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### RESEARCH ARTICLE

## QUALITY CONTROL TOOLS APPLIED TO PH VALUES IN AN INDUSTRIAL PRODUCTION OF CASSAVA STARCH

Genilso Gomes de Proenca, Erminio Pita Jasse, Camila Viapiana, Thais Garrido, Tassio de Moraes Garcia, Jose Airtton Azevedo dos Santos and Carla Adriana Pizarro Schmidt.

UTFPR - Universidade Tecnológica Federal do Paraná – Medianeira-PR, Brasil.

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### Abstract

The starch is present in many species of roots and tubers; the reserve carbohydrate has a great nutritional and industrial importance and is widely distributed in various plant species. Desirable limits to the pH of the starch are present in the national legislation. This study aimed to conduct monitoring of the same throughout the manufacturing process, with a view to checking the process's ability to comply with the legal limits, and to verify the control limits process. Therefore, we carried out 104 collections of product pH values, which were subjected to statistical analysis in Action Stat<sup>®</sup> software. By the performance analysis of the process, it was observed that it was able and kept within specification described in the governed legislation limits; the starch may be classified as type I. The resulting collected values indicated no normal distribution, when analyzed individually. The construction of control charts in this situation resulted in false alarms, and the grouping of values using averages collected for analysis 4 was sufficient to normalize the distribution and eliminate such alarms. It can be concluded that the process throughout the study period was under control and was able to stay within the legal limits.

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### Introduction:-

According to Brazil (2005), starch is a product, extracted from the cassava roots, unfermented and obtained by decantation, centrifugation or other suitable technological processes. The pH of starch refers to the characteristic of ionizable hydrogen potential of product; its limits must be between the values 4.0 and 7.0 in order to classify it, at least, as a starch type III. Starches that are not appropriate to the classifications are described as off type and end up having their impaired marketing.

Woodall (2000), explain that statistical methods represent a very important role for improving quality in the production processes, which aim to achieve quality improvement or get accredited by certification programs. Alencar et al. (2004), explains that the letters or control charts, was employed in the Statistical Control of Processes (SPC) in order to detect deviations of representative parameters considered within the production process, reducing the amount of product out of specifications, as well as production costs.

**Corresponding Author:-Carla Adriana Pizarro Schmidt.**

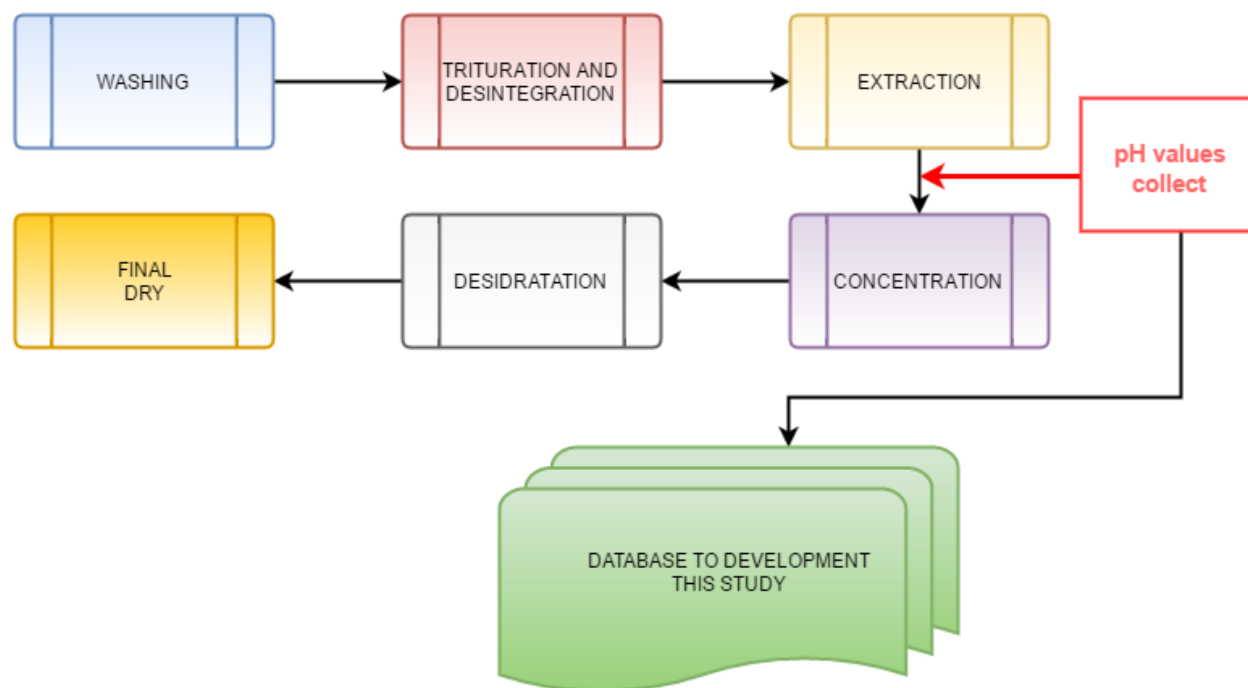
Address:-UTFPR - Universidade Tecnológica Federal do Paraná – Medianeira-PR, Brasil.

Statistical control of process, could be described, as one of the branches of quality control, which addresses the collection, analysis and interpretation of data to the deployment or implementation of product quality control proposal and or services, and such tool has lately been sought by companies. Beyond the control, it is still possible to conduct a process capability analysis, checking if it is able or not to meet the legal specifications or even a customer (Gonçalves and Werner, 2009). Costa, Epprecht and Carpinetti (2012), explain that the analysis of statistical control and capability are independent and it is possible that processes under control are not able and contrariwise.

Given this context, the objective of this study was the collection and evaluation of pH values of "starch milk" before the product enters the process of concentration and performing statistical analysis of temporal series, through the application of control tools, to assess the process of capacity building and Statistical Process of Control (SPC) charts.

### Materials and methods:-

The study was conducted in a cassava starch agroindustry, located in the west of Paraná state in Brazil. The production process of cassava starch is briefly explained in Figure 1. The pH values of "starch milk" were collected every sixty minutes, day after day, at the entrance of the concentration equipment, used in the production process of fresh cassava starch, forming a single discontinuous temporal series.



**Figure 1:-** Illustrative diagram of the processes involved in the production of cassava starch and indication of the data collection point.

For this purpose, 104 pH individual values were collected, because according to Ryan (2011), the minimum amount of data for the construction of control charts should be 100 values. The 104 collected data were submitted to descriptive statistical analysis and evaluation of the adequacy of the values to various probability distributions, as well as control tools, with the help of Action Stats® software.

The following 104 values were subjected to a process of performance analysis, using a nonparametric test called Kernel, compared to pH limits set by the Normative Instruction number 23 of December 14, 2005 (BRAZIL, 2005), which sets the limits of tolerance for various attributes of cassava starch, including pH and classify the product in 3 types, according to this quality.

With the 104 individual collected values, we built up a Statistical Process of Control chart (SPC) for medium and other mobile range. As the normal distribution was not obeyed for the individual data, still held the means by 4 in 4 measurements, obtaining with the collection data 26 mean values, with which again proceeded to the construction of

SPC graphs to mean and standard deviation. In all SPC charts were evaluated by software all the options presented in Table 1.

**Table 1:-** Alarm options evaluated by the Action Stats<sup>®</sup> software throughout the construction of control charts.

Identification Numbers	Description
1	1 point more than 3 Sigma axis
2	7 or more points in sequence on the same side of center line
3	6 or more points in sequence, all increasing or decreasing
4	14 or more points in sequence, alternating above and below
5	2 out of 3 consecutive points greater than 2 standard deviations from the center line
6	4 out of 5 consecutive points greater than 1 standard deviation from the center line
7	15 or more consecutive points within 1 standard deviation from the center line
8	8 consecutive points or more higher than 1 standard deviation from the center line

### Results and Discussion:-

The results of a statistical summary of the temporal series 104 pH values collected throughout the production process can be seen in Table 2.

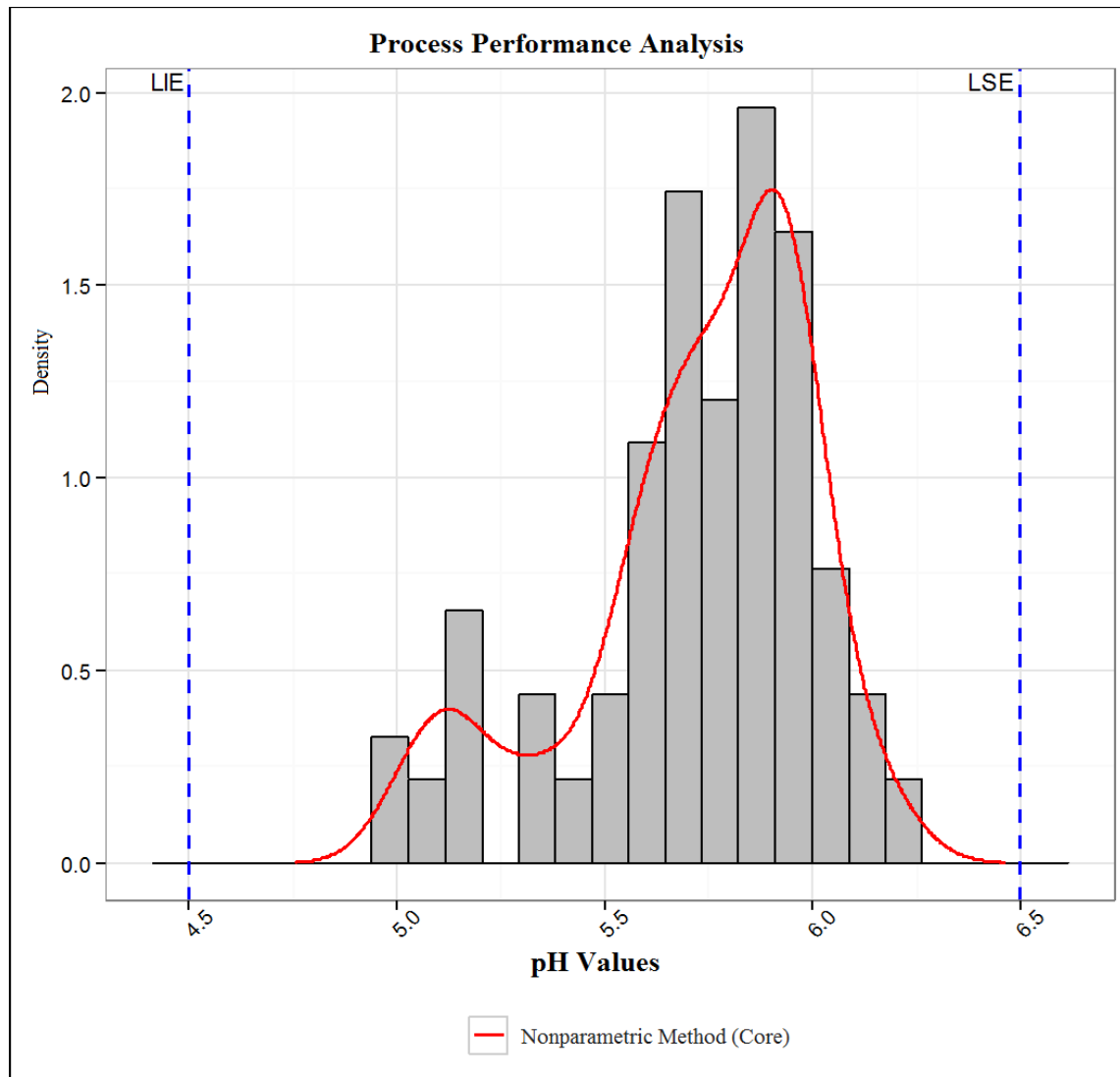
**Table 2:-** Results of descriptive statistics calculated for pH data obtained from 104 samples taken along the production process of cassava starch.

Descriptive Summary			
Minimum	5,02	Maximum	6,2
Average	5,722019	Standard Deviation	0,282569
Median	5,775	Variation Coefficient	0,049383
Asymmetry	-0,90981	Kurtosis	0,122547

The collected data showed no individual adaptation to any of the known distributions as shown in Table 3, as found p-values were all below 0.05. Thus, it can be seen that there would only be making a performance analysis of the individual data by means of a non-parametric test. It was then decided by choosing a non-parametric method of analysis called Kernel method, which is employed to estimate density curves wherein each point is weighted by the distance from the central value, which is the core (Portal Action, 2016). After the application of the method there was obtained the graph provided in Figure 2.

**Table 3:** Results of normality tests performed for pH data obtained from 104 samples taken along the production process of cassava starch.

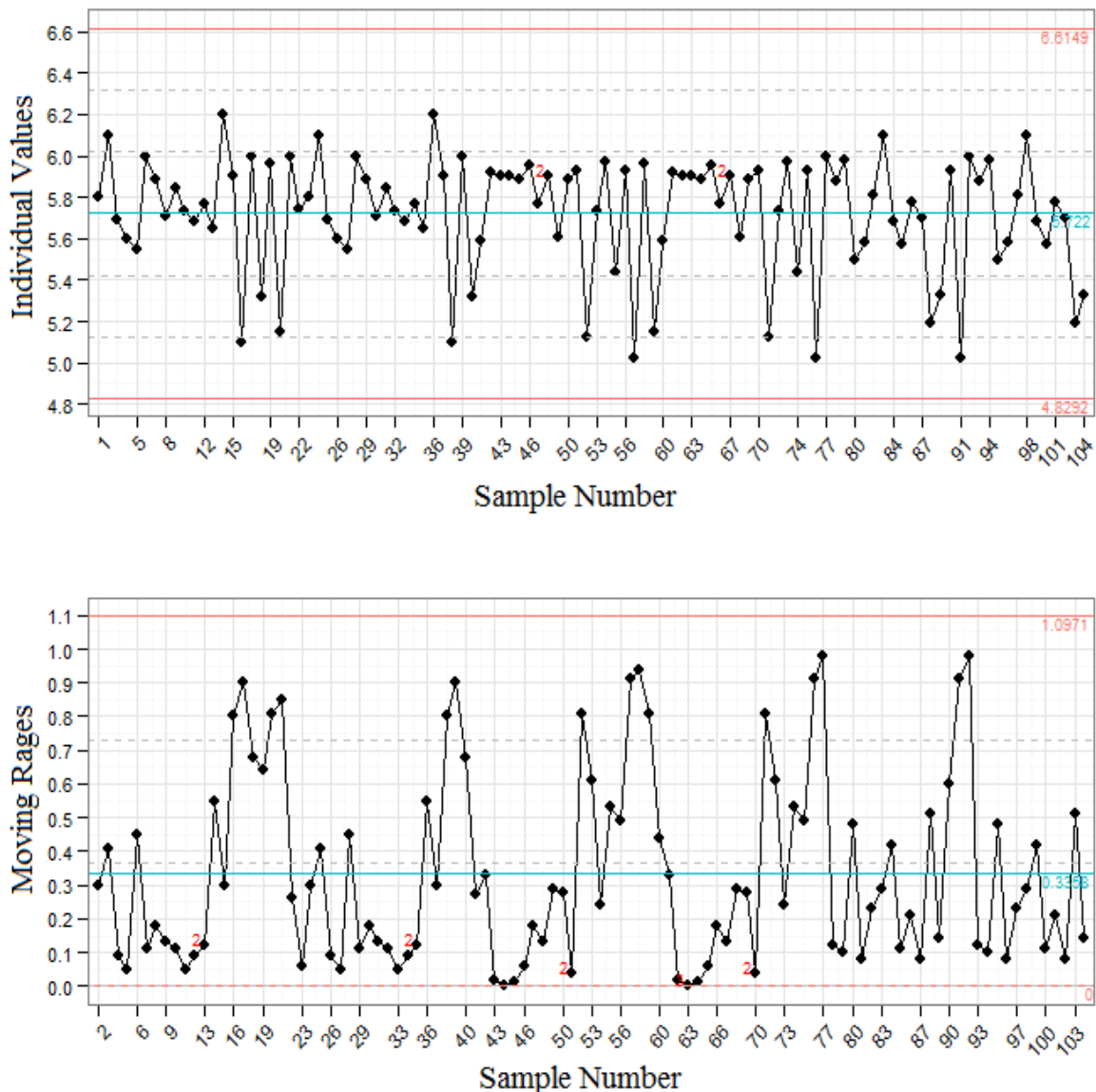
Distributions	Anderson-Darling		Cramer-von-Misés		Kolmogorov-Smirnov	
	Statistic	P-Value	Statistic	P-Value	Statistic	P-Value
Normal ( $\mu = 5.72$ , $\sigma = 0.28$ )	3.1291405	0	0.48611291	0	0.135026	0.00008
Log-Normal ( $\log(\mu)=1.74$ , $\log(\sigma)=0.049$ )	3.6948188	0	0.56454953	0	0.141806	0.00002
Normal Truncated ( $\mu = 5.72$ , $\sigma = 0.28$ )	3.1387197	0	0.48552874	0	0.135918	0.00007
Normal Tripe ( $\mu = 5.72$ , $\sigma = 0.28$ )	3.1387197	0	0.48552874	0	0.135918	0.00007
Exponential (Taxa = 0.17)	43.3910494	0	9.46933702	0	0.584105	0
Logistics (Location = 5.75, Scale= 0.16)	2.2971739	0.00001	0.24466283	0.00151	0.114261	0.00193
Gamma (Form = 400, Tax = 70)	3.4614561	0	0.54018757	0	0.136737	0.00006
Weibull (Form = 27, Scale = 5.8)	1.0769961	0.00761	0.14594644	0.02697	0.115051	0.00173
Cauchy (Location = 5.81, Scale = 0.15)	3.6643525	0	0.53243321	0	0.157716	0
Gumbel (Location = 5.6, Scale = 0.32)	6.3193262	0	1.07555196	0	0.174787	0



**Figure 2:-** Process Capability Analysis graph, regarding the adequacy of the values and quality for the product described by Normative 23 de 2005.

As specification limits, for this study, the pH standards was used specified for cassava starch by Normative number 23 published in December 2005 (BRAZIL, 2005). It was calls for cassava starch classification in type I pHs between 4.50 and 6.50. Based on the performance indices obtained by calculations performed by the Kernel nonparametric method, it can be said that the process average can be considered capable ( $PP = 1.36$ ), also being considered capable in meeting the limit lower ( $PPI = 1.41$ ) and reasonably capable in serving the upper limit of the process ( $PPS = 1.30$ ). Thus, it is suggested that the company mainly check the possibilities and risks of the product go outside the upper specification limits used as the starch exceeds the value of 6.5 according to the legislation would be considered Type III and this can lead to loss of more demanding markets.

For the construction of control charts, would also be appropriate the use of data thatsuit the normal distribution. However, some processes do not follow this distribution and as Korzenowski and Werner (2011), the Shewhart X chart can be considered robust in relation to slight deviations from normality of the data, such as those observed in distributions with less asymmetry coefficient than 1.5, which would be the case of the data collected in this study, which presented value of -0.90 for asymmetry. Through the construction of graphical representations of control afforded provided in Figure 3, for the observed individual values and their moving ranges. The process proved to be under control for both the average values as to the calculated moving ranges, as no point left outside the control limits calculated and presented in Figure 3.



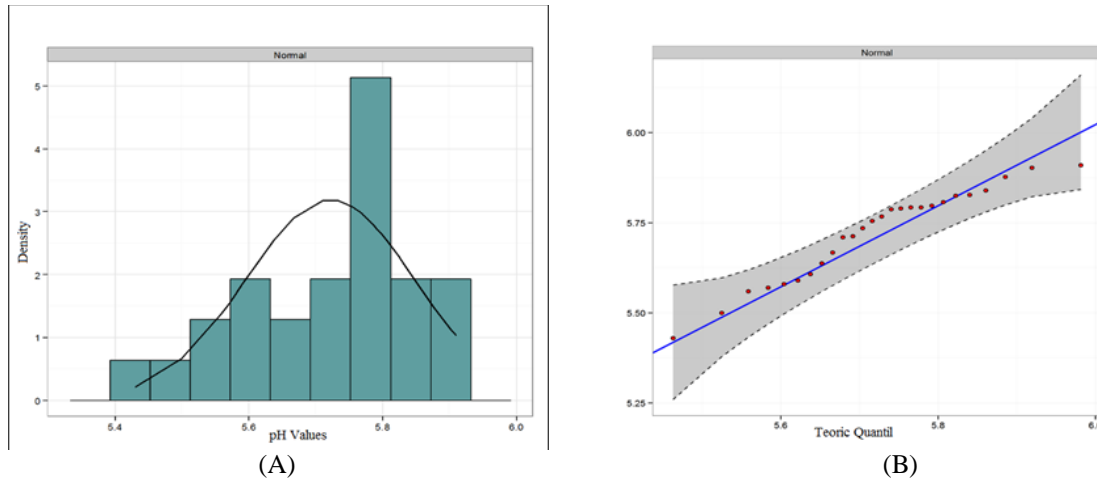
**Figure 3:-** Control Charts for 104 individual pH values collected in production process of cassava starch and their moving ranges.

Accordingly, the effect to consider is the increase of false alarms, and in such cases Korzenowski and Werner (2011), recommend increasing the number of collected data for the construction of graphics and establishment of control limits. Actually were observed multiple alarms of 7 or more points on the same side of the centerline, and in the middle graph these alarms appeared on top of the midline. The same occur in the amplitude graph, but on the lower side of the line, and a sixth alarm or decreasing more points in the mobile range graph. These alarms can be real or not because the increased number of false alarms is common when using data that do not meet the assumptions of normality.

Therefore, we chose to follow the use of means of these same collections, in order to reduce the problem of lack of normality, as based on the central limit theorem using averages of the collections makes the distribution of mean values approach normal. For example, the grouping of data 4 by 4 and using the average evaluation was able to normalize the data as shown in Table 4 and Figures 4 (A) and (B).

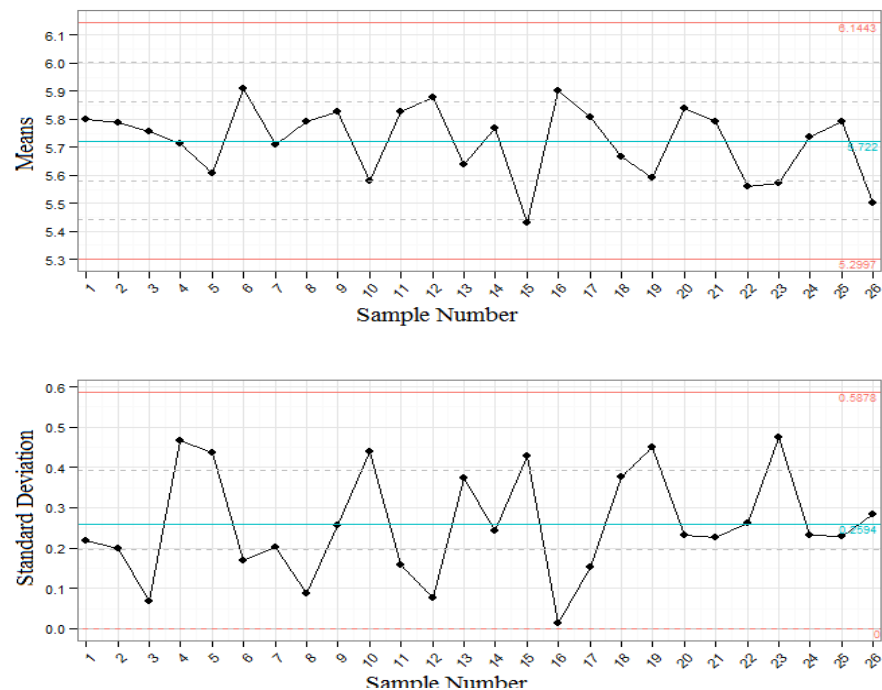
**Table 4:-** Normality test results performed for the average data from four repetitions of the temporal series of pH collections resulted from the 104 collections of individual values held throughout the production process of cassava starch.

Distribution	Anderson-Darling		Cramer-von-Misés		Kolmogorov-Smirnov	
	Estatistic	P-Value	Estatistic	P-Value	Estatistic	P-Value
Normal ( $\mu = 5.72$ , $\sigma = 0.28$ )	0,58978407	0,11363	0,11087433	0,07467	0,15743453	0,09648



**Figure 4:-** (A) Histogram and (B) Distribution of mean values of four collections followed over the temporal series of pHs data, collected in the process of drying cassava starch.

Then, it was built a new control chart with the means obtained (Figure 5). No alarm was observed, this shows that the alarms checked when the process was controlled based on individual values were not important and that the use of means of collections proved useful to avoid false alarms that only complicate the production process. According to Samohyl (2009), control charts can be updated and new limits might be calculated when necessary.



**Figure 5:-** Control Charts for the 26 middle of the process, obtained from 4 individual values of the temporal series of pHs collected in cassava starch production process.

However, it is here to emphasize that the use of averages in the accompanied process, makes the process has results to add to the control charts only every 4 hours and it is somewhat risky because the delay in taking corrective action is a big risk if there really is a point outside the control limits. Thus, could be suggested the following actions, initially trying to increase the size of the data collection, in search of normality. This action could be good and with more dates construct an individual values control charts more reliable. If it does not work, it is suggested to change the intervals among sampling times for collection half in half an hour or even 15 to 15 minutes, so that the use of means of sampling is safer for the quality control of the product.

At the time, control could be accomplished by the concurrent use of individual control charts and means for alarms to be confirmed, but at the same time, a large variation in pH of the product can be perceived.

### Conclusion:-

The process proved to be able to meet the performance required by the specification limits available by law, none of the found values were outside the specification limits for starch type I.

The amount of alarm was actually higher when using the individual data, which did not follow the normal distribution, and the use of the average of four in four sampling was able to normalize the distribution and eliminate false alarms. In none of the graphs built showed values outside the control limits.

Concomitant use of control charts developed in this study would be able to assist the industry in the implementation of statistical quality control in relation to the pH of the final product.

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