Reception: **November 25, 2016** | Acceptance: **December 8, 2017**

STATISTICAL METHODOLOGY FOR THE DECREASE OF VARIABILITY IN THE CHEESE SECTOR, CASE STUDY: COTIJA CHEESE PRODUCTION IN TONALÁ, CHIAPAS

—

Patricia Margarita Aguilar Alvarado
ii.patricia@hotmail.com

Ervin Durantes Cueto

Omar Hatziel Garza Pascacio

Instituto Tecnológico Superior de Cintalapa, industrial engineer division, México

To quote this article:

Aguilar, P., Durantes, C. y Garza, O. (2018) Metodología estadística para la disminución de la variabilidad en el sector quesero, caso de estudio: producción del queso Cotija en Tonalá, Chiapas. *Espacio I+D Innovación más Desarrollo, 7*(17) 45-63. Recuperado de: http://www.espacioimasd.unach.mx/articulos/vol.7/num17/pdf/04_Queso.pdf

— Abstract—

A company from Chiapas focused on the production of Cotija cheese was monitored in its production process by analyzing the variability for 5 quality characteristics: grams of calcium, grams of antibac, grams of rennet, kilograms of salt, and milligrams of water. The basis of the study was the implementation of a methodology that includes basic statistical tools such as the Ishikawa diagram, the verification sheets, the control charts for individual measurements and mobile ranges, the histograms and capacity indexes for processes with double capacity specification (potential and real). No indicators were detected for the process control, work based on empirical knowledge and no standardization of the process. Indicators were generated and it was obtained that the productive process works with common causes of variation, although with levels of potential capacity below 0.11. With the implemented actions, it was possible to control the variability of the Cotija cheese process obtaining levels of potential capacity above 1.30.

Keywords

ndividual control charts, capacity indexes, process control.

Statistics are vital in the control and monitoring of processes, and in the improvement and innovation of quality, since it is made up of a set of techniques and concepts oriented to the collection and analysis of data, taking into account the variation in them. Statistical techniques are of great importance in all types of companies and in a great diversity of situations. For example, they are useful for: Identify where, how, when and how often problems occur (statistical regularity).

The data coming from the key business guides must be analyzed, in order to identify the sources of variability, in addition to analyzing their stability and forecasting their performance in order to quickly, promptly, and at a low cost detect abnormalities in the processes.

This is in the pursuit of objectivity in planning and decision making, avoiding phrases such as "I feel", "I believe", "my experience" and the abuse of power in decision making. For this reason, the facts should be expressed in the form of data and objectively evaluate the impact of improvement actions; in addition to focusing on the vital facts; that is, in the really important problems and causes. Analyze in a logical, systematic and tidy way the search for improvements.

The quality of a product depends a lot on the variability. Variability limits are established, this to avoid defects or differences between one product and another. So we could conclude that "the less variability we will have a better quality in the product or service offered". Quality is a predictable degree of uniformity and reliability at low cost and adequate to market needs, so improving quality is reducing variability (Deming, W. Edwards).

In large companies the use of statistical tools for the control of variability is common. However, for small and medium-sized companies in the cheese sector, the development of their productive activities is carried out empirically, without a systematic measurement or documentation of the processes. Therefore, the variation of its processes affects the quality of the final product and the competitiveness of the companies.

The case study presents a methodological proposal based on statistical tools applied in a cheese company located in the municipality of Tonalá, Chiapas. This methodology is intended to include statistical thinking to control the variability of the process in small and medium-sized companies in the Chiapas sector of the cheese industry.

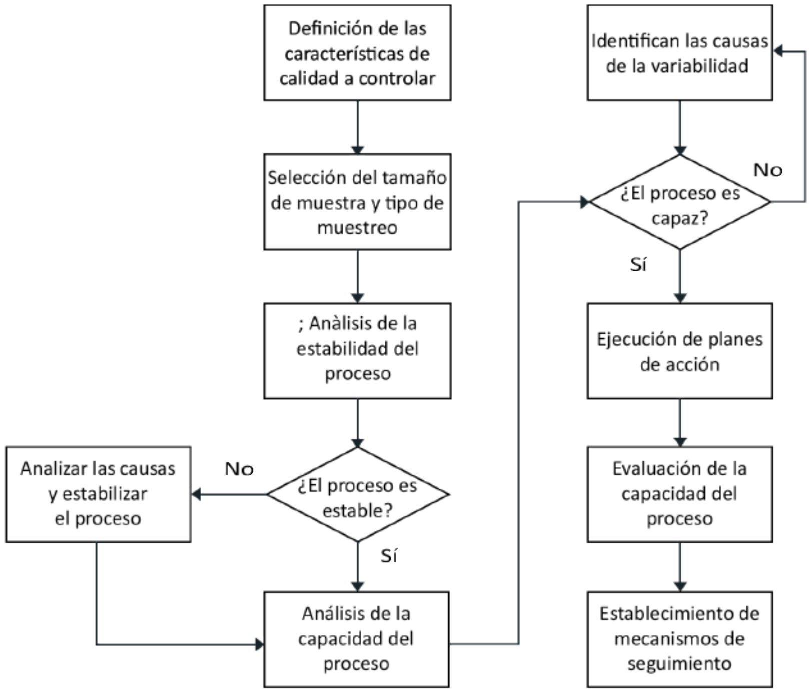
WORK METHOD

The statistical methodology used is based on the following steps:

1. Definition of the quality characteristics to be controlled
2. Selection of sample size and type of sampling
3. Analysis of the process stability by means of an individual control chart
4. Analysis of the process capacity
5. Analysis of the variability causes
6. Execution of action plans
7. Evaluation of the process capacity
8. Monitoring mechanisms

The statistical methodology requires the definition of the quality characteristics to be controlled, which will be continuous (step 1). The sampling will be probabilistic with a finite population and randomly (step 2). The analysis of the process stability will be carried out by means of the control charts for individual measurements (step 3), if the process is not stable, the analysis of the special causes of variation will proceed, otherwise the analysis will continue. The capacity analysis of the process will be carried out by means of the potential process capacity index and graphically by histograms (step 4). If the process is not capable, the causes will be analyzed (step 5); otherwise the action plans will be implemented to reduce the variability of the process (step 6). The effectiveness of the action plans will be evaluated through a new analysis of the capacity of the process (step 7). Finally, the monitoring mechanisms will be established to ensure control of the process variability (step 8). See Figure 1.

Image 1. Statistical methology for the project



DEFINITION OF QUALITY CHARACTERISTICS TO CONTROL

Five continuous quality characteristics were defined for the control of the production process (table 1).

Table 1. Process indicators for Cotija Cheese

Number	Quality feature	Indicator (per tub)	Unit of measurement
1	Salt	Quantity of salt used in the Cotija Cheese process	Kilograms
2	Antibac	Quantity of granulated antibac used in the Cotija Cheese process	Grams
3	Granulated Calcium	Quantity of granulated calcium used in the Cotija Cheese process	Grams
4	Rennet	Rennet quantity needed to set the milk	Milliliters
5		Quantity of water used to blend the antibac	Milliliters
6	Water	Quantity of water used to blend the calcium	Milliliters
7		Quantity of water used to blend the rennet	Milliliters

SELECTION OF SAMPLE SIZE AND TYPE OF SAMPLING

A confidence level of 85% was used, considering a finite population of 112 production tubs per week (formula 1).

Formula for finite sample:

$$n = \frac{N * Z_{\alpha}^{2} * p * q}{i^{2} * (N-1) + Z_{\alpha}^{2} * p * q} = 16$$

Formula 1

We used a systematic random probabilistic sampling considering a weekly production day. This selection procedure is very useful and involves choosing within a population N, for this case 112 tubs, a number n of elements, 16 samples, from a K interval (Sampieri, 2005) (formula 2).

$$K = \frac{N}{n} = 7$$

Formula 2

ANALYSIS OF THE PROCESS STABILITY BY MEANS OF AN INDIVIDUAL CONTROL CHART

Sixteen vats were sampled per week, recording, for each 7 tubs produced, the data for the quality characteristics. The individual control charts were implemented for the process analysis of the average and the mobile range chart to study their variability. According to Montgomery (2009) the control letters specialize in studying the variability over time to improve processes through three basic activities: stabilizing processes, improving the process itself, reducing variation due to common causes and monitoring the process to ensure that improvements are maintained and to detect additional opportunities for improvement.

The limits of the individual chart (formula 3) and those of the chart of mobile ranges (formula 4) were built.

$$LCS = \bar{X} + 3\frac{\overline{Rm}}{d_2} \qquad LCI = \bar{X} - 3\frac{\overline{Rm}}{d_2}$$

Formaula 3

$$LCS_{Rm} = D_4\overline{Rm} \qquad LCI_{Rm} = D_3\overline{Rm}$$

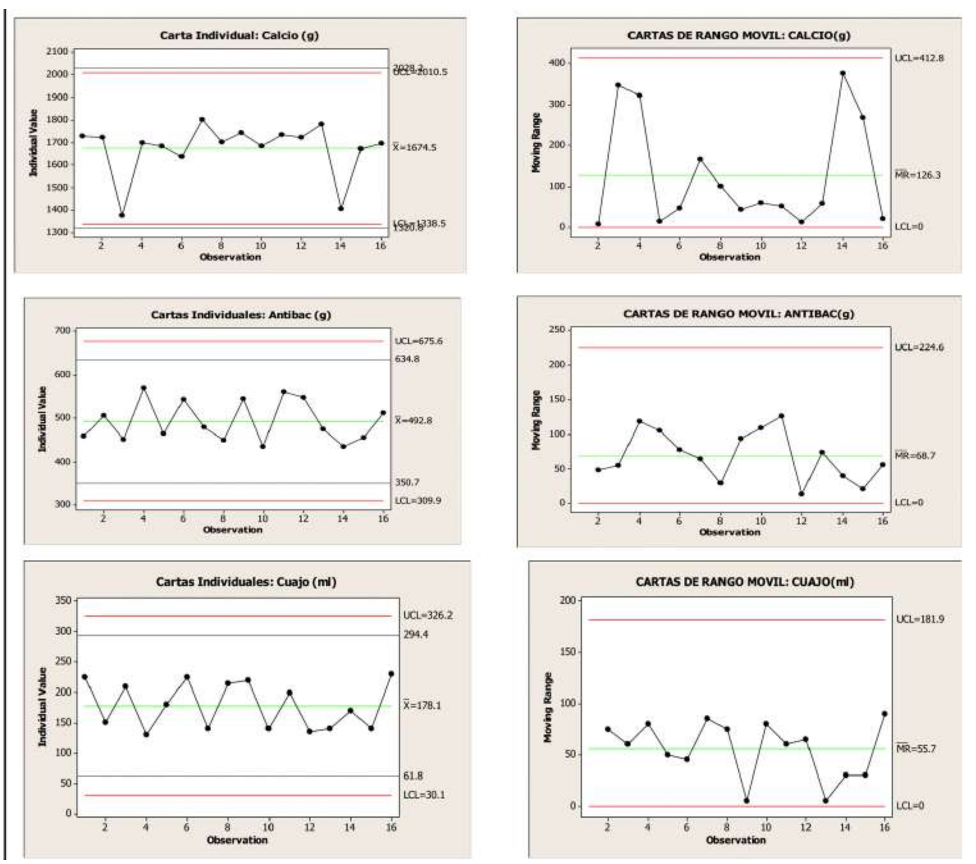
Formula 4

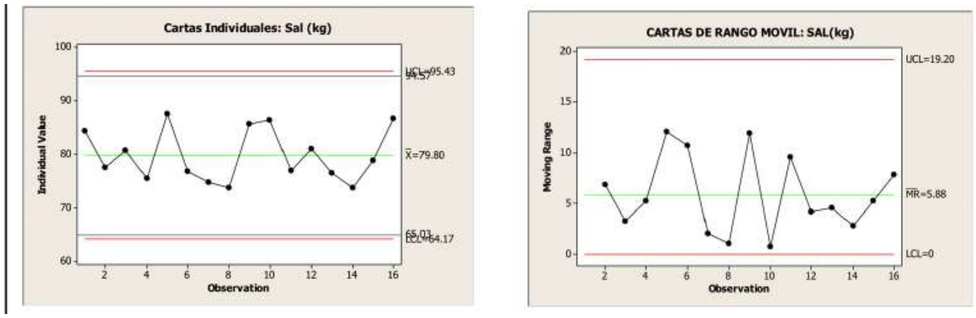
Figure 2 shows that, for the quality characteristic Calcium (gr), samples 3 and 14 tend toward the lower control limit without exceeding them and there is no apparent pattern in the behavior of the mean of the data which tends to 1674.5 grams. Regarding the letter R, no pattern is observed in the mobile ranges so it is concluded that the process is stable.

For the quality feature Antibac (gr), most of the means are detected in zone c of the individual card, with the exception of sample 4 that occupies zone B, with a tendency towards 492.8 grams. Regarding the mobile ranges, they do not show any special behavior, so it is concluded that the process is stable.

According to the individual's chart, the data for the quality characteristic of the rennet (ml) tends to an average of 178.1 milliliters and have very little variability. The process is stable.

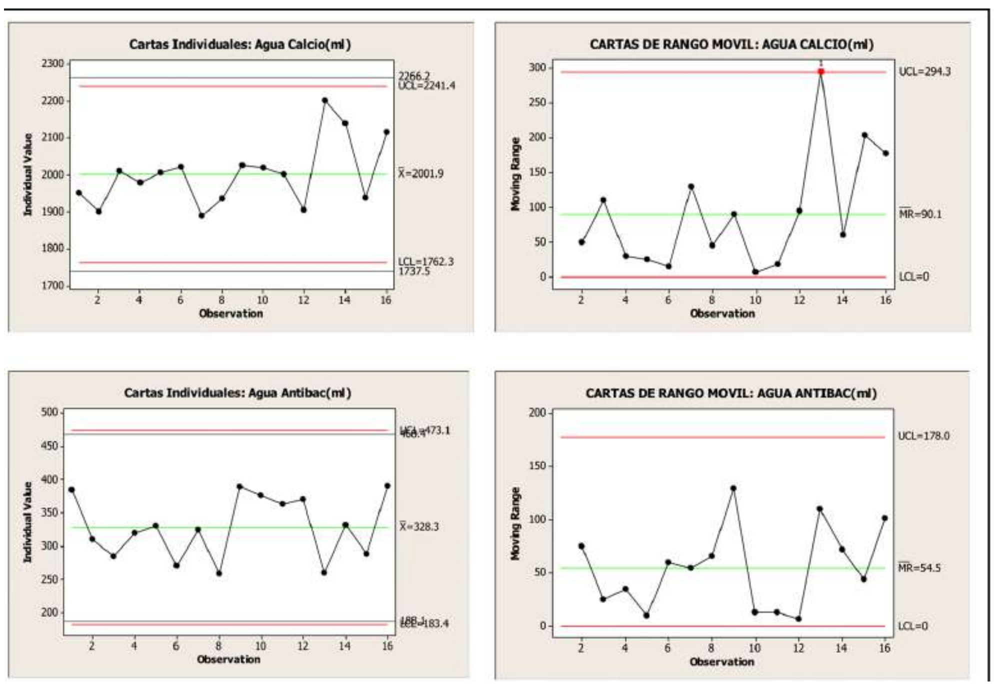
Figure 2. Control charts for individual and mobile ranges for the indicators: Calcium, Antibac, Rennet and Salt of the Cotija cheese process

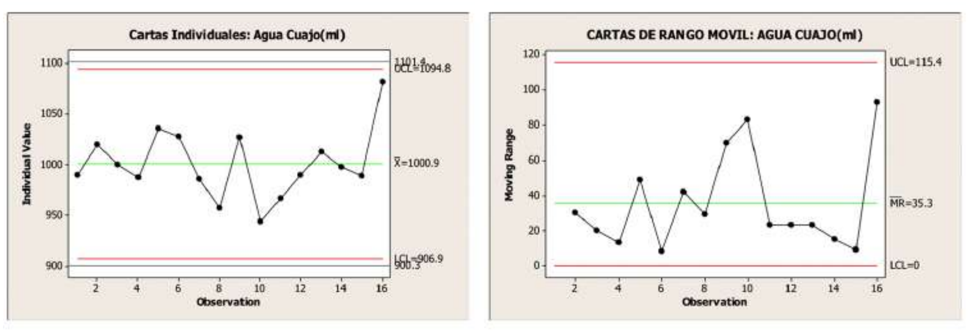




Finally, for the indicator Water for calcium, Water for Antibac and Water for rennet, a behavior without special standards for the average and a coincident point over the upper control limit is observed in the case of the range for the characteristic Water for Calcium. For this output variable, the process is considered stable (Figure 3).

Figure 3. Control charts for individual and mobile ranges for the Water indicator of the cotija cheese process





ANALYSIS OF THE PROCESS CAPACITY THROUGH CAPACITY INDEXES

Analyzing the capacity or ability of a process consists of knowing the amplitude of the natural variation of the process for a given quality characteristic (Gutiérrez Pulido and Román de la Vara, 2009); the capacity indexes are analyzed, which, as the name implies, are specialized measurements in evaluating capacity.

The capacity analysis of the process has been implemented with the calculation of capacity indicators and with histograms.

Once the control charts have been implemented and the process stability analyzed, the values of the Cp, Cpi and Cps Indices of the Indicators to study the capacity of the process are presented in Table 2.

Table 2. Capacity indicators for the Cotija cheese process

Capacity of the process indicators	Calcium (g)	Antibac (g)	Rennet (ml)	Salt (kg)	Water (ml)		
					Antibac	Calcium	Rennet
Cp	0.056544	0.105583	0.085982	0.10157	0.03568	0.0189	0.09944
Cpi	0.040994	0.1601342	0.0698609	0.18980	0.03746	0.0260	0.10814
Cps	0.07209	0.051031	0.102104	0.0133	0.0339	0.011	0.09074

As for the indicators for calcium, rennet, water for antibac, water for calcium and water for rennet, we have:

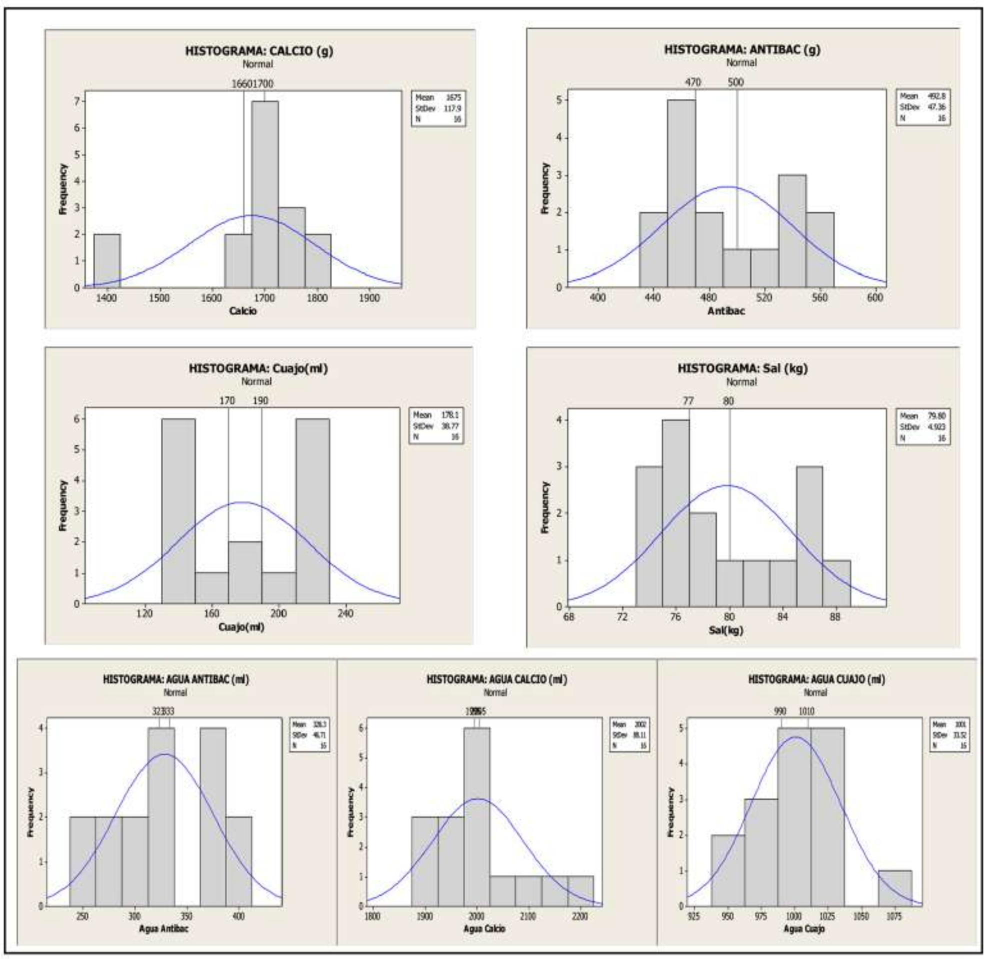
Cp≤0.67, means that it is not suitable for the job and requires very serious modifications.
Cpi, and **Cps <1.25**. It is suitable for the process

As for the indicators for the antibac and salt, we have: **1 <Cp <1.33** It is partially adequate and requires strict control. **Cpi**, and **Cps <1.25** is suitable for the process.

ANALYSIS OF THE PROCESS CAPACITY THROUGH HISTOGRAMS

According to the histograms built for each of the indicators: Calcium, Antibac, Rennet, Salt, and Water do not meet specifications, so the process is stable but not capable (Figure 4). Regarding the behavior of the data, normal behaviors are not observed for any of the indicators.

Figure 4. Histograms for the indicators: Calcium, Antibac, Rennet, Salt and Water



For calcium, a behavior of rare or atypical data is observed because one class appears isolated from the rest and there is a standard deviation of 117.9, which indicates a lot of variation.

For the antibac two fashions are appraised that show two different central tendencies. Regarding the variation, there is a standard deviation of 47.36, indicating a wide variation in the data.

For the rennet it can be observed, in the same way, two peaks showing two realities for these data. The standard deviation is 38.77; the data exceeds the specification limits.

For salt, two central tendencies are identified, similar behavior for antibac and rennet. The standard deviation is 79.80, the limits of specification exceeding the data.

Finally, for the antibac and rennet water, histograms with atypical data are shown, because two and one bars appear away from the rest of the classes. The data, for both histograms, exceeds the specification limits. For the calcium water, a skewed behavior towards the left is observed, with a standard deviation of 88.11, which indicates a high variation in the data.

ANALYSIS OF THE VARIABILITY CAUSES

The causes associated with the behavior of the data are the following (Montgomery, 2009):

- Rare or atypical data:

The data is incorrect, either due to measurement, registration or "finger" error. The measurement was made on an article that is not part of the process. If the two previous situations are discarded, the measurement is due to a rare or special event.

- Bimodal distribution;

Significant differences from lot to lot in the raw material, due to different suppliers or excess variation of a supplier.

When in the process several operators intervene with different criteria or work methods.

The measurements of the output variable were made by different people or instruments, therefore, different criteria or poorly calibrated instruments were used.

- Skewed distribution:

In general terms, a bias in the output variable reflects the gradual displacement of a process due to wear or maladjustments, and it may indicate vitiated procedures in the way of obtaining the measurements.

For the analysis of the variability causes of the Cotija cheese flavor, a cause-effect analysis was used by means of the 6M method, involving a team of 6 people between the person in charge of the production area, operators, in charge of the reception of the raw material and store manager, the main causes being the following (figure 5):

- Associated with rare or atypical data:

Lack of responsibility of the workers (they carry out the activities quickly in order to leave before their workday, some workers work more than others).

- Associated with a bimodal distribution:

The salt used is not the same in all the tubs (they use cans of 20 liters, measurements are not done correctly, they have more filled tubs than others and in some occasions a greater amount of salt is added because the workers do not remove the serum entirely).

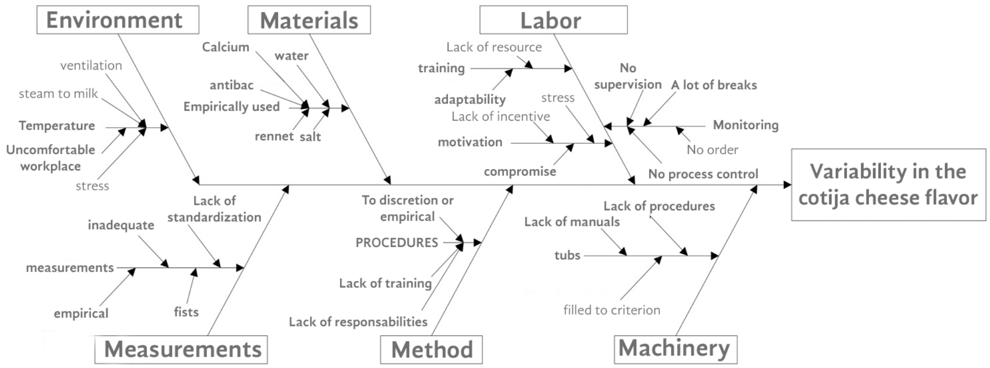
No standard measures are used in the preparation of the ingredients. They have been based solely on experience and using the method of scoring (fists to measure the antibac, a "cup" for calcium and the lid of a bottle to measure the amount of rennet needed).

Lack of units of measurements to make the most accurate measurements. Lack of production indicators. Lack of a process standardization.

- Associated with a skewed distribution

Lack of a procedure manual

Figure 5. Analysis of the variability in cheeses through the 6 M's



MEASURES TO REDUCE AND CONTROL THE VARIABILITY OF THE COTIJA CHEESE PROCESS THROUGH THE INDICATORS USED

The measures implemented to improve the capacity of the process are linked to the materials, methods and labor of the Cotija cheese process. The use of the following materials has been implemented:

- Scale from 1 to 5000 grams. It will serve to weigh the Calcium and the granulated Antibac.
- 500 ml test tube. It will be used to measure the amount of liquid rennet to be used.
- A 3000 ml beaker. It will be used to measure the quantity of water used to prepare the mixture of Calcium, Antibac and Rennet.
- Stainless steel table. It will be used to place the materials.
- 500 and 2000 gram containers. It will be used to deposit antibac and calcium to be weighed.

A new work method was implemented with the participation of the labor that interferes in the process, the new method was tested, the method was standardized and the implemented was followed up.

Once the new materials were defined, ranges were implemented for the 5 indicators of the process, which are in table 3.

Table 3. Ranges for each of the 5 indicators of the Cotija cheese process

N°	Indicator	Unit of measurement	Quantity in ranges
1	Quantity of salt used in the Cotija Cheese process	Kilograms	2000 liters= [80- 77] 1600 liters= [64- 62]
2	Quantity of granulated antibac used in the Cotija Cheese process	Grams	2000 liters= [470 – 500] 1600 liters= [376-400]

3	Quantity of granulated calcium used in the Cotija Cheese process	Grams	2000 liters= [1660-1700] 1600 liters= [1328-1360]
4	Rennet quantity needed to set the milk	Milliliters	2000 liters= [170 – 190] 1600 liters= [136-152]
5	Quantity of water used to blend the antibac	Milliliters	2000 liters= [323-333] 1600 liters= [259-266]
6	Quantity of water used to blend the calcium	Milliliters	2000 liters= [1995-2005] 1600 liters= [1596-1604]
7	Quantity of water used to blend the rennet	Milliliters	2000 liters= [990-1010] 1600 liters= [792-808]

After the implementation of the new materials and the application of the ranges, each one of the 5 indicators has been sampled again (Table 4) with the purpose of carrying out the new analysis of the capacity of the process.

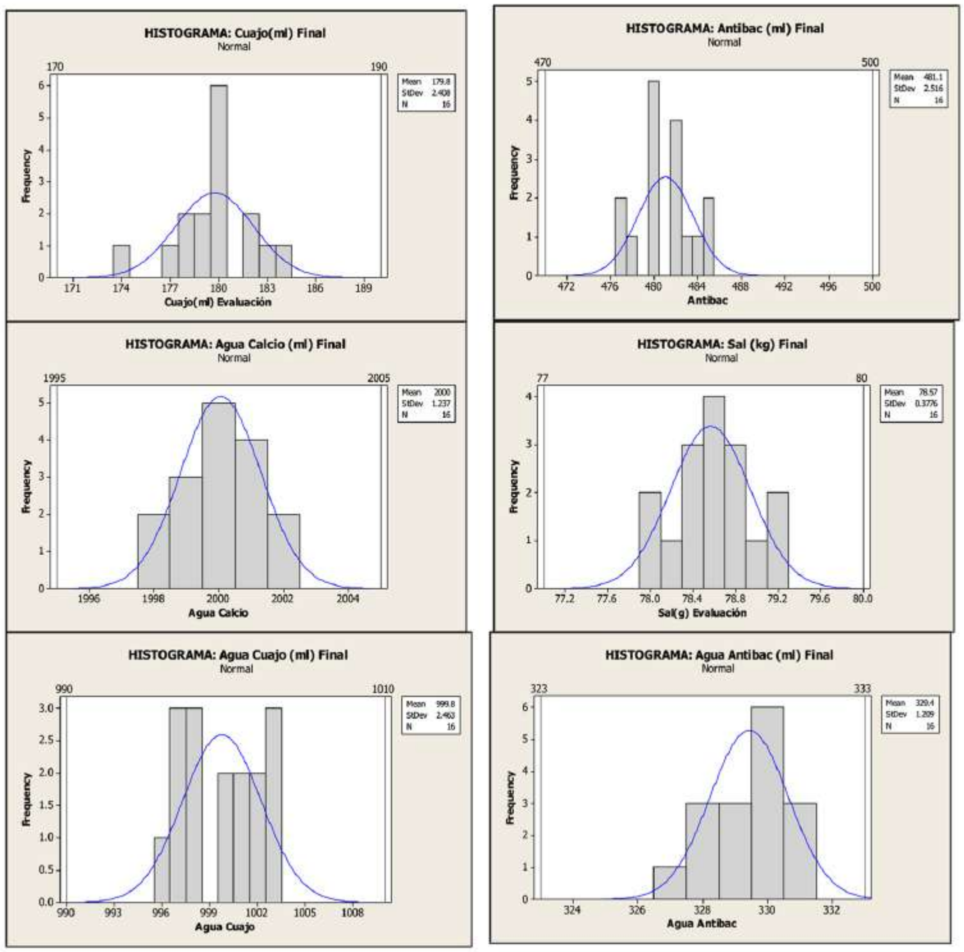
Table 4. Results of the 5 indicators of the process after the implementation of improvements

N°	Calcium (g)	Antibac (g)	Rennet (ml)	Salt (kg)	Water (ml)		
					Antibac	Calcium	Rennet
DESVEST. M	4.94637 915	2.51578 351	2.40831 892	0.37761 974	1.20933866	1.23659479	2.46306043
MEDIA	1682.75	481.062	179.75	78.568	329.437	2000.06	999.75
LES	1700	500	190	80	333	2005	1010
LEI	1660	470	170	77	323	1995	990
Cp	1.34778	1.98745	1.38409	1.32408	1.37816	1.34778	1.35332
Cpi	1.53310	1.46574	1.34948	1.38410	1.77438	1.36463	1.31949
Cps	1.16246	2.50915	1.41869	1.26405	0.98194	1.33093	0.33629

IMPLEMENTATION OF IMPROVEMENTS

According to the histograms applied after the implementation of the new measures, a capable process is observed for each of the indicators studied. The standard deviation for the rennet is 2.4, for the Antibac it is 2.516, for the salt it is 0.377, which shows a decrease in the process' variability and, for the case of the indicators Calcium and Salt, a normal behavior is observed (Figure 6).

Figure 6. Analysis of the process capacity by histograms, after the implementation of improvements



Once the improvements have been implemented and their results measured, it is important to standardize the process, which was carried out through the implementation of a procedures manual. Tables 5 and 6 show the results of the follow-up to the actions carried out, which evaluate:

A. Existence of indicators in the process.
B. Existence of personnel responsible for each area of the process.
C. Existence of control mechanisms for the variability of the process.
D. Statistical control of the process, without variability to special causes.
E. Standardized and documented process.
F. Compliance with the manual for the elaboration of Cotija Cheese.

Table 5. Monitoring: reception of raw material, quality of milk and elaboration of Cotija cheese

Criteria	PRODUCTION AREA																				
	Reception of Raw Material							Milk quality analysis							Cotija cheese production						
	No				Yes			No				Yes			No				Yes		
	Scale																				
	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
A							x							x							x
B						x								x							x
C							x							x							x
D							x							x							x
E							x							x							x
F							x							x							x

Table 6. Monitoring: Molded and pressed, unpressed and unmolded and stored

Criteria	PRODUCTION AREA																				
	Molded and pressed							Unpressed and unmolded							Stored						
	No				Yes			No				Yes			No				Yes		
	Scale																				
	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled	Unfulfilled	Fulfilled with deficiency	Fulfilled with dissatisfaction	Not completely fulfilled	Acceptably fulfilled	Fulfilled to a high degree	Completely fulfilled
	1	2	3	4	5	6	7	1	2	3	4	5	6	7	1	2	3	4	5	6	7
A							x							x							x
B						x							x							x	
C							x							x							x
D							x							x							x
E							x							x							x
F						x								x							x

FINAL COMMENTS

In the case of the study, the activities carried out in the transformation of the product were analyzed in detail through observation, measurement, monitoring and documentation, defining production indicators and variables to be controlled.

The proposed methodology is focused on small and medium-sized companies in the cheese sector with the purpose of incorporating statistical tools to control the variability of their processes. Statistical thinking, although widely used in large companies mainly in the manufacturing sector, is used very little in the cheese industry and almost unknown by MSMEs. It is sought with the proposed methodology that control and decision making is done with less uncertainty to ensure the quality of the final product and thus improve the competitiveness of companies in this sector.

The active participation of the staff and the commitment of the management are vital for the achievement of favorable results during the application of the methodology.

REFERENCES

Aguilar Alvarado; [*et a*l]. (2011). *Evaluación y análisis del control de calidad en una comercializadora de café*. Libro electrónico cim 2011. Coloquio de Investigación Multidiciplinaria. Instituto Tecnológico de Orizaba. Orizaba, Veracruz, México.

Álvarez Torres Martin. (1996). *Manual para elaborar manuales de políticas y procedimientos*. México: Panorama Editorial S.A. de C.V.

Camisón Cesar, Cruz Sonia, González Tómas. (2007). G*estión de la Calidad: Conceptos, enfoques, modelos y sistemas*. Madrid: pearson educacion, S.A.

Cuatrecasas Lluís, Cuatrecasas Arbós Lluís. (2003). *Gestión competitiva de stocks y procesos de producción*. Barcelona: Gestión 2000 S.A.

Heredia Álvaro José Antonio. (2000). *Sistema de Indicadores para la mejora y el control integrado de la calidad de los procesos*. Universidad Jaume I (Castello): Castelló de la planta.

Hitoshi Kume. (2002). *Herramientas estadísticas básicas para el mejoramiento de la calidad*. Bogotá: Norma.

Juran. Mc/ M. Gryna Jr. Franc / R.S. Bingham Jr (2005). *Manual de control de la calidad*. Barcelona España, Editorial reverente S.A.

Montgomery. *Control estadístico de la calidad*. (2005) Limusa Wiley. Tercera Edición. México D.F. 2009

Murcia Florián Jorge. (28 Mar 2008). *Manual de investigaciones: proceso y diseños*. Universidad Santo Tomás, Centro de Enseñanza Desescolarizada: Panorama Editorial S.A. de C.V.

Ortiz Flores, Fernando; [*et al*]. (2010). Análisis del flujo de vapor en el área de calderas de un Ingenio Azucarero mediante cartas de control. *Revista de la Ingeniería Industrial*. Vol. 4.

Quesada Madriz Gilberto. (2005). *Variabilidad de un proceso ¿cómo controlarla?.* Recuperado de: http://www.gestiopolis.com/variabilidad-de-un -proceso-como-controlarla/

R. Evans James, M. Lindsay William. (2008). *Administración y Control de la Calidad*. Corporativo Santa Fe. México, D.F. Cengage Learning Editores, S.A. de C.V

Torrents Albert Suñe, Gil Vilda Francisco, Arcusa Postils Ignasi. (2004). *Manual práctico de diseño de sistemas productivos*. Albasanz, Madrid: Díaz de Santos, S.A.