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Production Management Model to Reduce the Percentage of Rejected Products in a Food Company based on Lean Manufacturing Tools

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Abstract

The food industry is one of the most important around the world and in this sector, we can highlight the part dedicated to the production of fruit in its different presentations. In this area, customers are usually demanding when placing their orders to companies, so it has been an important issue to have proper control of the products that are rejected, otherwise it could even turn into a financial inconvenience. In accordance with the above mentioned, it has been decided to propose a model that could be useful for the problems previously raised, which consists of the use of 3 Lean Manufacturing tools: Jidoka, Standardized Work and Total Productive Maintenance (TPM) focused on its fourth pillar, in order to reduce the percentage of rejected products. The proposed model using Arena software was able to reduce the rejected products from 16.27% to a value of 7.61%. Likewise, the Jidoka tool reduced the lots rejected due to fruit pulp bags with extra air by 11.76%, Standardized Work tool reduced lots rejected due to bag improperly sealed by 18.89% and the TPM kept the levels of lots rejected due to presence of seed.

Keywords
Product process, procedures, comparison of indicators, rejected products, standardized work

1. Introduction
The food industry seemed to focus on reducing waste and production costs without paying much or any attention to customer satisfaction. However, human capital has the potential to find efficient ways to operate. Therefore, recently we can see that the industry has changed its focus towards the customer and is focusing on producing goods that are in line with customer demands (Alawamleh et al., 2022). Despite these changes, the problems have not disappeared from this industry and a common issue in this sector is the matter of packages that are rejected by customers for defective products. To mention one example, there is a case of study that shares this problem, focusing on the packaging stage, for which a technique was sought that achieves an automatic quality control while the production is being satisfied. Given this, the proposal had a CNN-based approach, obtaining significant results with respect to rejection rate and was able to detect at least 99. 93% of the sealing defects that occur in any production (Banus et al., 2021). Another case of study was related to the fulfillment of the requirements on the products by the customer that took place in a company exporting handle in which they applied Lean tools such as Jidoka, Kanban, Visual Control and Standard Work, from which they obtained positive results such as reducing labeling errors by 2%, the excess of platforms by 0. 72% and the search time of a product at 4.5 hours per day (Lua et al., 2022). Among all the investigation behind, the authors in this article have realized that there is a lack of information and research around the main issue: the rejection of defective products particularly in the food industry. Having said that, it is significant and outstanding to develop cases around this forgotten field, it will lend a hand to all future students and researchers involved and focused on the topic. In view of this, the authors have decided to develop a case of study in which it would be possible to highlight the considerable number of end products that are not accepted by customers and the impact this has on the company. This scientific article is composed of the following: Introduction, which contains an overview of the

sector and view from the perspectives of several authors; diagnosis of the problem, in which the central deficiency is specified; the methodology together with the theoretical basis for the description of the model to be proposed; results; discussion and conclusions.

1.1 Objectives

The main objective of this study is to reduce the percentage of products rejected by at least 10% of a food company dedicated to the production of fruit pulp. This will be achieved by developing a production management model using Lean Manufacturing tools such as Jidoka, Standardized Work and Total Productive Maintenance (TPM). Likewise, specific objectives were proposed to reduce the presence of passion fruit particles by 20% and reduce defective products in packaging by 15%. The study aims to highlight the importance of the number of final products that are not accepted by customers and the impact this has on the company.

2. Literature Review

2.1 Jidoka

Jidoka is a technique that is often applied in different sectors and is notable for describing a set of automation design principles that seek to separate human activity from machine cycles to allow an operator to operate multiple machines (Romero et al., 2019). In addition, under this approach, tools are often used to comply with the Jidoka principle of automating at low cost and putting people's talents into practice (Suarez et al., 2020). The incorporation of this tool into a production process aims to eliminate reprocessing and make a greater control with exact measures that could be managed by a codified alert or alarm; therefore, defective products will be detected (Cisneros et al., 2022).

2.2 Standardized Work

One of the procedures to take this methodology into account is to avoid the use of excessive materials and additional operations in the stations, to have a better use of natural resources (Pinto and Mendes, 2017). Also, among the improvements that this tool can offer is to reduce the time of operations and that in turn must consider the cleaning and organization of these to achieve a continuous flow (Vargas et al., 2022). On the other hand, with this tool it is hoped to eliminate the variation of the work, which is a key point to achieve the consistency of the work performance (Putri and Dona, 2019). It should be noted that it is difficult to find improvements if the standardization of work is not complemented by continuous maintenance and updating of standards (Mor et al., 2019). Furthermore, it can be highlighted that the application of this technique can considerably help those companies that lack production methods, so the objective to solve this problem will be to implement work routines, where there are positive results due to the balance between the operator activities and eliminating those that do not add value to the product (Santos et al., 2019).

2.3 TPM (Total Productive Maintenance)

About this tool allows you to study the maintenance parameters and their relationship with the manufacturing method in terms of its performance. In addition, within this technique it is important to discuss the decisions on the technical parameters that should be submitted to the action plan of the selected pillar in TPM (Johnson and Pramod, 2020). In addition, this technique may relate to self-maintenance and training activities to ensure proper control of the products to be manufactured (Paredes et al., 2022). Its main objective is to eliminate losses related to the maintenance of equipment and it is formed by 8 principles linked to preventive methods to maintain the reliability of equipment (Smirnov and Abdilova, 2021). In addition, this tool is considered as a health science for machinery, the purpose of which is to unite the function of production and maintenance (Sahoo, 2019).

3. Methods

3.1. Basis

During the analysis of the literature, various models aimed at improving productivity have been discovered. These models have facilitated the identification of tools linked to the problems that generate low productivity in a company in the food sector. The main authors who provide valuable ideas about these tools are mentioned in Table 1. There can be seen that every reference contains the Standard Work tool, meanwhile, two of them have Jidoka tool and two different studies have TPM tool. Within all the deep research, there was not found a mix of the three tools together.

Table 1. Comparative Matrix

Authors/Components	**Lack of inspection in packaging**	**Lack of standardized processes**	**Inadequate maintenance of pulping machine meshes**
Paredes-Rodriguez, A. M., Chud-Pantoja, V. L., and Peña-Montoya, C. C. (2022)		Standard Work	TPM
Sahoo, S. (2019)		Standard Work	TPM
D. Romero, P. Gaiardelli, D. Powell, T. Wuest, and M. Thürer (2019)	Jidoka	Standard Work	
M. F. Suarez-Barraza (2020)	Jidoka	Standard Work	
Vargas-Altamirano, A., Ulloa-Durand, J., Flores-Pérez, A., Collao-Diaz, M. and Quiroz-Flores, J. (2022)		Standard Work	
Proposal	**Jidoka**	**Standard Work**	**TPM**

3.2. Proposed model

To develop the production management model to reduce the percentage of rejected products, we considered as a reference the different proposals verified in papers that mainly apply Lean Manufacturing tools as well as alternative solutions for reducing rejected products. All these studies explain their models by considering some aspects. Comparing the model to be carried out with others already existing in the field, the one presented in this research is based on the use and union of three tools of the aforementioned methodology, these being Standardized Work, Jidoka and TPM. The named components are often relevant in this sector for improvements in production. In addition, the fact of having as input the high percentage of products rejected in the food sector, will try to solve a problem that arises at the end of the supply chain. Also, the use of the connection between Lean tools for a practical sequence that takes advantage of the reduction of unnecessary elements to maximize resource productivity contributes to the novelty of the model. All this description can be seen in Figure 1.

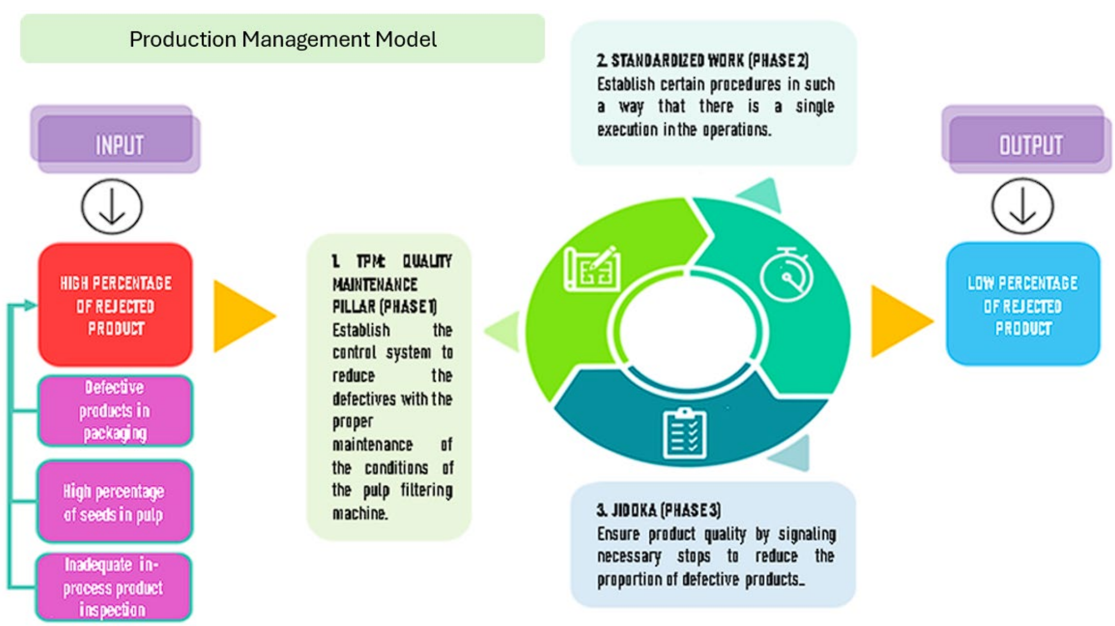

Figure 1. Proposed model

3.3 Components
The model is divided into three components, as mentioned in Figure 2.

3.3.1. Component 1: Total Productive Maintenance (TPM)
When applying this tool, we will take the fourth pillar, it consists of quality maintenance or also called Hinshitsu Hozen, here we will have to locate how many defects come out of the thread and if there is any level of tolerance, by the hand of a 4M analysis and the list of defects or "fuguais", these matrices belong to the pillar and help for the detection of mistakes. It is also known that after pulp processing, the seed particles are filtered so that as little as possible passes; however, it sometimes accumulates in the mesh and when a new mass is passed, despite having the filter, the previously retained particles can be taken with them, knowing that the grids measure 0. 5mm. must perform the quality maintenance matrix, since, unlike other pillars, the main thing looking for this is the minimum possible defect in the finished product. The summarized sequence to be carried out for this first component can be seen in Figure 2.

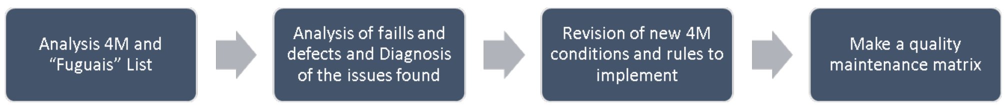

Figure 2. Steps to take in TPM – pillar number four

3.3.2. Component 2: Standardized Work
Subsequently, this phase focuses on establishing procedures in the packaging operation. It shall be sought in such a way that there is a single execution in the operations. At the beginning of this phase, the operations to be improved are defined, the time of each is identified, a restructured sequence is determined with the protocols to homogenize the work of all operators and a sheet is prepared with the established standards. Figure 3 shows the procedure to be carried out for this phase (Figure 3).

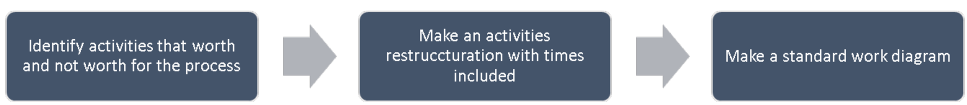

Figure 3. Procedure to enhance the sealing process

3.3.3. Component 3: Jidoka
Finally, for the use of the Jidoka tool, the stop point is first detected, in this case it is during the packaging operation, exactly the semi-automatic part in which the operator, after using a dosing machine that fills the PET/PEBD bags, seals it in a continuous sealing machine, it is here that it is proposed to introduce the belt that transports the bags at an analytical weight, being more accurate than a manual inspection, which will indicate the corresponding pure weight of 1 kg, for which it is proposed to install them connected to a warning light to enable the removal of these defective units. Operators are trained to use the equipment at this stage; however, making changes during the use of the sealing machine is not feasible since the contents are a liquid, which has an inaccurate volume due to the same movement of the bag and trying to incorporate some markings or markings into the bags to have the seal limit would not be significant. According to this, we will be able to avoid the rejection of whole boxes of finished product, since, according to customer specifications, if a unit does not exceed its set parameters, the whole batch is rejected. All the steps have been turned into a scheme shown in Figure 4.

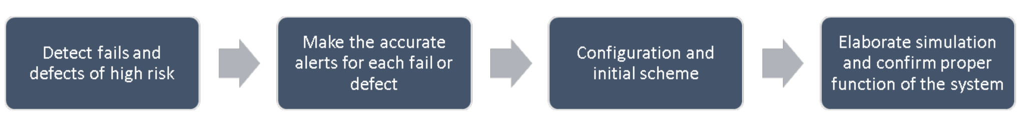

Figure 4. Scheme for the simulation of alerts

3.4 Indicators

The indicators of the proposed model are shown below in Table 2. With this it was possible to calculate a variation between the current system and the optimal one. As it can be seen in the table, we took three indicators, each one is related to a tool. For the first one, "Lots rejected due to bag with extra air" corresponds to the Jidoka tool. The "Improperly sealed bags" corresponds to the Standardized Work tool and the "Rejected lots due to seed" goes with the TPM tool (Table 2).

Table 2. Indicators

Indicator	Formula
Lots rejected due to bag with extra air	$= \frac{lots\ rejected\ by\ bags\ with\ extra\ air}{total\ rejected\ lots}$
Improperly sealed bags	$= \frac{improperly\ sealed\ bags}{total\ bags}$
Rejected lots due to seed	$= \frac{rejected\ lots\ due\ to\ seed}{total\ sent\ lots}$

4. Validation

The software used to perform the validation is Arena version 16, which allows us to simulate the process through modules that include operations, inputs, outputs, decisions, among other functions. The program allows us to obtain results according to the necessary repetitions for the sample.

With respect to the calculation of the number of replications, the Output Analyzer tool was used, and the following formula was used

$$n = n_0 \left(\frac{h_0}{h}\right)^2$$

n_0 = Number of initial or pilot replicates

h_0 = Absolute margin of error obtained with the n_0 replicates

h = Desirable margin of error

Using the formula for the calculation we have as data the 30 initial replications that were considered, so the simulator gave us an error of 3.13 minutes, but we are looking for an error of 2 minutes, so the number of replications needed is 74.

Within the program there were certain limitations, from the change of entities, for example, of what the fruit is going to be pulp and bags, it had to be handled as a single type of entity with change of certain attributes, considering unit times since Arena executes the process individually. A clear example of this was when the freezing operation was simulated, which in real life lasts 12 hours; however, it was placed in minutes, since the complete simulation would be too long for a single unit and the results would not be correct according to the program. All this is reflected graphically in Figure 5.

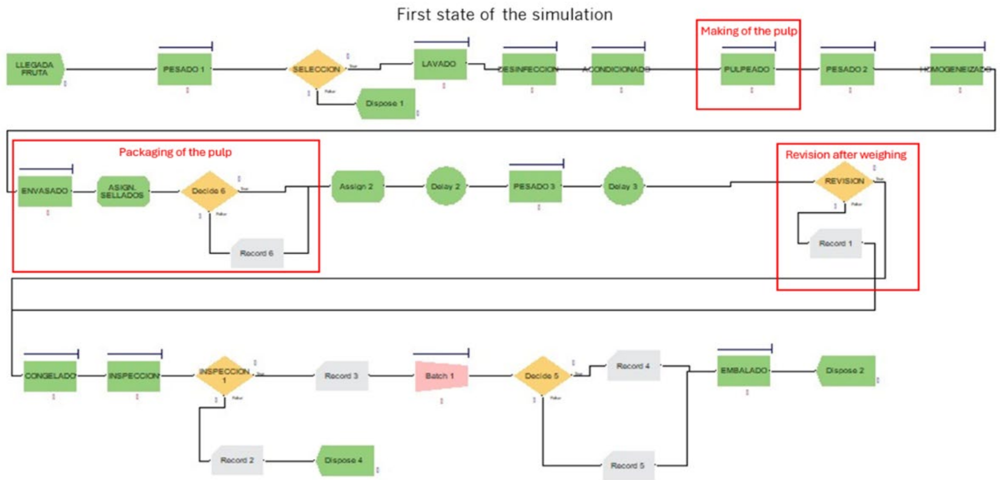

Figure 5. Simulation of the current model

This simulation has a programmed failure in the pulping operation, which symbolizes the stop of the pulping machine for cleaning purposes, likewise, in the packaging and revision there is no definitive exit of the defective products, thus symbolizing that they continue their course until they are packaged into lots.

In the second modulation of the scheme, it was considered to remove the failure of the pulping machine and put decision modules with an output symbolizing the significant removal of defective units. All this is shown in Figure 6.

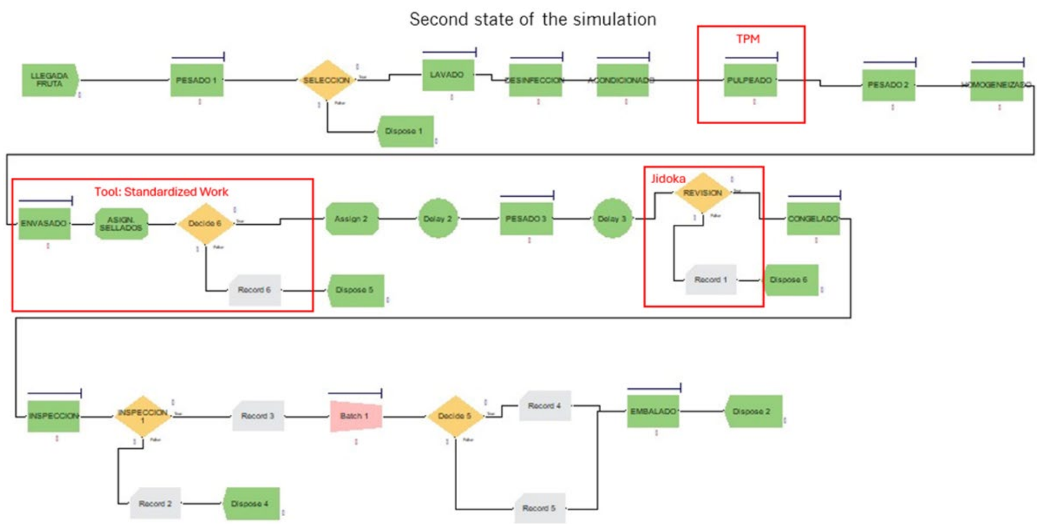

Figure 6. Simulation of the optimal model

5. Results and Discussion

5.1 Numerical Results

It could be said that, according to the Table 3 shown below, the indicators improved significantly, the first cause managed by the Jidoka tool went from 17% to 15%. The second cause managed by the TPM tool kept the levels of the indicator, meanwhile the third cause managed by the Standardized Work tool went from 16.30% to 13.22%. Especially, the overall result was lower than the percentage sought, going from 16.27% to 7.61% of rejected products.

Table 3. Model results

Measurement of the improvement								
Problem	**Actual**	**Objective**	**Improved**	**Cause**	**Indicators**	**Actual**	**Objective**	**Improved**
High percentage of rejected products	16.27%	10.80%	7.61%	Lack of proper revision after weighing	% of lots rejected due to bag with extra air	17%	10%	15%
				Low control in revision of the state of pure pulp	% of lots rejected due to presence of seeds	2.70%	1.35%	2.70%
				Lack of standardized processes	% of bags improperly sealed	16.30%	8.15%	13.22%

Parallel to the main simulation, two simulations were carried out with other scenarios, to compare the results and ensure that they can be applicable to other scenarios. In this case, for the first scenario, the modification was made in the weighing prior to washing, where a decision module was placed to symbolize the output of units; it should be mentioned that the rest of the operations within the process maintain their times and are in equal conditions to the situation proposed in the validation.

On the other hand, a second scenario was also carried out in which a weighing device is placed as a post-pulping check and, through a decision module, any unwanted material is discarded.

Table 4. Results for each simulation scenary

	Defective by inspection	Defective by overhaul	Mislabeled bags	Defective due to activity
Initial Situation	2	24	25	-
Final Situation	2	22	24	-
Scenary 1	2	19	20	12
Scenary 2	2	15	19	10

As it can be seen in the Table 4 above, the defectives due to inspection, which are equivalent to the defectives due to excess of passion fruit seeds, are maintained in the 4 scenarios; the defectives due to revision, which is the operation after weighing the bags, are equivalent to the defectives due to air inside the bags; these are reduced according to the change of scenario. The decrease is because in each scenario there is an extra decision module that discards defective material prior to the post-weighing overhaul. On the other hand, a comparison of the defective products coming out of the weighing activities was made only for each scenario, but not for our main validation (Initial and Final), where the objective was to apply the tools used to improve the situation; in this case, the defective products coming out of these activities were properly accounted for so as not to affect the final lot. Also, it can work as a record of how many defectives exist at the end of each process and analyze what actions can be taken to improve this situation.

On the other hand, a constant that should be mentioned is that, when searching for studies in the information banks, the tools selected for this case were not used in the food industry, the scenarios were scarce, and there was no pure application or modeling of them. However, the study by Lau and Tejada on shrinkage reduction in the manufacture of organic mango served as the main guide to continue with the research, since they use methodologies like those selected for this work. Knowing that there is a low presence of research where tools are compacted, the present study would serve to expand knowledge on the use of these tools in the food sector and could serve as a reference for other similar processes, such as the production of jams or fruit puree that implement machinery like that of the fruit pulp process.

5.2 Graphic Results
Among all this information collected, it is important to included visual summary of the results. To follow the guide of Table 3, the red color is considered as a high number or an aspect the authors must be concerned, the dark green is related to the objective, meanwhile the light green means that the objective have been surpassed and the yellow color is considered as a number not to worry about and in some cases reduced but not at the level of the objective. All this is shown in Figure 7.

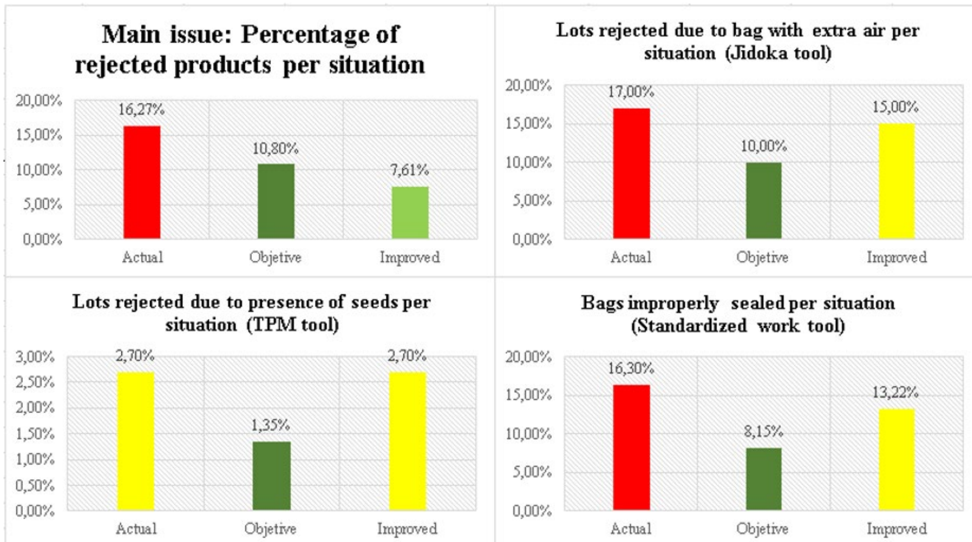

Figure 7. Visual summary of the results.

5.3 Proposed Improvements
Knowing that there is lack of research where tools, like Jidoka, TPM and Standardized Work, are compacted, this article would serve to expand knowledge about the use of those tools in the food sector, it could serve as a reference for other similar processes, such as the preparation of jams or fruit puree that usually implement machinery like the fruit pulp process. It should be noted that the way in which the tools have been put together is not intended to reduce time, but rather to distribute time by removing unnecessary activities (using Standardized Work) to give those minutes or seconds to more relevant activities and effectively perform a reduction in rejected products. To achieve a good outline of the process, it is necessary to maintain constant communication with the managers in charge of the production area through an intermediary that ensures requests for information. It must be considered that factories are not always enabled for external visits due to different reasons, having said that, it is also important to request the availability of those who provide the data so that the process is clearly explained in case it cannot be fully seen.

6. Conclusion
After having applied the simulation and having carried out the respective analysis, it was possible to reduce through the proposed model with the respective simulation, the percentage of rejected products, starting with a percentage of 16.27% up to a value of 7.61%.

Likewise, it was possible to achieve a decrease for the standardized packaging processes which were established so that there can be a considerable reduction in defective products from this operation, it can be noted that there was an improvement from a value of 16.30% to 13.22% with respect to the percentage of bag improperly sealed.

In addition, it was possible to establish an adequate system for the revision after the weighing, resulting in an improvement from 17% to 15% in relation to the percentage of lots rejected due to bags with air. Finally, in the pulping activity, thanks to the fourth pillar of the TPM tool, it was possible to establish schedules for the inspection of the respective machine and thus solve this problem and prevent a presence from continuing to appear, however, the expected impact was not generated because the percentage of lots rejected due to presence of seed remained at 2.70%;

nevertheless, that number was not as high as the other indicators, thereby technically it was not as much of a matter as the others. Besides this fact, the TPM tool served to keep protocols for that activity specifically.

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