

Production Management Model Based on Lean Manufacturing Tools and SLP to Increase Productivity in a Meatball (BARF) Plant

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Abstract

Currently, operational efficiency is key to competitiveness in Biologically Appropriate Raw Food (BARF) pet diet industry. In this context, the company under study faces a 30.46% technical gap in productivity, which limits its capacity to three batches per day and results in annual losses of S/ 166,100. To address this problem, this paper proposes an integral management model that articulates Lean Manufacturing tools (5S, SMED, and Standard Work), Systematic Layout Planning (SLP), and Simultaneous Operations. The study included a pilot stage at the plant, followed by technical validation using discrete event simulation in Arena software. Regarding the technical components, the integration of SLP and 5S reduced movement by 59.23% and eliminated search times (from 5.77 to 2.77 minutes). Likewise, SMED and Standard Work improved setup and cleaning times, freeing up 18.59 minutes per day, while the implementation of Simultaneous Operations reduced wait times for nutritional supplements from 11.06

to 1.95 minutes per batch. The results of the study confirm that by implementing the proposed model, it is possible to increase the company's production capacity from 3 to 4 batches per day.

Keywords

Lean Manufacturing, Systematic Layout Planning, Productivity and BARF Industry.

1. Introduction

By 2020, the pet food sector had experienced sustained growth, reaching global valuations exceeding \$102 billion and consolidating its commercial viability through a projected compound annual growth rate (CAGR) of 14.5% toward 2029 (Hobbs et al. 2024). Furthermore, in recent years, the raw meat diet market has recorded an annual sales increase of at least 15% driven by the emerging trend and demand for premium products, specialized diets, and human-grade ingredient foods, such as BARF (Biologically Appropriate Raw Food) diets (Lyu et al. 2025).

Nevertheless, this sustained growth imposes operational demands that small and medium-sized enterprises (SMEs) within the sector are not always prepared to accommodate. Unlike traditional kibble manufacturing, the production of BARF diets involves the handling of raw meat raw materials, whose food safety directly depends on the consistency of sanitation processes and the throughput speed of critical operations (Ferrer et al. 2024). The absence of a standardized work sequence not only compromises production cycle times but also introduces variability into biosecurity parameters a risk that exacerbates as enterprises attempt to scale their installed capacity to meet the aforementioned growing market demand.

The food processing industry consistently falls short of reaching its optimal production frontier. In Peru, this problem becomes more acute; Tello (2022) reports that the average Technical Efficiency Index (TEI) for local companies in this sector is merely 37.94%, demonstrating a significant waste of operational resources that undermines the industrial competitiveness of the sector.

The present study proposes a structured methodology designed to optimize the management of existing resources, standardize workflows, and elevate overall plant productivity through the implementation of low-scale strategic investments.

1.1 Objectives

- To enhance the production capacity of the BARF meatball processing line from 3 to 4 daily batches through the deployment of the production management model, validated via an in plant pilot test and simulation software.
- To mitigate transportation times, tool searching redundancies, and supplement preparation delays through the integration of Systematic Layout Planning (SLP), 5S methodologies, and parallel operations.
- To maximize production uptime, standardize operational processes, and optimize plant layout design by implementing Single Minute Exchange of Die (SMED), Standard Work and SLP.

2. Literature Review

The scientific literature identifies the Single Minute Exchange of Die (SMED) methodology as one of the most robust methods of engineering strategies to counteract capacity losses in food processing plants (Aranda et al. 2025). Under this approach, compressing elevated setup times is recognized as a crucial factor in mitigating operational interruptions and enhancing availability within the food sector (Castañeda et al. 2024). Following the application of this methodology across various production lines in the food industry, research has demonstrated that it is possible to reduce format changeover durations from an inefficient initial state of 30 minutes to an optimal range of less than 10 minutes; thus, converting internal setup activities to external ones decreases downtime due to setups without incurring additional fixed asset investments (Falconí et al. 2025). In small plants characterized by labor intensive manual operations, SMED shortens setup times by 35% across all workstations (Benites et al. 2024). Furthermore, a study demonstrated that when external SMED activities are enhanced through workplace organization using 5S visual boards, additional minutes are subtracted from the process (Dos Santos, W. et al. 2025).

Applying work measurement methodologies enables the identification of idle times and the rebalancing of labor workloads, achieving productivity increases exceeding 27% in manufacturing lines (Kumar et al. 2024). Consequently, for operational management to be effective, the utilization of tools such as Value Stream Mapping

(VSM) must be rigorously complemented by Standard Work practices (Ferrer-Blas et al. 2024). Within the Peruvian agro industrial sector, attempting to establish standard times without prior order is inefficient; therefore, the preliminary use of 5S redesign techniques is suggested to eliminate unnecessary transportation, thereby elevating processing capacity by 36.4% prior to initiating detailed time studies (Díaz Espinoza et al. 2025). On the other hand, research validated that in food SMEs where Standard Work is applied, it is possible to achieve operational stability that improves the Service Level, raising order fulfillment from 83% to 94% (Vargas et al. 2024). According to Bobadilla-Calderón et al. (2022), the standardization of work methods stands as the most cost effective strategy for resource constrained companies; indeed, its implementation reduces outsourcing costs by up to 80%, proving that the optimization of internal methods is superior to relying on external services.

Moreover, Herrera-Granda et al. (2026) introduce an innovative Industry 5.0 approach applicable to food production, where a hybrid facility layout redistribution methodology succeeds in improving material flow and occupational safety conditions, overcoming the limitations of traditional algorithms. Along the same lines, within the confectionery subsector, Cervantes et al. (2023) applied Systematic Layout Planning (SLP) and 5S in a candy manufacturing company, achieving a 43.77% reduction in material handling distance and an 8.75% reduction in transfer time, which is critical in processes where the management of high turnover batches defines profitability. Concurrently, in fresh cut food processing, Cabrera et al. (2020) validated that the integration of 5S, VSM, and statistical control drastically reduces product returns by 89.2%, mitigating cross-contamination and spoilage risks in work areas. Additionally, Fernández-Durán et al. (2024) demonstrated in a bakery that the joint application of 5S and SLP allows for a smoother flow, increasing productivity by 13% and reducing operational times through an optimal reorganization of the workspace. Meanwhile, in the processing of food raw materials, Huarcaya-Melendez and Platero-Mamani (2023) achieved a labor productivity of 25.02 Kg/Sol after implementing a model based on SLP, 5S, and Poka Yoke, attaining waste reductions of 54.17% and significant improvements in cleaning and packaging times.

In food processing, Kittichotsawat et al. (2025) demonstrated that transitioning from manual systems to automated lines, supported by Line Balancing (LB) techniques and ECRS (Eliminate, Combine, Rearrange, Simplify), elevates operational efficiency from 73.61% to 90.50%. Likewise, the integration of IoT and automation in consumer goods production, combined with Lean principles and Yamazumi charts for workload analysis, has increased productivity by up to 76%. In the same manner, Mortada and Soulhi (2023) presented a methodology based on the DMAIC framework and balancing techniques, where the use of Yamazumi charts was decisive in distributing the workload among 17 stations, identifying bottlenecks, and improving line efficiency from 78% to 95%, while additionally achieving labor savings by reducing personnel from 17 to 14 operators. Furthermore, Zengin et al. (2024) detail that analysis via Yamazumi charts is employed specifically to distribute the workload equitatively among operators and ensure proper balancing, enabling the identification of overloaded stations. Finally, Teshome et al. (2023) have evidenced that utilizing balancing tools, complemented by simulation software such as Arena, increases labor productivity by up to 66% and line efficiency above 55%, simultaneously optimizing capacity and waiting times.

3. Methods

As illustrated in Figure 1, the problem is addressed through two primary components and one standalone tool. The first component comprises the integration of Systematic Layout Planning (SLP) and 5S methodologies. The second component consists of the synergy between Single-Minute Exchange of Die (SMED) and Standard Work practices. Finally, the remaining root cause was tackled utilizing parallel operations.

3.1 Phase 1

The layout redesign was based on the Systematic Layout Planning (SLP) methodology, integrating closeness ratings (A, E, I, O, U, and X) alongside a coded list of reasons. This relational scheme was defined by prioritizing the operational requirements necessary to optimize flow continuity and safeguard the food safety of the meatballs.

3.2 Phase 2

The 5S methodology was applied to transform the physical environment into a standardized workspace under permanent visual control. The implementation included sorting objects to prevent cross contamination, installing ergonomic supports and visual aids to optimize workplace organization, and formalizing cleaning procedures and checklists to guarantee the sustainability of hygiene and order standards.

3.3 Phase 3

The SMED methodology was deployed by classifying the 24 cleaning activities according to their nature (internal or external). This enabled the conversion of setup tasks into external activities performed in parallel by both operators, effectively eliminating pre-setup tasks as non-value-added time and drastically reducing the overall cleaning cycle time.

3.4 Phase 4

Standard Work practices established the new operational baseline through standard work combination sheets that defined the execution sequence, task allocation between operators, and target times per activity. Consequently, this guaranteed the sequence of activities previously determined by SMED, transforming each task into a precise standard operating procedure for each operator.

3.5 Phase 5

The principle of parallel operations was executed to eliminate non-productive time generated by the sequential preparation of dietary supplements. As a result, the operator maintains a continuous production flow, experiencing only minimal transportation and mixing times, since the preparation task is transferred to the plant assistant thereby transforming the activity into an offline, parallel operation.

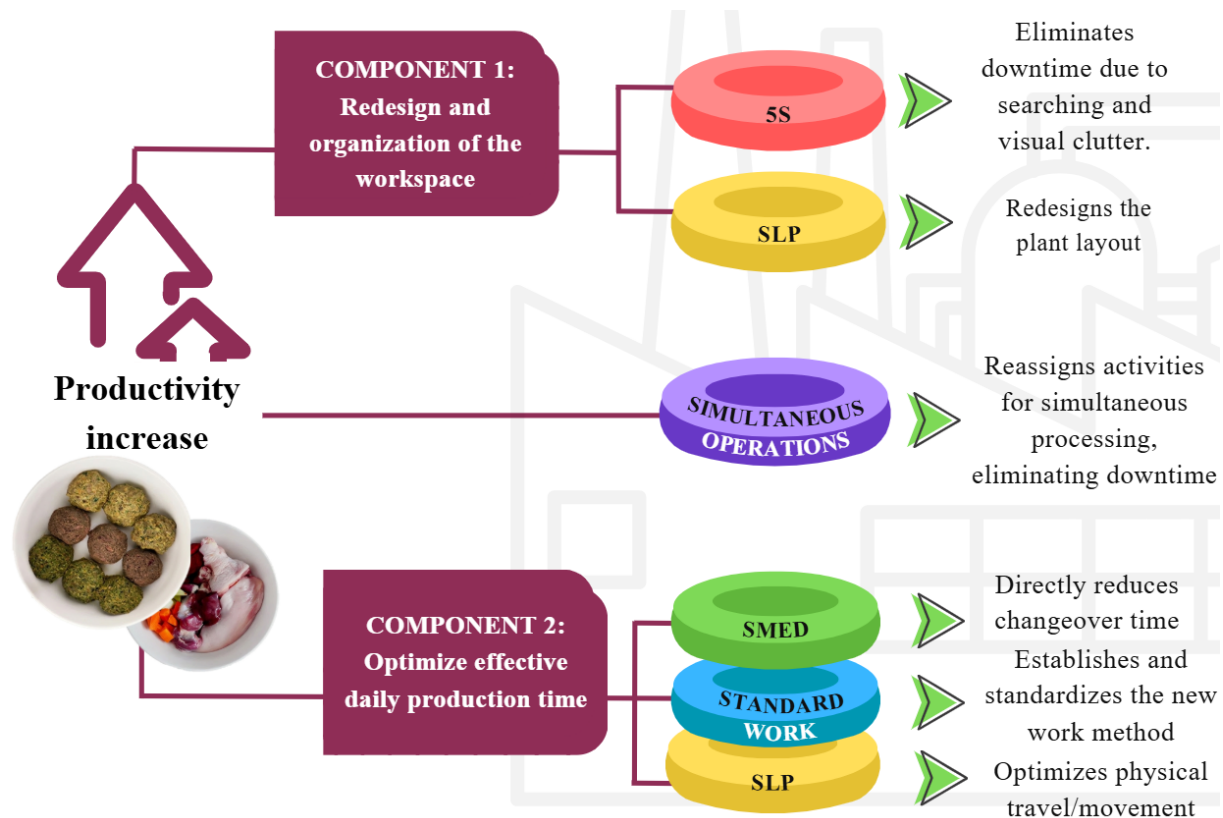


Figure 1. Conceptual model of the proposed solution

4. Data Collection

To diagnose the causes of low productivity in the BARF meatball manufacturing process, historical data collection and a direct time study were conducted under the guidelines of the International Labour Organization (ILO) methodology. The results of this analysis, which synthesize the core problem, its technical gap, economic impact, and root causes, are detailed in Figure 2.

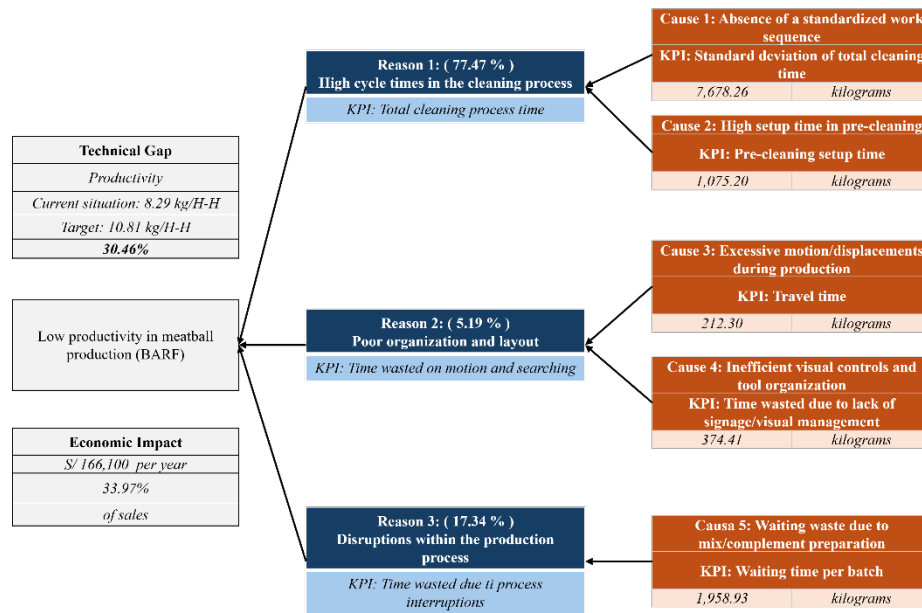


Figure 2. Problem tree

Currently, the plant yields 3 batches daily and operates at a labor productivity rate of 8.29 kg/man-hour. However, the target set by the enterprise is 10.81 kg/man-hour. This objective is fully justified by the plant's installed capacity, which is currently underutilized, as will be discussed in further detail in Figure 3.

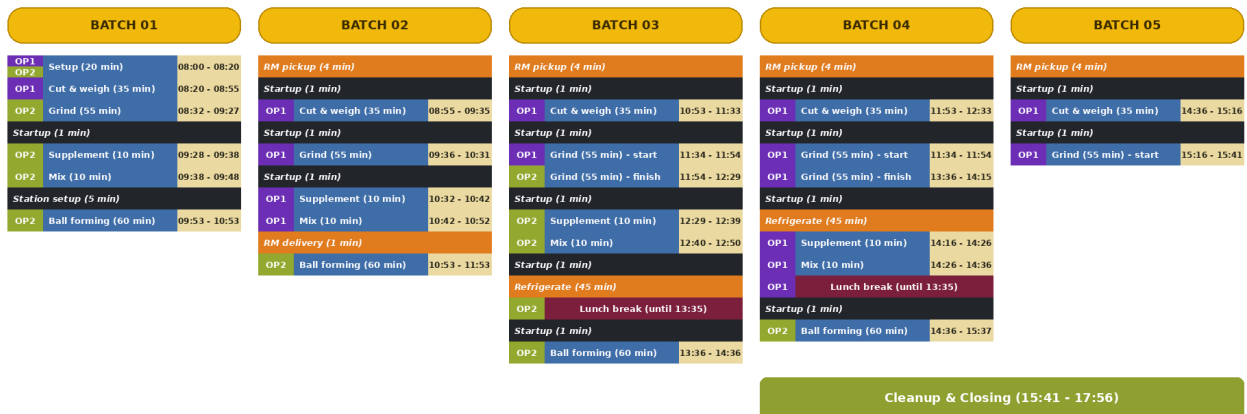


Figure 3. Plant capacity diagram

Under the current work configuration utilizing two plant operators, it is theoretically feasible to complete four daily batches. Consequently, it is determined that the core problem lies in the low productivity of the operational line, given that achieving a daily output of 200 kg of meatballs is entirely attainable. Therefore, in operational terms, an efficiency gap of 30.46% has been identified.

Current Labor Productivity = 8.29 kg/man-hour

Expected Labor Productivity = 10.81 kg/man-hour

$$Technical\ Gap = 30.46\%$$

5. Results and Discussion

5.1 Numerical Results

For the development of this project, it was necessary to compile quantitative evidence associated with the execution cycle times of each process stage. Based on this information, five Key Performance Indicators (KPIs) were defined, which enabled an objective evaluation of the efficacy of the proposed improvement tools and quantified their impact on the overall operational performance of the process.

Table 1 presents the cycle times recorded during the initial operational baseline of the process along with the results achieved following the implementation of the improvement tools:

Table 1. Results

Indicator	As-Is	To-Be	Improvement
Total cleaning time	123.38 min	102.16 min	-21.22 min
Total pre cleaning time	17.41 min	14.41 min	-3.00 min
Travel time	3.48 min	2.03 min	-1.45 min
Search time due to lack of visual control	5.77 min	2.77 min	-3.00 min
Waiting time for dietary supplement	11.06 min	1.95 min	-9.11 min
Productivity	3 batches	4 batches	+1 batch

The SMED methodology targeted the pre cleaning cycle time, a stage where the operator previously waited for production to conclude before initiating tasks. Of these six distinct activities, one was eliminated and four were successfully converted into external tasks. Consequently, as illustrated in Table 2, this tool liberated 12.83 minutes of non-value-added time.

Table 2. Pre cleaning time savings

Activity	Time saved
Eliminated	3.00 min
External (converted)	9.83 min
Total saved	12.83 min

Standard Work practices mitigated two quantifiable inefficiencies: operator coordination idle times and work sequence deviations. The engineered solution consisted of assigning dedicated cleaning zones to each operator; consequently, this implementation significantly reduced the variability of the total cleaning cycle time, as displayed in Table 3.

Table 3. Time savings through Standard Work

Activity	Time saved
Elimination of coordination downtime	3.00 min
Dedicated work zone assignment	4.00 min
Total saved	7.00 min

The facility layout redesign via SLP further contributed to the reduction of the tool and material searching cycle times by optimizing spatial redistribution. Work assets were relocated based on a frequency of use placement strategy, thereby mitigating non-value-added motion and operator transportation during the cleaning process. The resulting liberated time is documented in Table 4.

Table 4. Time savings through SLP

Activity	Time saved
Reduction of search time	1.39 min
Total saved	1.39 min

5.2 Graphical Results

Regarding the SLP implementation, a new nutritional supplement workstation was configured and strategically relocated closer to the production zone, consisting of a storage rack and a workbench equipped with an industrial scale. Concurrently, the vegetable refrigerator was repositioned based on its frequency of use to mitigate operator transit. Finally, the locations of the office and the cleaning storage room were interchanged; since this pair shared an unimportant proximity rating (closeness rating 'U'), this reconfiguration optimized searching and access times for sanitation supplies without compromising the primary production flow. The proposed layout is illustrated in Figure 4.

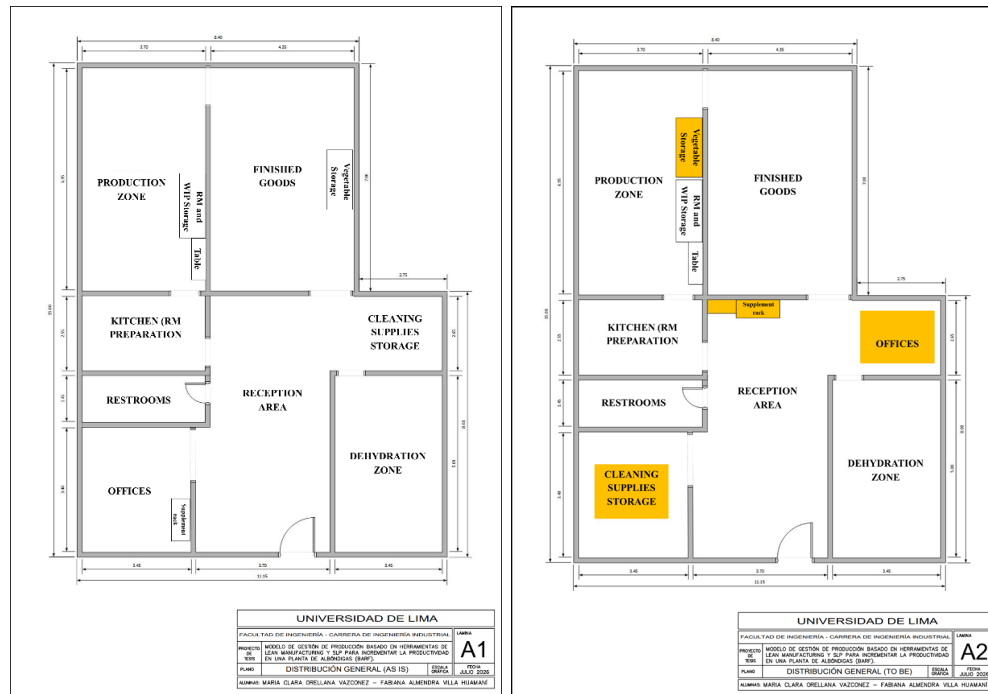


Figure 4. Plant layout: before and after implementation

Regarding the 5S methodology, the objects within the production zone were classified into four distinct categories. Obsolete and surplus items were permanently removed from the area. Concurrently, repairable items (such as recipes) and functional assets (including tools and machine heads) were retained, systematically organized, and serviced based on their current condition. Figure 5 demonstrates the digitization and standardization of recipes into a visual technical datasheet. This implementation eliminated the physical deterioration associated with the previously used notebook and enabled operators to consult the technical data directly from their workstations, thereby neutralizing non value added motion.



Figure 5. Recipe consultation method: before and after 5S implementation

It is worth noting that throughout the development of both tools, the ergonomic compliance of each proposal was guaranteed under the guidelines of the Institute for Industrial Technological Research and Technical Standards (ITINTEC, currently INACAL). The application of these national standards enabled the definition of optimal operational dimensions based on an average stature of 1.66 m.

For the implementation of the SMED methodology within this improvement project, a structured four step sequence was followed: Analysis, Separation, Conversion, and Streamlining. During the analysis phase, the cleaning process was studied in its current state utilizing a diagnostic assessment sheet. Subsequently, tasks were separated into internal activities (performed while the machine is stopped) and external activities (executed while the machine is running). Following this, the workflow was redesigned through the conversion of activities, as illustrated in Figure 6, which delineates the specific tasks assigned to each operator.

SMED — STEP 1: CLASSIFICATION OF ACTIVITIES AS IS / TO BE						
N°	Category	Activity	Operator	Avg. T (min)	AS IS Classification	TO BE Classification
1	Pre-clean	Wait for supervisor confirmation	OP1	3.00	INTERNAL	ELIMINATED
2	Pre-clean	Remove trays to the cold room	OP1	4.58	INTERNAL	INTERNAL
3	Pre-clean	Go to the cleaning room	OP1	0.89	INTERNAL	EXTERNAL ✓
4	Pre-clean	Get and move utensils to the area	OP1	2.81	INTERNAL	EXTERNAL ✓
5	Pre-clean	Prepare detergent / disinfectant solution	OP1	2.09	INTERNAL	EXTERNAL ✓
6	Pre-clean	Disassemble parts of inactive equipment	OP1	4.04	INTERNAL	EXTERNAL ✓
7	Equipment cleaning	Initial pressure rinse — Cutter	OP1	6.09	INTERNAL	INTERNAL
8	Equipment cleaning	Detergent application — Cutter	OP1	8.08	INTERNAL	INTERNAL
9	Equipment cleaning	Final rinse and drying — Cutter	OP1	4.32	INTERNAL	INTERNAL
10	Equipment cleaning	Initial pressure rinse — Grinder	OP1	4.24	INTERNAL	INTERNAL
11	Equipment cleaning	Detergent application — Grinder	OP1	5.28	INTERNAL	INTERNAL
12	Equipment cleaning	Final rinse and drying — Grinder	OP1	4.11	INTERNAL	INTERNAL
13	Equipment cleaning	Initial pressure rinse — Mixer	OP2	6.98	INTERNAL	INTERNAL
14	Equipment cleaning	Detergent application — Mixer	OP2	4.12	INTERNAL	INTERNAL
15	Equipment cleaning	Final rinse and drying — Mixer	OP2	4.31	INTERNAL	INTERNAL
16	Area cleaning	Floor debris removal — broom	OP2	7.05	INTERNAL	INTERNAL
17	Area cleaning	Wall cleaning with hose	OP2	4.98	INTERNAL	INTERNAL
18	Area cleaning	Washing trays, tubs, and containers	OP1+OP2	7.16	INTERNAL	INTERNAL
19	Area cleaning	Cleaning and disinfecting tables and portioning area	OP1+OP2	7.29	INTERNAL	INTERNAL
20	Disinfection	Disinfectant application on surfaces	OP1+OP2	6.11	INTERNAL	INTERNAL
21	Disinfection	Wait for disinfectant contact time (SENASA)	OP1+OP2	10.24	INTERNAL	INTERNAL
22	Disinfection	Final rinse of equipment and parts	OP1+OP2	5.21	INTERNAL	INTERNAL
23	Closing	Reassemble parts with visual instruction	OP1+OP2	3.69	INTERNAL	INTERNAL
24	Closing	Final tidying: utensils, PPE, and products	OP1+OP2	7.43	INTERNAL	INTERNAL
TOTAL AS IS TIME				127.52 min	External activities TO BE: 4 · Eliminated: 1 · Time freed: ~12.83 min	
LEGEND: Pre-clean Equipment cleaning Area cleaning Disinfection Closing · OP1 OP2 OP1+OP2 · INTERNAL = during stoppage · EXTERNAL ✓ = can be done before/after · ELIMINATED = removed in TO BE						

Figure 6. Internal to external activity conversion sheet

Once the external activities are classified, the SMED methodology requires streamlining the remaining internal tasks. Therefore, to standardize the new method, it is established that work execution will be conducted in parallel between OP1 and OP2.

Standard Work practices were executed through the implementation of two visual instruction sheets to ensure that the processes remain documented, as illustrated in Figure 7 and Figure 8.

WORK INSTRUCTION SHEET — CLEANING PROCESS TO BE						
Company: BBP Process: Post-production cleaning Operators: OP1 and OP2 Task time: 100 min Standards: D.S. 907-98-SA - D.S. 904-2011-AG, ISO 9001 Rev.: 2025						
N°	Phase	Step description	Op.	T (min)	Next step	PPE / material required
1	Pre-clean (garbage)	Go to the cleaning room	OP1	0.89	► Get and move utensils ◄ Utensil basket(s) ► Utensil shelf - cleaning room	Non-slip footwear
2	Pre-clean (garbage)	Get and move utensils to the area	OP1	2.81	► Prepare detergent solution ◄ Calibrated container, detergent ◄ Chemical shelf - right wall	Basket/cart of utensils
3	Pre-clean (garbage)	Prepare detergent/disinfectant solution	OP1	2.09	► Disassemble equipment parts ◄ Cut-resistant gloves ► PPE rack - room entrance	Gloves, mask, calibrated container
4	Pre-clean (garbage)	Disassemble parts of inactive equipment	OP1	4.04	► Initial rinse — Cutter ◄ Pressure hose (min: 2 bar) ► Hose tap - left wall	Cut-resistant gloves
5	OP1 Equipment	Initial pressure rinse — Cutter	OP1	6.09	► Detergent application — Cutter ◄ Stainless sponge + detergent solution ► Prepared container - step 3	Waterproof apron, boots
6	OP1 Equipment	Detergent application — Cutter	OP1	8.08	► Final rinsedrying — Cutter ◄ Hose + clean cloth ► Hose tap / cloth basket	Gloves, stainless sponge
7	OP1 Equipment	Final rinse and drying — Cutter	OP1	4.32	► Initial rinse — Grinder ◄ Pressure hose (min: 2 bar) ► Hose tap - left wall	Clean cloth
8	OP1 Equipment	Initial pressure rinse — Grinder	OP1	4.24	► Detergent application — Grinder ◄ Stiff brush + detergent solution ► Prepared container - step 3	Apron, boots
9	OP1 Equipment	Detergent application — Grinder	OP1	5.28	► Final rinsedrying — Grinder ◄ Hose + clean cloth ► Hose tap / cloth basket	Gloves, stiff brush
10	OP1 Equipment	Final rinse and drying — Grinder	OP1	4.11	► Washing trays and tubs (joint) ◄ Tub, detergent, gloves ► Washing area - central table	Clean cloth
11	OP2 Equipment	Initial pressure rinse — Mixer	OP2	6.98	► Detergent application — Mixer ◄ Sponge + detergent solution ► Prepared container - step 3	Apron, boots
12	OP2 Equipment	Detergent application — Mixer	OP2	4.12	► Final rinsedrying — Mixer ◄ Hose + clean cloth ► Hose tap / cloth basket	Gloves, sponge
13	OP2 Equipment	Final rinse and drying — Mixer	OP2	4.31	► Floor debris removal ◄ Wet broom, dustpan ► Tool rack - back wall	Clean cloth
14	OP2 Equipment	Floor debris removal — wet broom	OP2	7.05	► Wall cleaning with hose ◄ Hose with nozzle ► Hose tap - left wall	Broom, dustpan
15	OP2 Equipment	Wall cleaning with hose	OP2	4.98	► Washing trays and tubs (joint) ◄ Tub, detergent, gloves ► Washing area - central table	Hose with nozzle
16	Join	Washing trays, tubs, and containers	OP1+OP2	7.16	► Cleaning tables and portioning area ◄ Clean cloth, disinfectant ◄ Cloth basket - chemical shelf	Gloves, tub, detergent
17	Join	Cleaning tables and portioning area	OP1+OP2	7.29	► Disinfectant application on surfaces ◄ Sprayer, disinfectant ◄ Chemical shelf - right wall	Clean cloth, disinfectant
18	Disinfection	Disinfectant application on surfaces	OP1+OP2	6.11	► WAIT disinfectant contact time ◄ Do not handle surfaces ◄ Stay in area - start log	Sprayer, gloves, mask
19	Disinfection	WAIT disinfectant contact time	OP1+OP2	10.24	► Final rinse of equipment and parts ◄ Hose, clean cloths ► Hose tap / cloth basket	Do not handle treated surfaces
20	Disinfection	Final rinse of equipment and parts	OP1+OP2	5.21	► Reassemble parts with visual instruction ◄ Adjustment wrench, diagram ► Tool rack / WIS on wall	Hose, clean cloths
21	Closing	Reassemble parts with visual instruction	OP1+OP2	3.69	► Final tidying: utensils, PPE, products ◄ Cleaning logbook ◄ Logbook binder - entrance table	Adjustment wrench, diagram
22	Closing	Final tidying: utensils, PPE, products	OP1+OP2	7.43	✓ END OF PROCESS Area ready for production	Cleaning logbook
TOTAL TO BE TIME				116.52 min	Target: ≤ 100 min Task time met: ISO 9001:2015	
LEGEND: Pre-clean (garbage) OP1 Equipment OP2 Equipment Join Disinfection Closing OP1 OP2 OP1+OP2 ◄ Location ◄ Unconsumable						

Figure 7. Work instruction sheet

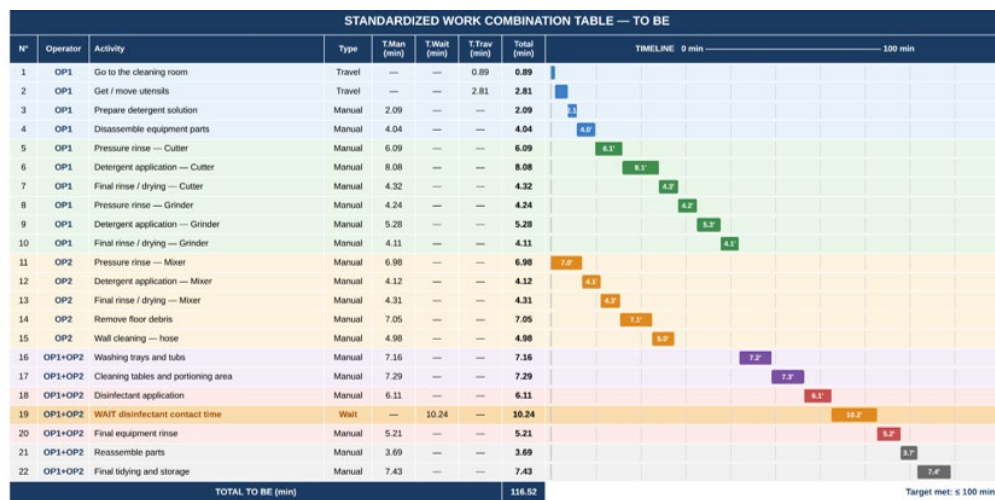


Figure 8. Standard work combination sheet

These results validate the trends documented in the specialized literature. On one hand, Cervantes et al. (2023) reported that integrating SLP and 5S within food sector enterprises enables a 43.77% reduction in material handling distances, a determining factor for operational profitability. On the other hand, the findings concur with those presented by Fernández-Durán et al. (2024), who confirmed that the synergy between both methodologies not only optimizes operational flow but also boosts system productivity by 13%. In this regard, the 59.23% improvement achieved in the present study confirms the high effectiveness of applying these tools concurrently.

Component 2: Single-Minute Exchange of Die (SMED) + Standard Work + SLP

The results obtained in Phase 2 are consistent with findings reported in the scientific literature regarding SMED implementation within food processing plants. Aranda et al. (2025) highlight SMED as one of the most robust strategies to mitigate capacity losses in production facilities; hence, 6 out of 24 setup activities were reclassified from internal to external, as detailed in Table 7.

Table 7. Conversion of pre-cleaning activities

Activity	Average time (min)	As-Is Classification	To-Be Classification
Wait for supervisor confirmation	3.00	Internal	Eliminated
Move trays to cold storage	4.58	Internal	Internal
Go to cleaning room	0.89	Internal	External
Search and transfer utensils to the area	2.81	Internal	External
Prepare detergent/disinfectant solution	2.09	Internal	External
Disassemble parts of inactive equipment	4.04	Internal	External

Regarding the magnitude of the reduction, Falconí et al. (2025) document a decrease in changeover times from 30 down to less than 10 minutes through activity conversion. This particular case eliminates 7 minutes.

This micro scale optimization validates the trends identified by Benites et al. (2024), who argue that small scale plants with manual intensive operations are capable of shortening setup times by up to 35% across all workstations.

Finally, the engineering design was reinforced through an SLP-based proximity analysis, and the storage room was relocated to an expanded environment of 11.73 m². This expansion enabled a systematic reorganization based on the frequency of use of the items. Figure 10 illustrates both the current state and the proposed state achieved by the improvement.

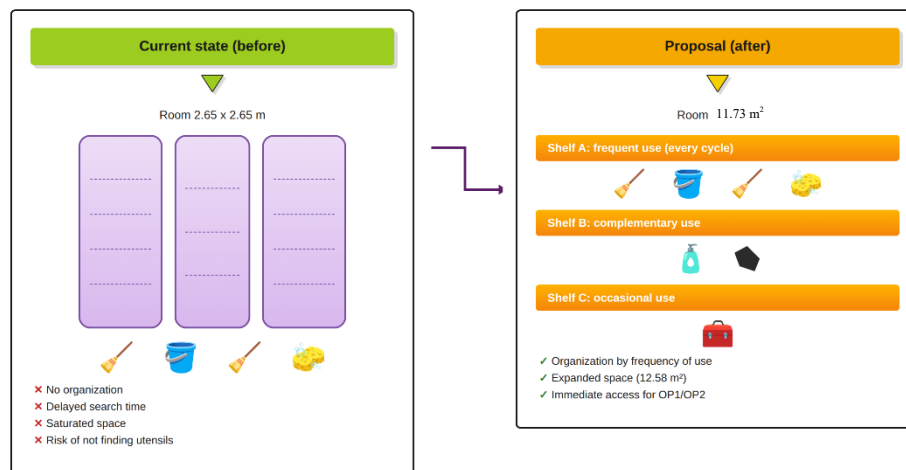


Figure 10. Storage room reorganization post SLP implementation

This interaction confirms the hypothesis outlined by Dos Santos et al. (2025), who conclude that the benefits of SMED are maximized when the operational environment is concurrently reorganized.

Simultaneous Operations

During the initial diagnosis, it was identified that one of the operators on the main line acts as the system's critical bottleneck, as the sum of their operational times significantly exceeds the takt time of 103 minutes. Therefore, the Yamazumi chart was employed to evaluate the workload of the production assistant in charge of the dehydrated products. This analysis revealed that the assistant processes the demand with a cycle time of 15 min/kg, a value significantly lower than the established takt time of 21 min/kg.

This operational slack allowed for the reassignment of supplement weighing to the assistant, enabling the main line operator to focus exclusively on mixing. As a result, the waiting time per supplement was optimized, reducing it from 11.06 min to 1.95 min.

This performance is comparable to current literature: while Kittichotsawat et al. (2025) report that the transition from manual systems to automated lines increases operational efficiency from 73.61% to 90.50%, the current project achieves a highly competitive time reduction through optimized manual balancing. Likewise, the use of the Yamazumi chart to identify the bottleneck replicates the function described by Zengin et al. (2024), who validate this tool as essential for distributing workload equitably and detecting overloaded stations.

5.4 Validation

The validation phase consisted of two distinct stages: pilot testing and discrete-event simulation utilizing Arena.

Regarding the pilot test, to ensure that the results from the full experimental execution were statistically significant, the minimum sample size for each variable was estimated using the formula for populations with a known variance, where σ represents the standard deviation of the As-Is state, with a 95% confidence level ($Z = 1.96\%$) and a 10% margin of error.

A full shift was designated as the sampling unit, given that the implemented tools impact operations both during and after the production of the three batches. Finally, the collected data served as the input data for the Arena model, which replicated the manufacturing process in its current state (as shown in Figure 11) and its improved state (as shown in Figure 12), executing a total of 120 replicas for the subsequent analysis of results.

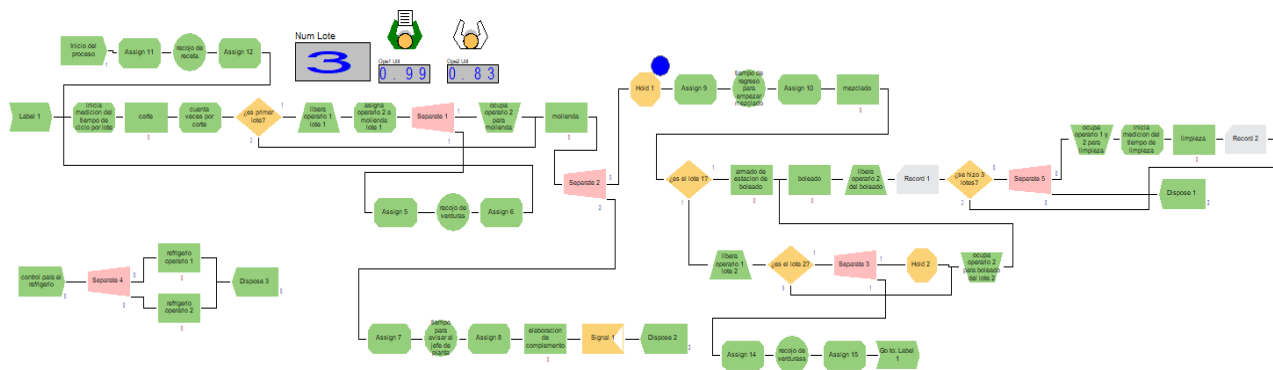


Figure 11. Arena simulation model: current state of the process

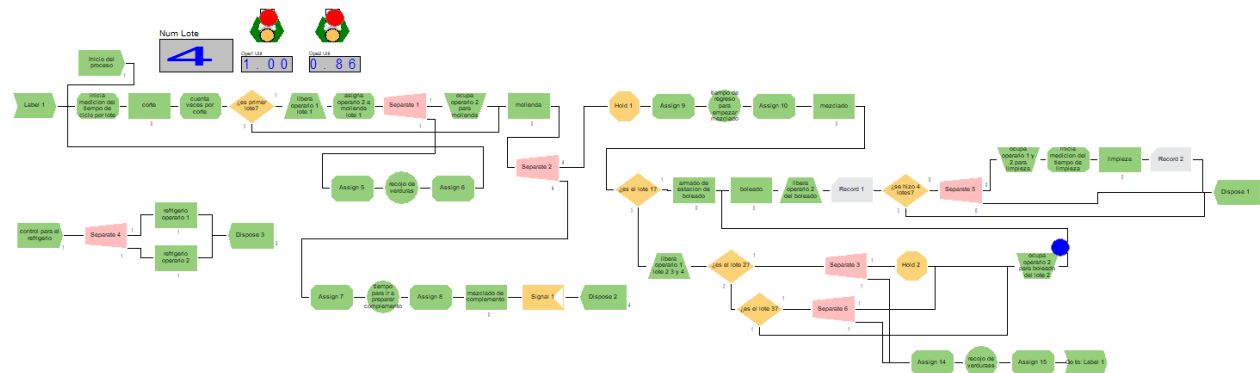


Figure 12. Arena simulation model: proposed state with process improvements

With a 95% confidence level, the Arena simulation results for the To-Be model are favorable, demonstrating that the implementation of the proposed tools neither alters the process sequence nor incorporates additional activities. Particularly, the proposed scenario verifies a reduction across all 5 key performance indicators (KPIs), proving that by applying the solution tools, it is feasible to achieve sufficient release time within the working day to successfully complete a fourth production batch.

6. Conclusion

- The implementation of the production management model enabled the enterprise to scale from 3 to 4 batches on its production days, successfully covering the existing unfulfilled demand. This was demonstrated through an in-plant pilot test and further validated via discrete-event simulation in Arena Simulator. Consequently, it is proven that process standardization and the reorganization of internal flows are sufficient to unlock idle capacity.
- The integration of SLP and 5S led to a reduction in the total meters traversed by the operator during the shift, recovering time previously lost to unnecessary transit and movements. Complementarily, the 5S methodology standardized the workstation conditions for the first time, establishing a visual control system that guarantees each item is in its correct place and immediately available, thereby eliminating searching times during the shift. Concurrently, the application of simultaneous operations leveraging the slack time of the production assistant successfully reduced the supplement preparation time per batch.
- The combined application of SMED, Standard Work, and SLP recovered available time dedicated to production. Through SMED, 6 internal activities were converted to external, ensuring that setup and pre cleaning tasks run in parallel with the operation and no longer block the initialization of the subsequent batch. Standard Work complemented this redesign by formalizing an official sequence of activities for each operator for the first time. Additionally, the layout interchange between the office and the cleaning storage room eliminated searching times, ensuring that the standardized sequence can be executed without operational disruptions.

References

- Aranda, D., Pareja, R. A. and Villafuerte, A. A., A model based on TPM, SMED, and Industry 4.0 to increase machinery availability in a fish flour processing company, Proceedings of the 23rd LACCEI International Multi-Conference for Engineering, Education, and Technology, 2025, <https://dx.doi.org/10.18687/LACCEI2025.1.1.1663>.
- Benites, S. G., Eustaquio, L. T. and Nunez, V., Performance improvement model integrating lean and internet of things: A food production case, Proceedings of the 10th International Conference on Industrial and Business Engineering (ICIBE 2024), 2024, <https://doi.org/10.1145/3716097.3716110>.
- Bobadilla-Calderón, J., Martínez-Flores, C. and León-Chavarri, C., Implementation of integrated autonomous maintenance and standard work to improve the productivity in post-harvest production: Case study of a Peruvian coffee farm, Proceedings of the 20th LACCEI International Multi-Conference for Engineering, Education, and Technology, 2022, <http://dx.doi.org/10.18687/LACCEI2022.1.1.732>.

- Cabrera, J., Corpus, O., Maradiegue, F. and Álvarez, J., Improving quality by implementing Lean Manufacturing, SPC, and HACCP in the food industry: A case study, *South African Journal of Industrial Engineering*, vol. 31, no. 4, pp. 194-207, 2020, <http://dx.doi.org/10.7166/31-4-2363>.
- Castañeda, S., Rodriguez, S., Yildiz, O., Aranda, D. and Alvarez, J. C., Increase of the availability of machinery in a food company applying the TPM, SMED and RCM methodologies, *International Journal of Engineering Trends and Technology*, vol. 72, no. 8, pp. 128-138, 2024, <https://doi.org/10.14445/22315381/IJETT-V72I8P114>.
- Cervantes, C., Kikushima, A. and Flores-Perez, A., Improvement proposal applying SLP and 5S in the confectionery industry: Case of a SME in Peru, *Proceedings of the 3rd Indian International Conference on Industrial Engineering and Operations Management*, pp. 322-331, 2023, <https://doi.org/10.46254/IN03.20230100>.
- Díaz Espinoza, N., Leon Berrios, C. X. and Tupia-De-La-Cruz, E. L., Enhancing productivity through lean and layout redesign: A case study in the frozen fruit industry in Peru, *International Research Journal of Economics and Management Studies*, vol. 4, no. 5, pp. 217-232, 2025.
- Dos Santos, W. Q., McDermott, O., & Trubetskaya, A., Lean Six Sigma 4.0 Application in the Food and Beverage Industry: A Case Study, *IEEE Engineering Management Review*, vol. 00, no. 00, pp. 1-21, 2025, <http://dx.doi.org/10.1109/EMR.2025.3538268>.
- Falconí, R., Núñez, L. and Jiménez, E., Optimizing efficiency in the Peruvian food sector: The impact of lean manufacturing methodologies, *Proceedings of the 23rd LACCEI International Multi-Conference for Engineering, Education, and Technology*, 2025, <https://dx.doi.org/10.18687/LACCEI2025.1.1.874>.
- Fernández-Durán, M., Quispe-Contreras, V. and Urbina-Rivera, C., Improving the productivity of an MYPE in the province of Palpa applying 5S and SLP methodology, *Proceedings of the 9th North American Conference on Industrial Engineering and Operations Management*, pp. 955-966, 2024, <https://doi.org/10.46254/NA09.20240239>.
- Ferrer-Blas, R. I., Galarcep-Barba, I. and Solano-Gaviño, J. C., Lean Manufacturing en la producción de alimentos: Revisión sistemática, análisis bibliométrico y propuesta de aplicación, *Scientia Agropecuaria*, vol. 15, no. 4, pp. 569-579, 2024, <https://doi.org/10.17268/sci.agropecu.2024.042>.
- Herrera-Granda, I., Alemany, M., Peluffo-Ordóñez, D. and Campos, J., A hybrid methodology for the facility re-layout problem of food production systems in Industry 5.0 context, *Cogent Engineering*, vol. 13, no. 1, 2026, <https://doi.org/10.1080/23311916.2026.2634432>.
- Hobbs, L., Shanoyan, A. and Aldrich, G., Assessing research needs for informing pet food industry decisions, *International Food and Agribusiness Management Review*, vol. 27, no. 5, pp. 923-940, 2024, <https://doi.org/10.22434/IFAMR2023.0004>.
- Huarcaya-Melendez, V. and Platero-Mamani, A., Production model based on Lean tools and SLP to increase labor productivity in companies in the food industry, *Industrial Engineering and Applications*, vol. 35, no. 1, pp. 651-660, 2023, <https://doi.org/10.3233/ATDE230092>.
- Kittichotsatsawat, Y., Wattanuchariya, W., Jongjareonrak, A. and Seesuriyachan, P., Enhancing manufacturing operations within the supply chain for sustainable frozen shrimp production, *Sustainability*, vol. 17, no. 6, 2412, 2025, <https://doi.org/10.3390/su17062412>.
- Kumar, A., Kumar, R. and Gul, A., Reduction of lean wastes by using value stream mapping: A case study of textile company in Pakistan, *International Journal of Supply Chain Management*, vol. 9, no. 2, pp. 37-61, 2024.
- Lyu, Y., Wu, C., Li, L. and Pu, J., Current evidence on raw meat diets in pets: A natural symbol, but a nutritional controversy, *Animals*, vol. 15, no. 3, pp. 1-15, Art. 293, 2025, <https://doi.org/10.3390/ani15030293>.
- Mortada, A. and Soulhi, A., Improvement of assembly line efficiency by using lean manufacturing tools and line balancing techniques, *Advances in Science and Technology Research Journal*, vol. 17, no. 4, pp. 89-109, 2023, <https://doi.org/10.12913/22998624/169257>.
- Tello, M. D., Índice de eficiencia técnica de las empresas de Perú, *Desarrollo y Sociedad*, no. 90, pp. 111-151, 2022, <https://doi.org/10.13043/dys.90.4>.
- Teshome, M., Meles, T. and Yang, C., Productivity improvement through assembly line balancing by using simulation modeling in case of Abay garment industry Gondar, *Heliyon*, vol. 10, no. 1, p. e23585, 2024, <https://doi.org/10.1016/j.heliyon.2023.e23585>.
- Vargas-Patroni, A., Jackson-Aguilar, A. and Collao-Díaz, M., Production model based on Lean Manufacturing-TPM to increase the service level in a SME in the food sector, *Proceedings of the 22nd LACCEI International Multi-Conference for Engineering, Education, and Technology*, 2024, <https://doi.org/10.18687/LACCEI2024.1.1.171>.
- Zengin, G., Ergün, H. and Efendioğlu, D., Providing business package services to SMEs using lean manufacturing and digital technologies, *Journal of Optimization and Supply Chain Management*, vol. 1, no. 2, pp. 73-97, 2024, <https://doi.org/10.22034/ISS.2024.8201.1015>.

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Professor Rafael Mauricio Villanueva Flores is an Industrial Engineer from Universidad de Lima and holds a Master of Science from Kansas State University. He currently serves as Operations Manager at Anita Food and is a professor at the Faculty of Engineering of Universidad de Lima. He is an executive with extensive experience in managing industrial operations and has authored multiple publications related to the food industry.

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