

Optimizing OEE in a Peruvian Fishmeal Factory Through TQM, TPM, and Standard Work: A Case Study

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Abstract – The Peruvian fishmeal industry faced persistent challenges from machinery failures, process variability, and lack of standardization, which limited its competitiveness. While previous studies explored TPM, TQM, and Standard Work individually, few addressed their combined application in fishmeal production—an existing research gap. This study addressed that gap by developing an integrated model to optimize the production of “Super Prime” fishmeal. The intervention focused on increasing equipment availability, reducing reprocessing, and standardizing key operational tasks. After implementation, OEE rose by 7.12%, MTBF increased by 7.5 hours, and MTTR decreased by 6.3 hours. The share of Super Prime fishmeal improved from 5% to 12%, and the cost-benefit ratio reached 8.83. These results provide practical insights for process-based industries seeking to enhance product quality and operational efficiency under resource constraints. The study offers a replicable framework for the fishery sector and highlights the potential for increased profitability through coordinated quality and maintenance strategies.

Keywords: Process Optimization, Equipment Availability, Quality Indicators, Failure Analysis, Production Standardization.

1. Introduction

The fishing industry is one of the main drivers of the world economy thanks to the exports of the sector, the fishing activity is one of the oldest and includes two important variants, artisanal fishing and industrial fishing [19]. One of the most important sectors in the world is based on maritime resources exposed to climatic changes and exploitation, which leads to a dilemma regarding the actions of regulatory entities. Fisheries authorities have always faced a major dilemma in trying to find a balance between economic benefits and conservation [2]. By depending on a raw material that is not freely available all year round, but on the contrary requires that production be adjusted to the seasons when it is closed, companies in the sector face the challenge of mitigating existing problems in the production process to avoid the loss or degradation of the raw material. Quality problems in the Peruvian fishing industry are of vital importance due to their economic, social and environmental impact. A deficiency in the quality of the final product directly affects the competitiveness of Peruvian fishery products in the global market. Climate variability can produce displacements of anchoveta that can negatively impact the sustainability of marine resources [3].

In addition, in recent years the fishing industry has proven to be one of the main sources of employment generation through the production and processing of marine resources [20]. The production of fish flour and fish oil worldwide depends on the availability of anchoveta. This activity is highly exploited in Peruvian territory because it has a rich and extensive variety of species, among which anchoveta stands out [1]. In recent years, the destination of fishery products has diversified in terms of destination markets, with China remaining the main buyer. China stood out as the main recipient of fishery exports and has maintained its leading position from 2000 to 2022 [1].

Overfishing and inadequate management is another factor that weakens the sector's operations, as unsustainable fishing and inefficient practices impact the quality of the resource extracted and threaten the biodiversity of marine resources. Resource waste is a risk if operations are poorly managed in the production process, quality problems can lead to loss of raw material during processing or unusable products, which increases the waste of such a limited resource. International regulations are an important consideration as this product is mostly destined for export. Importing countries, such as the European Union and the United States, impose strict quality requirements; non-compliance leads to sanctions, refunds and export restrictions.

The objective of this article is to propose engineering tools that allow greater availability of machinery, a focus on chemical indicators for the generation of quality products and a standardization of the production process. The methodology includes key indicators such as OEE, MTTR, MTB. These indicators allow an evaluation of the proposed solution and the measurement of the model's potential for scalability in the fishing sector. For our case study, the sector gap represents the difference between the average production of “Super Prime” and “Prime” fish flour (quality of the final product with better chemical indicators) of the sector versus what is produced by the company under study.

2. Literature Review

2.1 Application of the Total Productive Maintenance tool (TPM)

Total productive maintenance is a methodology that involves the entire organization, promoting efficient management, productivity and team collaboration in all areas. This tool not only maximizes the effectiveness of the system but also improves the overall efficiency of the organization [8]. Among the pillars of the philosophy is autonomous maintenance, whose main purpose is to improve the availability of machinery by reducing existing failures through improvement actions using preventive and periodic routines, which also reduces costs derived from operational downtime caused by machine failures [10][11]. Another pillar is preventive maintenance, which aims to minimize unexpected, accidental and unwanted failures that are common in a production process. Carrying out adequate maintenance of production equipment helps to reduce its breakdowns, which translates into an increase in its productivity [11]. A study developed in a mass consumption food company, based on the measurement of OEE before improvement, 84%, shows how the authors identified the critical problems, the downtime obtained by machinery breakdowns that generated 35% of the waste in the production of type D cookies. After the implementation, it was possible to eliminate unscheduled stops, which consequently increased the OEE by 3.47% [9]. In another study conducted in a food industry company, to verify the quality of maintenance, they used indicators such as availability in 80.27%, MTBF in 7 080 minutes, MTTR in 12 hours and OEE in 68.63%. In autonomous maintenance, they decided to draw up maintenance, cleaning and lubrication schedules to be carried out by the operators themselves. Similarly, the plan for preventive maintenance was to schedule monthly and annual maintenance before using the machinery to ensure that there are no problems with its operation. Finally, to perform inspections and maintenance to reduce the downtime of the main machinery, the pasteurizer. After the improvement, the availability was at 83%, MTBF at 6700 minutes, MTTR at 17 hours and OEE at 71% [12].

2.2 Application of the Total Quality Management tool (TQM)

The TQM methodology is oriented to the continuous improvement of processes for services and products, its main objective emphasizes customer satisfaction. Its bases focus on decision making, collaboration, commitment to training, staff development and customer focus. Studies confirm a strong effect between TQM implementation and company performance [13][18]. Currently one of the main competencies is focused on meeting customer requirements, literature supports the effectiveness of the tool in generating business growth that enables the development of higher quality services [14]. Its application is identified as a main source at the time of obtaining a competitive advantage for both product and service industries, the search for continuous improvement focused on quality within organizations is the objective that summarizes the concept of total quality management, a tool that generates success and change in companies that result in a positive impact due to the set of practices focused on meeting customer expectations for better performance [14][17]. For the case study, fish flour production involves multiple factors within the production process that impact the quality of the final product. Product quality classification is done according to the range of chemical indicators that reveal the value of protein, TBVN (capture time), histamine, chlorides, sand, FFA and ash; high amounts of these components are the result of machinery unavailability, the human factor and lack of uniformity in the process.

2.3 Application of the Standard Work tool

Standardized work is a method that precisely details and documents the activities that operators perform following a specific and repetitive sequence within a task. This system helps to maintain uniformity and order in operations, minimizing variations in the process and establishing a benchmark to encourage continuous improvement [4][10]. The application of this engineering tool brings benefits such as the documentation of the process that is performed in the various shifts, the reduction of variability and accidents, as well as the implementation of dynamic training for new workers and the generation of an

optimal basis for the improvement of activities [5]. The visual tool used shows a set of specific instructions that every worker can access and that are necessary to perform a task efficiently [10]. In the flour production process, the parameters that are used in the cooking, pressing, and drying stations can be standardized to reduce the time variation caused by the operators during production. By scheduling training for new operators in the handling of the machinery with respect to the control of temperature, speed, pressure, amperage, among other variables. Also, the spaghetti diagram is used as a technique used to represent the movement of an object, such as a worker or material, within a system, such as a production area, a section of a building or a workshop. This is done by means of lines drawn on a specific plane, using different colors or styles to distinguish the different flows. This approach allows analysis of the length of the paths, the number of movements, the areas where they overlap or cross, and other relevant characteristics according to the categorization used. The optimized design should minimize the length of the lines and avoid excessive intersections [4]. In the production plant, it was sought that the personnel try to make the shortest route, and this is given with the help of standardization, since they no longer have to ask questions to the quality control department about the parameters.

2.4 Production models for improving Overall Equipment Effectiveness in the food industry

The Overall Equipment Effectiveness is an essential indicator to evaluate the performance of a process. This indicator considers equipment availability, calculated as the total time minus planned and unplanned breaks, the quality of the products generated, quantity of units in good condition, and the speed of execution in relation to the set target [12][15][16]. Its main advantage over other KPIs lies in the fact that it combines three independent factors into a single numerical value, recognized as a comprehensive performance indicator [9]. Food manufacturers usually focus on product quality, delivery times and costs to maximize their economic value in highly competitive markets. In this framework, the OEE metric proves to be a valuable tool to detect critical points and optimize both efficiency and quality in production lines. This study aims to apply the OEE approach to ensure continuous operations, since interruptions in a production line not only decrease productivity but also affect product quality [15][16]. From the reviewed literature, a comparison is presented between the classical OEE (AIM) and variants such as the fuzzy OEE, considered as the main uncertainty, the duration of stoppages and the speed losses in the edible oil purification process. The results obtained using fuzzy OEE reflect these uncertainties using a triangular membership function, together with uncertain values. Regarding this metric, an improvement of 3% in total availability, 2% in yield efficiency and 5% in quality rate was observed [16]. In another article consulted, it was shown how the OEE's increased in three of its machines, pasteurizer, homogenizer and cooling tank, after the implementation of the engineering tools, this indicator showed that the percentage improvement of the machines was between 2% to 4% [12]. Finally, a cookie manufacturing company sought to eliminate the impact of waste generated during the process. With an initial OEE of 79.6% in the first quarter, after the improvement made with the TPM tool, which directly attacked the problem, which was based on the adaptations of the equipment due to the rotary belt used, they were able to observe that after the implementation, the OEE increased to 86.7%, this percentage obtained was higher than expected, which was an increase of only 3% [9].

3. Methodology

The research was carried out using a quantitative approach and began with a research stage where the main objective was to identify the deficiencies in the production process and quantify them.

As shown in the figure 1, the findings collected during the research stage on the left side of the image, in the center of which the engineering tools proposed to combat the problems identified can be seen. The expected results after completion of the implementation are on the right side of the figure.

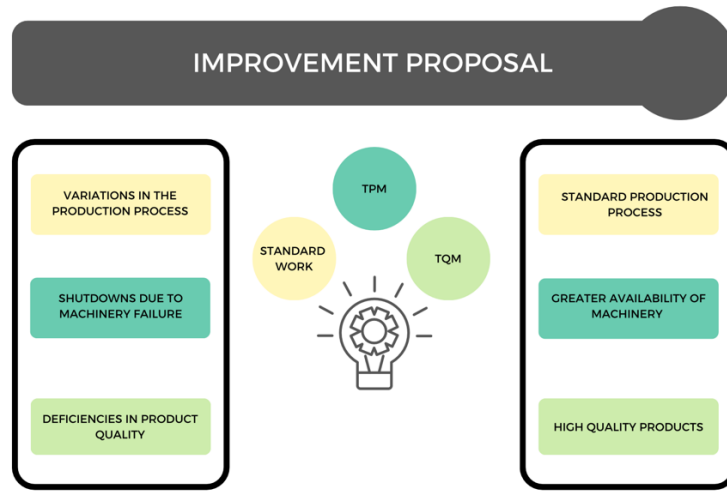


Fig. 1: Proposal for improvement

Fish flour is classified into five categories: Superprime, Prime, Taiwan, Thailand and Standard Steam according to the amount of protein, TBVN, histamine, chloride, sand, FFA and ash. The value of chemical indicators can be affected by unavailability of machinery, variability of operating parameters or poor execution of the task, since there are workstations that have a direct impact on quality: cooking, pressing and the three drying stations. It is therefore essential to align the availability of machinery to avoid waiting times and decomposition of raw material, standardize operating parameters to obtain similar batches in quality and reduce variability from one batch to another, and finally, focus on improving quality at all levels.

3.1 Pilot tests: Total Quality Management and Standardized Work

The Total Quality Management tool helps to combat the lack of commitment to meeting high quality standards and guides the approach to constant improvement. The initial proposal was developed with a training plan for the plant's administrative and operational personnel, reinforcing the training of temporary personnel who enter the plant during the high season and permanent personnel in direct contact with operations. In addition, quality circles were implemented to focus the production process on quality and encourage worker participation in the continuous improvement of processes. The quality circle is made up of workers from different levels and areas who meet frequently to identify problems, analyze causes and propose solutions. For better management and organization of the meeting, a data collection tool was developed, a report template that operators must complete when performing each of the activities, indicating the start time and end time of the activity, duration, stops and justifications for each downtime. Finally, an evaluation structure was designed that classifies the operators by level of knowledge so that the operation managers can assign the appropriate personnel to each activity.

In the case study, the production of fish flour involves multiple factors within the production process that affect the quality of the final product. The standardization of parameters used in the cooking, pressing and drying stations is intended to reduce the variation in production time generated by reprocessing. The training of new operators in the handling of machinery with respect to the control of temperature, speed, pressure, amperage, among other variables, is key to this objective. The logistics and time of a reprocessing for the fishing sector implies a very strong negative impact, because the additional time of the reprocessing generates degradation of the raw material and a fall of the chemical indicators. The spaghetti diagram was used as a technique to represent the movement of an operator within the system before making the implementations, the diagram visualized the multiple routes made by a single operator to perform its task, the justification was the consultations to the quality department for variations in raw material, reprocesses, etc. After standardizing the operating parameters under normal and contingency conditions due to variations in the raw material, a reduction in the number of routes was visualized, generating greater operational control.

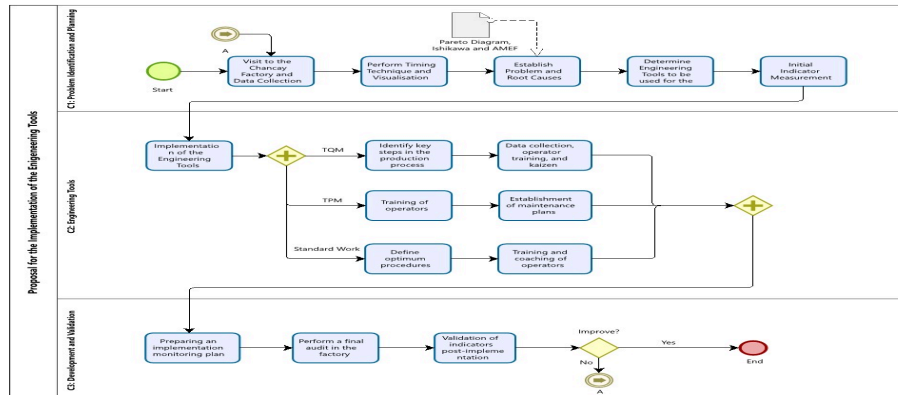


Fig. 2.: Process of the Proposed Model

3.2 Simulation: Total Productive Maintenance

To validate this work with the Total Productive Maintenance tool, the objective is to improve the OEE, and therefore, increase the availability and performance of the production process. Because of this, figure 4 shows the improved model used for the simulation using the Arena software, which aims to show the flow of raw material circulating between the tanks of each station of the fish flour plant. 12 machines are used in the production process, of which 3 were identified as generating losses, pre-strainer, presser and dryer 1.

The amount produced was 10,531 tons, which has been considered as data, and likewise the inoperative time of the machines varies in a range of 72 to 96 minutes. The total process has an approximate duration of 15.6 hours per arrival of raw material.

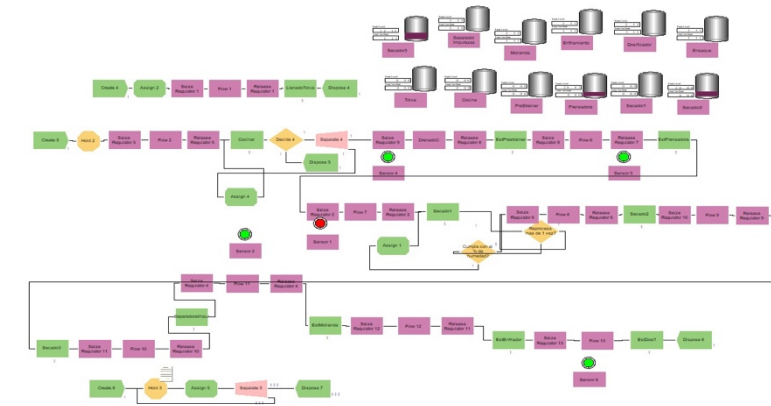


Fig. 3: TPM simulation model

The representative sample size is then calculated, for which the production of fish flour in tons for the last 5 years for each season was counted.

Table 1: Sample Size Data

Components	Description	Values
Z	Statistical parameter	1,96
S	Probability of the event success	0,5
E	Estimation error	0,05
N	Population size	10 531

$$n = \frac{(N * (Z)^2 * (S)^2)}{(N - 1) * (E)^2 + (Z)^2 * (S)^2} \quad (1)$$

$$n = 370,67 \approx 371 \text{ ton.} \quad (2)$$

Finally, it was determined that the sample size required for the work was approximately 371 tons. This is equivalent to 7400 bags of 50 kg of fish flour of various qualities. For this purpose, the quantities produced in the last 5 years that met the inclusion criteria were randomly selected.

4. Results

After implementation, an optimized design was obtained that minimizes the length of the lines and avoids excessive intersections. In the production plant, the objective was for the personnel to make the shortest possible route, with the standardization of the parameters it is possible to eliminate unnecessary routes and therefore a better concentration of the operator in the execution and monitoring of the task.

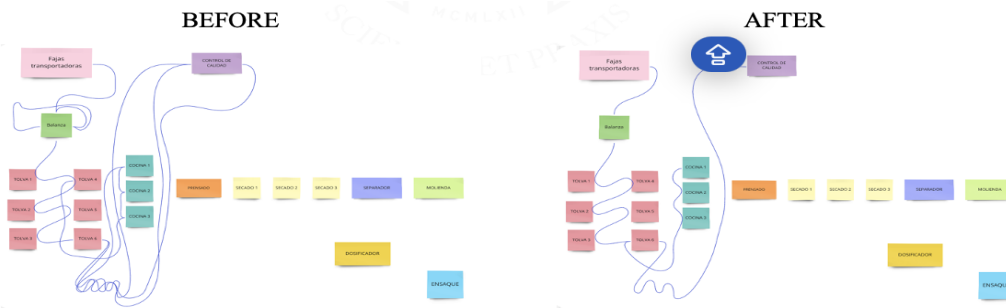


Fig. 4: Spaghetti Diagram

In Figure 4, we can see that the traditional tour of the workstations used to spend a lot of time in consultation with the quality control area to verify changes in the state of the raw material and the conditions of entry to each station. The image shows the route of an operator in charge of the baking activity.

To validate the result of the implementation of the TQM tool, an accounting of the resultant for each batch produced according to the quality classification was performed. Before the implementation, the average of fish flour produced in Super Prime quality was 5%, i.e. of all the fish flour obtained in a batch, only 5% corresponded to the expected quality. After the implementation was completed, the percentage increased to 12%, making it more competitive in the market.



Fig. 5: (a) Before Implementation (quality) (b) After Implementation (quality)

The table 2 shows the indicators used to corroborate the improvement through the implementation of the TPM tool. As can be seen, the mean time between failures increased by 7.5 hours, which also improves the availability of the machinery.

On the other hand, the mean time to repair was reduced by 6.3 hours, which means that machinery can be put back into operation more quickly if it breaks down.

Table 2. Results from the TPM simulation

Indicator	Unity	As Is	To Be	Improvement
Cycle time	Hours	18.72	16.90	1.82
Availability	Percentage	83%	88%	5%
Performance	Percentage	88%	92%	4%
OEE	Percentage	65.74%	72.96%	7.12%
MTBF	Hours/failure	32.63	39.78	7.5
MTTR	Hours/failure	9.53	3.24	6.3

Regarding Table 3, in the economic evaluation the results obtained show a positive NPV as well as a financial one. This indicates that the project is financially and economically profitable. In the financial aspect, having a benefit/cost of 8.83 suggests that for each sol invested, the project generates S/ 8.83 in benefits. While the value of 5.05 obtained from the economic point of view implies that for each sol invested, S/ 5.05 is received in benefits. The time needed to recover the investment is less than a year from the financial point of view and a little more than a year from the economic point of view.

Table 3. Economic and Finance evaluation

Indicators	Economic	Finance
NPV	S/ 66 867,09	S/ 77 557,72
IRR	121%	200%
Cost-benefit	5,05	8,83
Payback	1,19 años	0,68

5. Discussion

It is pertinent to mention that previous studies performed a diagnosis on the impact of TQM, TPM and Standard Work tools in various industries that have a production process, obtaining a better organizational performance in all cases. According to Thunyachairat, Jangkrajarn and Theeranuphattana, they conclude that Total Quality Management directly impacts business performance [12]. This article details the model and its validation in comparison with previous studies where it is evident that the OEE indicator has increased by approximately 7.1%. However, it is not the only KPI because the implementation managed to increase the availability of the machinery by 5% and regarding maintenance, the MTBF was increased by 5% and the MTTR was reduced by 3%. Likewise, the project demonstrates an improvement in the production time per batch that reveals the effectiveness of the three implemented methodologies that directly impacted the reduction of reprocessing and stoppages.

Likewise, the study of the implementation of the TPM tool demonstrates the optimization of production in plastic manufacturing [13]. For the case study, the methodology managed to increase the availability of the machines, generating the same impact on production. Another study on the implementation of work standardization managed to improve availability [8]. For the case study, the implementation of the SW tool achieved greater operator efficiency.

6. Conclusion

The study demonstrates a significant improvement in the operational efficiency of a Peruvian fishmeal plant following the joint implementation of Total Quality Management, Total Productive Maintenance, and Standard Work. The OEE increased from 65.74% to 72.96%, MTBF rose by 7.5 hours, and MTTR decreased by 6.3 hours. Additionally, the share of Super Prime fishmeal increased from 5% to 12%, while the cost-benefit ratio reached 8.83. These results confirm that the integration of quality, maintenance, and standardization tools effectively reduces reprocessing, stabilizes production, and enhances profitability in demanding industrial environments. This research is relevant because it shows that even in resource-constrained contexts with seasonal variability, structured and low-cost interventions can generate competitive advantages. The study offers a replicable model that connects technical indicators with economic outcomes, strengthening the empirical foundation for continuous improvement strategies in process industries. The coordination of workforce training, operational

standardization, and proactive maintenance produces cumulative effects that surpass the impact of isolated tool implementation. Moreover, the model's validation through simulation allows for reliable projection of outcomes without interrupting production. As a final remark, future research should focus on longitudinal studies to assess the sustainability of improvements and explore the integration of digital monitoring technologies for real-time decision-making. It is also relevant to evaluate the model's effectiveness across different plants within the fishing sector, incorporate environmental metrics such as carbon footprint, and examine how organizational culture influences the adoption of improvement practices. These perspectives would contribute to building a more robust evidence base to drive operational transformation in the industry, aligning productivity with sustainability and innovation.

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