Case study: Analysis and application of lean manufacturing in a cake mix production line

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ABSTRACT
Lean Manufacturing, the literal translation of the quality tool Lean Manufacturing, is suitable for a wide variety of industries, and can be widely applied in the food industry, which has increased demands due to the growing population. With the expansion of the brand market, there is an urgent need to apply effective methodologies in the company. One of these methodologies is Lean Manufacturing, a management system focused on reducing waste and improving quality. Its central objective is to deliver maximum value with the least amount of resources possible, using tools that are applied according to the needs of the industry. Among the most commonly used tools are: Method and Time Studies, SMED, 5'S, Kanban, Flow Mapping, Poke-Yoke, Kaizen and Set-Up, Brainstorming, among others. The term brainstorming means a storming of ideas, which consists of forming a group of people who have knowledge of the subject to be addressed, which can help to discover solutions to a problem (Pauling, 1960; Soares and Brito, 2008).

Keywords: Lean manufacturing, Production, Cake mixes.

INTRODUCTION

Lean Manufacturing, a literal translation of the Lean Manufacturing quality tool, is suitable for the most varied segments, and can be widely applied in the food industry, which has greater demands with the growing population. With the expansion of the brands' market, there is an urgent need to apply effective methodologies in the company. One of these methodologies is *Lean Manufacturing*, a management system focused on reducing waste with quality gains, whose main objective is to deliver the maximum value with the least amount of resources possible, through tools that are applied, according to the needs of the industry. Among the most applied tools are: Methods and Times Studies, SMED, 5'S, Kanban, Flow Mapping, Poke-Yoke, Kaizen and Set-Up, *Brainstorming*, among others. The term *brainstorming* means a storm of ideas, which consists of the formation of a group of people who have knowledge in the subject that will be addressed, and can help in the discovery of solutions to a problem (Pauling, 1960; Soares and Brito, 2008).

For reflection, the results of the application of the previous methodologies are provided by means of graphs and index markers. One of these index markers is called Overall Equipment Efficiency (OEE), which has been increasingly used in the industry not only to control and monitor the productivity of production equipment, but also as an indicator, and driver, of continuous improvement and process

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performance (GARZA et al., 2010). Therefore, OEE is able to measure performance, identify development opportunities, and direct the focus of improvement efforts in areas related to equipment or process utilization, operating rate, and quality. Associating the lean manufacturing methodology with the OEE index results in noticeable changes on the shop floor, expressed in graphical form or percentage (GARZA et al., 2010). At the same time, another method of obtaining results through applied studies is the study of mass balance, which is of great weight in the food industry for process control.

In the cake mix production line, various equipment is used, including mixers, feeder boxes and automated filling mugs, which have high amounts of product retention in their walls and propellers, causing operational problems. For these reasons, the flow rate of the product, the variation of humidity due to the physicochemical characteristics and the possible losses, must be analyzed according to the scenario of the company in question, because the lack of control of different types of materials, such as weight, specification and thickness of the packaging divergent from the company's standard, can cause specific problems for this production line.

In this way, the application of mass balance in the cake mix production line was used to obtain results within the *Lean Manufacturing* methodology, expressing the loss of product during the process, in which it was discarded as waste and the addition in each package filled, which in turn was directed to the consumer. Both losses are irreversible, which contributes to spending beyond production within the industry.

OBJECTIVE

The objective of this work was, through a supervised internship carried out in a food company located in the Northwest of the state of Paraná, the collection of data necessary for the elaboration of documents that express the losses of the process, the lack of standardization of the auxiliary material and the non-conformities observed, using them in the determination of the OEE index after the implementation of the Lean Manufacturing methodologies.

METHODOLOGY

PROCESSING IN THE CAKE MIX INDUSTRY

According to the flowchart in Figure 01, it is possible to visualize the cake mix production process. The raw material arrives at the industrial center and a sample is previously collected for quality control analysis. After authorization, the raw material is sent to the responsible sector and stored. Once the flavor that will be produced in the daily schedule has been determined (brownie, chocolate, pineapple, coconut, anthill, orange, cassava, party line, cornmeal and lemon), the raw material is taken to the mixer, located on the upper floor of the sector, passing through the sieve, which is directly connected to the storage of the finished product, through pipes, as shown in Figure 02.

Figure 01 – Flowchart of the cake mix production process

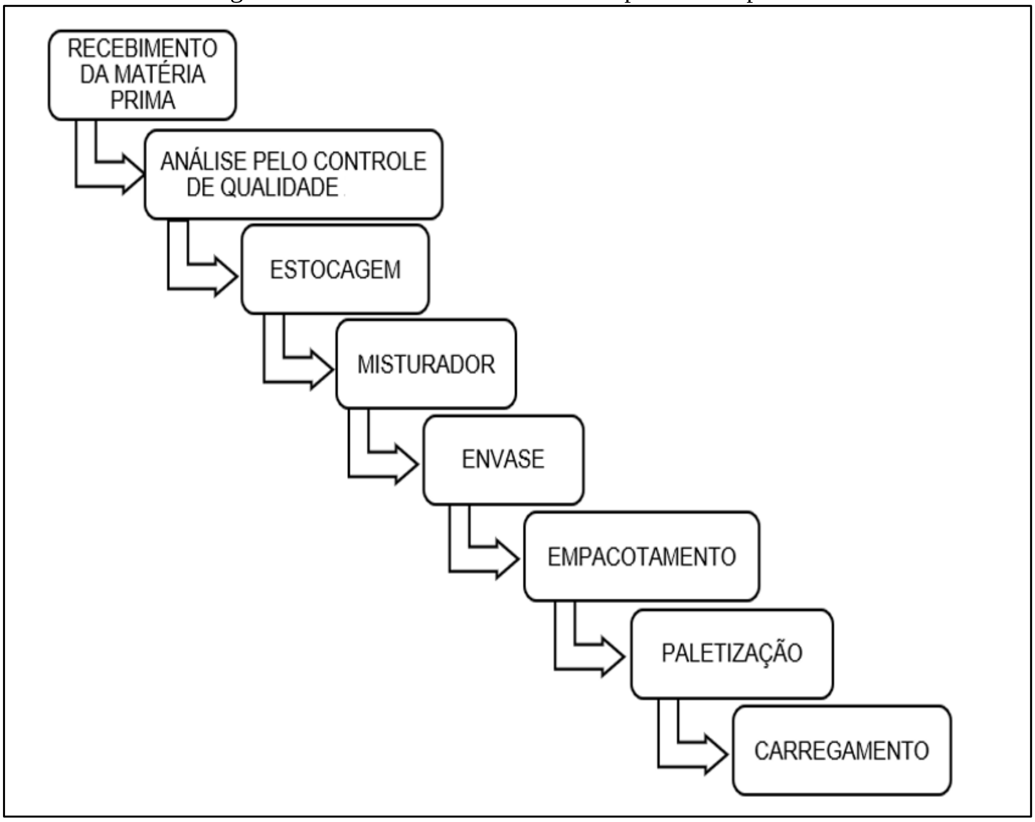


Figure 02 – Flow chart of cake mix process

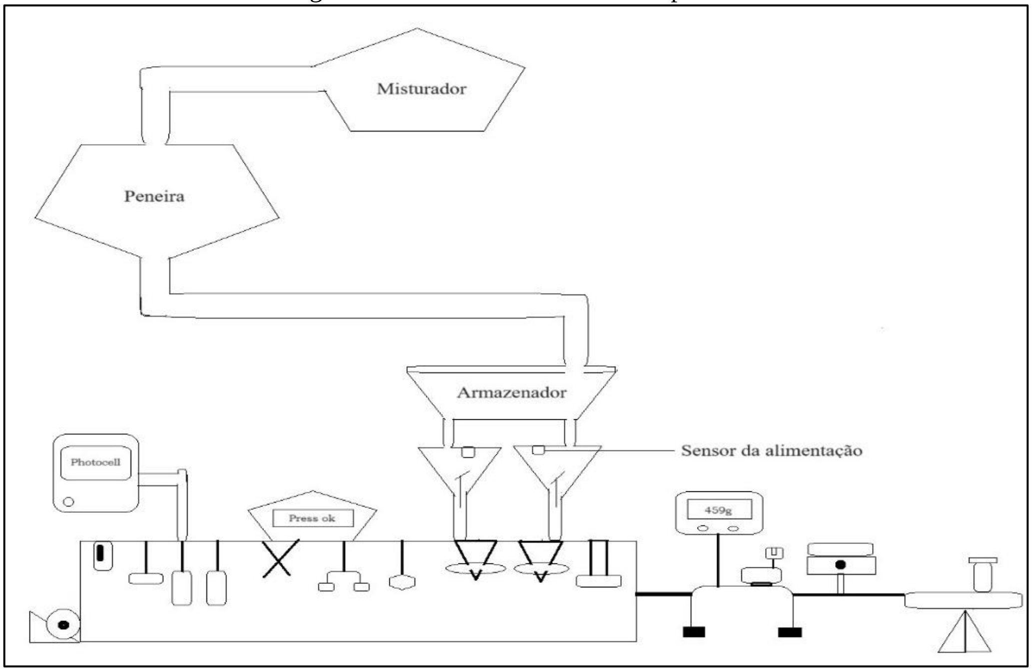
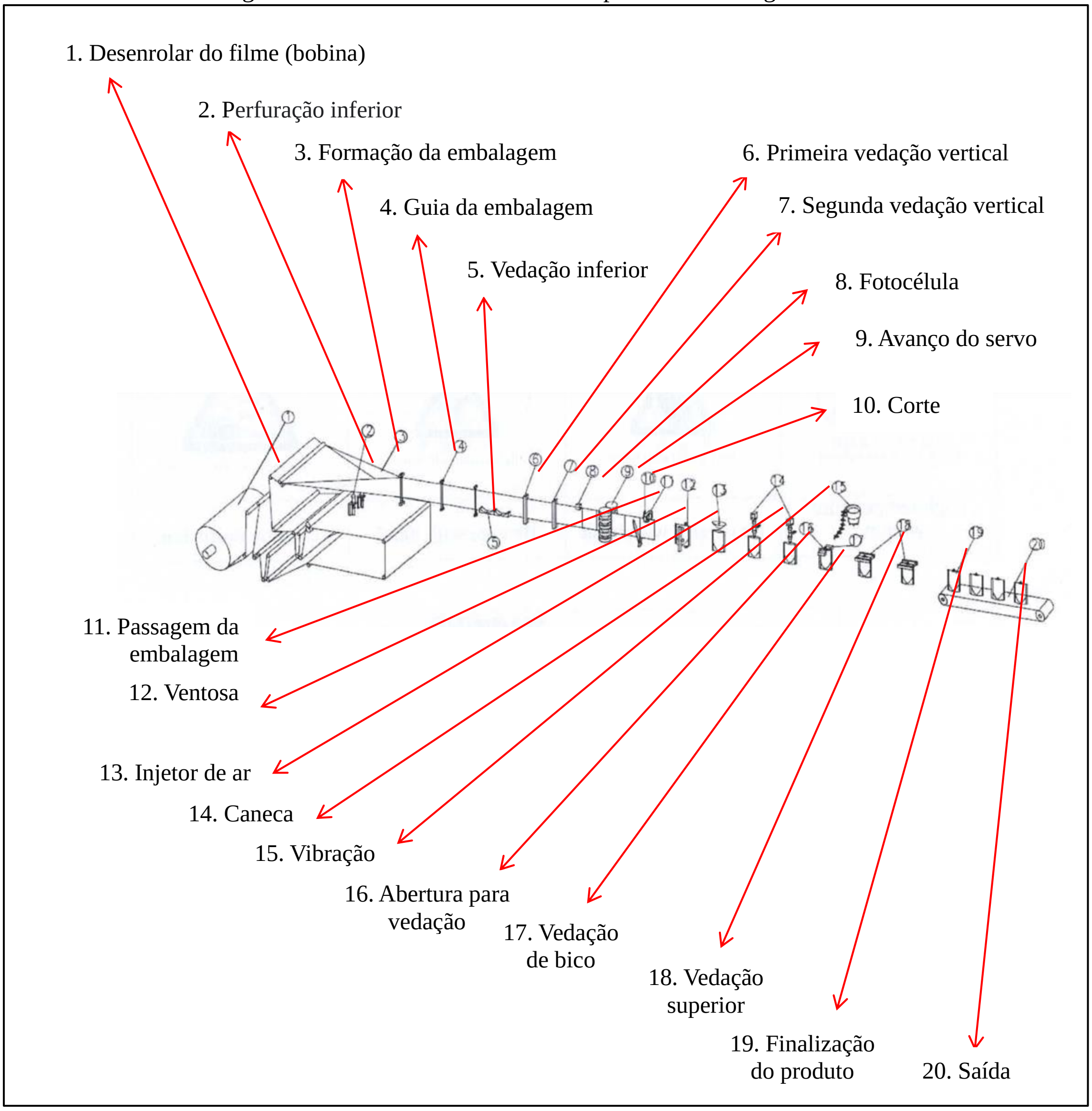


Figure 03 shows the flowchart of the inside of the filling machine. The empty bundles are formed at points 1 to 13, where the coil unwinds following the pattern configured on the machine panel (Figure 04). The mug (14) is responsible for filling the product into the package, which undergoes a vibration (15) to accommodate the mixture, since from points 16 to 20, adjustments occur in the upper part of the package. This vibration is important so that the product is not retained when it is sealed, because if poorly sealed, reprocessing and loss of packaging occurs. The packages containing 500 g of cake mix are directed to the secondary package, cardboard boxes, which are manually stored 12 packages by the line employees.

Figure 03 – Flowchart of the internal part of the filling machine



Thus, the methodology of the research was based on two main approaches: the first was the observation in the cake mix production line, seeking to identify and analyze the losses during the process and the second aimed to evaluate the data prior to the new procedure taken to improve the production line, such as graphs, the global efficiency index, justifications of the machine stoppages, behavior of the entire manufacturing environment in the face of the problem encountered, spreadsheets of values involving the entire process, in addition to the machine manual, for a better mechanical understanding of the same, being translated for the understanding of the line employees.

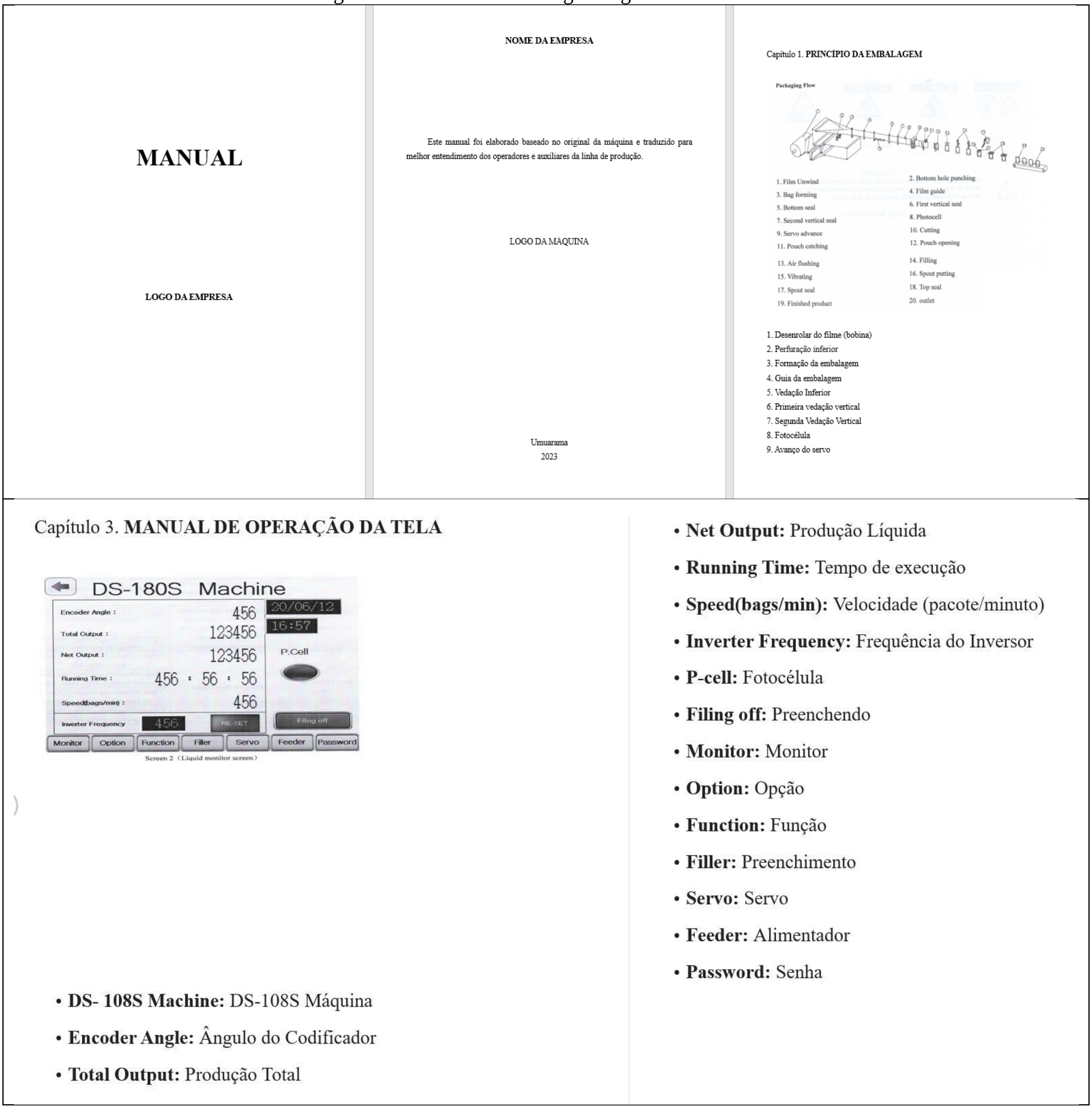
DEVELOPMENT

The development of this work, together with the development of the supervised internship, began with a meeting with the manager of the cake mix sector. It was oriented how the study should be elaborated during the internship period and what problems should be observed. On a weekly basis, at the general meeting of the sector, the evolution of the adopted methods was demonstrated, in the form of graphs and in succinct texts, evidencing improvements or unsatisfactory indexes, for possible new action plans to be adjusted. In one of these meetings, there was a presentation of the new project to be developed during the internship, alerting everyone to the essential role that each employee could play.

Therefore, for the development of the internship, the alignment of ideas between the teams, observation and brainstorming, a Lean Manufacturing tool used in this study, were essential, because, through these, it was noted that the machine, which performed the entire process of filling the cake mix packages (Figures 02 and 03), had the highest waste rates and, consequently, the greater need for change. The filling mug (14), represented by Figure 03, had greater prominence during the study in relation to product waste, because when it touched the top of the already formed package, it folded it, resulting in the reprocessing of the cake mix that was injected out of the package. By sequence, the cutting stage (10), in which the packaging material, when in contact with the heated blade, was melted, not obtaining standardization by the machine, generating successive errors, such as misalignment of the photocell (8) and product without correct filling by the mugs (14). Both caused excessive loss of product and auxiliary material.

In addition, through brainstorming, the employees of the operational line with the maintenance sector detailed the entire process of purchase, installation and operation of this machine, demonstrating the lack of standardization of this in the process, which caused a lack of solid data from the company. One of the points observed during the research was the lack of comprehension of the machine's information that was expressed on a control panel, in which the operator in charge demonstrated that he did not have knowledge of the original language. As a solution, a new manual was developed with the descriptions translated in parallel to the source texts, as shown in Figure 04. The printed document was delivered to the employees of the process and made available to answer any questions regarding the machine.

Figure 04 – Translated mixing/filling machine manual


MANUAL

LOGO DA EMPRESA

NOME DA EMPRESA

Este manual foi elaborado baseado no original da máquina e traduzido para melhor entendimento dos operadores e auxiliares da linha de produção.

LOGO DA MAQUINA

Umuarama
2023

Capítulo 1. **PRINCÍPIO DA EMBALAGEM**

1. Desenrolar do filme (bobina)
2. Perfuração inferior
3. Formação da embalagem
4. Guia da embalagem
5. Vedação Inferior
6. Primeira vedação vertical
7. Segunda Vedação Vertical
8. Fotocélula
9. Avanço do servo

Capítulo 3. **MANUAL DE OPERAÇÃO DA TELA**

- **DS- 108S Machine:** DS-108S Máquina
- **Encoder Angle:** Ângulo do Codificador
- **Total Output:** Produção Total
- **Net Output:** Produção Líquida
- **Running Time:** Tempo de execução
- **Speed(bags/min):** Velocidade (pacote/minuto)
- **Inverter Frequency:** Frequência do Inversor
- **P-cell:** Fotocélula
- **Filing off:** Preenchendo
- **Monitor:** Monitor
- **Option:** Opção
- **Function:** Função
- **Filler:** Preenchimento
- **Servo:** Servo
- **Feeder:** Alimentador
- **Password:** Senha

It was deduced that the waste in the process could be linked to the lack of adequate machine commands, which generated reprocessing of the finished product, loss of constant auxiliary material, and non-perishable waste for consumption when they fall to the ground, requiring a new action plan. After the changes were made, the line employees paid more attention to standardization, as the commands were now expressed in a language that could be understood.

Within the available resources, following the objective of a direct and cost-free study, the need arose to validate the company's mass balance, with detailed monitoring of the product mass during industrial unit operations. For the elaboration of this study, the control volume of the complete process, the set of equipment and the currents involved were defined. Thus, the mass balance would function as an "inventory" of mass in relation to a defined system.

Figure 05 – Daily production report (Document 1 - Part 1 of 3).

DOCUMENTO 1

RELATÓRIO DIÁRIO

MÁQUINA: INÍCIO:

PRODUTO: PARADA:

DATA:

PERDA DE EMBALAGEM

CAUSA	QUANTIDADE (Kg)
TOTAL	

*Todos os valores expressos foram descontados 0,008kg do saco plástico que armazena a perda de embalagem.

CAUSA	PORCENTAGEM (%)
TOTAL	

*Para a perda total não é considerado o valor da troca de produto, pois os pacotes pertencem a bobina anterior.

Total de bobina gasta na produção: ______Kg

In addition to the translation of the manual (Figure 04), aiming at a possible reduction in waste, there was also a need to prepare a new document that would fulfill the functions foreseen in the *Lean Manufacturing* methodology. This document would provide the company with daily control, by means of numerical survey of the application of mass balance, of production and waste, both of product mass and packaging, in the production line for cake mix. Thus, the document shown in Figure 05, called the Daily Report, was prepared.

The Daily Report was filled in with the name of the machine to be evaluated, the product filled in the given period of the analysis, the start and end date of production. For the loss of packaging, the cause of this loss and the respective amount lost, in kilograms, according to this cause, were identified and separated in tabular form. At the end of the day, the value of 0.008 kg was subtracted from the total mass of packaging, which represented the mass of the plastic that stored all the packaging, making it possible to calculate the total mass lost, as well as the percentage of loss in relation to the total packaging used. These packages were identified as waste, as they were all discarded. By means of this segregation of values together with the total loss of auxiliary material, it was possible to evaluate which were the points of greatest waste during the process, taking the action plan to the main focus, quickly solving the problem found, and successively making corrections.

The calculations performed to express this packaging loss as a percentage were:

$$MB = PT * ME * QC \tag{01}$$

Where:

$MB =$ Coil mass spent in the process (kg);

$PT =$ Total Production (kg);

$ME =$ Mass of the product packaging (0.009 kg);

$QC =$ Number of packages per box (12).

The coil spent in the process represents the mass of packages successfully when filled. The value, as represented by Equation 01, is given by multiplying the total production, expressed in kg, by the company's program (SAP), which counts how many packages were actually produced, multiplied by the mass of the standardized packaging, which was 0.009 kg, and by the number of packages per box, in this case equal to 12. The total coil spent during the entire process was provided by Equation 02, i.e., the sum of the coil mass spent in the process (Equation 01) and the mass of the packaging loss (kg), which was determined from the weighing of all damaged (or rejected) packages at the end of the same process.

$$MTB = MB + MPE \tag{02}$$

Where:

MTB = Total coil mass spent in the process (kg);

MB = Coil mass spent in the process (kg);

MPE = Packing loss mass (kg).

After obtaining these values and in order to express them as a percentage of packaging losses, the ratio between the packaging loss mass (MPE) and the total mass of the coil spent in the process (MTB) was calculated, expressed by Equation 03.

$$Packaging\ loss(\%) = \frac{MPE}{MTB} * 100 \tag{03}$$

This calculation shows the mass of auxiliary material waste in relation to the total coil mass spent in the process. In order to segregate these values, it was necessary to individualize the waste generated at each point of production, calculating the loss in relation to a respective factor. Equation 04 shows the calculation of the percentage of loss for each point of production.

$$Loss\ because\ (\%) = \frac{MPF}{MTB} * 100 \tag{04}$$

Where:

MPF = Lost coil mass by factor (production point).

In order to use the values obtained by Equations (01) to (04), it was also necessary to apply the mass balance throughout the process, given by Equation 05.

$$ENT - SAI \pm GER/CON = AC \tag{05}$$

Where:

ENT = Mass input into the process (kg);

SAI = Mass output in the process (kg);

GER = Generation of mass in the process (kg);

CON = Mass consumption in the process (kg);

AC = Accumulation of mass in the process (kg);

Since the process was considered to be steady-state and there was no presence of any kind of chemical reaction, the previous equation becomes:

$$ENT = SAI \quad (06)$$

The term dough starter was composed of the cake mix dough of the previous reprocess of the respective flavor to be produced, which was stored in stock, added to the formulation stipulated by the company's PCP. On the other hand, for the term dough output, it was necessary to obtain the quantity of filled dough, the reprocess of the new manufacture and also the addition of mass. Thus, by means of the equations presented, it was possible to fill in the second part of the proposed Daily Report, represented by Figure 06. $(ENT)(SAI)$

Figure 06 – Mass balance to obtain the increase (Document 1 - Part 2 of 3).

BALANÇO DE MASSA

O balanço de massa consiste em:

- Reprocesso anterior (Kg)
- Formulação (Kg)
- Produto (Kg)
- Reprocesso gerado (Kg)
- Acréscimo (Kg)

REP. ANTERIOR + FORMULAÇÃO = PRODUTO + REP. GERADO + ACRÉSCIMO

Considera-se nos cálculos a quantidade de formulação;

Considera-se nos cálculos a produção obtida.

Resultado do Acréscimo gerado: _______Kg

PADRONIZAÇÃO DO MATERIAL AUXILIAR

LOGO DA EMPRESA	PESO DA EMBALAGEM	ESPESSURA (mm)
MÉDIA		

Média peso da embalagem: _______Kg

Média do acréscimo: _______Kg

In Figure 06, the formulation dough was the component to be confirmed with the company's formulators, who divided the raw material into plastic packages, which contained the entire mixing recipe for the cake to be produced. These plastic packages were called kits. The mass of each kit, multiplied by the quantity, was used as the input term in mass balance. In addition, the input mass via reprocess should also be confirmed, i.e., the mass coming from the previous production of the same flavor, but which acted as an "input" to a new production, given by the term "previous reprocess". To obtain the value of the "product" mass, the quantity of packages filled was calculated, supplied by the company's system, multiplying this value by 500g, referring to the weight of each of the packages produced. The "reprocess generated" was weighed on a sector-specific scale, which, after calibration, was destined for storage for the next production (previous reprocess).

Within the mass balance, the value to be found was the value of the increase in mass per package in production, for comparison with the value calculated through sampling. Equation 07 shows the calculation for the increase in production of each package.

$$Addition\ (kg) = \frac{MPP}{0{,}500} * 100 \qquad (06)$$

Where:

$MPP =$ Average mass of packages produced (0.509 kg);

The value of 509 g corresponds to the value of the mass of the package added to the packaged product. During the study, it was noted that there was variance in the weight of the packages formed by the filling machine, without the addition of cake mix, that is, the coil used to form the packages underwent changes in thickness and dough during the process, sometimes being less than 9 g as stipulated by the company. When questioning those responsible for the auxiliary material, they advised them to carry out a more detailed verification of the results, thus, Document 2 was elaborated, in which the analysis consisted of measuring, on a precision scale, the mass of 10 empty packages and their respective thicknesses, because, as the company did not have this control, it could use them to compare the results of the process. Figure 07 shows the table filled in Document 2.

Figure 07 - Table for collecting the weight of effective packages from the machine (Document 2).

DOCUMENTO 2

ACRÉSCIMO

AMOSTRAGEM

MÉDIA										

It is worth remembering that the values obtained in Document 2 were attached to Document 01 (Part 3 of 3), in the field "average weight of packages". Document 1 (part 3 of 3) is shown in Figure 08. Finally, the blank field of Document 1, identified as "Causes of Loss During the Process", was intended for a detailed description of what was observed during production, with a view to raising new action plans. This space is designed for future brainstorming and concluding observations of the analysis. At the end of the shift, it was discussed with the sector manager.

Figure 08 – Space for observations during the process (Document 1 - Part 3 of 3).

Para o cálculo:

- Média do Acréscimo (g)
- Peso Padrão dos pacotes envasados (g)
- Média do peso das embalagens (g)

$$\frac{\text{Média do Acréscimo - (Peso Padrão dos pacotes + Média do peso das embalagens)}}{\text{Peso Padrão dos Pacotes x 100}}$$

CAUSAS DA PERDA DURANTE O PROCESSO

FINAL THOUGHTS

With the methodologies applied and the results presented, aiming at the application of Lean Manufacturing in a food factory in the Northwest of the state of Paraná, it is hoped that this document can facilitate the elaboration of the article by the authors, as well as the review of the evaluators. The action plans taken within the Lean Manufacturing methodology with the application of the mass balance tool, made improvements and reductions of waste in the production of cake mix, demonstrating that continuous improvement is applicable in the most varied manufacturing environments.

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