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Full Length Research Paper

Construction of $\bar{X}$ - S control charts in production process of soybean oils

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When dealing with a production line, we usually think that all products are exactly alike, but if you look a little more closely, we will realize that they are not as equal as well, and if these differences are large, it will be easily noticed. The whole process, however well designed and controlled as it is, has a variability component that cannot be eliminated. It is the natural variability of the process, which is the result of a series of small perturbations (random causes) against which virtually nothing can be done. However, disturbances may occur more (special causes), which has the effect of moving the distribution of the random variable X and/or enhance their dispersion. In this study, the aim was to apply the techniques of statistical quality control, constructing the $\bar{X}-S$ control charts in order to verify whether or not the process is under control. The techniques of control charts were applied to the variables of the process of production of soybean oil at one Industry, where one hundred samples were collected, with the following variables: acidity of oil soybean, protein and humidity content of soybean meal.

Key words: Soybean, statistical process control, $\bar{X}-S$ control charts.

INTRODUCTION

According to Woodall et al. (2004), to better understand the statistical process control (SPC) technique, it is necessary to know that the quality of a product manufactured by a process is inevitably subject to variation, and when these variations are significant in relation to the specifications, there is the risk of getting non conforming products, that is, products that do not respect production specifications. A task within a process that takes an irregular period of time to complete can cause so much confusion in the production line, as the irregularity of a number of measures, one hour out may be too big and another may be too small. That's how Shewhart (1931) understood that measuring, analyzing and monitoring variability is the field of statistical study, and that, through applications of statistics in the plant, processes and products could reach the highest levels of quality. For better quality, it means less variability in measures of process and product, and more accuracy in achieving goals and targets (Samohyl, 2010).

Control charts distinguish the random variability from non-random. The basis of the graph is the distribution control samples, which tends to curve the probabilities associated with a Gaussian distribution, that is, through the control graph, it is possible to evaluate trends, non-random patterns and instability of the process, allowing its disruption and corrective action before they take items out of specification limits (Montgomery, 2008). This article will study the $\bar{X}-S$ control charts. These charts are tools used to monitor processes, and indicate the presence of special causes, thus the risk of getting non conforming products will be reduced. When the quality

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characteristic of interest X is a measured magnitude, the graph that is best suited to monitor the process is $\bar{X}-R$ and is also known as control charts of the mean and range. Moreover, when n > 10 and 12, it is preferred that the $\bar{X}-S$ control charts are used, since for larger samples, the R amplitude sample loses efficiency to estimate σ, when compared to the sample standard deviation s. Thus, this article seeks to establish improvements in the production process of the company, seeking an ever lower percentage of defective products.

MATERIALS AND METHODS

Control Charts

Control charts serve to examine whether or not the process is under control, synthesize a wide range of data using statistical methods to observe the changes in the process, based on sampling data. This can inform us at any given time how the process is behaving, if it is within prescribed limits, thus signaling the need to seek the cause of variation, but not showing us how to eliminate it (Shewhart, 1931).

$\bar{X}$ - S control charts

The $\bar{X}$ - S control charts are generally preferred over the $\bar{X}$ - R charts when $n > 10$ or 12, since for larger samples the amplitude sampling R loses the efficiency to estimate σ, when compared to the sample standard deviation. The $\bar{X}$ control charts is used in order to control the mean of the considered process. The two charts should be used simultaneously (Werkema, 1995). The limits of the $\bar{X}$ - S control charts are obtained in a similar manner, calculated under the assumption that the quality feature of interest (x) has a normal distribution with (μ) mean and (σ) standard deviation, that is, in abbreviated form $x \sim N(\mu,\sigma)$ (Panagiotidou and Nenes, 2009; Werkema, 1995). However, satisfactory results are obtained even when this assumption is not true and distribution of x can only be considered approximately normal. In practice, the μ and σ parameters are unknown and must be estimated from sample data. The method of estimation of μ and σ again involves taking *m* samples (subgroups rational) primary, each containing *n* observations of the quality characteristic considered.

Estimation of μ

The (μ) mean is estimate through the overall average of the sample ($\bar{\bar{x}}$) as defined in the equation:

$$\bar{\bar{x}} = \frac{\bar{x}_1 + \bar{x}_2 + \dots + \bar{x}_m}{m} = \frac{1}{m}\sum_{i=1}^{m}\bar{x}_i$$

Where $\bar{x}_i, i = 1,2,\dots,m$ is the i-ésima sample mean;

$$\bar{x}_i = \frac{x_{i1} + x_{i2} + \dots + x_{in}}{n}$$

Estimation of σ based on sample standard deviation

The (σ) standard deviation is estimate based in the ($\bar{s}$) standard deviation mean as defined by:

$$\bar{s} = \frac{s_1 + s_2 + \dots + s_m}{m} = \frac{1}{m}\sum_{i=1}^{m}s_i$$

Where $s_i, i = 1,2,\dots,m$ is the i-ésima sample of the standard deviation;

$$s_i = \sqrt{\frac{1}{n-1}\sum_{l=1}^{n}\left(x_{ij} - \bar{x}_i\right)^2}$$

It can be shown that the standard deviation sigma must be estimated by $\hat{\sigma} = \frac{\bar{s}}{c_4}$, where c_4 is a correction factor, tabulated as a function of size *n* of each sample.

Expressions for calculating the limits of $\bar{X}-S$ control charts

$\bar{X}$ *control charts*

$$LSC = \bar{\bar{x}} + 3\bar{s}/c_4\sqrt{n} = \bar{\bar{x}} + A_3\bar{s}$$

$$LM = \bar{\bar{x}}$$

$$LIC = \bar{\bar{x}} - 3\bar{s}/c_4\sqrt{n} = \bar{\bar{x}} - A_3\bar{s}$$

Where $A_3 = 3/c_4\sqrt{n}$ is a constant tabulated as a function of size *n* of each sample.

S *control charts*

$$LSC = \bar{s} + 3\hat{\sigma}_s = B_4\bar{s}$$

$$LM = \bar{s}$$

$$LIC = \bar{s} - 3\hat{\sigma}_s = B_3\bar{s}$$

Where $\hat{\sigma}_s$ is an estimative of the standard deviation of the distribution of the S, and B_3 and B_4 are constants tabulated in

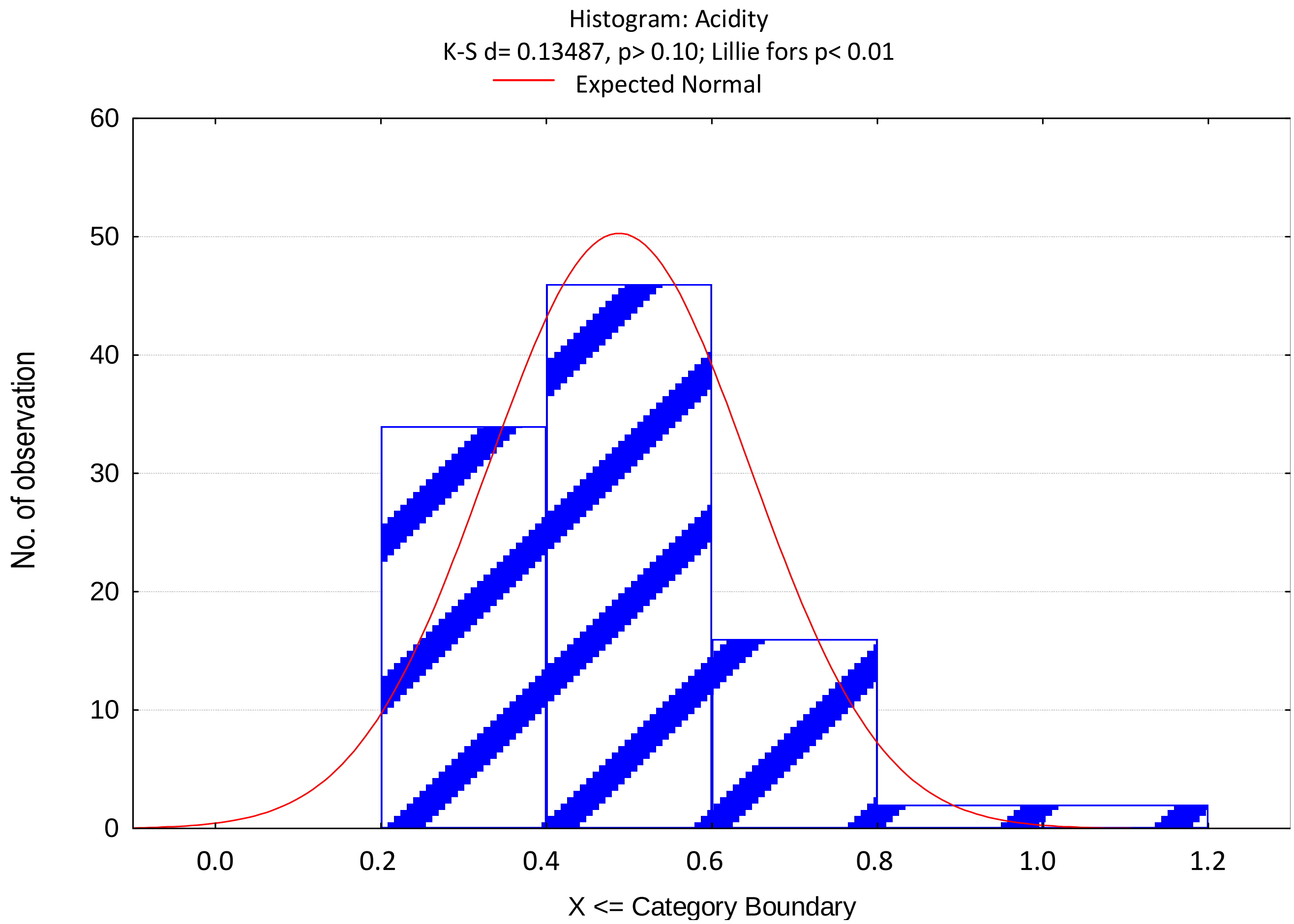

Figure 1. Test of the normality.

function of size *n* of each sample (Panagiotidou and Nenes, 2009; Werkema, 1995).

RESULTS AND DISCUSSION

In soybean oil, the samples were provided by one Industry, where they were collected from 100 (one hundred) samples, with the following variables: acidity of soybean oil, protein and humidity content of soybean meal.

Series acidity of soybean oil

Before applying the control charts, there is the need to verify that the data have normal distribution. Was applied the test Koolgomorov-Smirnov (K-S) in the acidity data of soybean oil (Figure 1) and found the value to 0.13487, which is smaller to the tabulated value of 0.136, thus confirming the normality of the data. The data collected from the acidity of the soybean oil samples were divided into twenty samples in five periods, the mean of the averages of each sample was $\bar{\bar{X}} = 0.49$ and standard deviation of the sample was $\bar{\sigma} = 0.13$. Figure 2b represents the mean and standard deviation of the series acidity of soybean oil. We can see from Figure 2a that the average of the series acidity of soybean oil varied, having its largest peak value of 79% in the 17th sample, possibly being a grain older, that is, it was stored for a long time, giving rise to a high acidity of the grain, on the other hand, the 20th sample showed an acidity of 35%, possibly because it is a new grain.

$\bar{X}$ - S Control charts

Figure 3 shows the performance of $\bar{X}$ - S control chart for acidity variable. From Figure 3, we see that two points fell outside the control limits for both the mean control chart as the standard deviation control chart, indicating that the process is apparently out of control.

Series protein of soybean meal

The Koolgomorov-Smirnov (K-S) test was applied in the

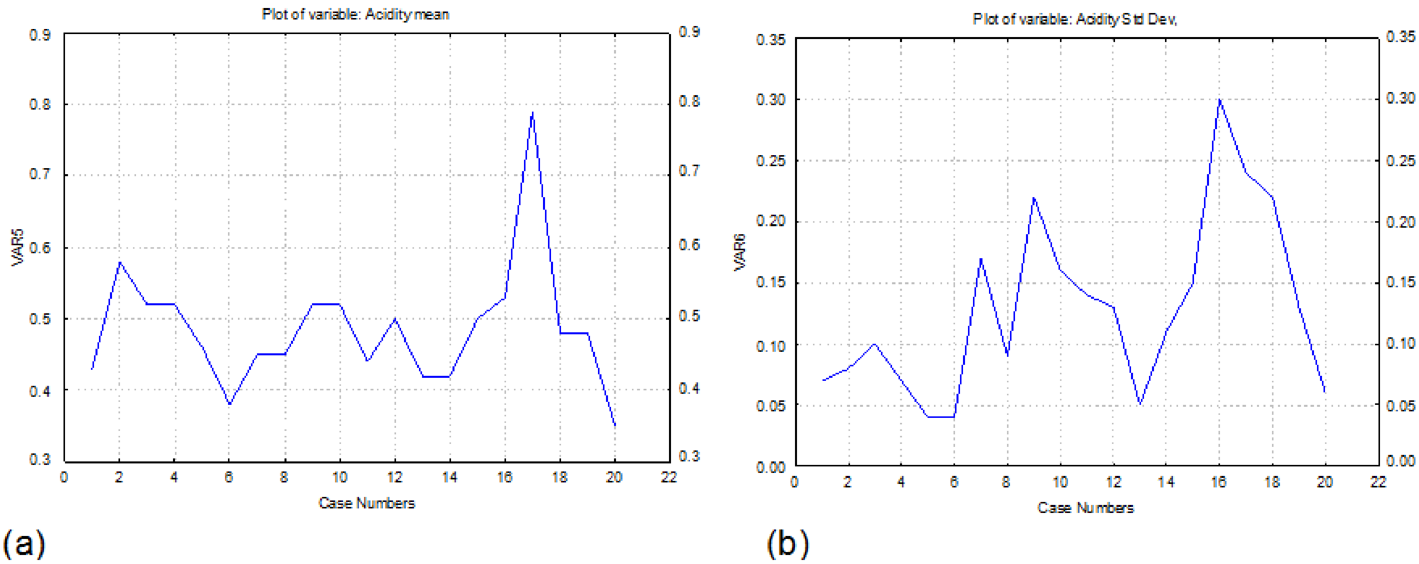

Figure 2. Represents the (a) mean and (b) the standard deviation of variable acidity; (b) representative of deviation of the five items of varying acidity of soybean oil indicating that the 16th sample showed a greater variation 0.30, on the other hand, samples 5 and 6, showed the lowest variation 0.04.

protein data of soybean oil meal (Figure 4) and a calculated value of 0.13487 was obtained, which is smaller to the tabulated value of 0.136, thereby confirming the normality of the data. The data collected from the protein meal soybean oil samples were divided into twenty five periods, the average of the means of each sample was $\bar{\bar{X}}$ = 45.23 and standard deviation of the sample was $\bar{\sigma}$ = 1.18. The following charts will represent the average and standard deviation of the series of soybean meal protein. We can see from Figure 5a that the average number of protein soybean meal varies widely, having its largest peak value of 46.42% at the 6th sample; on the other hand, the 10th sample had a value 44.08%. The sample had the lowest percentage of protein in soybean meal during the study period, the higher the percentage of protein from soybean meal, the lower the percentage of humidity in it. Figure 5b represents the standard deviation of five items of protein soybean meal variable, where it was found that at the 16th sample, the distribution showed the greatest variation 4.62, on the other hand, the sample 14 had the lowest 0.62 variation.

$\bar{X}$ - S Control charts

Figure 6 shows the performance chart for the protein variable. From Figure 6, it can be seen that all the points are within the control limits for the control graph of the average, but there is no point outside the limits to the graph of standard deviation, which apparently shows that the process is under control.

Series humidity soybean meal

Was applied the Koolgomorov-Smirnov (K-S) test in the protein data of soybean oil meal (Figure 7) and found a calculated value of 0.13499, which is smaller to the tabulated value of 0.136, thereby confirming the normality of the data. The data collected from the humidity of the soybean meal were divided into twenty samples for five periods, the average of the mean of each sample was $\bar{\bar{X}}$ = 13.15 and standard deviation of the sample was $\bar{\sigma}$ = 0.80. The graphs in Figure 8 represent the mean and standard deviation of the series humidity soybean meal. We can see from Figure 8a, that the average humidity of the series of soybean meal varied widely, having its largest peak value of 13.92% in the 9th sample, and the 15th sample had a value of 12.08%, so that the sample had the lowest percentage of humidity in soybean meal during the study period. The higher the humidity contents of soybean meal, the lower the percentage of protein in it, and vice versa. Figure 8b represents the standard deviation of five items of varying humidity of soybean meal, where it was found that the 3rd sample distribution showed the greatest variation 1.52, on the other hand, the sample 14 had the lowest 0.18 variation.

$\bar{X}$ - S Control charts

Figure 9 shows the performance $\bar{X}$ - S control charts for the humidity variable. Figure 9 shows that two points are outside the control limits for the control chart of the standard deviation. This means that the process is under

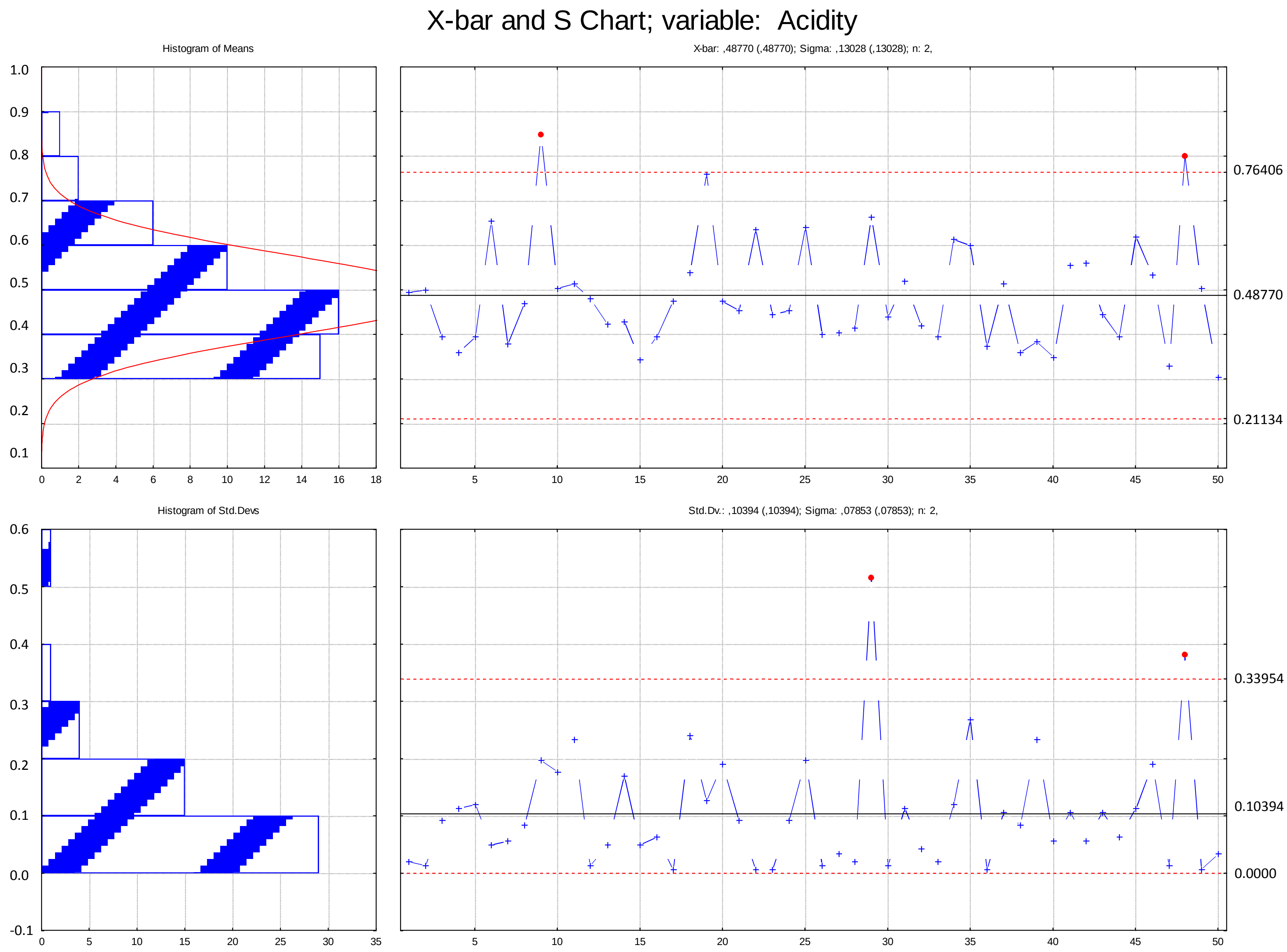

Figure 3. Control chart for acidity variable.

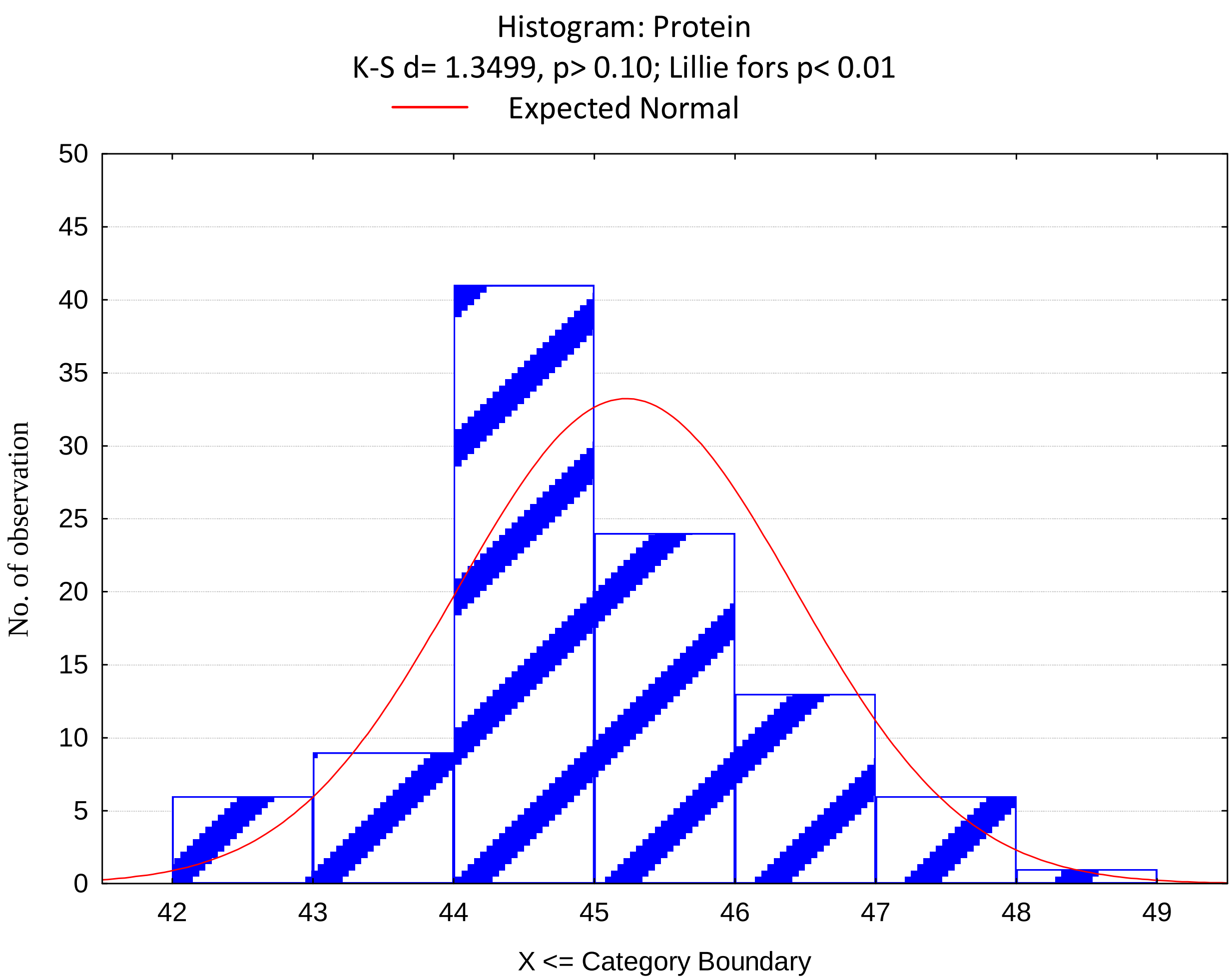

Figure 4. Test of normality.

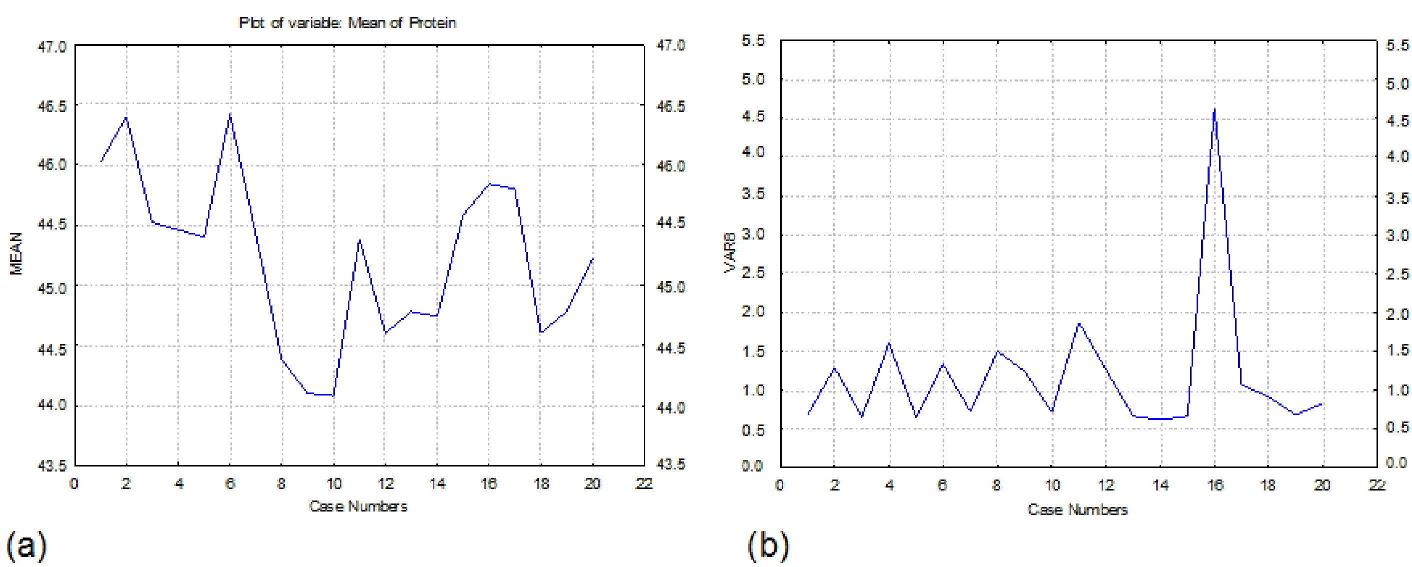

Figure 5. Graph of (a) the mean and (b) the standard deviation of protein variable.

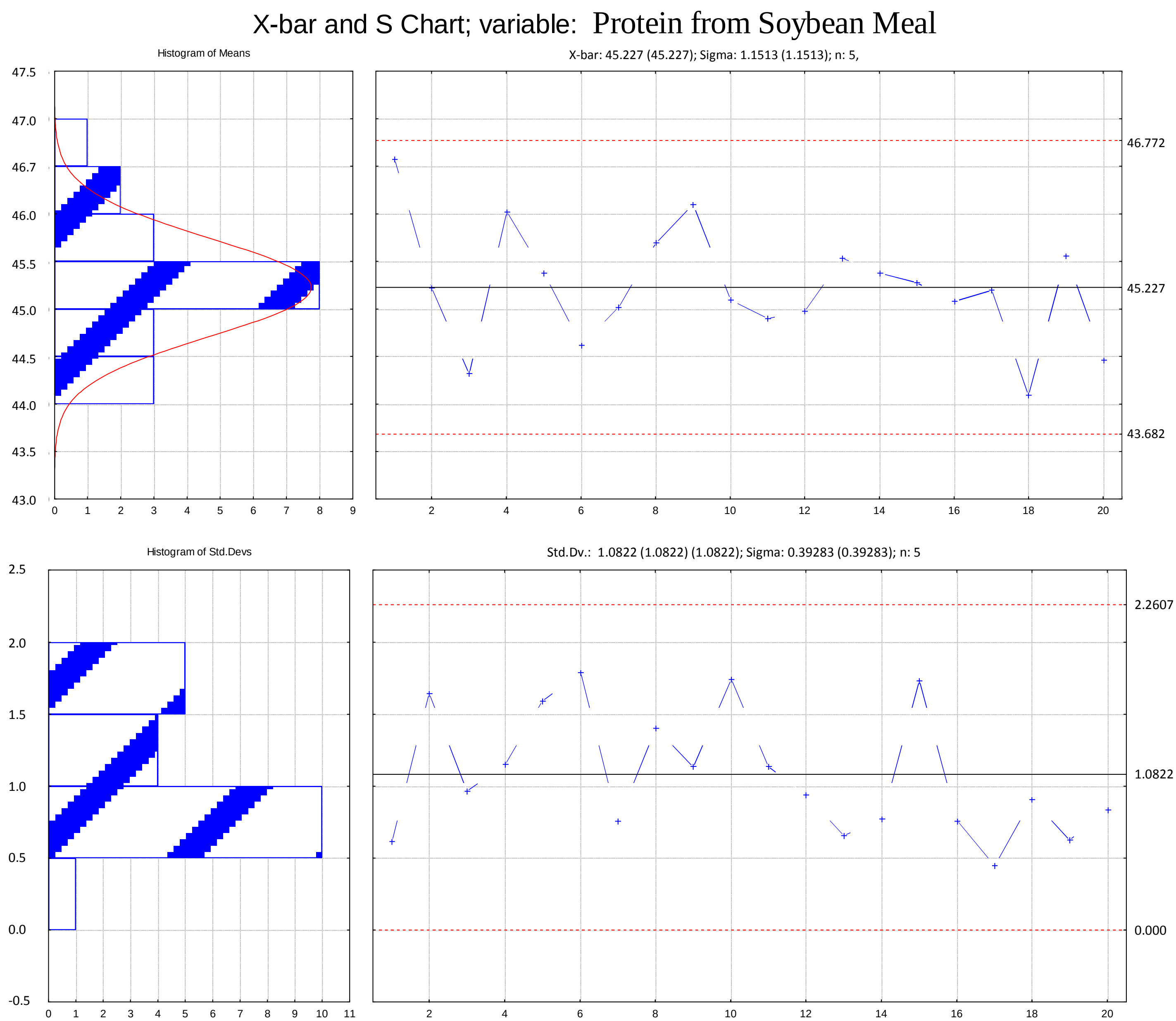

Figure 6. $\overline{X}$ - S Control chart to Protein variable.

control only in the mean control chart.

Conclusion

The procedure of Shewhart control charts is useful and practical. It has the advantage of easy implementation and use, having a high ability to identify errors. The construction of these control charts showed that the analyzed values show little variation from the data obtained from soybean, the averages were seen in zones B and C, that is, 1 and 2 standard deviation values did not show little indication of loss statistical control, ensuring high reliability in the results provided. By analyzing data through quality control charts, it was observed that the process is not under control for variable humidity and acidity because in these variables humidity and acidity, there were two points outside the limits of control charts. We conclude that the studied process is apparently out of control. Control charts were deployed as decision rules to keep the process under control, preventing the production of items outside specification. The results were shown to the industry as well as suggestions for improvement made. As further work, we

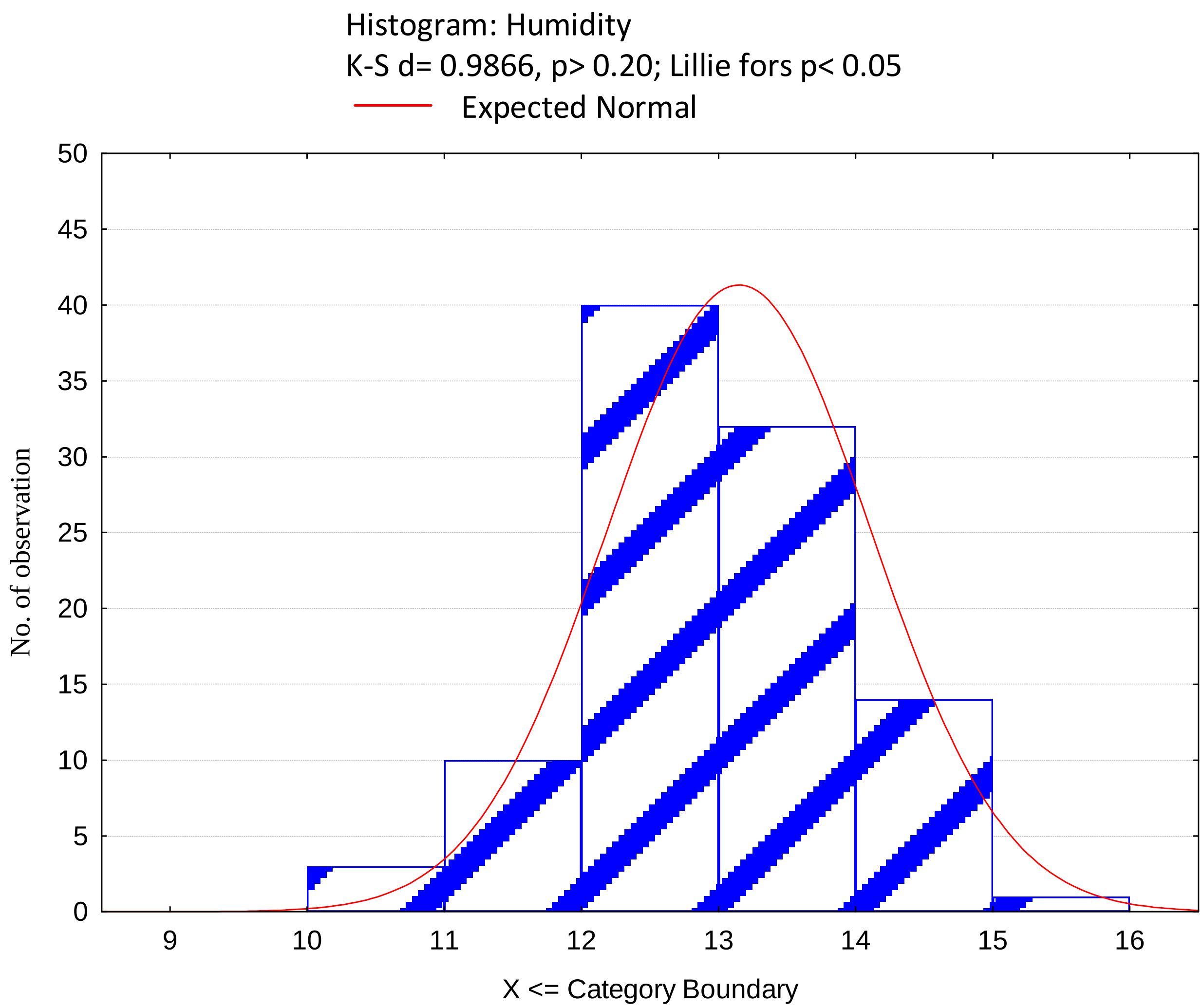

Figure 7. Test of normality.

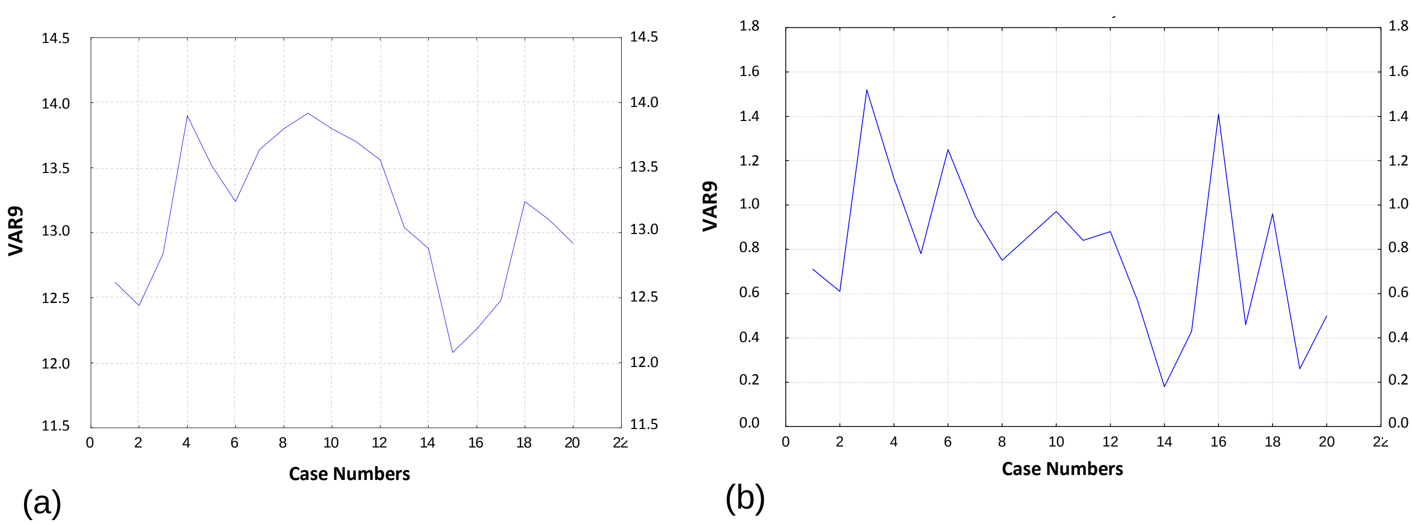

Figure 8. Graph of the mean and standard deviation of the humidity variable.

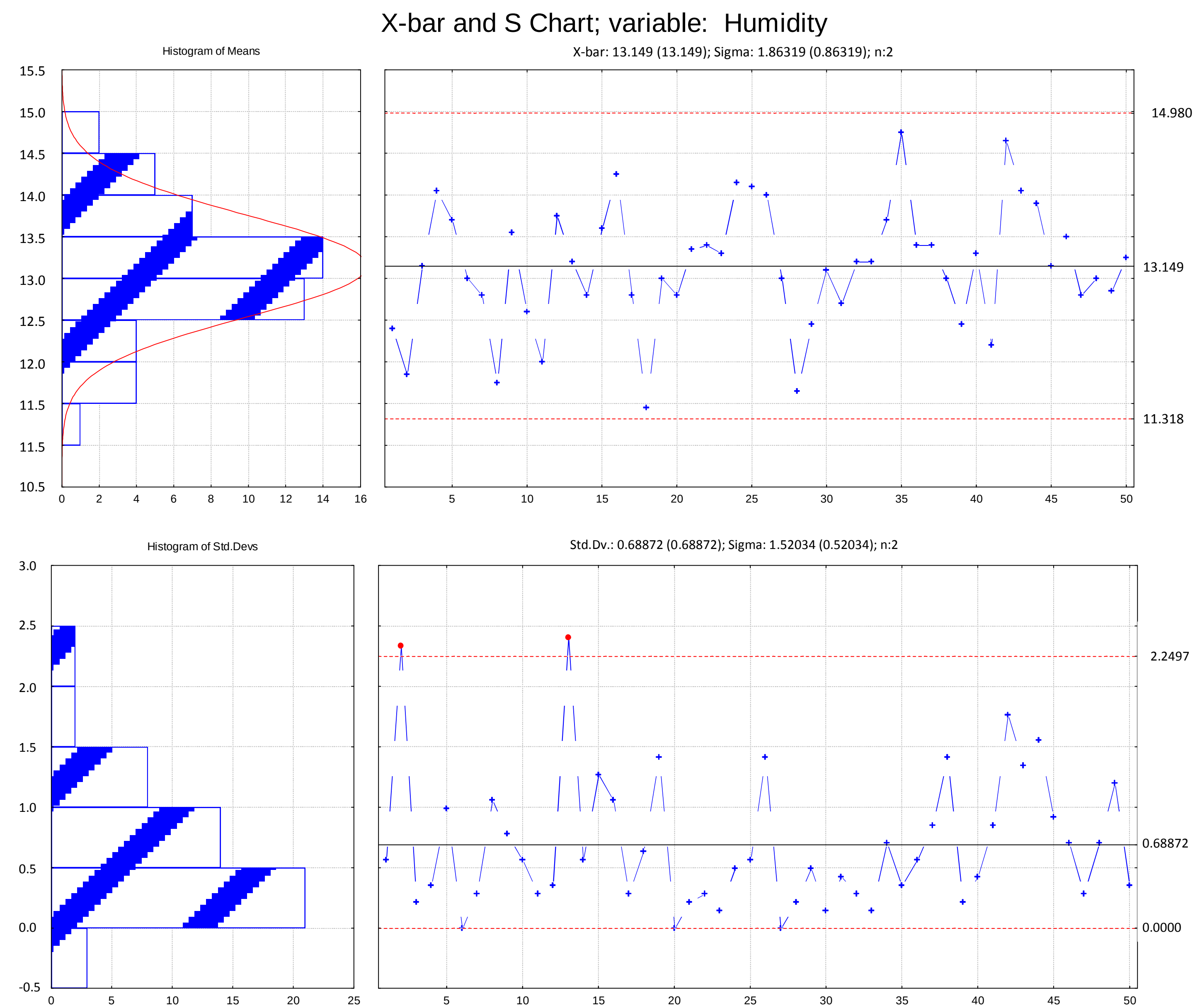

Figure 9. $\overline{X}$ - S Control chart for humidity variable.

suggest that other control charts are implemented in the production of other products of the industry where they expect to obtain benefits similar to those obtained in the manufacturing process of soybean oil.

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