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Improvement of anchovy meal quality using six sigma and analytical tools in the supply process

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***Abstract*–The fishing industry began to be regulated with fishing quotas in 2008, defining an anchovy catch limit for each company, forcing the sector to operate optimally from capturing the anchovy and taking care of its processing. Among the activities is transporting the anchovy from the ship to the factory, ensuring that the anchovy is not damaged so that the transformation into the fishmeal is more profitable and a better quality**

The Six Sigma methodology will allow for diagnosing and analyzing the improvement opportunities, implementing and controlling them to be sustainable over time.

The business analytics will allow the definition of the control plans for the selected variables with the Six Sigma methodology and, with the help of both ways of working, define Poka yokes in the process.

We get an improvement of 0.5 in the sigma level, equivalent to a profit of $4.3 per ton.

Keywords—Six Sigma, Analitycs, Sigma level.

I. INTRODUCCION

The extraction of anchovy in Peru began at the industry level in 1955 [1], currently fishing in Peru has a growth of 15.7% from 2020 to 2021 GDP [2], so it is what it is one of the main economic activities of the country, generating jobs and commercial relations [3].

In 2008 it was reduced to 50 days of fishing, establishing fishing limits for each fishing vessel to take care of the reproduction of the anchovy and formalize employment in the sector [4]. In this way, the ship has efficient fishing days to finish its fishing limit before the 50 days established by the Peruvian authorities.

Along the Peruvian coast, there are ports and authorized anchovy fishing zones [5], so that any vessel can unload its anchovy in the port of its choice, taking care of the TBVN (Total Volatile Basic Nitrogen), which measures the freshness of the anchovy, having a fresher anchovy can produce a better quality of the fishmeal.

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II. LITERATURE REVIEW

This section describes the main concepts used in the research.

A. Six Sigma

Six Sigma projects focus on deleting errors and reducing process variability through statistical methods and quality management tools [6]. The advantage of this methodology is that it allows the opportunity to improve the process to be determined using the normal distribution [7].

B. Analytics

Business analytics applies a combination of descriptive (what is happening), predictive (why it is happening), diagnostic (why it happened), and prescriptive (what is the best option for the future) analysis. [8]. In different companies, predictive statistics and machine learning models such as GLMs, CART, etc., are used being vital tools of high impact in organizations [9].

C. Clustering

Clustering has different applications, such as a case of summarizing information, segmenting groups, detecting atypical data, or intermediate steps to other models. [10]. Within the evaluation metrics, we have Calinski-Harabasz: where having N represents the number of records, B(K) and W(K) are the sum of squares between and within groups, respectively, with K groups [11], to obtain the optimal number of clusters, CH has to be maximized, see figure 1.

$$CH(K) = \frac{\frac{B(K)}{(K-1)}}{\frac{W(K)}{N-K}}. \quad (1)$$

III. CURRENT SITUATION

The study is about a factory located in the port of Pisco in Peru, which extracts anchovy from the fishing areas of Callao and Pisco, as shown in Fig. 1. The factory operates five months a year, with an average production of 17,000 tons of fishmeal.

The final product of the factory is classified according to its composition into five qualities, which take into account its protein, fat, moisture, and ash, see, Table 1. Therefore, protein must be maximized, and fat and ash minimized in the processing stages process.

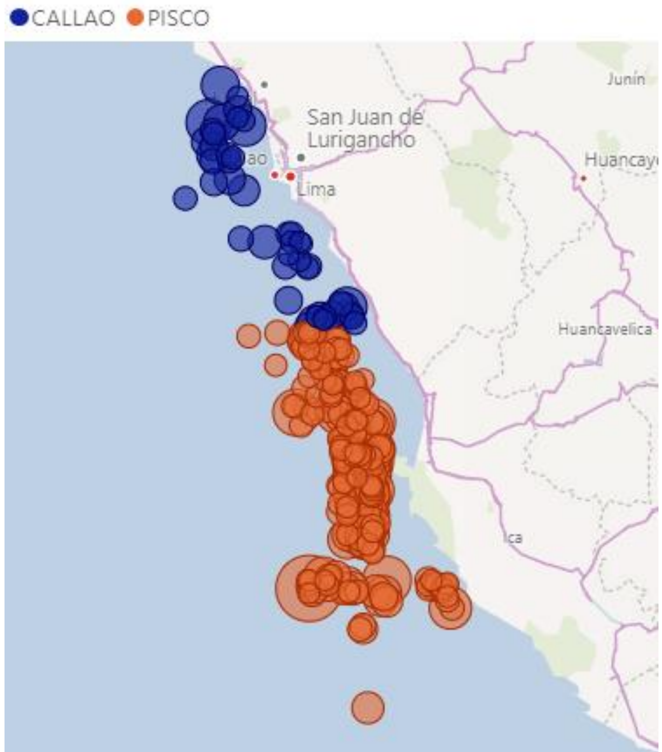

Fig. 1 Anchovy fishing – Port Pisco

The anchovy is sampled for size and weight parameters to assess it in an adult stage and to preserve it.

TABLE I
FISHMEAL PARAMETERS

Parameters	Quality 1	Quality 2	Quality 3	Quality 4	Quality 5
Protein (%min.)	≥68	≥67	≥67	≥67	>65
Fat (%max.)	10	10	10	10	12
Water (%max.)	10	10	10	10	10
Ash (%max.)	≤16	≤17	≤18	≤18	-----

The parameters of ash, fat, protein and humidity are characteristics of the anchovy from the port of Pisco. In Fig. 2 each graph has the quantiles 0.25, 0.5, and 0.75 marked, i.e. the size usually processed in Pisco is between 11.5 and 12.5 cm, has ash between 3.75 and 4.2 %, fat between 3.5 and 5.2 %, weight between 11.25 and 12.6 g, protein between 16 and 17%, and moisture between 74.5 and 76%.

The production of fishmeal has five groups of processes and machines, each with a purpose. The transport stage affects the fat and ash due to the destruction that occurs in the transport pipes, the cooking stage is related to the fat, the water treatment stage with the fat and ash, and the drying stage with the humidity, see Fig. 2, the fat, the water treatment with the fat and ash, the drying with the humidity, see Fig. 3

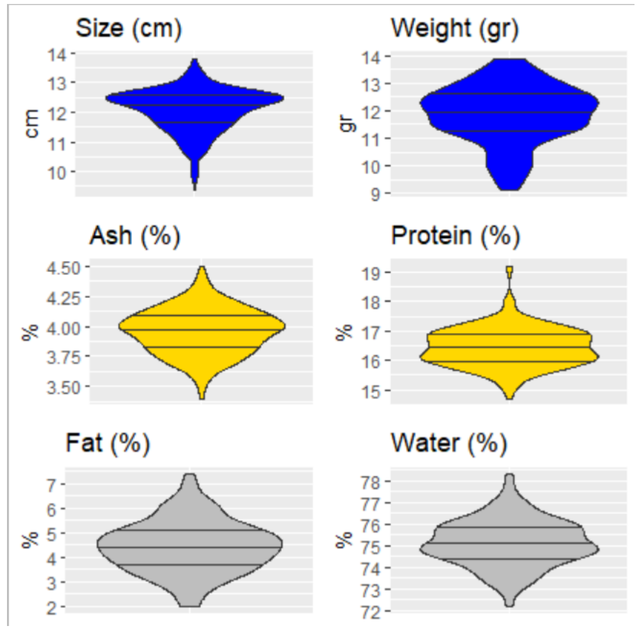

Fig. 2 Anchovy fishing – Port Pisco

In the transportation stage, two quality variables are fat in water to be treated and Solids in water to be treated, where the specification limits are 8000 and 7500 ppm, respectively.

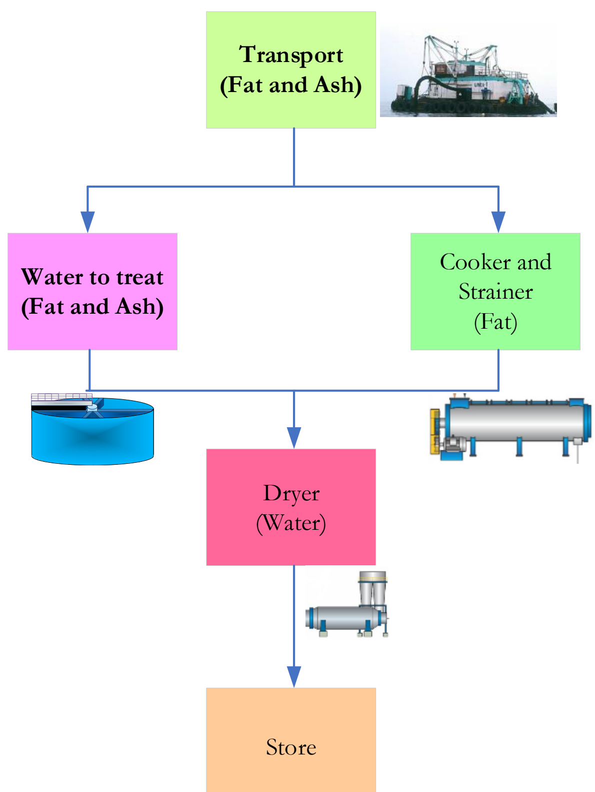

Fig. 3 Flour production stages

Fig. 4 shows that the Fat in water to be treated had an average of 5368 ppm in the second part of 2021, with its sigma level being 0.54 in 2021.

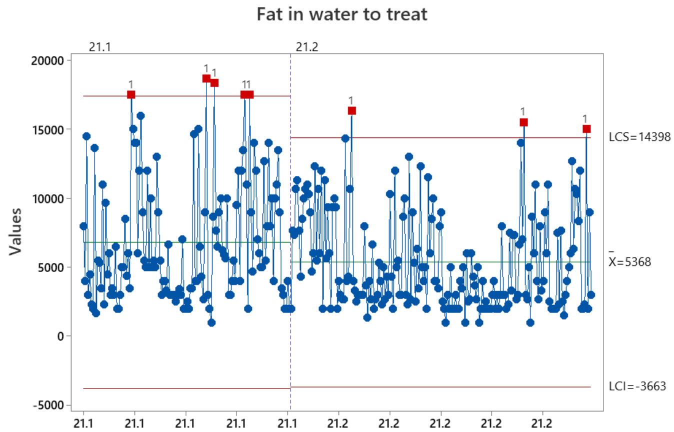

Fig. 4 Control Chart of Fat In water to treat (ppm)

Fig. 5 shows that the Solids in water to be treated had an average of 5379 ppm in the second part of 2021, with its sigma level in 2021 being 1.06.

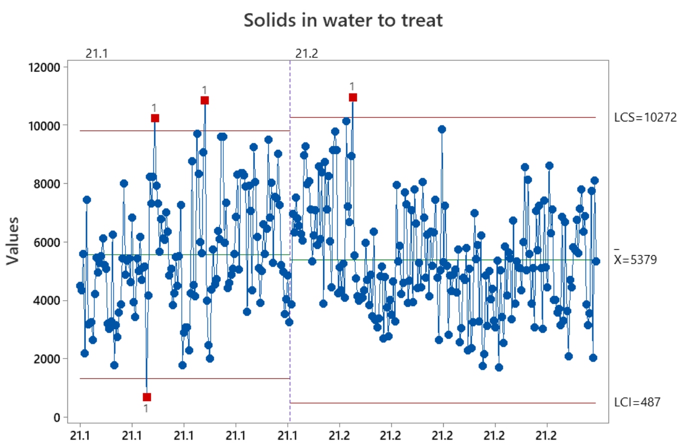

Fig. 5 Control Chart of Solids In water to treat

IV. IMPROVEMENT PROPOSAL

The research was carried out in transporting the anchovy to the plant, as it is the process with the lowest sigma level and process control. For which the stages of the DMAIC that you propose, the Six Sigma methodology was used.

A. Define

The project scope was defined, covering from when the boat is parked next to the raw material transport equipment. Being the variables to improve the Grease of the water to be treated and the solids in the water to be treated. For which the Project Charter was elaborated where the problem, objective, scope, and the work team are detailed, See Table 2.

TABLE 2
PROJECT CHARTER

Project	Reduction of the variability of fat and solids in water to treat in the anchovy transport stage	
Problem	The production of Quality 1 flour is less than 20% of the total production, being disqualified due to the amount of fat and ash produced in the transportation stage.	
Project goals	Reduce the amount of fat and solids in the transport of anchovy, for this, operational variables such as discharge pressure, vacuum pressure and water flow must be taken care of. In this way, fat and solids in the water to be treated will be guaranteed to be less than 8,000 ppm and 7,500 ppm respectively, expecting an improvement of 0.5 in the sigma level for both quality variables, expecting a benefit of $2.5 for each processed ton.	
Scope	The scope of the project is from when the ship is beginning to park until the last ton of anchovy is finished transporting	
Work Team	**Name / Position**	**Role**
	Plant Manager	Champion
	Head of production	Property
	Production analyst	Staff
	Transport Staff	Staff
	Bradith Zevallos	Green Belt
	Miguel A. Rodríguez	Green Belt
	Jonatán Rojas	Green Belt

B. Mesuare, Analyze and Improve

We interviewed workers, and the problems of the process were compiled, and the issues that most impacted the process were prioritized together with the team of experts. Of which, the three most important were selected, see Table 3.

TABLE 3
PROBLEM PRIORITIZATION

Problem	**Fat (ppm)**	**Solids (ppm)**	Score
Location of the hoses in the fish pools	9	9	81
Control on the discharge hose	8	9	72
Standardization of operational variables	8	8	64

B.1) Location of the hoses in the fish pools:

The hose that absorbs the anchovy is placed in the pools of the boats, for which this hose has to be aligned with the pool. This condition is achieved when the boat aligns its hold with the suction hose, as shown in the fig. 6.

During the diagnosis, the use of a visual guide for both the boat and the transport area was determined, and a phosphorescent arrow was placed at the height at which the boat's hold should be aligned to have better control of the hose. suction.

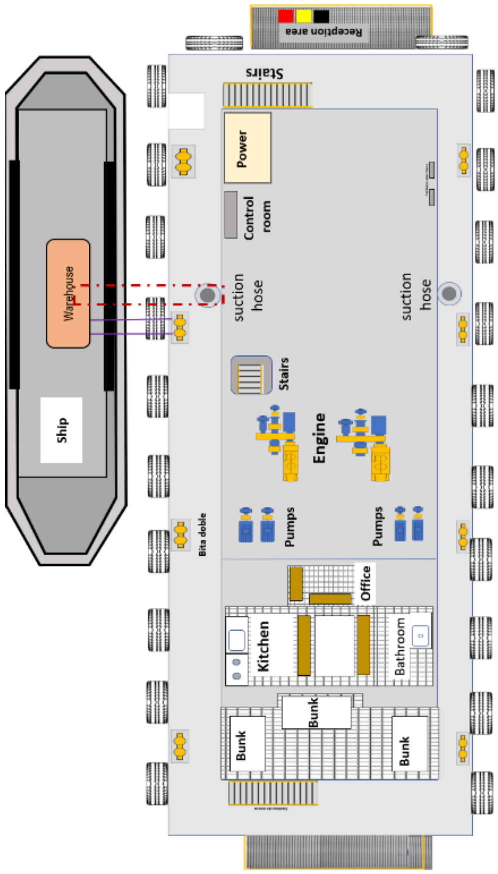

Fig. 6 Transportation zone layout with ship

In Fig. 7 the visual guide is shown, helping to have the most controlled operation.

Fig. 7 Visual guide to alignment of pools

B.2) Control on the discharge hose:

When placing the hose in the anchovy pools, a minimum distance of 30 cm deep must be maintained to avoid the suction of air bubbles and take care of a balanced flow between water and anchovy, achieving a rapid discharge. Given the problem, a welding ring was placed as a visual mark, see Fig. 8, to take care of the depth of the hose and achieve a stable process..

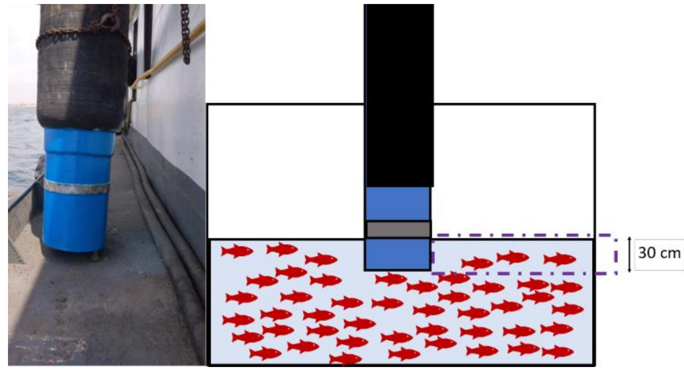

Fig. 8 Reference weld ring

B.3) Standardization of operational variables:

The anchovy is susceptible to exposed pressures, so it is segmented according to freshness (TBVN) and variables of interest, that is the Fat of water to be treated and Solids of water to be treated, to evaluate from what value of TBVN you should have other treatment. A model based on Gaussian finite parameters was made. The model is detailed in figure 9

```
> summary(BIC_sc)
Best BIC values:
              VVV,3        VVV,2        VEV,3
BIC       -2147.441 -2156.769681 -2159.88608
BIC diff      0.000    -9.329119   -12.44552
```

Fig. 9 mclust optimized

For each of the proposed shapes, the Silohuette and Calinsky metrics were evaluated, see Table 4. The model chosen was "VVV-2" (Volume: Variable, Shape: Variable, and Orientation: Variable), as both metrics were high..

TABLE 4
CLUSTER PERFORMANCE

Model	Silohouette	Calinsky
VVV-3	0.21	200.54
VVV-2	0.43	287.4
VEV-3	0.3	221.45

Visually, it can be seen in Fig. 10 between Solids and TBVN (freshness) that from 25 of TBVN, both clusters are segmented, so the control plans to be elaborated will take this point to classify the vessels.

The vessels will be segmented into vessels without a refrigeration system with a TBVN of less than 25, vessels without a refrigeration system with a TBVN greater than 25 TBVN, and vessels with a refrigeration system. The last group will not be segmented by freshness since the refrigeration system contributes to the preservation of the anchovy.

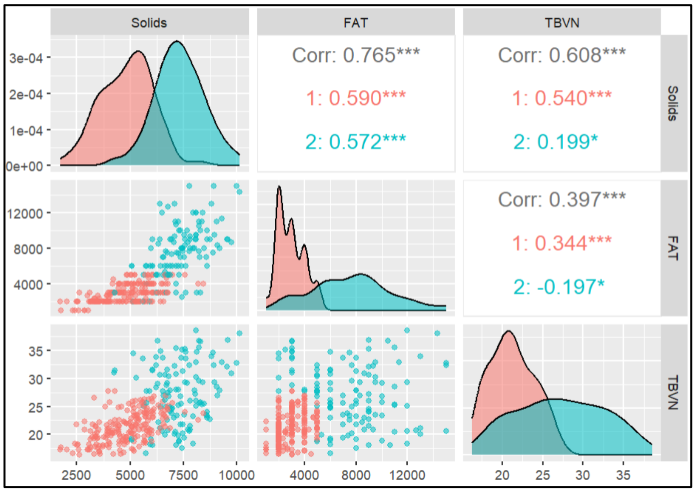

Fig. 10 TBVN segmentation

For each one of the scenarios, a model was elaborated, setting the Solids of water to be treated as the dependent variable and the independent variables as the discharge pressure, vacuum pressure, and water flow. As can be seen in Fig. 11, each of the models was evaluated for RMSE and SD. In all cases, there is an RMSE < SD, these models being valid.

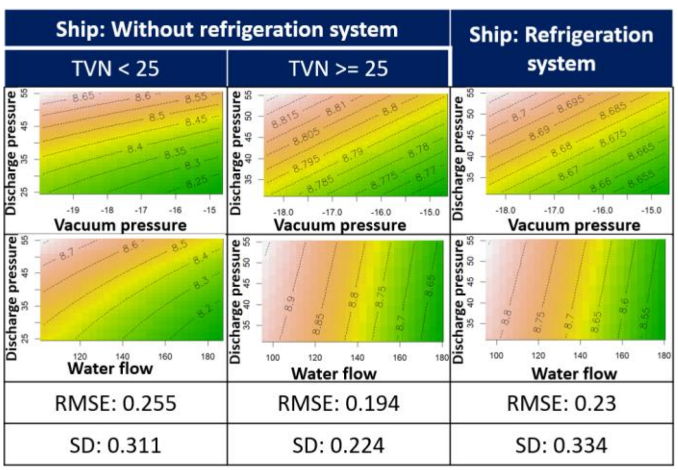

Fig. 11 Countor chart per scenario

Due to the complexity of the interpretation during the operation and the diversity of scenarios in each subgroup, the recommendations are grouped in a summary table so that the personnel in charge of the transportation process can have an easier interpretation, see Table 5.

C. Control

Posters were placed in the work area indicating the use of visual guides and the table of operational variables by scenario so that the personnel in the work area have facilities in complying with each service to the vessels.

TABLE 5
SUMMARY OF THE RANGE OF OPERATIONAL

Ship	TBVN	Water flow	Discharge pressure	Vacuum pressure
Without refrigeration system	< 25	[140, 150]	]-,40]	[-18, - [
	>= 25	[140, 150]	]-,45]	[-16, - [
Refrigeration system		[150, 160]	]-,45]	[-17, - [

V. RESULTS

The research was developed based on the year of production, 2021, where data collection began in the second half of 2021, with the year to implementation being the period 2022. As it is an improvement proposal, work was done to disseminate it to the people involved. and their accompaniment to the work team to resolve doubts or raise observations that came out during the process. As can be seen in Fig. 12, more controlled pressures are observed with respect to the year 2021.

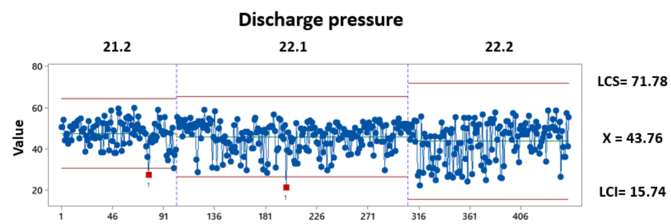

Fig. 12 Control chart: discharge pressure

It was statistically validated using the Tukey test. In table 6, it is observed that the second period of 2022 had lower pressures compared to previous periods, which shows that the proposed improvements helped in operational control.

TABLE 6
TUKEY TEST: DISCHARGE PRESSURE

Time	N	Mean	Group
21.2	102	47.476	A
22.1	204	45.817	A
22.2	142	43.761	B

The vacuum pressure is shown to be more controlled compared to the year 2021, so we can visually see that this operating variable had a better performance. The detail of the behavior is observed in figure 13.

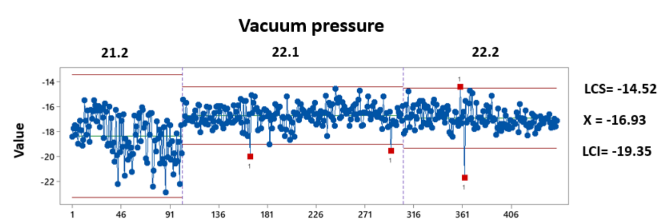

Fig. 13 Control chart: Vacuum pressure

It was statistically validated using the Tukey test. In table 7, it is observed that in both periods of 2022, there were lower pressures (seen as absolute value) compared to 2021, which shows that the proposed improvements helped in operational control.

TABLE 7
TUKEY TEST: VACUUM PRESSURE

Time	N	Mean	Group
22.1	204	-16.6966	A
22.2	142	-16.9340	A
21.2	102	-18.3470	B

Additionally, the level of compliance with the control plan of the operational variables was validated, improving the discharge pressure by 4.2% and the suction vacuum by 12.3%, see table 8.

TABLE 8
CONTROL PLAN MONITORING

Variable	Baseline (2021.2)	2022
Discharge pressure	10.8%	15.0%
Vacuum pressure	5.9%	18.2%

At the level of the quality variables, we see that the Fat in the treatment water was lower compared to the year 2021 and the first months of the year 2022, observe the detail in figure 14.

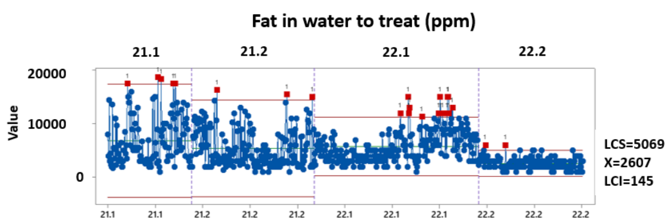

Fig. 14 Control chart: Fat in water to treat

When carrying out the capacity analysis for Grease in the treatment water, with its upper specification limit being 8000 ppm, we see that the sigma level in 2021 was 0.51, and in 2022 it increased to 1.24, evidencing a better-than-expected status, see Fig. 15.

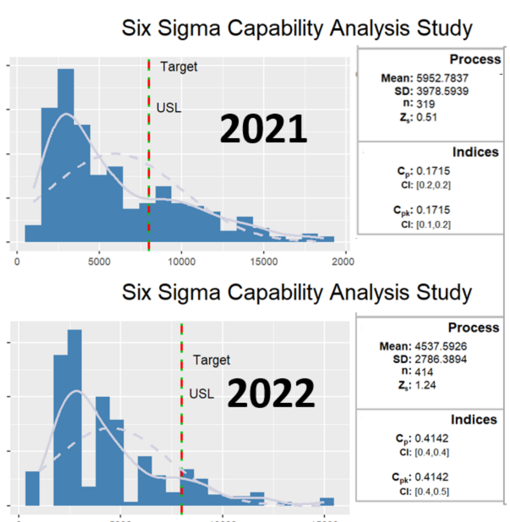

Fig. 15 Capability Analysis: Fat in water to treat

The solids of treatment water remained in great control during 2022 compared to 2021, see Fig. 16.

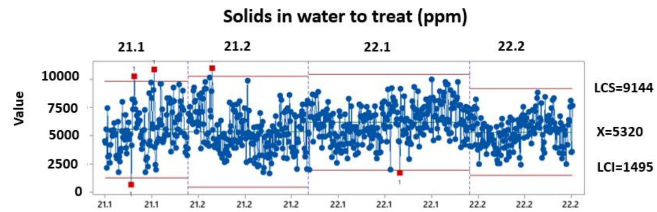

Fig. 16 Control chart: Solids in water to treat

When carrying out the capacity analysis for the Solids in the treatment water, its upper specification limit being 7500 ppm, we see that the sigma level in 2021 was 1.06, and in 2022 it increased to 1.53, evidencing a better-than-expected status, see Fig 17.

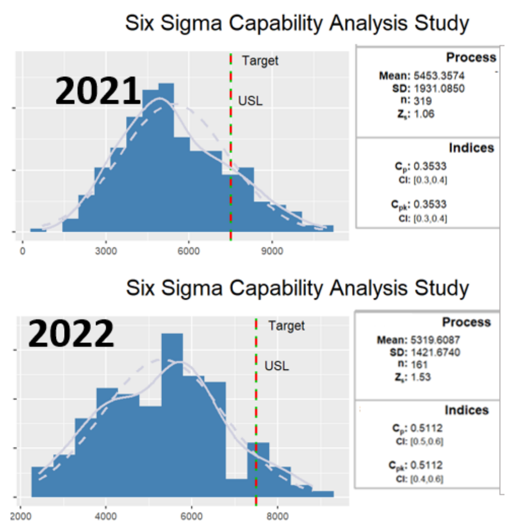

Fig. 17 Capability Analysis: Solids in water to treat

Regarding the Sigma levels, we see that the Fat of treatment water improves to 0.73 and the Solids of treatment water to 0.47 in their sigma levels, observe the detail in Table 9.

TABLE 9
SIGMA LEVEL BASELINE AND 2022

Variable	Baseline (2021)	2022
Fat in water to treat (ppm)	0.51	1.24
Solids in water to treat (ppm)	1.06	1.53

VI. CONCLUSIONS

Developing this methodology helps approach an industry problem practically and sequentially. On the other hand, visual guides help everyone involved in a process to act promptly and clearly during their workday.

Having action plans according to possible scenarios helps better control the process and standard results.

The Six Sigma methodology and business analytics complement each other to have results and conclusions based on data, in addition to the fact that the implementation of sensors in the processes requires more sophisticated tools and data processing methods, such as analytics.

The improvement of the sigma levels and an improvement of $4.3 for each produced ton of flour, corresponding to the implementation of visual guides and implemented process control, were achieved.

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