Received: 23 May 2026 | Accepted: 20 Ago 2026 | Available online: 23 Ago 2026
DOI: http://dx.doi.org/10.18180/tecciencia.2026.40.1

TECCIENCIA

RESEARCH ARTICLE

Engineering , Applied Sciences

Implementing lean manufacturing to reduce production variability of prefabricated products in a restaurant chain in trujillo

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The publication of this journal is funded by Universidad ECCI, Bogotá-Colombia.

Editor: Christian Alonso Becerra Rivas.

Editorial assistant : Alejandra Barrero Gmez.

How to cite
Rai R., *et al*, **Implementing lean manufacturing to reduce production variability of prefabricated products in a restaurant chain in trujillo**, TECCIENCIA, Vol. 21, No. 40, 1-20, 2026

ABSTRACT. This research was conducted to achieve the objective of implementing Lean Manufacturing to reduce production variability in prefabricated items for a restaurant chain in the Huanchaco district of Trujillo by 2024. The Lean Manufacturing methodology was used with the Jidoka tool for process automation while maintaining human intervention. The research findings showed a 47.47% reduction in defective products; a reduction in variability after increasing process capacity (C_p) from 0.13, a process with inadequate capacity requiring significant modifications, to a final capacity of 1.92, resulting in an adequate process; an increase in real process capacity (C_{pk}), achieving a final capacity of 1.53, a capable and focused process; and finally, an increase in Taguchi capacity (C_{pm}), achieving a final capacity of 1.33, a process that meets specifications.

keywords: Production management; Lean Manufacturing; Jidoka; defective products; variability.

RESUMEN. La investigación se llevó a cabo con el objetivo de implementar la metodología *Lean Manufacturing* para reducir la variabilidad en la producción de artículos prefabricados de una cadena de restaurantes en el distrito de Trujillo (Huanchaco) para el año 2024. Se empleó dicha metodología junto con la herramienta *Jidoka* para automatizar procesos preservando la intervención humana. Los resultados mostraron una reducción del $47,47\%$ en productos defectuosos; una disminución de la variabilidad tras incrementar la capacidad del proceso (C_p) desde $0,13$ —un valor que indicaba una capacidad inadecuada y la necesidad de modificaciones significativas— hasta una capacidad final de $1,92$, lo que resultó en un proceso adecuado; un aumento en la capacidad real del proceso (C_{pk}), alcanzando un valor final de $1,53$, lo que denota un proceso capaz y centrado; y, finalmente, un incremento en la capacidad Taguchi (C_{pm}), logrando un valor final de $1,33$, lo que indica un proceso que cumple con las especificaciones.

Palabras clave: Gestión de la producción; Lean Manufacturing; Jidoka; productos defectuosos; variabilidad.

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1 | INTRODUCTION

Globally, customer satisfaction has become a vital element in today's competitive business landscape, which drives companies to improve the quality of their offerings to meet customer desires and ensure loyalty and continued patronage. This also leads them to focus their efforts on resolving problems and errors that could generate complaints or lead to customer churn. This aspect is one of the most important and decisive for businesses, and a fundamental pillar for maintaining their market position [1].

In factories that produce prefabricated elements for restaurants, various types of waste appear due to inefficient production management, such as excess inventory and excessive processes [2]. Furthermore, another major drawback affecting this sector is the lack of supply and the increase in material costs due to global problems [3].

In the province of Trujillo, food sector businesses are grappling with a crisis stemming from political instability, road closures, natural disasters, and rising food and beverage prices, which has resulted in increased operating costs for food establishments [4]. In the district of Huanchaco, there are several restaurants geared towards tourism that cater to both foreign visitors and local tourists from Peru [5].

Quality management has been an essential component of production systems for many years. Deming succeeded in persuading the leaders of Japanese industry that quality was fundamental to conquering the market. This message had a significant impact on one company in particular, Toyota, which at that time was already testing "total quality" concepts such as Jidoka, automation with a human touch [6].

In the restaurant sector, countries like France and Spain excel, offering top-notch food and service, which has earned them accolades such as the coveted Michelin stars. These stars are awarded for the quality and originality of their dishes and the attention they provide to their customers. A key factor when paying for a meal is customer satisfaction. It is vital that they feel happy with what they receive for the business to thrive [7].

This research aligns with three of the Sustainable Development Goals: SDG 12: Responsible Consumption and Production; SDG 8: Decent Work and Economic Growth; SDG 9: Industry, Innovation and Infrastructure. Therefore, this research aims to analyze the aspects that link restaurants to the promotion of sustainable development and propose practical alternatives that can be implemented in these businesses to contribute to the SDG targets of the 2030 Agenda [8].

The general problem was defined by the following question: To what extent will the implementation of Lean Manufacturing reduce the production variability of prefabricated items for a restaurant chain in the Huanchaco district of Trujillo in 2024? Subsequently, the specific problems were defined: 1) Will the implementation of the Jidoka tool reduce the percentage of defective products in the production area of the prefabricated items plant of a restaurant chain in the Huanchaco district of Trujillo in 2024? 2) Will the implementation of the Jidoka tool reduce variability in the production area of the prefabricated items plant of a restaurant chain in the Huanchaco district of Trujillo in 2024?

The research is theoretically justified once the potential of the knowledge is demonstrated and validated with experimental evidence subsequent to the reduction of the number of defective products [9]. Additionally, it is important in practice, as the scientific basis of the Jidoka technique is applied and the worker's experience is integrated with process improvement [10]. All of this goes hand in hand with its importance in social application, since it generates more efficient jobs by reducing the workload once reprocessing is eliminated [11].

Upon understanding the importance of the research, the objective was established: To implement Lean Manufacturing to reduce the variability in the production of prefabricated items for a restaurant chain in the Huanchaco district of Trujillo city in 2024. Thereafter, the specific objectives were defined: 01) To implement the Jidoka tool to reduce the percentage of defective products in the production area of the prefabricated items plant of a restaurant chain in the Huanchaco district of Trujillo city in 2024; 02) To implement the Jidoka tool to reduce variability in the production area of the prefabricated items plant of a restaurant chain in the Huanchaco district of Trujillo city in 2024.

2 | THEORETICAL FRAMEWORK

2.1 | Lean manufacturing

It is a strategy used in production or service systems that focuses on eliminating waste, understood as activities that do not add value [12]. Its purpose is also to reduce actions that hinder the flow of the process without contributing any value [13].

2.2 | Jidoka

Jidoka should facilitate the maximization of manufacturing efficiency, as well as increase production, decrease errors, reduce products that do not meet standards, and lower process costs [14]. This concept involves the automation of processes with a human element, using people's intelligence to identify errors or non-conformities through detection tools [15]. It is not necessary to have advanced machinery to identify faults, since the essence of Jidoka lies in using the capabilities of the team with a simple machine that can recognize the malfunction of the process and prevent the production of defects [16].

The Jidoka method aims to reduce variability by lowering the number of defective products through human ingenuity. This is achieved by halting production upon identifying an error or nonconformity using various detection tools [15]. The Jidoka methodology was once again employed to reduce manufacturing fluctuations. To this end, the process capacity index (C_p), adjusted process capacity (C_{pk}), and Taguchi metric (C_{pm})—key elements for managing these variations—were evaluated. The main objective is to optimize these variations and ensure that production remains within defined parameters. Through the application of acceptance sampling systems, a considerable number of non-conforming products were detected in the area. Additionally, the Andon system (to warn of malfunctions), Poka-Yoke (designed to prevent errors), and operator-assisted automation, which stops the line if a defect occurs, were integrated. Adopting this strategy is recommended as it facilitates workflow improvement, thus enabling deliveries to be made in the stipulated quantity and timeframe [17].

2.3 | Statistical process control

Shewhart developed statistical process control by combining Deming's quality tools [18]. Implementing statistical process control helps improve quality, which optimizes actual capacity. Knowing how capable a process is allowing informed decisions to be made based on specifications, product needs, and the amount of material that must be reworked or discarded if tolerances are insufficient. Finally, it is also important to know if production meets exact specifications and if components are interchangeable [19].

2.4 | Short term capacity

Short-term capacity is determined by a wide variety of data collected over a short period of time, meaning that the standard deviation is analyzed over a brief period and is also evaluated from small batches or subgroups in nearby sectors obtained over a longer period. For this reason, capacity reflects the potential of the process [13].

2.5 | Process capacity (C_p)

Process capacity helps identify changes in operating settings and the variation of the organization's internal processes against the established objective [20]. Processes are under statistical control if their capacity reaches six sigma. [19], The calculation is represented in equation (1) "Process capacity index (C_p)".

$$C_p = \frac{US - LS}{6\sigma} \tag{1}$$

US = Upper specification; LS = Lower specification; σ = Standard deviation of the process. The explanations for the performance results are shown in Table 1.

TABLE 1 Interpretation of process capacity results

Result	Interpretation
$C_p \geq 2.00$	The process is considered "world class", with 6σ quality.
$C_p > 1.33$	The process is considered adequate.
$1.00 < C_p < 1.33$	The process is considered partially adequate, requiring strict control.
$0.67 < C_p < 1.00$	The process is considered inadequate, therefore reviewing it and making adjustments to achieve a quality standard that meets the requirements is paramount.
$C_p < 0.67$	Process considered inadequate and modifications are suggested.

2.6 | Real process capacity (C_{pk})

The C_{pk} index gives an idea of the process variability within the specification, but it does not take into account the ability to focus on the target value, so it is limited. It restricts the process outcome, but does not know how much it differs from ideal expectations, consumers, and market competitiveness [20]. The real capacity index represents the minimum lower capacity (C_{pi}) and the upper capacity (C_{ps}); the process is centered when C_p equals C_{pk} [19]; The calculation is presented in equation (2).

$$C_p = \frac{\mu - LS}{3\sigma} \tag{2}$$

C_{pi} = Lower real process capacity; μ = Process means; LS = Lower specification; σ = Standard deviation of the process.
The lower capacity (C_{pi}) is obtained by comparing the difference between the mean and the lower limit with three times the standard deviation [20]; the calculation is presented in equation (3).

$$C_{ps} = \frac{US - \mu}{3\sigma} \tag{3}$$

C_{ps} = Upper real process capacity; μ = Process means; US = Upper specification; σ = Standard deviation of the process.
The upper capacity (C_{ps}) is obtained as a result of the ratio between the difference of the upper specification and the mean with respect to 3 times the standard deviation [20]; the calculation is presented in equation (4).

$$C_{pk} = \min\left[C_{pi}, C_{ps}\right] \tag{4}$$

C_{pi} = Lower real process capacity; C_{ps}=Upper real process capacity.
The real capacity index shows the lowest value between the lower capacity (C_{pi}) and the upper capacity (C_{ps}) [19]. A process is considered balanced if C_p equals C_{pk} [20]. The following section details the analysis of the performance results shown in Table 2.

TABLE 2 Interpretation of the real process capacity results (C_{pk})

Result	Interpretation
$C_{pk} > 1.25$	The process is capable and focused
$0 < C_{pk} \leq 1.25$	The process has unsatisfactory capacity; some improvements are required to optimize centering.
$C_{pk} \leq 0$	The process is not capable and is outside the customer's specifications.

2.7 | Taguchi ability

Capacity and performance metrics are analyzed to reduce process variability and ensure specifications are met. However, from Taguchi's perspective, meeting specifications does not guarantee adequate quality. Variability reduction must occur around the ideal value, which represents improved quality. In other words, Taguchi argues that process improvement should focus on reducing variability around the optimal point N, rather than simply meeting specifications [13].
The Taguchi index is used to manage process capacity, taking into account the bias and variability present in them [21], calculated by equation (5).

$$C_{pm} = \frac{US - LS}{6\tau} \tag{5}$$

US = Upper Specification; LS = Lower Specification; τ = Taguchi index. Taking into consideration the calculation of τ.Equation (6).

$$\tau = \sqrt{\sigma^2 + (\mu - \text{Nominal value})^2} \tag{6}$$

σ = Standard deviation; μ = Process means; $Nominal value$ = Target or ideal value for the characteristic being evaluated.
The interpretations of the results of the real process performance shown in Table 3.

2.8 | Percentage of defective products

Defective products are those that do not meet the specifications established by the customer, leading to returns, complaints, and the need to redo the work. These items are part of the seven types of waste identified by Lean Manufacturing, and their elimination is one of the objectives of the Just-in-Time approach and the Toyota Production System. This emphasizes the importance of learning, knowledge transfer, and the delegation of responsibilities to employees [22]. "Defective or non-conforming products" are problematic because

TABLE 3 Interpretation of the Taguchi capacity Results

Result	Interpretation
$C_{pm} < 1.00$	The process does not meet the consumer's specifications or requirements due to inadequate centering or high variability.
$1.33 > C_{pm} > 1.00$	The process does meet the consumer's specifications or requirements, indicating that the average is within the central third.
$C_{pm} > 1.33$	The process does meet the client's specifications or requirements, indicating that the average is within the central 5th.

a high quantity of defective products generates additional processes and causes dissatisfaction among end consumers. Process efficiency is improved once the number of products that do not meet quality standards is reduced [23].

3 | DESIGN AND METHODOLOGY

The research carried out was practical in nature, because this type of work focuses on using what is already known to address the variables in a test situation [24]. With a quantitative approach, this technique allowed for the analysis of data and the various quantitative expressions presented in the metrics [25]. This longitudinal experimental study, which included pre-test and post-test analysis in a single group, lacked internal validity due to the absence of a control group [26]. It was of explanatory scope, since, by linking the phenomenon with the variables, they could be connected using prior knowledge to optimize processes, such as Lean Manufacturing, and waste in the factory of prefabricated elements of a restaurant chain could be minimized [27].

The most common approach to implementing Jidoka was adopted: the Deming cycle, as adapted by Shewhart. This cycle is considered a continuous improvement-focused approach, aligned with research, which acts as a logical framework that facilitates the application of Lean Manufacturing in different contexts and helps find solutions to problems [28].

The general hypothesis was defined: The application of Lean Manufacturing improves the production management of the prefabricated plant of a restaurant chain in the Huanchaco district of the city of Trujillo in the year 2024. Subsequently, the specific hypotheses were established: 01) The implementation of the Jidoka tool reduces the percentage of defective products in the production area of the prefabricated plant of a restaurant chain in the Huanchaco district of the city of Trujillo in the year 2024; 02) The implementation of the Jidoka tool reduces the variability in the production area of the prefabricated plant of a restaurant chain in the Huanchaco district of the city of Trujillo in the year 2024.

The unit of analysis for this research was the "production batch" from the prefabricated food plant of a restaurant chain in Trujillo between 2023 and 2024. The population was defined as the production batches from the prefabricated food plant of the "Mar y Arena" restaurant in Trujillo. One hundred percent of the production batches from the prefabricated food plant were selected due to their accessibility, using convenience sampling [25].

To determine if the data followed a normal distribution, the Kolmogorov-Smirnov test was used, which is useful for large datasets greater than 50 [29]. Regarding hypothesis testing, the Mann-Whitney U test was applied, ideal for comparing independent groups by analyzing the median without requiring normality in the data. Since the indicators in this research are non-parametric and the experimental design included a longitudinal pre- and post-test, the unrelated data are perfectly suited to the Mann-Whitney U test [25].
Finally, Rosenthal's effect size analysis was performed, which examined the strength of the connection by

showing the true effect of the findings beyond the p-value, highlighting the practical importance of the results in the field of applied research [30].
The analysis and understanding of the data were carried out using Lean Manufacturing, by following the Deming Cycle, an approach used for continuous improvement in organizations. The scientific method used in this approach is understood as a process characterized by its orderly nature for discovering reality [26]. The process began with direct and documentary observation. Once the evidence was identified, the information was compared with the context of the processes, including both the historical analysis of these production processes and their statistical analysis. An analysis of the current manufacturing situation at the prefabricated elements plant for the restaurant chain was conducted. The process lines impacted by the problem were identified, highlighting the difficulty of poor production management due to the excessive creation of kitchen packages, as well as the lack of a production planning system.

3.1 | Ethical and scientific integrity considerations

For the development of this research on automation and process improvement, the principles of scientific integrity and research ethics were rigorously applied, aspects that are unavoidable when addressing dilemmas related to the production of new knowledge and empirical validation in the organizational field [31]. By directly intervening in the operational processes and metrics of the restaurant chain's prefabricated plant, strict compliance with confidentiality and the protection of corporate data was guaranteed, obtaining the respective institutional authorization under the premise that the information collected would be used for exclusively academic and scientific purposes [32]. On the other hand, given that the experimental methodology of the research and the implementation of the Jidoka tool involve the experience of the collaborators, it was ensured at all times that the quantitative data collection procedures did not violate the rights, integral well-being, or dignity of the production workers involved in the sample [33]. Similarly, and in strict accordance with the Sustainable Development Goals, the actions of the study were supported by the ethical perspective of simplifying production processes to promote the common good, improving the work environment by eliminating excessive workloads resulting from reprocessing [31].

4 | RESULTS AND DISCUSSION

The results are presented subsequent to the implementation of the Jidoka tool in the indicators defined as percentage of defective products (Table 4), process capacity (, real process capacity and Taguchi process capacity, with an identification of the pre test, post test and its reduction.

TABLE 4 Percentage of defective products

Family	Pre test	Post test	Reduction
Seafood	54.15	0.00	54.15
Chunked fish	48.31	0.00	48.31
Chunked root vegetable	58.87	0.00	58.87
Ground vegetable	33.33	0.00	33.33
Chopped vegetable	42.68	0.00	42.68

The reduction to 0 is evident in all product families analyzed. The chopped tuber family was identified as the one with the greatest reduction, whereas the chopped vegetable family presented the least reduction.

TABLE 5 Process capacity

Family	Pre test	Post test	Conclusion
Seafood	0.22	2.00	Sigma quality
Chunked fish	0.26	1.78	Appropriate process
Chunked root vegetable	0.06	1.92	Appropriate process
Ground vegetable	0.06	2.00	Sigma quality
Chopped vegetable	0.06	1.88	Appropriate process

An increased capacity across all analyzed product families is evident. The seafood and ground vegetable families showed the greatest increase, while the chopped fish family registered the smallest increase.

TABLE 6 Real process capacity

Family	Pre test	Post test	Conclusion
Seafood	0.10	1.50	Capable and focused process
Chunked fish	0.08	1.51	Capable and focused process
Chunked root vegetable	-0.02	1.59	Capable and focused process
Ground vegetable	-0.05	1.50	Capable and focused process
Chopped vegetable	-0.09	1.56	Capable and focused process

The real process capacity of all the analyzed product families increased notably. The chopped tuber family registered the most significant surge, whereas the seafood and ground vegetable families experienced the smallest growth.

TABLE 7 Taguchi process capacity

Family	Pre test	Post test	Conclusion
Seafood	0.19	1.31	Process meets specifications with its mean within the middle 3rd.
Chunked fish	0.20	1.36	Process meets specifications with its mean within the middle 5th.
Chunked root vegetable	0.06	1.31	Process meets specifications with its mean within the middle 3rd.
Ground vegetable	0.06	1.31	Process meets specifications with its mean within the middle 3rd.
Chopped vegetable	0.05	1.35	Process meets specifications with its mean within the middle 5th.

Similarly, an improvement in the Taguchi capacity across all evaluated families is evident. The chunked fish family presented the most significant improvement, whereas the seafood, chopped tuber and ground vegetable families experienced the least variation.

4.1 | Normality test – Percentage of defective products

For the percentage of defective products indicator, the normality test was performed with a sample size of 150 data points. The Kolmogorov-Smirnov normality test was used, and it was determined that most normality tests resulted in a non-parametric distribution, as the values were less than the significance level of 0.05. However, with respect to the percentage of defective products index, we observed that the "cut fish" category had a normal distribution in the data before the improvement and a non-normal distribution post-improvement. Table 8 presents the normality test of the percentage of defective products data.

TABLE 8 Percentage of defective products normality test

Family	Pre Test		Post Test	
	p-value	Observation	p-value	Observation
Seafood	< 0.01	Not normal	< 0.01	Not normal
Chunked fish	> 0.15	Normal	< 0.01	Not normal
Chunked root vegetable	< 0.01	Not normal	< 0.01	Not normal
Ground vegetable	< 0.01	Not normal	< 0.01	Not normal
Chopped vegetable	< 0.01	Not normal	< 0.01	Not normal

4.2 | Normality test – Process capacity

For the process capacity indicator, the normality test was performed with a sample size of 150 data points, and the Kolmogorov-Smirnov normality test was used. It was determined that most normality tests resulted in a non-parametric distribution, as the values were less than the significance level of 0.05. Table 9 presents the normality test of the process capacity.

TABLE 9 Normality test of the process capacity

Family	Pre Test		Post Test	
	p-value	Observation	p-value	Observation
Seafood	< 0.01	Not normal	< 0.01	Not normal
Chunked fish	< 0.01	Not normal	< 0.01	Not normal
Chunked root vegetable	< 0.01	Not normal	< 0.01	Not normal
Ground vegetable	< 0.01	Not normal	< 0.01	Not normal
Chopped vegetable	< 0.01	Not normal	< 0.01	Not normal

4.3 | Normality test – Real process capacity

For the Real process Capacity indicator, the normality test was performed with a sample size of 150 data points, and the Kolmogorov-Smirnov normality test was used. It was determined that most normality tests resulted in a non-parametric distribution, as the values were less than the significance level of 0.05. Table 10 presents the normality test of the real process capacity. Table 10 presents the normality test of the real process capacity.

TABLE 10 Normality test of the real process capacity

Family	Pre Test		Post Test	
	p-value	Observation	p-value	Observation
Seafood	< 0.01	Not normal	< 0.01	Not normal
Chunked fish	< 0.01	Not normal	< 0.01	Not normal
Chunked root vegetable	< 0.01	Not normal	< 0.01	Not normal
Ground vegetable	< 0.01	Not normal	< 0.01	Not normal
Chopped vegetable	< 0.01	Not normal	< 0.01	Not normal

4.4 | Normality test – Taguchi capacity

For the Taguchi capacity indicator, the normality test was performed with a sample size of 150 data points, and the Kolmogorov-Smirnov normality test was used. It was determined that most normality tests resulted in a non-parametric distribution, as the values were below the significance level of 0.05. However, with respect to the Taguchi process capacity index, we observed that the "cut fish" data group showed a non-normal distribution before the improvement and a normal distribution after the improvement, while the "chopped vegetables" data group also showed a non-normal distribution before the improvement and a normal distribution after the improvement. Table 11 presents the normality test of the Taguchi capacity.

TABLE 11 Normality test of the Taguchi capacity

Family	Pre Test		Post Test	
	p-value	Observation	p-value	Observation
Seafood	< 0.01	Not normal	< 0.01	Not normal
Chunked fish	< 0.01	Not normal	> 0.15	Not normal
Chunked root vegetable	< 0.01	Not normal	< 0.01	Not normal
Ground vegetable	< 0.01	Not normal	< 0.01	Not normal
Chopped vegetable	< 0.01	Not normal	> 0.15	Not normal

4.5 | Specific Hypothesis 1. The implementation of the Jidoka tool reduces defective products.

Upon deploying the improvement tools to decrease the percentage of defective products, data were collected until the investment was recovered. This approach determined an equitable change in the amount of data before and subsequent to the test. For the percentage of defective products indicator, it was determined that most normality tests resulted in a non-parametric distribution, as they were below the significance level of 0.05. However, regarding the percentage of defective products index, we observed that the "cut fish" product category had a normal distribution in the data before the improvement and a non-normal distribution following the improvement. Regarding this point, the Mann-Whitney U test will be applied, as the other indicators of the same nature raise doubts about the normality of the data, thus making the use of the Mann-Whitney U test necessary. Table 12 shows the hypothesis tests for the indicator.

TABLE 12 Percentage of defective products hypothesis test

Sample	p Value	Z	r Rosenthal
Seafood	0.00	9.55	0.55
Chunked fish	0.00	10.70	0.61
Chunked root vegetable	0.00	10.70	0.61
Ground vegetable	0.00	10.13	0.58
Chopped vegetable	0.00	10.70	0.61

The null hypothesis stated that the median of the data equaled zero, while the alternative hypothesis proposed a median below zero. A p value of 0.00 was recorded for the five evaluated product families, which falls below the significance level. Consequently, the null hypothesis is rejected and the alternative hypothesis is accepted. Furthermore, a r Rosenthal value greater than 0.50 statistically demonstrates a large effect size for all families.

4.6 | Specific hypothesis 02. The implementation of the Jidoka tool reduces variability.

Process capacity. Following the application of the improvement tools to increase process capacity, data were collected until the investment was recovered to establish an equitable change in the amount of data before and post test. For the process capacity indicator, it was determined that most normality tests resulted in a non-parametric distribution, as they were below the significance level of 0.05. Given the similar nature of the indicators, the Mann-Whitney U test was considered for use. Table 13 shows the hypothesis tests for the indicator.

TABLE 13 Process capacity hypothesis test

Sample	p Value	Z	r Rossenthal
Seafood	0.00	10.65	0.61
Chunked fish	0.00	10.70	0.61
Chunked root vegetable	0.00	10.70	0.61
Ground vegetable	0.00	10.70	0.61
Chopped vegetable	0.00	10.70	0.61

The null hypothesis posited that the median of the data equaled zero, whereas the alternative hypothesis suggested a median greater than zero. The p value obtained for the 5 product families evaluated was 0.00, which is less than the significance level. Therefore, the null hypothesis was rejected and the alternative hypothesis accepted. A r Rosenthal value greater than 0.50 statistically proves a large effect size for all product categories. Real process Capacity. Subsequent to the execution of the improvement tools to increase the real process capacity, data collection continued until the investment was recovered to ensure an equitable change in the amount of information prior to and following the test. For the Real process Capacity indicator, it was determined that most normality tests resulted in a non-parametric distribution, as they were below the significance level of 0.05. Given the similar nature of the indicators, the Mann-Whitney U test was considered for use.

In this case, the null hypothesis defined the median of the data as equal to zero, and the alternative hypothesis

TABLE 14 Placeholder Caption

Sample	p Value	Z	r Rossenthal
Seafood	0.00	10.70	0.61
Chunked fish	0.00	10.70	0.61
Chunked root vegetable	0.00	10.70	0.61
Ground vegetable	0.00	10.70	0.61
Chopped vegetable	0.00	10.70	0.61

defined the median as greater than zero. A p value of 0.00 was obtained for all the five product families, falling below the significance threshold. As a result, the null hypothesis is rejected and the alternative hypothesis is accepted. A r Rosenthal value greater than 0.50 provides statistical evidence of a large effect size for all groups.

4.7 | Taguchi Capacity.

Once the improvement tools were implemented to increase the Taguchi capacity of the process, data retrieval was sustained until the investment was recovered in order to determine an equitable change in the amount of pre-test and post-test data. For the Taguchi capacity indicator, it was determined that most normality tests resulted in a non-parametric distribution, as they were below the significance level of 0.05. However, with respect to the Taguchi process capacity index, we observed that the "cut fish" data group showed a non-normal distribution before the improvement and a normal distribution once improved, and the "chopped vegetable" data group showed a non-normal distribution before the improvement and a normal distribution thereafter. Regarding this point, the Mann-Whitney U test will be applied, since this test is designed for analysis when parametric data do not fully meet the assumptions of normality, a feature that makes it more powerful than other tests that require the data to be normally distributed. The presence of other indicators of the same nature raises doubts about the normality of the data, which is why the Mann-Whitney U test was deemed appropriate. Table 15 shows the hypothesis tests for the indicator.

TABLE 15 Taguchi capacity hypothesis test

Sample	p Value	Z	r Rossenthal
Seafood	0.00	10.70	0.61
Chunked fish	0.00	10.70	0.61
Chunked root vegetable	0.00	10.70	0.61
Ground vegetable	0.00	10.70	0.61
Chopped vegetable	0.00	10.70	0.61

The null hypothesis assumed the median of the data equaled zero, and the alternative hypothesis proposed a median greater than zero. A p value of 0.00 was recorded for the five evaluated product families, which is less than the significance level; therefore, the null hypothesis is rejected and the alternative hypothesis is accepted. The r Rosenthal value, being greater than 0.50, statistically confirms a large effect size for all families.

5 | DISCUSSION

Regarding the reduction of defective products, a reduction of 47.47% was achieved; these findings are confirmed by Cabrera's research [34], who achieved an 89.20% reduction in defective inputs in pre-manufactured foods through the implementation of Lean Manufacturing tools such as Value Stream Mapping, statistical process control, and continuous improvement techniques inspired by Kaizen, which required an examination of materials, inputs, and production procedures. This approach is based on value stream analysis, which helps identify critical points that cause defective products, thus making the implementation of appropriate process control and the use of efficient error-prevention tools such as Poka-Yoke and Andon necessary.

The reduction in variability during the weighing and packaging operations is indicated by an increase in process capacity to 1.92, a process sigma power, an increase in real process capacity to 1.53, a process capable of manufacturing to customer specifications and centered, and a Taguchi index of 1.33, which allows us to determine that the process mean is within the central third. The optimization of variability is supported by Rocha's research [35], those who optimize the initial (and real) process capacity indices from 0.38 to 1.82. These results are theoretically consistent, since in practice the restaurants achieve a reduction in process variability, a reduction in defective products, in addition to the maximization of process capacity to meet the production requirements of the process.

6 | CONCLUSIONS

The proportion of defective products was reduced from 47.47% to 0.00 by implementing statistical process control in the sample; as demonstrated in the Mann Whitney hypothesis tests, for all product families that were part of the research, a p value of 0.00 was recorded, which is below the significance threshold of 0.05, indicating statistically significant results, with a Rosenthal r value greater than 0.50, evidencing a large effect size for all categories.

Variability was reduced by increasing process capacity (C_p) upon the implementation of Kaizen tools for variability control in the sample. With an initial capacity of 0.13, indicating an inadequate process requiring changes, a final capacity of 1.92 was achieved, thus establishing an adequate process. As demonstrated by the Mann-Whitney U test for all product categories in the study, a p Value of 0.00 was obtained, below the significance level of 0.05, indicating that the results are statistically relevant.

Regarding the real process capacity (C_{pk}), an increase was achieved once variability was reduced in the processes of the selected sample. The initial capacity was 0.00, indicating that the process was incapable and outside of production specifications. A final capacity of 1.53 was reached, signifying that the process is capable and well-centered. This is demonstrated through Mann-Whitney U test; for all product categories involved in the study, a p value of 0.00 was recorded, which is below the significance level of 0.05, indicating that the results are statistically significant.

Finally, the Taguchi Capacity (C_{pm}) score was improved in the processes, with a focus on reducing production variability through the application of Kaizen tools and value stream analysis. Previously, the capacity score was 0.11, indicating that the process did not meet customer specifications due to high variability; however, a capacity scores of 1.33 was achieved, now meeting specifications and with the mean falling within the middle third. Mann-Whitney U test results for all product groups considered in the study yielded a p Value of 0.00, below the significance level of 0.05, indicating statistically significant results. Furthermore, a Rosenthal r value greater than 0.50 demonstrates a statistically significant effect size for all product groups.

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