	51,4	51	51,2	51,9	52,1
Média das amostras	50,9	51,1	52	52,8	53,3	50,9	50,9	51,4	52,4	51,6	50,9	50,9	55,3	51,3	52,6	51,2	51,3	51,2	54,1	51,4
Nº de amostras não conformes	1		2	3	4				1				1	1	3	2			2	
Necessidade de tara do equipamento					tarou															

Source: The authors.

Table 5 – Machine Check Sheet 4

Foha de Verificação																				
Máquina 04																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	53,8	52	51,1	51,1	51,5	51,2	50,6	52	52	50,9	51,4	51,9	50,6	51,4	52,8	51,4	51,4	51,5	50,9	51,7
Amostra x2	52,3	51,9	51,9	51,8	51,4	51,8	51,2	52	52	50,8	51,4	51,7	51,2	51,2	51,2	51,2	51,5	51,3	51,2	51,9
Amostra x3	54,2	52,1	51	50,6	51,5	51,6	51,4	52	52	52	50,8	51,3	51,4	51,2	51	51,5	51,8	51,1	50,4	51,6
Amostra x4	52,1	52,1	51,7	51,9	51	51,5	51,8	52	52	51,5	51,2	52,3	51,8	50,3	51	51,7	51,6	52	51,8	51
Amostra x5	59,2	51,4	51,5	51,7	51,3	51,8	52	52	52	51,4	51	51,8	52	50,8	56,7	51,1	51	51	51,2	52
Média das amostras	54,3	51,9	51,4	51,4	51,3	51,6	51,4	52	52	51,3	51,2	51,8	51,4	51	52,5	51,4	51,5	51,4	51,1	51,6
Nº de amostras não conformes	3														2					
Necessidade de tara do equipamento	tarou																			

Source: The authors.

Table 6 – Machine Check Sheet 5

Foha de Verificação																				
Máquina 05																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	50,3	50,1	50,8	49,7	48,6	50,3	49,7	51	49,5	49,2	48,8	51,7	51	51,8	49	50	50,7	50,4	50,5	49,4
Amostra x2	49	49	50,4	49,6	50,2	49,5	48,4	51,2	49,9	49,5	51,5	49,2	52,8	50,3	51,1	50	51,1	51	50,6	50,3
Amostra x3	50	49,6	47,5	51,1	48,5	50,9	48,1	50,9	49	48,4	51	51,5	49,4	52,1	50,8	49,3	50	48,8	51,8	51,5
Amostra x4	51	49,9	51	49	50,7	50,7	50,4	52	49,1	50,4	50,8	48,9	50,7	50,1	51,2	49,2	51	50,5	50,6	51
Amostra x5	50	49,1	50,9	49	50	50,9	50	51	50	49,2	51,2	52	51	51	50,4	48,7	51,2	51	50,2	51,2
Média das amostras	50,1	49,5	50,1	49,7	49,6	50,5	49,3	51,2	49,5	49,3	50,7	50,7	51	51,1	50,5	49,4	50,8	50,3	50,7	50,7
Nº de amostras não conformes	1	4	1	4	2	1	3		4	4	1	2	1		1	3		1		1
Necessidade de tara do equipamento		tarou		tarou	tarou		tarou		tarou	tarou						tarou				

Source: The authors.

Table 7 – Machine Check Sheet 6

Foha de Verificação																				
Máquina 06																				
	Número de amostras realizadas no mês de Maio/2022																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Amostra x1	52,5	50,5	51,5	51,7	51,2	50,8	50,7	52,5	52,9	50,4	51	51,2	58,4	41,6	51,3	50,8	50,2	50,4	51	51,2
Amostra x2	50,1	51,9	51,9	46,2	52	52,4	52,3	51,3	53,7	50,9	51,5	51,1	51	52,2	50,3	49,2	54,5	50,9	51,5	51,1
Amostra x3	50,5	50,1	50,2	51,1	51,2	50,6	53,8	51,2	54,7	49,3	51,5	49,6	51,2	50,9	51,8	51,2	51,7	49,3	51,5	49,6
Amostra x4	55,8	51	50,6	51	51,8	50,2	50,7	51	52,6	50,4	51,4	50,7	51,7	50,8	52	51,8	49,8	50,4	51,4	50,7
Amostra x5	48,8	50,7	52,2	56,3	52,2	51,8	49,8	51,3	52,8	51,4	51,7	50,2	53	52,8	51,8	50,3	51	51,4	51,7	50,2
Média das amostras	51,5	50,8	51,3	51,3	51,7	51,2	51,5	51,5	53,3	50,5	51,4	50,6	53,1	49,7	51,4	50,7	51,4	50,5	51,4	50,6
Nº de amostras não conformes	2			2			2		3	1		1	2	1		1	2	1		1
Necessidade de tara do equipamento	tarou			tarou					tarou											

Source: The authors.

The averages of the means and amplitudes were calculated:

Table 8 – Mean of the averages

Médias:	Máquina:
51,61	1
51,03	2
51,65	3
51,45	4
51,02	5
51,26	6
Média total:	51,35
Média das médias:	51,34

Source: The authors.

Table 9 – Mean amplitudes

Amplitude M1	
65,1	18,2
46,9	
Amplitude M2	
59	12
47	
Amplitude M3	
71,9	22,4
49,5	
Amplitude M4	
59,2	10,7
48,5	
Amplitude M5	
82,3	36,2
46,1	
Amplitude M6	
58,4	16,8
41,6	
Média das amplitudes:	
19,38	

Source: The authors.

For the sake of observation, we split the "High variability in potato chip package weights" into smaller problems. To do this, he used the Brainstorming tool, in which the following question was raised: "There is a great variability in the weights of potato *chip packages*, we need to find the causes. Do you have any idea what could be causing this variability?"

The following are the answers obtained:

Quality Intern: Lack of preventive maintenance on machines. There is no maintenance plan for the machines, they are only checked when they stop working or for some major problem that the employees have not been able to solve. In addition, the machine is only damaged when I or the other trainee observe, during the inspection, that the weights are non-compliant.

Shift supervisor: the working day is long, at the end of the day the employees are already too tired to check if everything is right with the work. Weighing. In addition to the discomfort of working standing for long periods of time and having a lot of pain in the spine as the desk is very low.

Quality analyst: there is a lack of training for employees to operate the machines. They learn from other employees who have learned from others. A vicious cycle, and in the end, there is no training with experts in machine operation.

Head of Maintenance: Employees do not calibrate the machines every day before production. The 5 machine gives more problems because it is not the same model as the others. Machine 4 has been serviced for the last 6 months, so it should show a better performance.

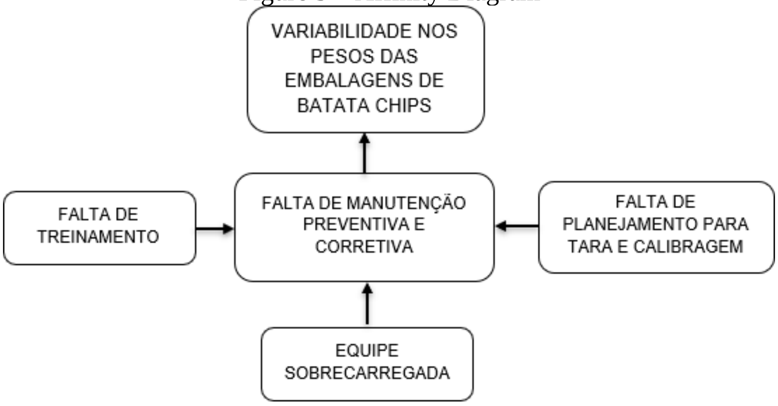
Packer employee: Maintenance does not give priority to the maintenance of machines, which are always giving problems. And it is not the employee's obligation to weigh the packages to check if it is correct.

Analyzing the results obtained, it is possible to list the possible problems:

- Lack from maintenance Preventive only the machine 4 Spent for maintenance in the last 6 months;
- Lack of planning for tare and bucket calibration actions;
- Long and exhausting working hours;
- Ergonomic issues;
- Lack of training;
- Machine 5 has some differences from the others;
- Non-collaborative thinking.

For better visualization, an Affinity Diagram was elaborated:

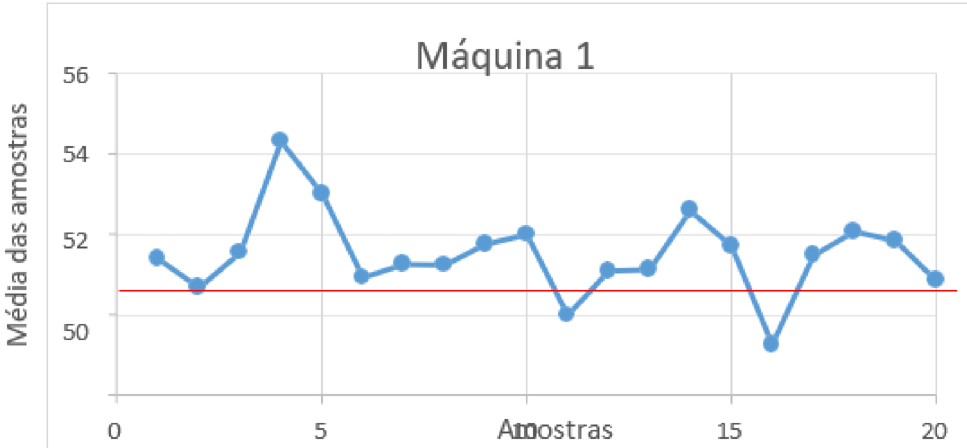
Figure 3 – Affinity Diagram



Source: The authors.

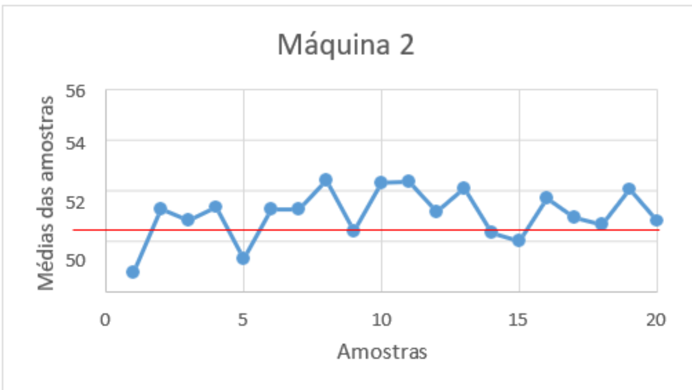
Based on the data collected by the Verification Sheet, sequential graphs were created with the averages of the samples from each machine for a better visualization of the points outside the specification limits:

Figure 4 – Machine 1 Sequential Chart



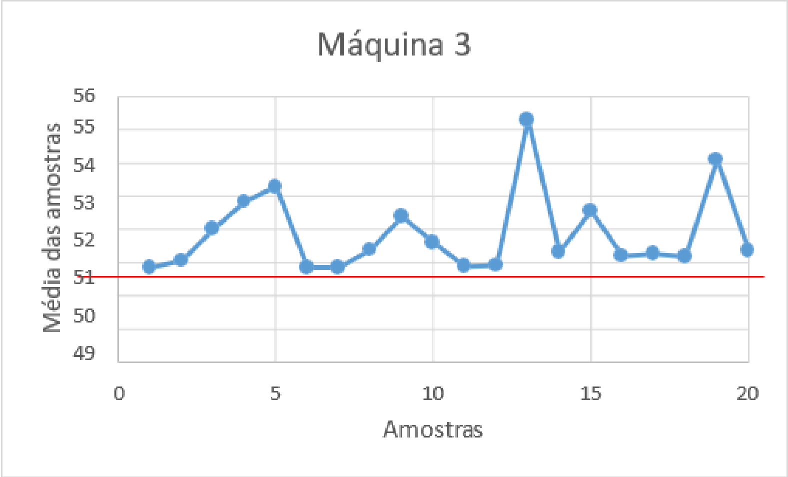
Source: The authors.

Figure 5 – Machine 2 Sequential Chart



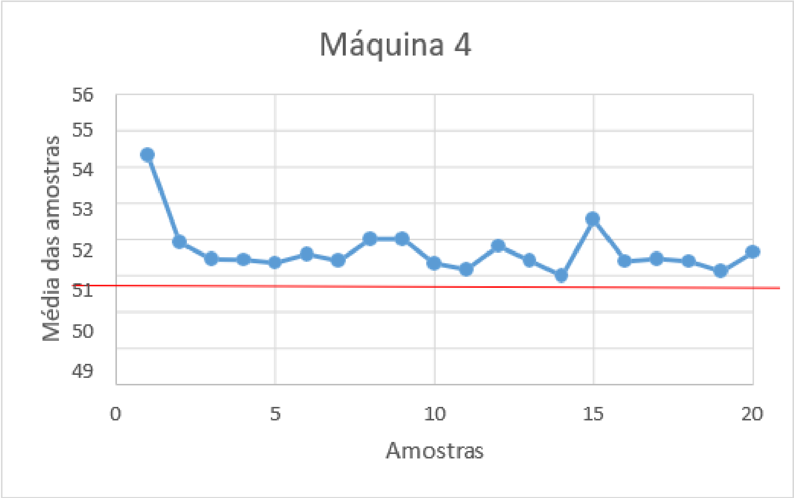
Source: The authors.

Figure 6 – Machine 3 Sequential Chart



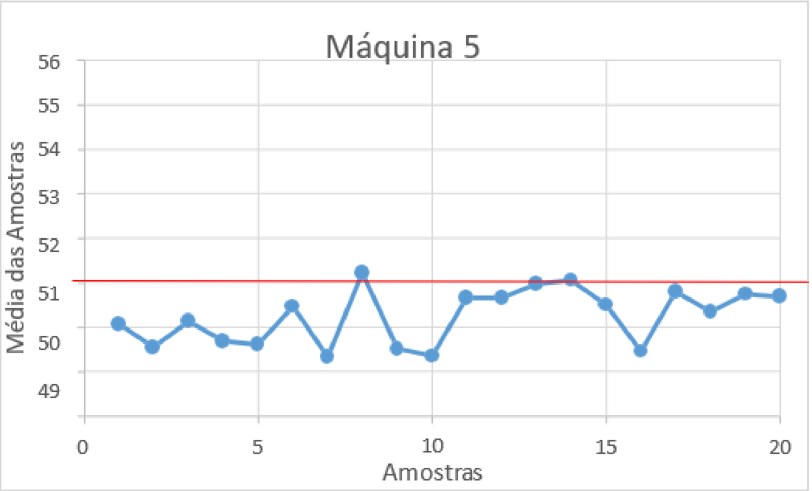
Source: The authors.

Figure 7 – Machine 4 Sequential Chart



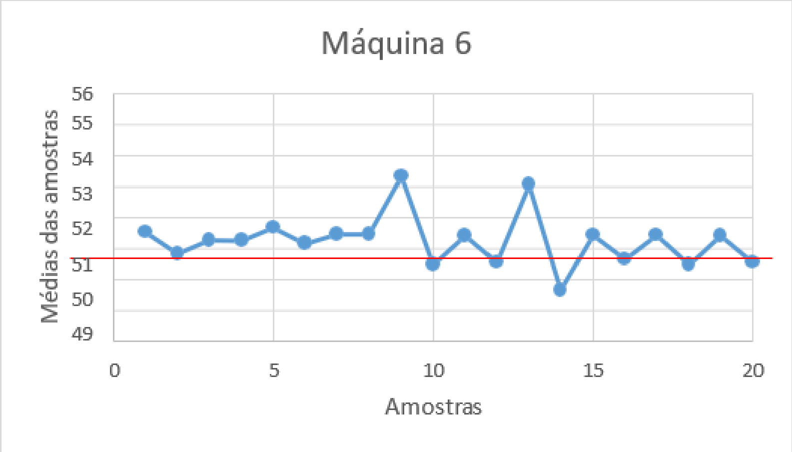
Source: The authors.

Figure 8 – Machine 5 Sequential Chart



Source: The authors.

Figure 9 – Machine 6 Sequential Chart



Source: The authors.

5 ANALYSIS

Analyzing the data from the Verification Sheets, a survey of the number of non-conforming samples was carried out in the group of 100 (one hundred) data collected for each machine and the following result was obtained:

Machine 1: 15 non-conforming samples;

Machine 2: 28 non-conforming samples;

Machine 3: 20 non-conforming samples;

Machine 4: 05 non-conforming samples;

Machine 5: 34 non-conforming samples;

Machine 6: 19 non-conforming samples.

Machine 5 has the highest number of non-conforming samples, being 34% (thirty-four percent) and machine 4 has the lowest number, with only 5% (five percent) of the total samples of the referred machine.

It was possible to verify that when the tare process of the equipment was performed at certain times, there was a significant improvement in the following results.

When analyzing the means of the means, it was found that it is very close to the ideal weight, but in the calculation of the mean amplitudes, the result of 19.38 is not satisfactory.

6 RESULTS

In view of the results obtained in *the Brainstorming* and the analysis of the sequential graphs presented, it is possible to validate the possible causes:

In relation to the long and exhausting workday, ergonomic issues and non-collaborative thinking, it was found that these are problems related to the inspection stage, having no effects on the packaging process, since it is all automated and only after the packages have already been sealed, that the employees work on their storage. Not underestimating these causes raised by the collaborators, we made a report with this data and this will be work at the appropriate time.

The lack of preventive maintenance is a cause that has been validated by the fact that it is visible in the sequential graph that machine 4, which has undergone maintenance in recent months, is the machine that has the lowest number of non-conforming samples and very little need for the tare action of the equipment.

The lack of planning for the tare and calibration actions of the buckets was also validated, because in the Verification Sheets we can see that soon after carrying out the tare process of the machines, the following measurements are close to the ideal weight and thus, the cause of lack of training was also validated, as the tare and calibration actions depend on trained employees to be performed and have the desired effect.

7 CONCLUSIONS

As a way to improve and/or eliminate the problem, an action plan was prepared in order to achieve that the weighing target is within the control limits and the number of non-compliant samples to fall to the lowest possible number, with the goal of minimizing non-conformities by 80% (eighty percent), we propose that the company follow the following procedures:

- Hire more employees for the maintenance team, divide and sector the team in order to speed up the service when the request is opened;
- Train the employees who work in the calibration actions of the machines, paying attention to the fact that machine 5 has a slightly different model and needs to meet its particularities;
- Develop a schedule of tare actions and machine calibration.

After the implementation of this action plan, new samples must be collected and the analysis process must be redone and the schedule should be adjusted according to the current scenario.

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