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Original Article

Minimization of Smashed Products in Sustenance Industries by Lean and Machine Learning Tools

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Abstract - *This study focuses on developing a solution to one of the main problems in the food sector, product deterioration, often due to poor inventory management, low turnover, and lack of shelf-life control, among other causes. Therefore, this study is based on the design of a lean inventory management model proposed to reduce the number of deteriorated products in an egg product company in Peru, based on the analysis of the problem within the company and the study of previous research. As a result, the proposed method uses the tools of Machine Learning, Material Requirement Planning (MRP), 5S, and First Extended First Out (FEFO), reducing the main problem by 65.57% and the demand forecast error by 47.21%, thus reducing one of the leading root causes of the main problem. Thanks to this improvement, this research can contribute knowledge so that other companies with similar issues can implement the model and improve their results.*

Keywords - *Lean manufacturing, Machine Learning, 5S, MRP, FEFO, Smashed products, Protein food industry.*

1. Introduction

In recent years, egg production has increased worldwide, with the United States and China being the primary producers of these products. Likewise, according to experts, the consumption of these products could continue to increase over the years, as can be seen in Spain, where the sector has grown in size in recent years owing to the development of new egg products for different types of food preparations, which has caused an increase in competition in the country [1]. Peru's food and beverage sector accounts for 26.2% of manufacturing Gross Domestic Product (GDP), representing approximately 3.7% of the national GDP [2]. In addition, the size of the egg market has increased annually by around 7% over the last five years [3]. The main products found among egg products are whole eggs, egg whites, or yolks in liquid, frozen, or powdered forms. These products mainly include sauces, pasta, confectionery, pastries, bakery products, and ice cream [4]. As these products are related to the food sector, taking specific precautions to produce and store them is essential. In addition, according to a report published by The United Nations Food and Agricultural Organization (FAO), one-third of the food produced becomes part of the global waste mainly due to distribution and storage due to many problems that can precede poor inventory management, such as the evaporation of products, expiration, bacteria, chemical damage, and drastic temperature changes [5].

According to the literature, deficiencies in the sector are evidenced by incorrect forecasting methods, inefficient inventory management, and inadequate storage of products. In one article, we find that after a thorough analysis, it is concluded that the company's low profitability was due to its poor inventory management [6]. Another company had a central problem: the need for proper storage management and supply administration, which caused a high percentage of deteriorated products [7]. Likewise, another article also mentions that the highest rate of decomposed products is due to the low level of inventory management within the warehouse and, in addition, to problems in the demand forecasting system. In other research, we found that the need for more control in forecasting and inventories causes complications when facing a situation where increased demand causes additional costs and delays in the process. For all the reasons mentioned above, we can affirm that companies in the food sector have deficient management processes in their respective approaches, so solutions should be evaluated in the face of the problem.

In this respect, companies in the sector must achieve the correct control and management of each part of their processes to become more efficient and reduce deficiencies. For this research, an egg product company was chosen as a case study, which tends to have a high percentage of deteriorated products because of the raw material of its products and their short shelf life. The products that the company manufactures and sells are pasteurized liquid egg, pasteurized liquid egg white, and pasteurized liquid yolk; however, the products that generate the highest percentage of deterioration are the first two products mentioned because, unlike the third, these have a shelf life of five days from the time they are refrigerated, while the other can be kept frozen for up to one year. The leading causes of this problem were a deficient demand analysis process, inadequate inventory management, and errors in the picking process. To solve these problems, a Lean Inventory Management (LIM) model will be created, combining machine learning, MRP, 5S, and FEFO tools, specializing in products with a short shelf life.

2. Literature Review

2.1. Lean Inventory Management in the Food Sector and the Use of MRP

This methodology attempts to minimize inventory and the costs that may be incurred by improving efficiency in operations and seeking to implement optimal inventory levels that can be adapted to the actual demand of the company, thereby reducing costs, maintaining the company's competitiveness, and increasing market share [8].

A study of a Peruvian bakery company presented a rate of 11.43% defective production and more than 70,000 PEN penalties for noncompliance. This was due to inefficient inventory control and supply processes and the need for more standardization. For this reason, LIM tools have been used to improve inventory management, such as MRP, which increased the company's total profit by 4% by reducing the percentage of defective products from 11.43% to 6.67% [9], addition, in a study conducted in a company producing noodles that have overstock due to the delay in receiving raw materials, it was decided to implement an efficient inventory control system so that through an MRP could determine the necessary quantities to be requested for raw materials and when to do so to solve the problem of overstock [10].

In conclusion, the practice of LIM is very efficient within the food sector because of all the existing requirements; reducing waste helps provide a higher-quality product and responsiveness, which benefits. The supply chain can be streamlined and facilitated with an MRP. Better communication and coordination with suppliers are maintained when accurate information about requirements is provided, thereby reducing costs that reflect a higher profit [11].

2.2. 5S Methodology

In the food industry, productivity and quality methods must be continuously improved to maintain competitiveness, as customers demand short delivery times, product variations, and price reductions, in addition to controlling product shelf life [12]. The 5S tool belongs to the lean methodology category and is a set of practices for organizational improvement, productivity, and efficiency.

This tool promotes selection, which consists of classifying the indispensable elements for different activities, order that is based on the efficient organization of the material involved in the workspaces, cleanliness to keep the workplace tidy and clear, standardization that refers to maintaining procedures that promote the use of this tool, and discipline that refers to the commitment of the organization to create habits to preserve the use of this tool. Implementing this tool provides better teamwork, greater productivity and efficiency, a better workplace, and coexistence [13].

In a study of a Peruvian company that aims to reduce waste generated in the production of processed potato bags that have difficulties with noncompliance and inefficiency of the operator, quality losses, labour imbalance, and long waiting times, the use of lean techniques such as 5S through signalling, cleaning, and organization of the work area was proposed. The process efficiency increased from 59% to 74%, and the yield of raw materials entering the production process improved from 79% to 89% [14].

It is concluded that the absence of a management tool in the food industry and, in general, as 5S can produce many unproductive times, the inefficiency of operators, low-quality processes, increased risk of accidents, disorganization, and neglect of the work area, which causes noncompliance of orders, low customer satisfaction, and lower profit. Therefore, it is essential to use systems that streamline and improve these factors to make a company sustainable [15, 16].

2.3. Machine Learning and Demand Forecasting Application

In the food industry, companies are highly competitive, so it is essential to have an efficient demand forecast, as it will allow streamlining of the supply chain, have less unproductive times, and allow estimating costs, investment, and profit [13, 14]. A good demand forecast is essential for production planning, as it can manage the inventory of raw materials and avoid a shortage of products or overproduction; it also helps to make long-term decisions by identifying demand trends, which can be achieved through machine learning techniques [17, 18].

In the case study of the meat products company in which for the demand forecast, a 4-week moving average is used for each product, although the most recent data should provide us with more important information, it should not be the only thing to be analyzed; therefore, an exponential smoothing demand forecast based on a weighted average of the time series provides more significant weight to the most recent information without leaving out the previous one in which a lower error was obtained, similar to the Autoregressive Integrated Moving Average (ARIMA) model [19].

Demand forecasting can be beneficial if it is performed with an appropriate method with which the demand can be represented, including seasonality trend changes, and this allows for better decisions in the face of any unforeseen event. It also helps inventory control and production planning, and this is reflected in the increase in the company's profit; however, if it is done in a non-representative way, it could also cause deficiencies in the supply chain and inventory management, so it is recommended to perform with studied tools such as Machine Learning tools (ARIMA, exponential smoothing), as these take into account historical sales with seasonality weightings [20, 21, 22].

2.4. FEFO Methodology

In many cases, the food industry is characterized by high inventory turnover due to the short shelf life of products. There are annual losses of 1.3 million tons of food, which in monetary value is approximately 1 trillion per year, which could feed 2 billion people, so a methodology that optimizes the rotation of these is needed to avoid losses due to deterioration of products or raw materials, such as FEFO [23, 24].

This method is because the products with the closest expiration date are sold or used before those with the farthest expiration date. With the implementation of this method, the products or inputs are ordered such that those that are closer to expiring than the rest are at a better reach to ensure their consumption, considering before if the type of product fits more with the FEFO or FIFO "First in First Out" method, which is based on the first products to arrive, are those that are sold first [25, 26].

In a study by a grape company, the reasons that altered the variability of shelf life were analyzed. It was determined that fruits such as strawberries had a reduction in deterioration and quality loss from 37% to 23%. It was deduced that using the FEFO methodology instead of FIFO is necessary in this company because, in this case, it is not essential to the order of arrival of the products but the shelf life of the products.

Therefore, the factors affecting the grapes' shelf life, such as humidity and temperature, were studied to calculate and organize the grapes for the FEFO method [27]. The use of FEFO is crucial in the food industry because the quality and safety of the products can be altered over time, resulting in the loss of their properties. To prevail in this industry, providing quality food for better customer acceptance. To perform this method, it is necessary to consider whether the product meets the requirements to apply it that has to go hand in hand with LIM tools such as 5S so that the process is more straightforward and more orderly in addition to an adequate demand forecast, which is the basis for determining inventories and production planning [28, 29].

3. Innovative Proposal

3.1. Fundamentals

The proposed model was developed to reduce the expenses incurred by the high percentage of deteriorated products, thus increasing the company's net profit. For this purpose, the analysis of articles related to the case study was carried out, obtaining, as a result, different methodologies, models, and tools that will serve as a guide for the project. The literature highlights the use of the LIM model, which emphasizes using specific tools to eliminate problems such as high inventory storage costs, large amounts of waste, high values of defective or deteriorated products, warehouse disorganisation, and process delays [30, 31].

Despite the similarities found, some tools that are not required are mentioned owing to differences in the characteristics of the case. The selected company, belonging to the food sector, manufactures products with a short shelf life, which is one of the main factors of the problem; therefore, more closely related tools should be used. Therefore, as a proposal, the tools analysed in the literature review were combined to implement a new LIM model that focuses on reducing the percentage of product deterioration, considering the main factor of shelf life.

3.2. Proposed Model

The proposal was based on an analysis of literature with similarities to the case study, from which the tools most closely related to the characteristics of the problem defined in the problem analysis were obtained. The most outstanding model was Lean Inventory Management; however, because it did not present any policy or methodology related to inventory management according to its useful life, one of the main shortcomings of the case study, it was necessary to investigate other methods that could be implemented. Consequently, new tools are integrated, focusing on each cause determined in the problem tree to form an efficient new model to achieve the proposed objectives and facilitate continuous improvement.

To develop the model, the Deming cycle technique or Plan, Do, Check, and Act (PDCA) cycle was used to delimit the process into four phases or components that allow the company to maintain the focus of continuous improvement. Figure 1 shows the phases to be followed and their respective tools used.

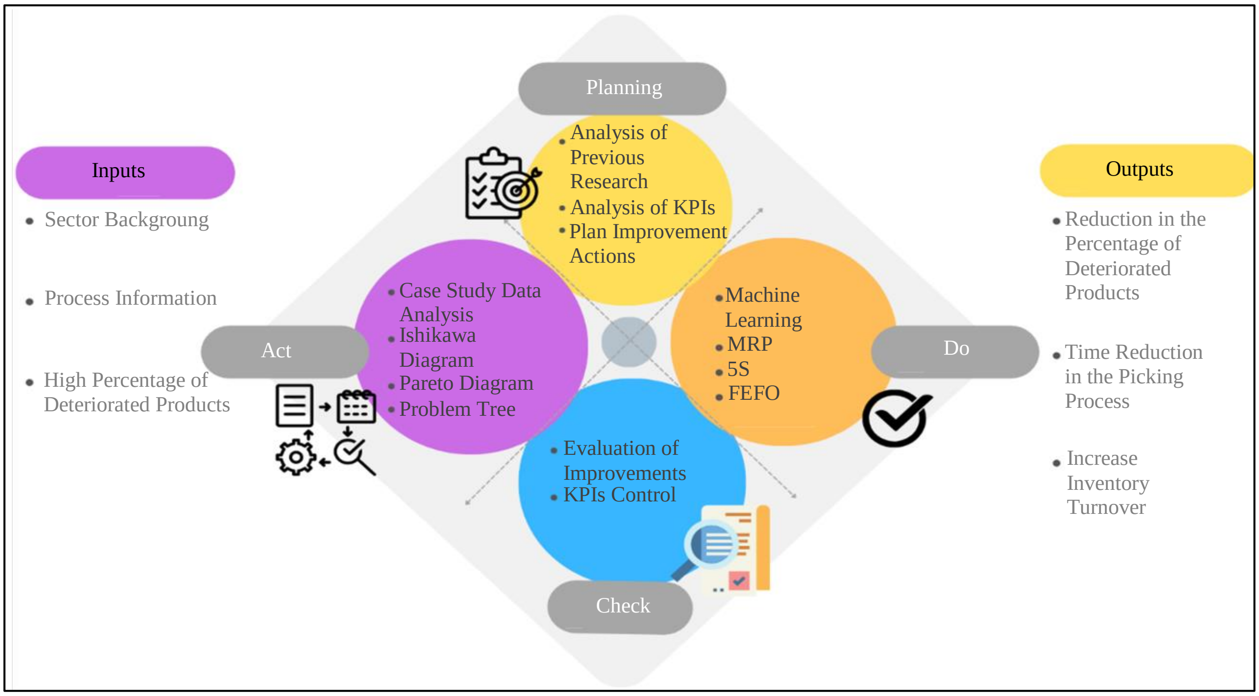

Fig. 1 Proposed model

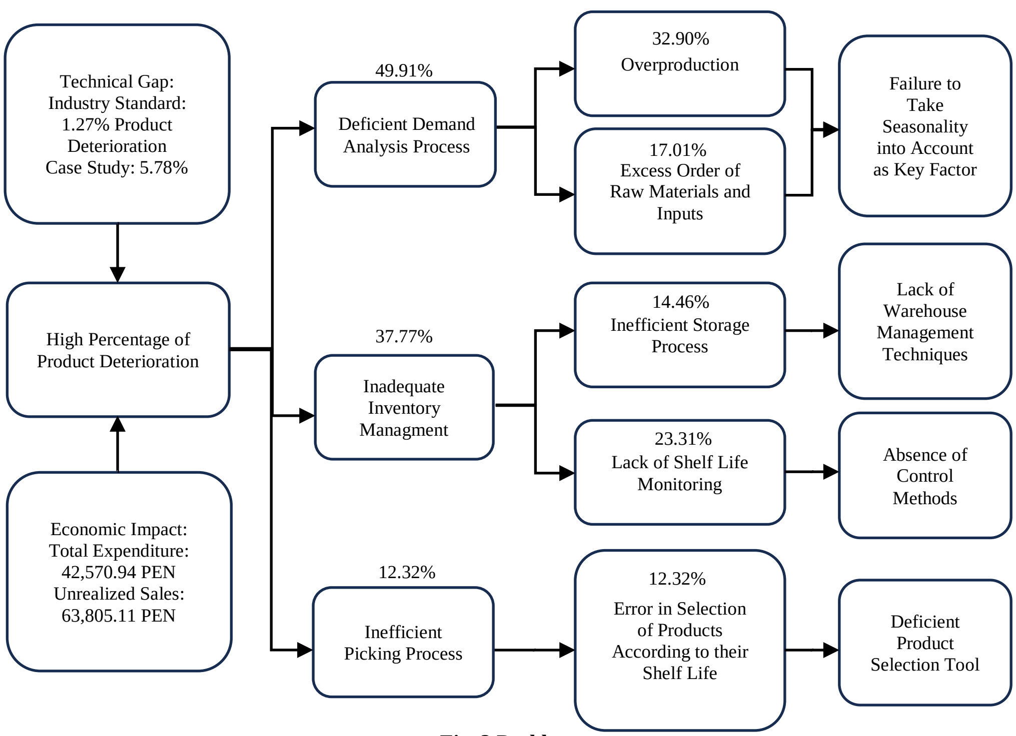

Fig. 2 Problem tree

3.3. Components of the Model

3.3.1. Phase 1: Act

In this phase, the inputs were considered for the problem analysis. First, we began by collecting the current data from the case study to study them and distinguish the primary deficiencies in their processes. Subsequently, their respective causes and sub-causes were explicitly identified based on the Ishikawa and Pareto diagrams. In addition, the problem-tree tool was used to summarize the highlights of the analysis of the resources mentioned above. The following is a diagram of the problem tree shown in Figure 2.

3.3.2. Phase 2: Planning

As part of the continuous improvement process according to the PHVA technique, the next phase was to plan the procedure to improve the analyzed problem. To do this, we studied previous research, which helped us find methodologies, tools, and models to guide planning actions for improvement. We also evaluated the objectives to be met and controlled by analyzing KPIs indicators.

3.3.3. Phase 3: Do

This phase focuses on applying tools to solve the identified problems. The model was implemented in the following order: Demand forecast, MRP, 5S, FEFO.

Machine Learning

To improve the problem of overproduction that causes the deterioration of products and, in turn, makes the company's processes more efficient, demand forecasting was used as a tool, taking into account its use of the machine learning technique, which for its implementation requires the collection of data, mainly the history of past sales, and the selection of specific characteristics to achieve a more accurate demand prediction [32].

MRP

As a second tool, MRP or Material Requirement Planning is used to improve the management of raw materials, mainly to prevent the creation of excess orders and to create efficient planning. For its implementation, it is necessary to use a computer tool to create a planning table where the inventory register, quantities required, order time, time of reception, and respective safety stock are indicated [33, 34].

5S

For the implementation of this tool, the lack of ordering techniques that the company had in its respective raw material and input warehouses and the finished product warehouse was considered. The steps to be followed are the following 5S: [35]

- Seiri (Sort): Remove and clean everything unused or used from the space.
- Seiton (Give an order): Prepare items to be placed and identify them so that it is easier to arrange them according to a particular place.
- Seiso (Clean): To provide cleanliness to the items in the area regularly, not allowing clutter to be created or irregular items in the area.
- Seiketsu (Standardize): Documenting and standardizing the created order method and communicating and promoting it in the respective process activities.
- Shitsuke (Sustain): Maintains the procedure and provides audits and control to promote the continuity of the 5S.

FEFO

As a fourth tool, we have the FIFO method, which is an improvement to the problem of lack of control of the valuable life of raw materials and inputs, as well as to improve the error in the picking process of the company.

The management of this method consists of using the products with the shortest remaining shelf life, that is, the closest to expiring [36].

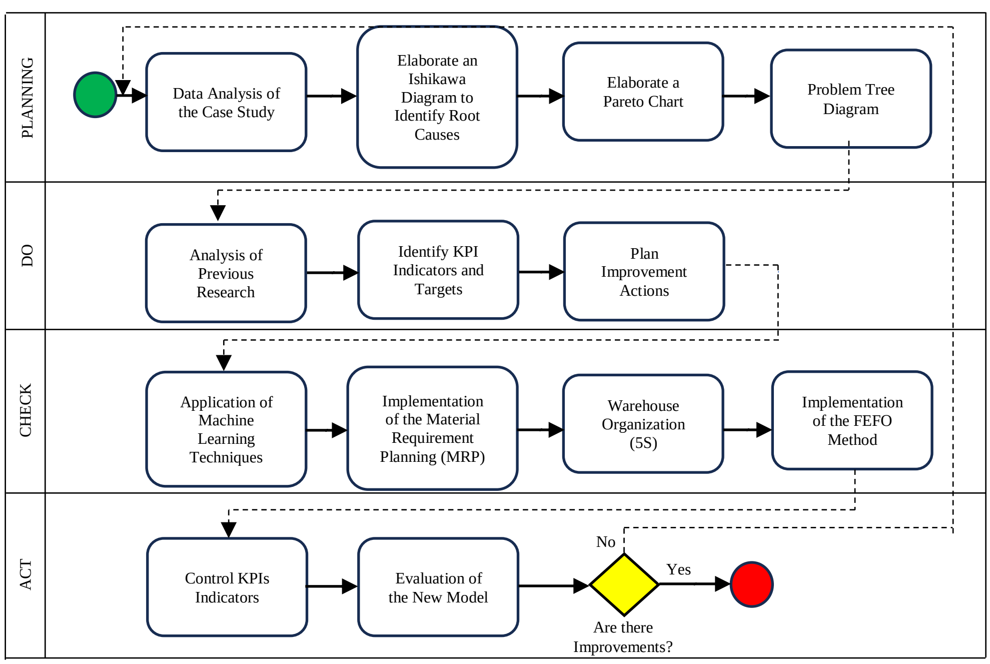

Fig. 3 Proposed process

3.3.4. Phase 4: Check

In this last phase, as part of the PDCA cycle, the respective verification was performed, in which the control of the KPIs indicators and the individual evaluations of the improvements were considered to ensure the efficiency of the newly implemented model. Some tools, such as 5S, have an audit method as the control process, whereas others, such as MRP, are based on the control of indicators.

3.4. Proposed Process

The model was based on the process presented in Figure 3.

3.5. Indicators of the Proposed Model

To monitor and control the improvements achieved after implementing the proposed tools, the following indicators were used to measure them.

3.5.1. Index of kg of Deteriorated Products

This gives the percentage of decomposed products out of the total amount produced and presented in Equation 1.

$$f\ kg\ of\ Deteriorated\ Product = \left(\frac{Kg\ of\ Deteriorated\ Product}{Kg\ of\ Production}\right) \times 100\% \quad (1)$$

Objective: To reduce the rate to less than 3%.

3.5.2. Demand Forecast Error

This indicator shows the margin of error of our demand forecast, is presented in Equation 2.

$$Forecast\ error = \left(\frac{|Demand\ forecast - Actual\ demand|}{Actual\ demand}\right) \times 100\% \quad (2)$$

Target: Keep it at a maximum of 5%.

3.5.3. Turnover Rate

This will help us understand how much our inventory rotates, is presented in Equation 3.

$$Turnover\ rate = \left(\frac{Sales\ per\ period}{Average\ Inventory}\right) \quad (3)$$

Objective: Increase the rate.

4. Validation

This chapter of the research work aims to validate the proposal's implementation. For this purpose, the implementation development of each previously selected tool was described, the system was evaluated using the Arena software and the Input Analyzer tool, and the results were presented.

4.1. Machine Learning

The SARIMA model was chosen for demand forecasting, and a Machine Learning model was used to analyze and predict the time series. With this method, autoregression, moving average, and integration components are mixed with the calculation of the trend and seasonality of the time series, allowing forecasts to be made that fit the model considering the history and repetitive patterns.

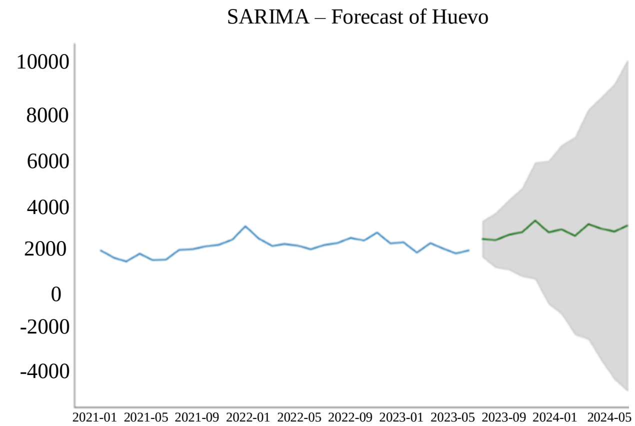

Fig. 4 Forecast of pasteurized egg whites

Table 1. Pasteurized egg whites forecast

Date	Forecast
2023-06-01	5388.288500
2023-07-01	5494.948991
2023-08-01	5622.572315
2023-09-01	6217.351473
2023-10-01	6437.852737
2023-11-01	6396.735608
2023-12-01	6368.132797
2024-01-01	5956.102855
2024-02-01	5356.496452

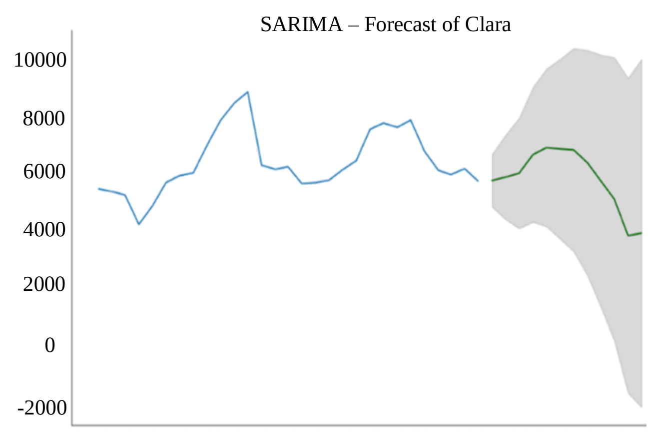

Fig. 5 Forecast of pasteurized liquid egg

Table 2. Pasteurized liquid egg

Date	Forecast
2023-06-01	2178.290584
2023-07-01	2120.407587
2023-08-01	2363.398429
2023-09-01	2484.230209
2023-10-01	3003.643928
2023-11-01	2475.605170
2023-12-01	2606.197544
2024-01-01	2316.246784
2024-02-01	2844.523057

To model the demand forecast, it is necessary to check the seasonality of product sales, for which the time series of the products to be analyzed is used in the SARIMA model. The following tables and figures show the implementation of demand forecasting using the Machine Learning tool (Figure 4, Table 1, Figure 5, and Table 2).

Using the forecast obtained, we calculated the model's error by comparing it with the eggs and egg whites sales. The result of the calculation was 3.88%, whereas before the forecast, it was 7.32%.

4.2. MRP

Implementing this tool will significantly help the company because it currently needs a supply and management plan for materials and supplies. To obtain the necessary items for production, the person in charge of the respective area orders large quantities in short periods owing to the shelf life of the products; however, not all products have the same shelf life, which often leads to excess inventories and their deterioration. Therefore, it is necessary to use tools such as MRP to provide programming and order to their orders.

For the simulation of the MRP tool, the raw material, eggs, was considered the material with the shortest shelf life and most frequently ordered by the company. It should be noted that the company usually orders the product when needed because there is no current plan. To create the plan, we used the demand for June, safety stock, and inventory amount available before the month's beginning.

Table 3 shows a sample of the first seven days with the MRP tool. As can be seen, the daily requirement was 383 kg of eggs to fill the orders that arrived in June. This amount was calculated based on the monthly demand, with an additional 10% of the product requested for product loss divided by the days worked during the month, which was 22 days. An essential fact of eggs available at the end of May was 1,530 kg.

For the scheduled reception, it was considered that the suppliers that worked with the company took three days to deliver the product, so the amount of 1100 kg of order was calculated, including the additional 10% of the product. With these values placed in the MRP table, the fluctuation in the available quantities of the product can be evidenced, achieving that by requesting an amount of 1100 kg every three days, most of the product is used, obtaining greater efficiency in inventory turnover, and maintaining its shelf life under control. As a result of the simulation of the 22 working days, a rotation index of 6.56 was obtained, an improvement over the previous month when 4.64 was calculated.

4.3. 5S

4.3.1. Pilot Plan

To implement the 5S tool in the raw materials and supplies warehouse, as well as in the finished products and chemical products warehouse, a pilot plan was considered to help us demonstrate possible improvements.

The main objective of the test is to reduce the time spent searching for products and to obtain a more organized place where operators can efficiently perform their functions because disorder usually causes errors in inventories and their respective shelf lives.

4.3.2. Initial Audit

Before the implementation, an audit was conducted to analyze the warehouses' initial state and the main points to improve. As a result, the following graph was obtained, in which the evaluation of the 5S can be observed, in which improvement is most needed; in this case, the first S is the one that mainly needs improvement. The initial evaluation results are shown in Figure 6.

Table 3. Egg supply scheduling using MRP

		Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Requirements		383	383	383	383	383	383	383
Scheduled Reception		0	0	1,100	0	0	1,100	0
Quantity on Hand	1,530	1,147	764	1,481	1,098	715	1,432	1,049
Purchase Plan		0	0	1,100	0	0	1,100	0

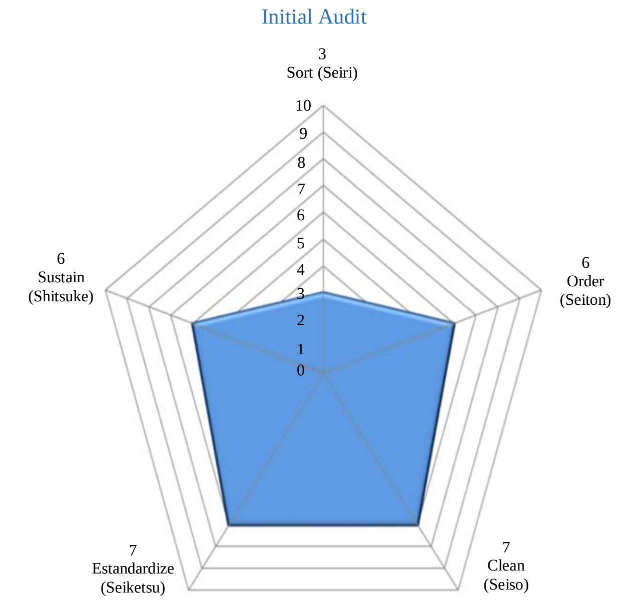

Fig. 6 5S initial evaluation results

4.3.3. Implementation

Seiri - Sort

As a first step, we classified the materials to be organized, so we proceeded to remove each input, material, or product from its current location to count them, identify their expiration date and frequency of use, and then begin to evaluate their new location. For this purpose, labels were used for visual support and to note possible observations as required.

Below are the images of the initial situation of each warehouse before starting the implementation (Figures 7, 8 and 9). The three warehouses are without any classification or respective labels for each product.

In addition, it is worth noting that the materials and supplies are in the same production area, close to one side, despite having the raw material and supplying warehouse parallel to the area (Figure 10).

Fig. 7 Initial situation of the raw material and supplies warehouse

Fig. 8 Initial situation of the finished goods warehouse

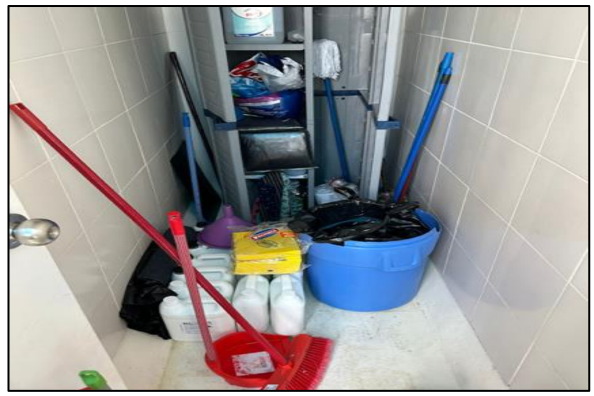

Fig. 9 Initial situation of the chemical warehouse

Fig. 10 Initial situation production area

Seiton - Order

In this activity, we arranged the warehouses according to the evaluation of products made in the classification previously carried out.

The raw material and input warehouse used were of different sizes to store large quantities of components, so they were primarily accumulated in the production area.

Hence, the staff indicated another area destined for a new warehouse. Thanks to this, we can collect the products from the production area and start sorting them in the new location. In addition, yellow tape was used to delimit the spaces where the pallets were placed, and labels were placed to classify the products better.

On the other hand, an area with red tape was placed where the products with shelf life soon to end would be located so that they would be selected before those with more time. This order is achieved if there is constant control over the products entering the warehouse and their shelf-life periods. This is illustrated in Figure 11.

Fig. 11 Improvement of the raw material and supplies warehouse

The products were redistributed to the finished product warehouse according to shelf life. It was suggested to continue using the order from right to left to control the entries to the warehouse and make it easier to locate the products that had just entered because they were located wherever they could reach, making it difficult to search for products and causing delays.

In addition, some elements, such as baskets that hindered product selection, were removed. This is illustrated in Figure 12.

Fig. 12 Warehouse improvements for finished products

Finally, in the chemical warehouse, the products were organized according to their use on shelves found in the space. In addition, classification labels were placed for each product, and items that should not be located there, such as garbage cans, were removed. This new order made it easier to enter the warehouse. This is illustrated in Figure 13.

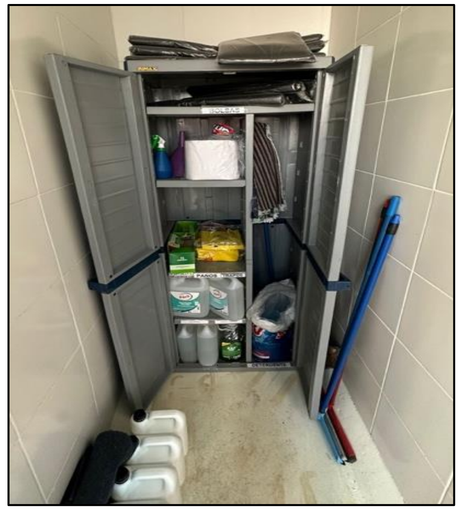

Fig. 13 Improvement of the chemical warehouse

Seiso - Clean

In the third activity, despite the cleaning program, with the help of the cleaning team, the entire warehouse area was cleaned and disinfected.

This step is crucial, not only because of the organization of the warehouse but also because when using food materials and supplies, it is essential to maintain high levels of cleanliness in the storage areas, thus reducing the risk of contamination, bacterial growth, and even pests.

Seiketsu – Standardize

In the fourth step, didactic material was produced, which mentions the need to keep the respective warehouses organized and clean and the rules and instructions to be followed when performing any function within the warehouses. Training was also provided to explain the procedure and its importance. This is shown in Figures 14, 15, and 16.

Shitsuke - Sustain

As a final activity, a training schedule was established on maintaining order and cleanliness and continuing with the 5S methodology.

In addition, a discussion was held with the housekeeping area to improve control over the use of warehouses so that order and cleanliness could be maintained. We also discuss the correct management of inventories.

Fig. 14 Didactic material in the raw material and supplies warehouse

Fig. 15 Teaching material in the finished product material warehouse

Fig. 16 Training material in the chemical warehouse

4.3.4. Final Audit

Four weeks after the implementation of 5S, a final audit is conducted to evaluate the state of the warehouses. Some operators indicated that maintaining order was complicated during the first few days of implementation. However, placing them in new locations was easy when new materials arrived, encouraging them to maintain the classification.

In addition, training was conducted during the second week to indicate some rules and communicate the importance of maintaining order and cleanliness in the company, especially in the areas where the food is. It was controlled more frequently than the areas that were kept clean. No dirt was found on the floors as in the initial evaluation. The results of the final audit are shown in Figure 17.

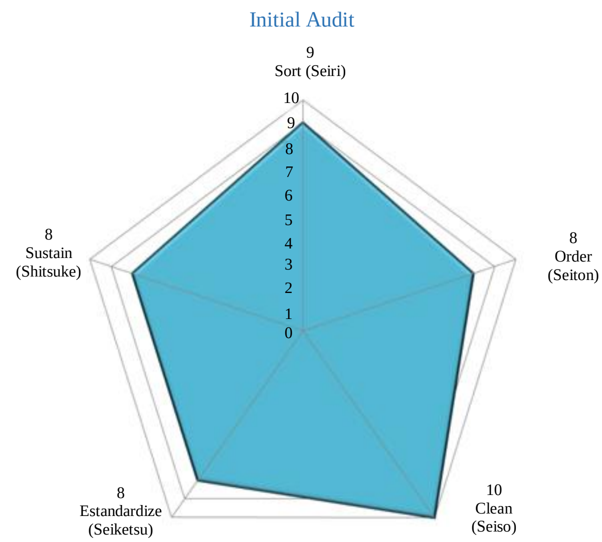

Fig. 17 5S final evaluation results

To contribute to the implementation analysis, Table 4 compares the results of both audits and the expected objective.

Table 4. 5S implementation results

Type of S	Initial Audit	Objective	Final Audit
Seiri – Sort	3	10	9
Seiton – Order	6	10	8
Seisou – Clean	7	10	10
Seiketsu – Estandardize	7	10	8
Shitsuke – Sustain	6	10	8
Total	29	50	43

4.4. FEFO

For the implementation of this method, the operators who assembled the orders were trained on the benefits of using this new method. It should be noted that most of the time, they used FIFO as a tool, but they had several inconveniences because the essential thing to consider when working with food is the shelf life of the products. In addition, with products from different suppliers, their expiration dates are different, so selecting the first to arrive could have been more efficient. To use FEFO, the expiration dates and shelf life of all the products to be used, both materials and inputs, as well as finished products and chemical products, must be controlled, and the 5S tool helped in its implementation, promoting a more orderly rotation of products.

4.5. Simulation in Arena Software

Arena software was used to validate the process simulations. As required data necessary for the effectiveness of the simulation, values such as the product picking time, order assembly time, and incoming order values were taken. The simulation model is shown in Figure 18. Next, the replications for the simulation in Arena were calculated using Equation (4), as presented below.

$$N = No \times \left(\frac{ho}{h}\right)^2 \tag{4}$$

Two runs were carried out for better results, the first with 10 replications, obtaining a half-width value of 166.86. Using the formula, we received a mark of 220 replications, which will be used as data to conduct the analysis again. This is evidenced by Equation 5.

4.5.1. First Run

$$N = No \times \left(\frac{ho}{h}\right)^2 = 10 \times \left(\frac{166.86}{35.6}\right)^2 \tag{5}$$

$= 220$ replications

4.5.2 Second Run

Finally, with 220 replicates, a half width of 57.54 and a confidence interval of {344.4, 459.5} were obtained. It was confirmed that the average monthly quantity of deteriorated products in the previous year was 356, which validates the simulation performed within the interval.

4.6. Results

Finally, after implementing the tools and simulation in the Arena software, the results of the indicators are presented in Table 5.

Table 5. Results of indicators

Indicators	Actual	Improvement	Percentage Change
% Deteriorated	5.78%	1.99%	- 65.57%
Demand Forecast Error	7.35%	3.88%	- 47.21%
Inventory Turnover Rate	4.64	6.56	41.38%
5S Audit	29	43	48.28%
Picking Process Time	9.39 min	6.43 min	- 31.52%

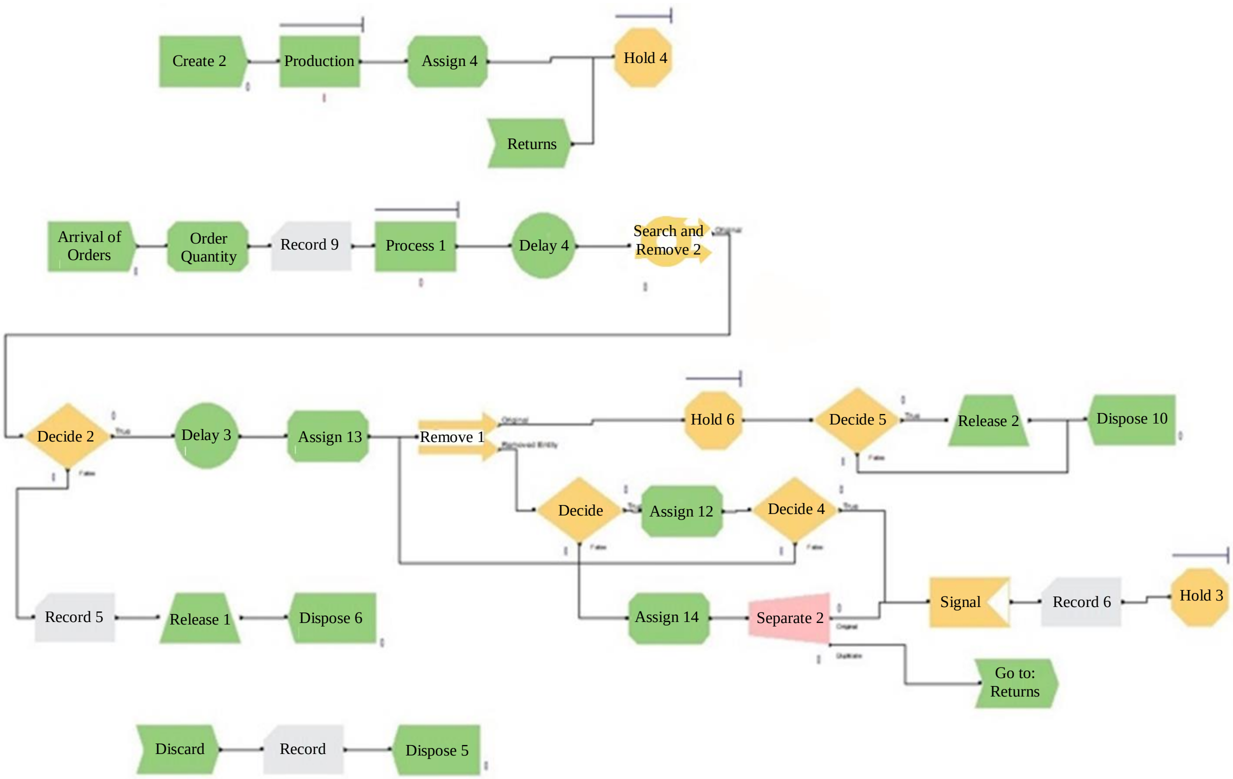

Fig. 18 Simulation model

Table 6. Comparative table of results

Indicators	Actual	Improvement	Scenario 1	Scenario 2	Scenario 3
% Deteriorated	5.78%	1.99%	2.1%	1.88%	1.9%
Demand Forecast Error	7.35%	3.88%	3.88%	3.88%	3.88%
Inventory Turnover Rate	4.64	6.56	8.97	8.85	11.74
5S Audit	29	43	43	43	43
Picking Process Time	9.39 min	6.43 min	6.43 min	6.43 min	6.43 in

5. Discussion

As a final analysis of the research, three additional scenarios were evaluated in addition to the month selected for the simulation, June, which resulted in values that can demonstrate the proposal's effectiveness.

It should be noted that for all scenarios, some values obtained in June were maintained, such as the demand forecast error, the 5S audit, and the times improved owing to the 5S because it is estimated that they will be held in the following months or will continue to improve with activities carried out by the personnel, as is the case with the 5S.

Table 6 presents the results of the three simulated scenarios after the simulated improvement in the company's current situation. The percentage of deterioration continues to decrease despite fluctuations in the demand forecast.

Moreover, the effectiveness of the MRP tool is confirmed because it keeps increasing the inventory turnover rate, adequately maintaining the monthly demands, programmed receptions, and available quantities. [37]

5.1. Analysis of Results

As shown in Table 7, the primary indicator of the research, the percentage of deteriorated products decreased by more than 63% in the three-month scenarios, with an average deterioration of 1.96 %.

The forecast error remains constant because it is obtained from the same model and is calculated using the actual demand. However, the inventory turnover rate increases as the scenarios pass, ending with a rise of 153.02% over the current model.

Finally, the 5S audit score and picking process time remained constant, with increases of 48% and reductions of 31.52%, respectively. Although the 5S audit score did not reach 50, it is a significant improvement that can increase if they apply continuous improvement with the tools provided.

Table 7. Comparative table of percentage variation of the scenarios with the current model

Indicators	Scenario 1	Scenario 2	Scenario 3
% Deteriorated	- 63.67%	- 67.47%	- 67.13%
Demand Forecast Error	- 47.21%	- 47.21%	- 47.21%
Inventory Turnover Rate	41.38%	90.73%	153.02%
5S Audit	48.28%	48.28%	48.28%
Picking Process Time	- 31.52%	- 31.52%	- 31.52%

5.2. Limitations

To contribute to this research, mentioning some limitations found during the process is necessary. The first was to obtain previous research on companies focused on egg products or food with a short shelf life; it is essential to research the most similar characteristics within the sector to find the necessary tools to use in the model.

However, it should be considered that when validating the simulation in the Arena software, the process to be simulated may vary. Therefore, although the variation may be modified to resemble the actual process, the accuracy of the simulation will only be partially correct because of different changes that may be found in reality owing to different external factors. Therefore, it is suggested to focus the process on a specific product and obtain all the necessary data to make the simulation as close as possible to the real one.

Finally, it is essential to consider that for the simulation or pilot of some tools, as in the case of the 5S methodology, it is necessary to have support personnel to carry out each step of the process as well as to carry out the audits and control of the same correctly.

Likewise, to implement these tools in the company, it is recommended that activities such as training and control programs be carried out to keep the implementation in operation and allow continuous improvement.

6. Conclusion

In conclusion, implementing the lean inventory management model proposal achieved its primary objective of reducing the percentage of deteriorated products of the company, with a value of 65.57%. This significant improvement for the company could be achieved using the following tools: demand forecast, MRP, 5S, and FEFO, in addition to the support of Arena software for validating the simulation.

Likewise, the research also provided evidence that the root causes of deterioration were overproduction (32.9 %), lack of control of raw material shelf life (23.31 %), excess raw material and input orders (17.01 %), inefficient storage processes (14.46 %), and errors in product selection in the picking process (12.32 %).

Based on the analysis of root causes and previous research, it was possible to identify tools to achieve each indicator's main objective and expected improvement. Each device supported the progress of the main problem and was a continuous improvement initiative for the company.

With the aid of the demand forecast, the proposed lean inventory management model improved the error from 7.35% to 3.88%. Meanwhile, the MRP achieved a 41.38% increase in the inventory turnover rate. Implementing 5S significantly increased the final audit, obtaining a score of 43. Additionally, 5S and FEFO improved the picking process time by 31.52%. Finally, it was confirmed that the model allows continuous improvement in the company, with significant results in the three scenarios presented.

This not only allows us to prove the effectiveness and efficiency of the proposed model but also contributes to the knowledge and allows other researchers with similar problems to use this article as a reference.

6.1. Future Work

Future work on this research could include the following.

Conducting long-term monitoring of the implementation of the proposed improvements at the company to assess their effectiveness over time and adjust if necessary.

The possibility of using more advanced machine-learning techniques to improve demand forecasting accuracy and optimize production planning.

Explore the application of other lean tools in addition to the 5S methodology to further improve the efficiency and productivity of the company.

Conduct a cost-benefit analysis to assess the economic impact of implementing the proposed improvements and determine if they are cost-effective in the long term.

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