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Six Sigma Model And Its Impact On The Productivity Of An Organic Banana Exporting Company

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Abstract
The importance of applying a six sigma model in an organic banana exporting company was demonstrated. The main objective was to determine the impact on productivity by the application of the methodology. The study was applied, pre-experimental, with a quantitative approach and an explanatory level. The five phases of the model were implemented. The population was made up of productivity records grouped in weeks for eight months: from July to October 2021 and from March to June 2022, that is, four months before and four months after the application of the improvement. The techniques used in the collection of information were observation, documentary analysis. It was concluded that the application of the improvement had a positive impact on productivity, being evidenced with the increase of 24.7%. The t student test was applied to perform the contrast of the hypothesis, obtaining a significance level of 0.001.

Keywords: productivity, six sigma, variability.

INTRODUCTION

Bananas are considered one of the main tropical fruits in the world, abundant in Latin America, especially in Ecuador. In Peru, 160,000 hectares of bananas and bananas are cultivated. 70% is concentrated in the Amazon. For two decades, production in the country has been increasing, becoming one of the main exporters, improving the quality of life of producers. Peruvian bananas target 15 countries (Ministry of Agriculture and Irrigation, 2020). The most important destinations are the United States, the Netherlands, Germany, Belgium, South Korea, Finland and Japan. In the banana industry, market access is highly concentrated, as is production and economic benefits. It is very complicated for small producers and workers, due to the difficult working and living conditions. To that is added losses due to banana discarding, as a result of premature ripening, handling, mechanical damage, deformities, pests, among others. In other cases, bananas are not suitable for export because they do not meet the quality parameters demanded by customers, finished in local markets, or sold as a by-product, affecting the productivity of the expresses (Vásquez et al., 2019).

Peru is no stranger to this problem, added to the lack of knowledge in process improvement, the scarce access to new technologies prevents national and local banana production from increasing its production rates and being more competitive at the international level. The main producers are small farmers, who have often organized themselves into associations to be able to export, in which low productivity, high production costs and inadequate working methods are evident. The most demanding customers and globalization have contributed to the implementation of tools and methodologies for continuous improvement by companies, seeking to reduce costs, increase productivity, making them more efficient and competitive (Dubé et al., 2017). Six sigma is an improvement methodology that aims to reduce costs, increase productivity, by decreasing the number of defective products and the variability of processes (Sharma, Shani and Sharma, 2019). It also seeks to satisfy the requirements and needs of the client with perfect products and processes. This brings benefit to organizations, reflected in increased productivity, lower costs, consumer and employee satisfaction (Deniz and Çimen, 2018).

To the north of the La Libertad Region, in the province of Chepén there are associations that bring together banana producers in order to export their products to various countries. The company under study is in full growth, presents a monthly production of 9 thousand boxes on average, its organic product is welcomed in the international market, but does not take advantage of its resources efficiently, the processes and the product vary constantly, inadequate working methods are executed, to this we must add the incorrect quality control. If this situation continues, productivity will decrease, the organization will be less competitive, even generating losses. That is why it is necessary to take corrective measures that allow you to improve continuously. The problem that has been formulated in this research is: To what extent does the application of the six sigma model affect the productivity of an organic banana exporting company?

This project is socially justified because it provides techniques for improvements in production processes. It is justified in a practical way because it sought to improve productivity and reduce the variability of processes in the organic banana exporting company. Methodologically, the research was justified because it was carried out with the purpose of providing an improvement model based on the six sigma methodology for organic banana exporting organizations. The general objective is: To determine the impact of the six sigma model on the productivity of an organic banana exporting company. The specific objectives that will help in the fulfillment of the general objective are: to measure productivity before the application of the six sigma model, as a second objective, to apply the six sigma model in the company's processes, as a third objective, to determine the incidence of the six sigma model on productivity and as a last objective to design at the level of a proposal to improve a six Sigma model for companies exporting organic bananas. The hypothesis is: the implementation of the six sigma model increases productivity in an organic banana exporting company.

METHODOLOGY

Type and design of research

The research was quantitative, experimental, applied with pre-experimental design. The research sought to determine the impact of the six sigma model on productivity.

The scheme of the design was:

$G\ O_1\ X\ O_2$

Where:

G: Experimentation group

X: Stimulus

O: Observation or measurement of the dependent variable

Variable and operationalization

Independent variable: Six Sigma

Conceptual definition: It is considered a methodology of continuous improvement that seeks to increase the value of the company, improve quality, customer satisfaction, the reduction of defects and costs (Sabri et al., 2018).

Operational definition: Six sigma makes use of the DMAIC sub-methodology: define, measure, analyze, improve and control. This variable was evaluated by the dimensions of process capacity and sigma level (Sabri et al., 2018).

Indicators:

Process capacity

($Cp= ES- EI/6\ \sigma$),

Six Sigma Level

DPMO= DPO x 1000000

Measurement scale:

Reason

Dependent variable: Productivity

Conceptual definition: Productivity is an indicator that allows to determine the way in which resources are being used to achieve the proposed objectives. The resources employed can be measured in number of workers, man hours, raw material, machine hours (Jacobs and Chase, 2018)

Operational definition: According to Render and Heizer (2017), productivity can be measured partially (e.g. labor, raw material) or totally.

Indicators:

Labor Productivity = Boxes / H-H.

Raw material productivity=Boxes/kg raw material

Measurement scale:

Reason

Population, sample, sampling and unit of analysis

The study population was made up of the company's productivity records.
Inclusion criteria: The inclusion criteria were considered to be the organization's productivity records for the years 2021 and 2022.

Exclusion criteria: Productivity records for the months of January, February, March, April, May, June, July, November, December 2021 and January, February, July, August, September, October, November, December 2022 were excluded because they were not part of the study period.

Sample: Formed by the records of the productivity grouped in weeks for eight months: from July to October 2021 and from March to June 2022, that is, four months before and four months after the application of the improvement.

Sampling: For this study the sampling was non-probabilistic for convenience, because the next elements are selected, before and after applying the improvement.

Data collection technique and instrument

The techniques of documentary analysis and observation were used, which allowed the collection of the information of the independent variable, with the productivity record sheet instrument, collecting information from four months before and four months after the application of the six sigma model to later determine its effect.

Data analysis method

The method used, after collecting the information was the descriptive one that allowed to organize it, analyze it in tables and figures to process it in the Microsoft Excel software. On the other hand, inferential statistics were used to contract the hypothesis in the SPSS program, ending with the normality test and t student.

RESULTS

Initial productivity

For the calculation of productivity, boxes of 80 units were taken into account, weighing from 19.7 to 20 kilos. The raw material was considered the harvested bananas and for the labor the qualified collaborators. Table 1 se shows that for each worker 32 c bananas are produced weekly on average.

Table 1. Initial labor productivity semanal (Months July-October 2021).

Week	Production (Boxes)	Labor (Workers)	Productivity (Cashiers/Worker)
1	2200	70	31.43
2	2300	70	32.86
3	2400	70	34.29
4	2300	70	32.86
5	2200	70	31.43
6	2200	70	31.43
7	2100	70	30.00
8	2300	70	32.86

9	2400	70	34.29
10	2100	70	30.00
11	2000	70	28.57
12	2300	70	32.86
13	2200	70	31.43
14	2400	70	34.29
15	2200	70	31.43
16	2300	70	32.86
Average	**2244**	**70**	**32.05**

In table 2 se verifies that for each kilogram of raw material is produced 0.72 boxes of bananas per week on average.

Table 2. Weekly initial raw material productivity (Months July-October 2021).

Week	Production (Boxes)	Raw material (kilograms)	Productivity (Boxes/kilogram)
1	2200	3000	0.73
2	2300	3200	0.72
3	2400	3450	0.70
4	2300	3300	0.70
5	2200	3000	0.73
6	2200	3000	0.73
7	2100	2900	0.72
8	2300	3200	0.72
9	2400	3250	0.74
10	2100	2950	0.71
11	2000	2800	0.71
12	2300	3200	0.72
13	2200	3100	0.71
14	2400	3350	0.72
15	2200	3100	0.71
16	2300	3250	0.71
Average	**2244**	**3128**	**0.72**

Table 3 shows that for every sun invested in labor and raw material, 0.097 boxes of bananas are produced weekly average.

Table 3. Combined initial productivity index (Months July-October 2021).

Week	Combined productivity index (boxes/soles)
1	0.096
2	0.100
3	0.103
4	0.099
5	0.096
6	0.096

7	0.092
8	0.100
9	0.104
10	0.092
11	0.088
12	0.100
13	0.096
14	0.104
15	0.096
16	0.100
Average	**0.097**

Six Sigma Model

Define Phase

Table 4 shows that the most important specification required by the customer is the calibration of the banana, in a range of 39 to 46 millimeters, as shown in the table above.

Table 4. Voice of the customer.

Characteristics	Objective	Specs
Calibration	42.5 mm	39-46 mm
Cluster	5 dedos	4-7 dedos
Longitude	7.7 pulg	7.5-8 pulg
Weight	19.85 kg	19.70-20 kg
Tags	>2 etiquetas por clúster.	
Fruit health	No tener mal formaciones de los dedos, rayas, manchas negras.	
Cleaning	No contener insectos, hongos y pedúnculos.	
Fruit cream	Blanco y consistente.	

Table 5 of the main problem shows that 42% of products do not meet customer requirements.

Table 5. Six Sigma Project Framework.

Marco del proyecto six sigma	
Purpose:	Improve labor and raw material productivity
Needs of the company to be met:	Eliminate waste in the production process, decrease product and process variability
Problem Statement:	42% of products do not meet customer requirements, and resources are not used efficiently

Objective:	Increase productivity by at least 15% Decrease variability and increase sigma level.		
Scope:	The entire production process.		
Work team:	Participants	Team role	Dedication
	Luis Cruz Salinas		100%
Metric:	Variation in calibration, PPM, DPMO and sigma level.		

Measure Phase

Repeatability and reproducibility study

The measurement system was evaluated. The test was carried out with three operators, ten bananas and two replicas, giving a total of 60 measurements. Table 6 se shows that the total R&R is 0.2%, less than 10%, meaning that there is repeatability and reproducibility of the data by the personnel and the instrument used respectively. The part by part resulted in 99.8%, that is, the greater variation of the process is due to differences between the parties.

Table 6. Variability contribution percentage.

Fountain	**Components of Variance**	**%Contribution(from the components of Variance)**
Gage R&R total	0.0702	0.20
Repeatability	0.0146	0.04
Reproducibility	0.0557	0.16
Operator	0.0000	0.00
Operator*Part	0.0557	0.16
Part by part	34.3268	99.80
Total variation	34.3970	100.00

In Table 7,the percentage change in total R&R is 4.52%, below 30%, which is acceptable. The part by part is 99.9%, representing the ability of the measurement system to differentiate between the parts. It can be concluded that the measurement system is reliable.

Table 7. Evaluation of the measurement system.

Fountain	**Desv.Est. (DE)**	**Var. study (6 × DE)**	**%Var. study (%VE)**
Gage R&R total	0.26502	1.5901	4.52
Repeatability	0.12065	0.7239	2.06
Reproducibility	0.23597	1.4158	4.02
Operator	0.00000	0.0000	0.00
Operator*Part	0.23597	1.4158	4.02
Part by part	5.85891	35.1534	99.90
Total variation	5.86490	35.1894	100.00

Process capability

In Figure 1, theprocess capacity Cp=0.60, less than 1, indicates that it is not able to meet customer requirements. A large number of calibers are below specifications and others above. In addition, the process is off-center.

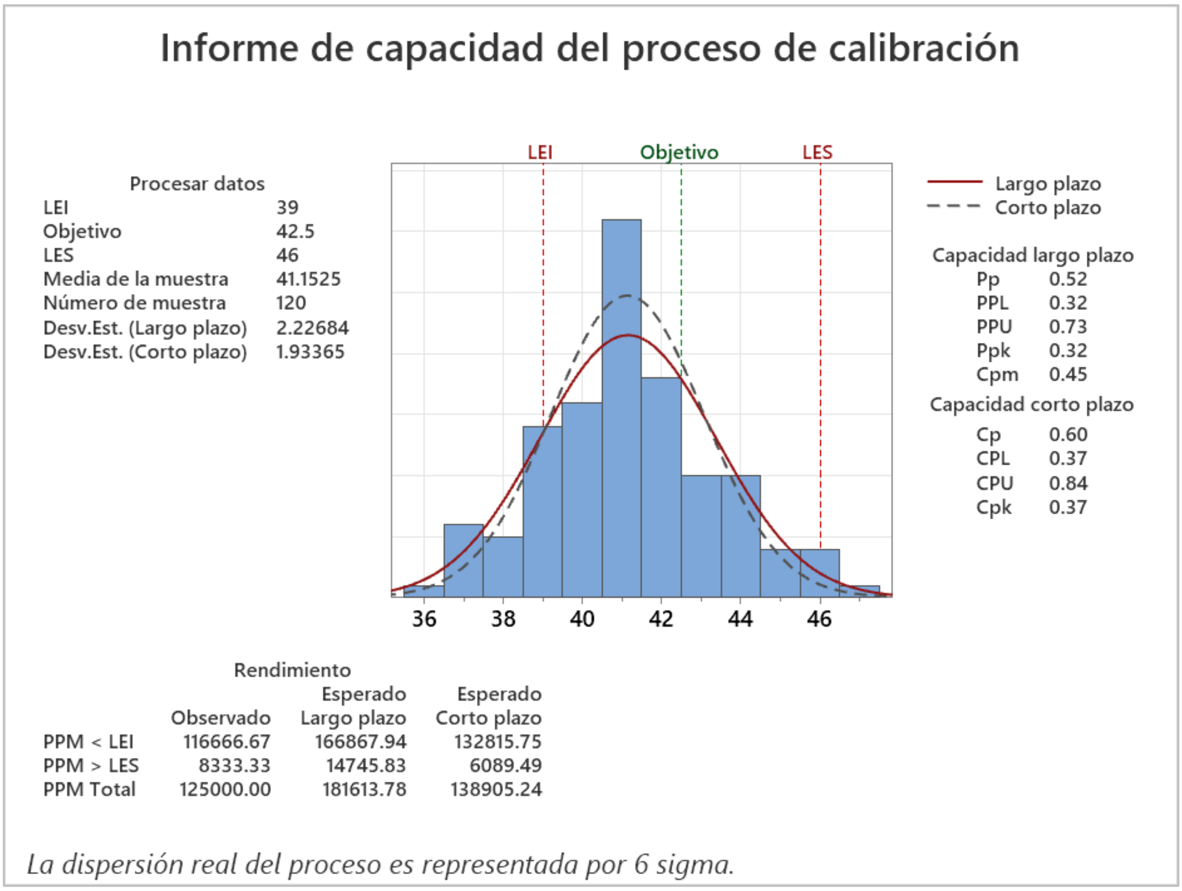

Figure 1. Calibration process capability.

Process stability

We proceeded to the creation of the control charts X and R with 30 samples of 4 elements. In Figure 2, it is observed that the process is unstable, 14 of the 30 samples are outside the control limits.

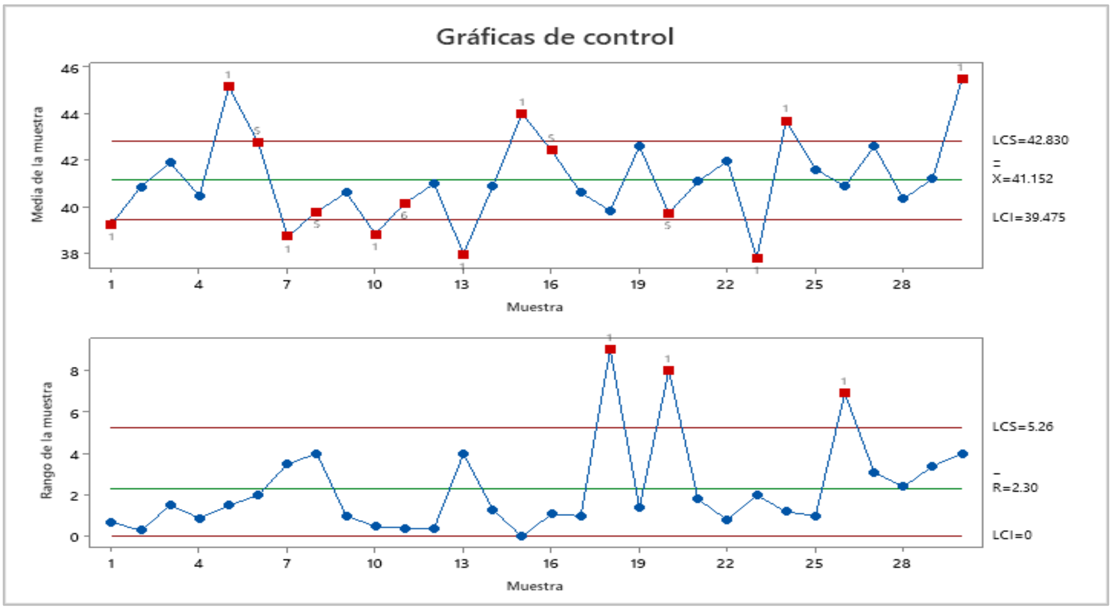

Figure 2. X and R control charts.

Sigma level

Table 8 shows that 79167 defects were found per million bananas produced reaching a sigma level of 2.9.

Table 8. Defects per million opportunities.

Number of bananas inspected (U)	600
Number of bananas with defects (D)	380
Opportunities (O)	8
DPMO	79167
Sigma Level	2.9

Analyze phase

Figure 3 shows the causes that have an effect on the decrease in productivity.

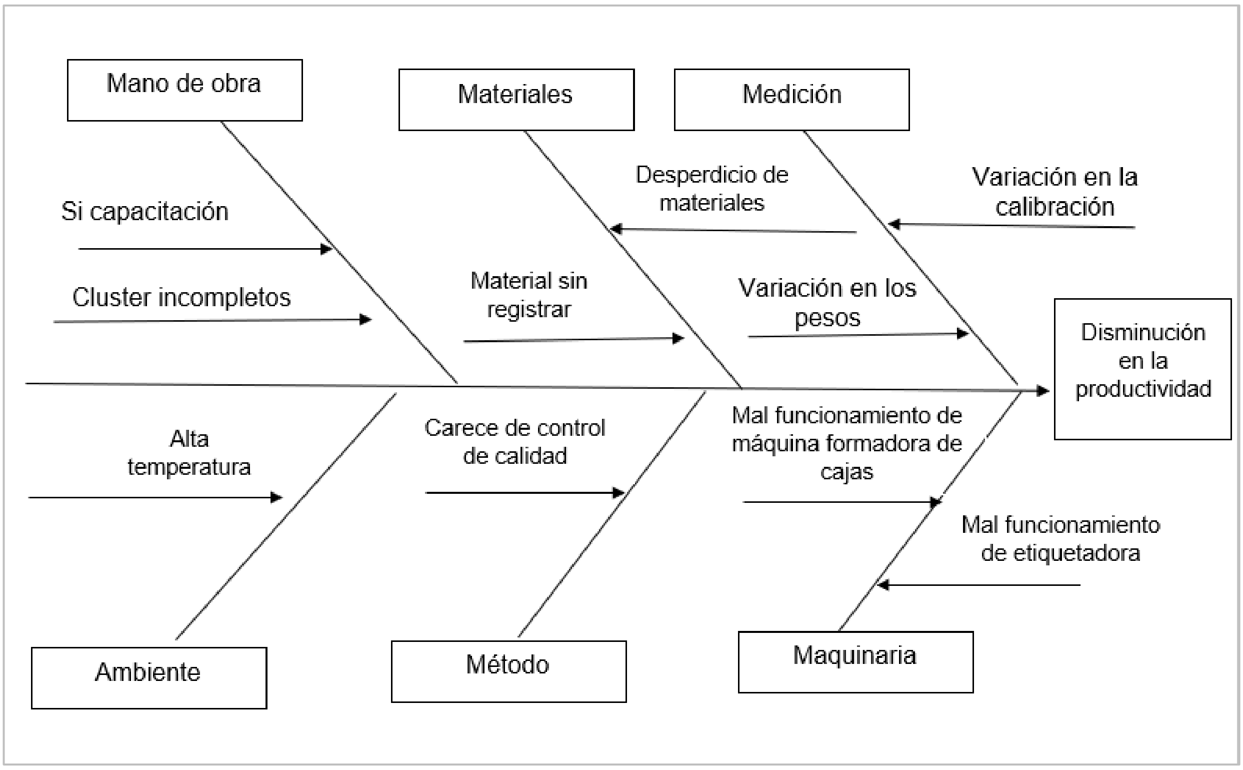

Figure 3. Ishikawa diagram.

In Table 9**,** by pareto criterion se observes that the main causes that influence the decrease in productivity are the variation in calibration, the variation of the weights of boxes and to a lesser extent the waste of materials.

Table 9. Categorization of causes.

Causes	Frequency	%	% Accumulated
Variation in calibration	180	37%	37%
Variation in box weights	160	33%	69%

Waste of materials	50	10%	80%
Incomplete clusters	40	8%	88%
Untrained staff	20	4%	92%
Unregistered material	15	3%	95%
Box forming machine malfunction	10	2%	97%
Labeler malfunction	5	1%	98%
Lacks quality control	5	1%	99%
High temperature in the environment	5	1%	100%

Table 10 shows the influence between the calibration and productivity variables. It is observed that the Spearman correlation coefficient was 0.785, which means that there is a high correlation between calibration and productivity.

Table 10. Spearman correlation incalibration and productivity.

			Calibration	Productivity
Rho de Spearman	Calibration	Correlation coefficient	1.000	.785**
		Sig. (bilateral)	.	<.001
		N	16	16
	Productivity	Correlation coefficient	.785**	1.000
		Sig. (bilateral)	<.001	.
		N	16	16

**. The correlation is significant at level 0.01 (bilateral).

Table 11 shows the coefficients that determine the model. In this sense, the linear regression model was established by the following equation:

Productivity=0.033+0.01 calibration

Table 11. Coefficient of the linear regression model of calibration and productivity.

Model		Non-standardized coefficients		Standardized coefficients	t	Sig.
		B	Desv. Error	Beta		
1	(Constant)	.033	.014		2.332	.035
	Calibration	.001	.000	.779	4.653	<.001

a. Variable dependiente: Productividad

Table 12 showsthe summary of the linear regression model between the variables calibration and productivity established in Table 12. The R^2=0.607, 60.7% of the variation in productivity is explained by the calibration variable.

Table 12. Summary of the linear regression model of the calibration and productivity variables.

Model	R	R square	Adjusted R square	Standard estimation error
1	.779[a]	.607	.579	.00292

a. Predictors: (Constant), Calibration

Table 13 shows the causes that generate the variability in banana calibration: Harvest week, deflowering week and temperature. In this sense, the multiple linear regression showed that, fora significance level of 5%, the temperature variable is not significant for the model, so it is discarded.

Table 13. Levels of significance of the variables.

Model		Non-standardized coefficients		Standardized coefficients	t	Sig.
		B	Desv. Error	Beta		
1	(Constant)	7.280	6.118		1.190	.248
	HarvestWeek (X1)	2.804	.688	.583	4.077	<.001
	WeekDesflore (X2)	.578	.202	.411	2.863	.010
	Temperature(X3)	-.039	.047	-.038	-.829	.417

Table 14 showsthe new linear regression model. The linear regression model is expressed by the expression:

Calibration = 5,607+2,904 WeekCost+0.546 WeekDesflore

Table 14. Significance levels of the new linear regression model.

Model		Non-standardized coefficients		Standardized coefficients	t	Sig.
		B	Desv. Error	Beta		
1	(Constant)	5.607	5.732		.978	.339
	HarvestWeek	2.904	.672	.603	4.321	<.001
	WeekDesflore	.546	.197	.388	2.776	.011

Table 15 shows the summary of the model. The R^2=0.957, means that 95.7% of the variation of the calibration is explained by the variable's week of deflowering and week of harvest included in the linear model.

Table 15. Summary of the new linear regression model.

Model	R	R square	Adjusted R square	Standard estimation error	Durbin-Watson
1	.978[a]	.957	.953	.65872	1.349

Table 16 shows the validation of the multiple linear regression model with the variable's week of deflowering and week of harvest. The test statistic F=235.971 and p=0.001<0.05. At a significance level of 5%, it was stated that the linear model is valid, i.e. the variables harvest week and deflowering week significantly influence the calibration.

Table 16. Linear regression model validation.

Model		Sum of squares	gl	Quadratic mean	F	Sig.
1	Regression	204.781	2	102.391	235.971	<.001[b]
	Residue	9.112	21	.434		
	Total	213.893	23			

Improve phase

Table 17 shows a factorial experiment design 3^2 with two factors: harvest week and deflowering week, each with three levels and three replicates.

Table 17. Factorial design 3^2.

	B: Deflower		
A: Harvest	**Elder (7-12)**	**Regular (5-S6)**	**Minor (3-4)**
10	39- 38-38	43-43-42	47-46-46
11	38-38-38	42-42-43	46-45-46
12	38-37-36	41-41-42	45-45-45

Table 18 shows theresults of the factorial experiment design. It is verified that for a significance of 5%, p<0.05, both the variable of harvest and week of deflower influence the calibration.

Table 18. Analysis of the variance of factorial design 3^2.

Fountain	GL	SC Ajust.	MC Ajust.	F-value	P-value

Model	8	289.407	36.176	108.53	0.000
Linear	4	289.259	72.315	216.94	0.000
Harvest week	2	8.296	4.148	12.44	0.000
Deflowering week	2	280.963	140.481	421.44	0.000
2-term interactions	4	0.148	0.037	0.11	0.977
A*B	4	0.148	0.037	0.11	0.977
Error	18	6.000	0.333		
Total	26	295.407			

Table 19 se presents the summary of the factorial model. It is observed that the variation of the calibration is explained by 97.07% by the variable's week of harvest and week of deflowering.

Table 19. Factorial Design Summary 3^2.

S	**R-square**	**R-square(adjusted)**	**R-square(pred)**
0.577350	97.97%	97.07%	95.43%

Figure 4 shows the optimization of the factorial design model. It is observed that, theoptimal values for A = week of harvest = 11 and for B = week of deflowering = regular (5-6) to obtain a caliber of 42.5 mm.

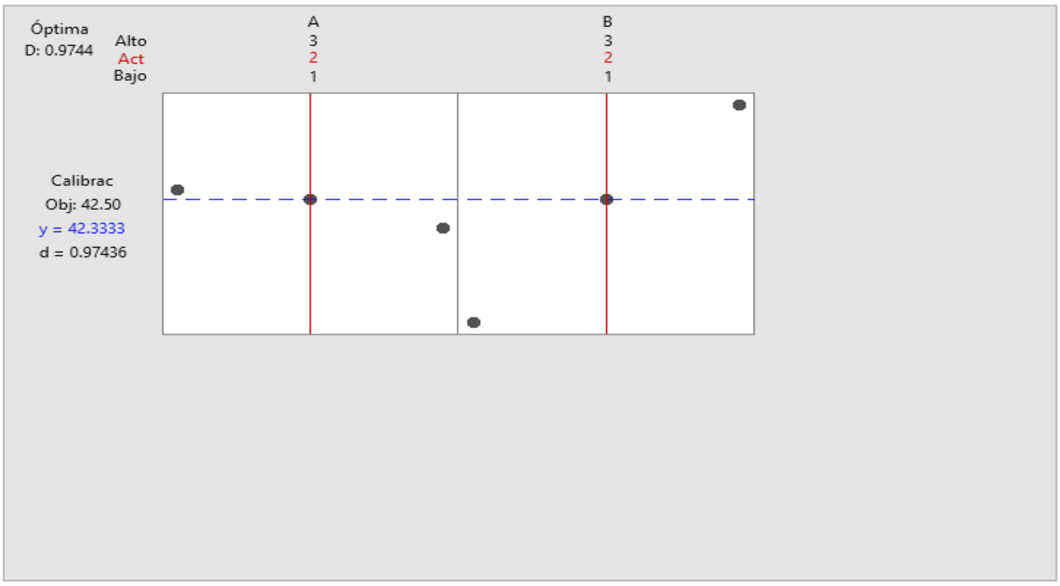

Figure 4. Optimization of the factorial design model.

Figure 5 shows the4-month follow-up of the process capacity index. The processing capacity Cp=1.16, which means that it is at an adequate level.

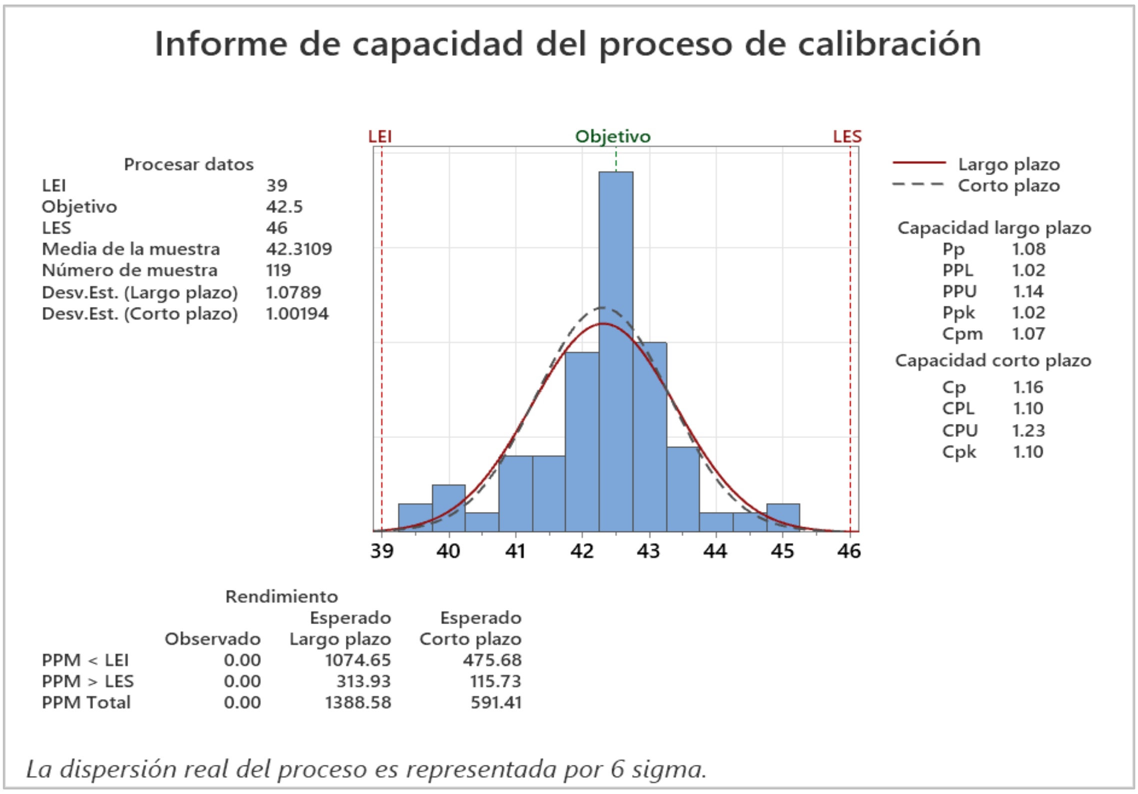

Figure 5. Improved process capacity.

Table 20 shows that the variation in calibration was the most important cause affecting productivity. Through brainstorming, the reasons and solution to the other causes that less affect productivity were found.

Table 20. Solutions of the rest of the causes that affect productivity.

Cause	Reason	Solution
Inaccurate box weight	The sealed box stops the weighing without the exact weight. It has to open and regulate the weight, often causing agglomeration	The box should be sealed after having the proper weight.
Waste of materials	Lack of control of materials in the entry and exit of the same.	Supervise the use of materials, leftovers are entered into the warehouse. Implemented records of inputs and outputs of materials.

Problems with the cardboard forming machine.	Machine in poor condition, detecting a broken rod at the bottom, decreasing the pressure when gluing the box.	Change of rod to the cardboard box forming machine.
Lack of quality control	Few quality control interventions	A schedule of interventions for the quality control of the process was established

Note. Brainstorm workers

Table 21 shows the calculation of the new sigma level. It is observed that the sigma level improved, achieving 10208 defects per million bananas produced reaching a sigma level of 3.82.

Table 21. Defects per million opportunities.

Number of bananas inspected (U)	600
Number of bananas with defects (D)	49
Opportunities (O)	8
DPMO	10208
Sigma Level	**3.82**

Control phase

Figure 6 shows the follow-up to the activities emitted by the collaborators, by means of control graphs and samples of size four, three times a day. Observations are within control limits, which means that they are meeting established specifications.

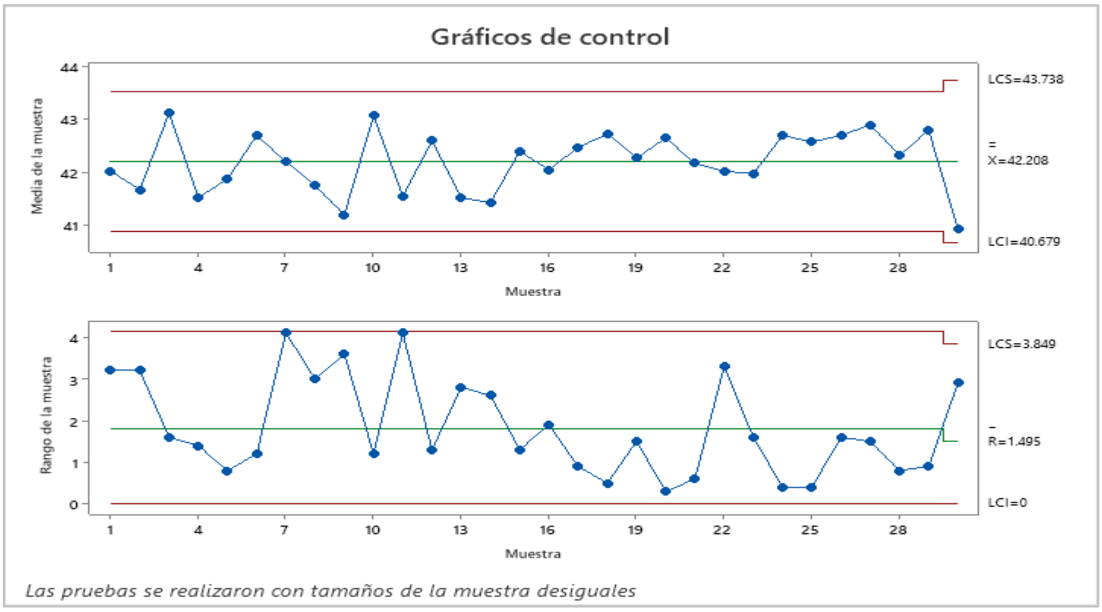

Figure 6. Improved process control charts

Final productivity

Table 22 shows the calculation of productivity indicators after improvements. Se observes that for each worker 40.44 boxes of bananas are produced weekly on average.

Figure 6. Improved process control charts.

Week	Production (Boxes)	Mano de obra (Trabajadores)	Productivity (Cashiers/Worker)
1	2500	70	35.71
2	2600	70	37.14
3	2550	70	36.43
4	2600	70	37.14
5	2650	70	37.86
6	2700	70	38.57
7	2700	70	38.57
8	2850	70	40.71
9	2875	70	41.07
10	2915	70	41.64
11	2950	70	42.14
12	3000	70	42.86
13	3000	70	42.86
14	3000	70	42.86
15	3200	70	45.71
16	3200	70	45.71
Average	**2831**	**70**	**40.44**

Table 23 shows that for each kilogram of raw material, 0.80 boxes of bananas are produced weekly on average.

Table 23. Weekly final raw material productivity (Months March-June 2022).

Week	Production (Boxes)	Raw material (kilograms)	Raw material (kilograms)
1	2500	3100	0.81

2	2600	3200	0.81
3	2550	3200	0.80
4	2600	3300	0.79
5	2650	3400	0.78
6	2700	3400	0.79
7	2700	3500	0.77
8	2850	3500	0.81
9	2875	3600	0.80
10	2915	3600	0.81
11	2950	3700	0.80
12	3000	3700	0.81
13	3000	3750	0.80
14	3000	3800	0.79
15	3200	3900	0.82
16	3200	3950	0.81
Average	**2831**	**3537.50**	**0.80**

Table 24 shows that for every sun invested in labor and raw material, 0.121 boxes of bananas are produced weekly average.

Table 24. Combined Final Productivity Index (Months March-June 2022).

Week	**Combined productivity index (boxes/soles)**
1	0.109
2	0.113
3	0.110
4	0.112
5	0.114
6	0.116
7	0.116
8	0.122
9	0.123
10	0.125

11	0.126
12	0.128
13	0.128
14	0.128
15	0.136
16	0.136
Average	**0.121**

Table 25 shows that the variation in productivity resulted in 24.7%.

Table 25. Comparison of productivity indicators.

Factor	Before	After	Units
Labor productivity	32.05	40.44	$\frac{\text{Boxes}}{\text{Worker}}$
Raw material productivity	0.72	0.80	$\frac{\text{Boxes}}{\text{kg}}$
Raw material productivity	0.097	0.121	$\frac{\text{Boxes}}{\text{S/.}}$

Hypothesis testing

Table 26 shows the normality test. The significance p>0.05 suggests that productivity data follow a normal distribution.

Table 26. Normality test.

	Shapiro-Wilk		
	Statistical	**gl**	**Sig.**
Pretest	.936	16	.305
PostTest	.932	16	.263

Table 27 shows the t student test. It is verified that p = 0.001, less than 0.05, the null hypothesis is rejected. It is concluded that the application of the six sigma model increases the productivity of the company.

Table 27. Paired sample t student test.

		Matched differences							Signification	
		Average	Standard deviation	Standard deviation	95% confidence interval difference		t	gl	P of a factor	Two-factor P
					Inferior	Superior				
Par 1	Pretest - PostTest	-.023750	.009963	.002491	-.029059	-.018441	-9.535	15	<.001	<.001

DISCUSSION

It was possible to determine that the impact of the six sigma model on productivity was reflected in an increase of 27.7%, these results are opposed to those of Arrega (2020), who achieved 12.13% in a banana company in Ecuador, his improvements were focused on the areas of labeling and packaging, it follows that a comprehensive approach was lacking. In the same way they oppose those of Matzunaga (2017), with 8.37% increase, it follows that the variation is due to the difference in the types of production process. On the other hand, the results of Espejo (2018) are similar with 22.87%. In all cases, productivity increases are confirmed, which is corroborated by Raman and Basavaraj (2019), who state that six sigma is a business philosophy, adds profitability, improves productive indicators, quality, consolidating teamwork. Likewise, the results are strengthened by Saryanto, Purba, and Trimarjoko (2020), Raman and Basavajararaj (2018) by stating that organizations improve their processes, eliminate the causes of defects, decrease variability, meet customer needs, increase competitiveness, maintain and maximize business success. It can then be deduced that productivity is an indicator of success in business and its improvement will lead to business competitiveness (Maheshwari and Taparia, 2019).

A six sigma model can be applied in all organizations, both small and large and in various sectors such as: manufacturing (Riddick, et al., 2016). Service, construction (Karakhan, 2017), etc. It comprehensively combines various tools to improve productivity, quality, constraint theory, balance score card, among others (Gajbhiye, et al., 2017). It is very advantageous with respect to others, because it is developed systematically following the five DMAIC stages (Trimarjoko et al., 2019), reduces the variability of the product, the number of defective, leading to increased profitability, productivity and customer satisfaction (Gandhi, et al., 2019; Syafwiratama, et al., 2017). Then it can be said that it has a systematic and structured methodology, turning out to be suitable for current organizations that seek to satisfy the customer, improve productivity and profitability (Jhon and Areshankar, 2018). The application of the model was carried out in its five stages, which allowed to identify the problem, raise and implement the solution, improving the process, quality and complying with the client's specifications. This was evidenced by the improvement in the capacity index (it went from 0.6 to 1.16), the sigma level rose from 2.9 to 3.82, the DPMO decreased from 79167 to 10208, which ensures a more stable process. These results are confirmed by Espejo (2018), Aguirre (2017), who achieved sigma levels of 3.00 and 3.592 respectively. Likewise, Rahman et al., (2018) in their work, managed to reduce defects such as broken stitches and open seams by 35% and increase the sigma level from 1.7 to 3.4. Gupta et al. (2018) in research in India on tires, obtained an increase of this index from 1.65 to 2.56. The process capacity indicator is used to determine how capable the process is to meet customer specifications (Purba and Aisyah,

2017) and to know if it remains within the limits they expect or if adequate controls are necessary.

To achieve these results, various statistical principles and other tools had to be efficiently implemented, which identified, analyzed and solved the problems of the organization (Navarro et al, 2017). From what was stated by the previous authors, it is demonstrated that the model improves quality by increasing the sigma level, which is verified in the reduction of costs and greater productivity, generates measurable indicators together with statistical tools which reduces the variability of the product, processes, grows the capacity having a direct impact on customer satisfaction, productivity, and sustainability of the organization. It was possible to determine the initial indicators of productivity, taking into account the information of four months consolidated in weeks, the production was established in boxes, the labor in workers, the raw material in kilos, the results obtained on a weekly basis on average were: 32.05 boxes / worker (labor), 0.72 boxes / kilogram (raw material), 0.097 boxes/sun (combined index), these values served for the final comparison and to test the research hypothesis when the study was treated with a pre-experimental design. These results are corroborated by Fontalvo et al., (2018) when stating that human resources are a predominant factor in productivity, because it plays a living role in the production activities of the business in favor of achieving business objectives. Due to the importance of this indicator, it is necessary to have measurement tools in order for managers to have certainty and make appropriate adjustments.

Regarding the define stage, the voice of the client was determined with eight specific requirements: calibration, cluster, length, weight, number of labels, health, and cleaning, each with its respective specification, which allowed to have clear objectives before starting the project, involving all stakeholders. In the same way, the framework of the project was defined, where the purpose, needs, problem statement, objective, scope of the work team and the metric to be used were highlighted, giving the work route. On the measurement stage, it allowed to know in a more detailed way the processes specified in the scope of the project, providing information on the variability, capacity, sigma level and what the client expects. A repeatability and reproducibility study were conducted in order to verify the reliability of the measurement system. The capacity of the initial process was determined, resulting in 0.6, which indicated that it was not able to meet the client's specifications, in addition it turned out to be off-center. In terms of stability, the mid- and mid-range control charts corroborated instability by almost 47%. At sigma level it was set at 2.9 meaning 79167 defects per million opportunities. These subtractions allowed the respective analysis to take the appropriate corrective measures.

The result obtained in the variation of the repeatability and reproducibility model was 4.52%, the differentiation between the parts 93.80%, means that the measurement system is under control and is able to differentiate between the measured elements. These results are confirmed by those given by Ozturkoglu et al. (2021) who after improving calibration in the operating room lighting process, obtained repeatability and reproducibility (%R&R) of 8.21%. Similarly, they coincide with those established by Sharma and Sahni (2019), who evaluated the system a measurement system with a two-level design and six factors, the total R&R of the caliber was 8.63%, meaning that there is no special cause and the collaborators present similar levels of performance despite the design of destructive parts. For the success of R&R studies, batch homogeneity is essential (Bhakri and Belokar, 2017). The findings of the research reinforce this statement, otherwise it is possible that it would have failed and the operators would not pass the validation, on the other hand, they helped to obtain information on the execution, performance of the processes, finding and isolation of defective products (Castañeda et al., 2019).

Regarding the analyzed phase, the results of the previous stage were examined and interpreted, comparing the situation found with the history. In this part, the causes of problems were found out, through the Ishikawa diagram, which allowed to bring to light the factors that have an effect on productivity, ordering and categorizing according to their importance. Carvalho et al. (2021), endorses the above mentioned, considering it an effective tool in the reduction of a main problem, through an integration of cause and effect. As a result, variation in banana calibration was the main influencing element. Correlation, simple and multiple linear regression were applied, which allowed to evaluate the influence and importance of the variables. In the search for a relationship between calibration and productivity, the Spearman test was applied, resulting in a high correlation between the study variables, represented by an index of 0.785, which allowed to move to the next level and determine the factors of variation of the banana calibration. The application of simple linear regression was focused on verifying the influence of calibration on productivity, resulting in an R^2 of 60.7%. Similarly, the multiple regression model allowed the temperature variable to be identified as not significant, concluding that the week of deflowering and week of harvest explain 95.7% of the variation in banana calibration. These results are corroborated by Carrasquilla et al. (2016) when modeling the variables of temperature, light, pH, etc., in order to determine their influence on the growth of microalgae, which demonstrates the usefulness of the models in the analysis of the behavior of the input and output variables, setting predictions. In the present study it was used to evaluate and rule out influencing factors. In relation to the improvement phase, the solutions that will attack the root causes, found in the analyze phase, were planned and implemented. Actions were required to solve the problem to achieve the objective of the research, using a series of tools. An experiment design model was applied in order to achieve the most influential variables in calibration and the degree of explanation between them. Optimization was the next step; the right values were obtained and the improvement plan was developed.

Regarding the application of the factorial design of two factors, three levels, three replicas, an R^2 = 97.07% was obtained, which confirms that the calibration of bananas is explained by the variables harvest week and deflower week. The model was optimized, resulting in week 11 being optimal for harvest, and weeks 5, 6 for deflowering. It had been identified that the lack of standardization in the planting and harvesting procedures generated variability in the product, which led to the determination of the best values. This factorial technique gives advantage to the six sigma model in identifying key factors, compared to other improvement methodologies (Sharma, Sahni and Sharma, 2019). Similarly, Primanintyo et al. (2016), used an experiment design model as an improvement methodology, managing to increase the sigma level from 3.10 to 4.01, in a company in Indonesia. This result is reaffirmed by Gerger and Firuzan (2016), who state that this approach reduces the variability of the processes. Once the results are achieved, implementation and control had to be carefully considered (Sreedharan et al., 2019), because, if adequate control and follow-up procedures are not defined, it is possible that the process will return to its initial defect state (Muraliraj et al., 2018). It is for this reason that the project emphasized this stage with the design of graphics, the improvement of the monitoring of operations and the participation of the work team. It could be concluded that the model followed a systematic, structured methodology that helped improve the development of the organization, quality, customer satisfaction, productivity and eliminate waste (Mohamad et al., 2019).

In terms of the stability of the improvements, despite the remarkable progress made in the short term, perhaps the performance may decrease. The project did not reach six sigma, so it is possible that there will be a setback, being necessary actions for sustainability. On the other hand, the factors that generate the variability of the calibration were detected and due control was exercised to maintain long-term stability, being likely to decrease the capacity or quality of the process. Finally, the productivity indicators were calculated after the application of the model: that of labor increased 26%, of raw material 12% and the combined index 24.7%, which evidences the effectiveness of the six sigma methodology used. It was possible to reduce the variability of the process and the product, the resources are used more efficiently. These favorable results were due to the decrease in waste, the optimal establishment of the week of deflowering and harvesting. By increasing productivity, due to the improvements achieved, production costs decrease, allowing the sale price to improve, achieving greater competitiveness. López (2016) corroborates the above, when he states that quality improvement is a primary factor that affects productivity, as it allows the reduction of defective products, reprocesses, waste, returns, etc., obtaining an adequate use of resources.

The main limitation of the study was the short time of its completion. Because it is an experimental investigation, greater follow-up to the variables is required. Therefore, research with greater temporality is suggested, adding other factors that have an impact on the variability of processes and productivity. In addition, in the implementation of the model, some critical factors must be taken into account, such as the commitment of the management, which is fundamental to guarantee its success (Magodi, Daniyan and Mpofu, 2022). It is essential that managers give rise to opportunities for employees to start changes. Another factor is training, to preserve improvements and involve employees in the solution of problems and, finally, the organizational culture, to understand, accept, make the application and practice of six sigma part of the processes of the organization. Likewise, it must be taken into account that six sigma solutions must be examined continuously by the hand of worker training, which leads to the generation of costs that must be annexed in future analyses (Rathi et al., 2022). It can be concluded that productivity is an important indicator in organizations that reflects the efficient use of resources and the success of an organization. The six sigma model (DMAIC) follows a structured method that identifies, analyzes the causes of problems, seeks opportunities for improvement by achieving process stability, improving product quality, decreases variability, the number of defects, reflected in the increase in profitability and productivity (Barboza et al., 2017).

CONCLUSIONS

With the implementation of the six sigma model, it was possible to increase the productivity of the organic banana exporting company from 0.097 boxes/sun to 0.121 boxes/sun, which represents an increase of 24.7% compared to the initial state, which shows the effectiveness of the improvement. Regarding the initial productivity, the labor indicator was established at 32.05 boxes / worker, the raw material at 0.72 boxes / kilogram, the combined index was 0.097 boxes / sun. These indicators were below the industry average, so an improvement model was proposed based on the six sigma methodology. In the application of the improvement, the model with its five phases was implemented. It was determined that the variation in the calibration of bananas is the main cause that affects productivity, being explained with 0.785 correlation and an R^2 of 60.7%. in the analysis of the variation of the calibration three factors were taken into account being ruled out the temperature. Multiple regression explained with 95.7% the influence of the variable's week of deflowering and week of harvest in the calibration. The factor analysis model found as an optimal solution the eleventh week for the harvest, the five and six for the deflowering, which allowed to standardize these production procedures. After the improvements, the process capacity was 1.16 and the sigma level was 3.82, which indicates an adequate process. The final productivity improved compared to the initial one, the labor productivity was 40.44 boxes / worker, the raw material 0.80 boxes / kilogram and the combined index was determined at 0.121 boxes / sun. Regarding the contracting of the hypothesis through the paired sample test, the level of significance was 0.001, less than 0.05, concluding that the application of the six sigma model increased productivity.

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