CHAPTER 178

Use of control chart in the evaluation of garlic (*Allium sativum*) for industrial processing

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ABSTRACT
Garlic is a horticultural plant of excellent spice, nutritional and herbal value. The conditions to which vegetables are subjected in minimal processing can result in a series of important physiological changes, caused by mechanical damage suffered in the transformation steps. The control chart or chart is a statistical quality tool, which aims to identify deviations and point out possible failures in the production process. Therefore, the work aimed to implement control charts in a company that produces garlic paste. Analyses of the colorimetric parameters L, *a and *b, pH, moisture and ash were made for 20 samples of crushed garlic paste, where it was stored in drums, then 20 grams of garlic paste were collected in 10 different points of each drum. The graphs were assembled with the determined control limits and the results obtained were analyzed. For all analyses the processes were under control, were predictable and stable, except for the colorimetric parameter *a, where a sample exceeded the determined control limit making the process out of control.

Keywords: Humidity, Ash, pH, Colorimetric parameters.

1 INTRODUCTION

Garlic *(Allium sativum*) belongs to the *Alliaceae* family, being part of the same family as the onion. Its size oscillates between 50 and 70 cm in height and its roots can be 50 cm deep, and may vary from cultivar to cultivar (EMBRAPA, 1993, p. 7). It is a vegetable that has narrow and pointed leaves and the bulb is fractionated into bulbs that are grouped and wrapped by a wrapper of numerous tunics. It is a cultivar that adapts better in places of cold climate, ideal condition that provides the vegetable, a stable flowering and an increase of chemical and physico-chemical substances in its composition. Garlic is made up of essential oils; sulphur compounds; proteins; Carbohydrates; vitamins and minerals (MARCHIORI, 2003, p. 14).

According to MAPA (2022), the general requirements for marketing ensure that garlic must present the characteristics of the variety or cultivar well defined and be physiologically developed, healthy, clean, whole, firm and with the roots cut close to the stem. They must not present elements or agents that compromise the hygiene of the product and must be free of abnormal external moisture, odor and foreign taste. The batch of garlic that does not meet the general requirements may not be marketed for consumption in natura, and may be reprocessed and reclassified.

According to Anunciação and Lopes (2018), Statistical Process Control has been implemented in an increasing number of industries in Brazil, either by imposition of some client, or by the company's own initiative, aiming at obtaining gains in productivity and quality of its products.

The Statistical Process Control (SPC) is more than a total domain of quality is a way to encourage changes in the way the company operates, seeks to work on the quality of the product produced, aiming at variability and teamwork. Thus, the company begins to aim not only to obtain products within the condition required by customers, but also, from acts that correct the way the company works, seeking to reach a point at which its production process provides products with the specifications controlled around a central or average value (ANNOUNCIATION; LOPES 2018, p. 2). Thus, the tools of Statistical Quality Control were developed to ensure the improvement or adaptation of a process to the control standards, certifying its quality and performance, with the interest of providing products with desired characteristic, appropriate price and in the quantity demanded (ISHIKAWA, 1993, p. 221).

Quality management addresses the implementation of methods of continuous improvement and optimization of processes, and presents tools that can contribute to the identification and analysis of problems, consequently, assists in reducing costs and meeting customer needs (NASCIMENTO, 2018).

The techniques used for statistical analysis using the software, have contributed to the analysis of various products, identifying and mitigating possible abnormalities, where companies can work with stocks within the quality parameters. One of the main results of the industrial quality study was the widespread use of statistical process control methods to eliminate special causes in processes and reduce common causes of variation (MONTGOMERY, 1997).

The control chart or chart is a statistical quality tool, where it aims to reduce the number of failures in the manufacture of the product, with the reduction of failures in production, the company aims to reduce production costs by taking advantage of the largest amount of raw material possible. With the use of the control letter the technical responsible can follow the entire manufacturing process of the product, then doing the quality control finding where the adversity is. In the case of problems in the production line the correction happens before the product enters the market (CAMPOS, 2018).

This work aims to analyze the quality of garlic *(Allium sativum)* as a raw material for the manufacture of garlic paste in an industry located in the South of Minas Gerais.

2 THEORETICAL FRAMEWORK

2.1 GARLIC

Garlic (*Allium sativum*) is a vegetable of the *Alliaceae family* belonging to the same family as the onion and chives is an asexual plant identified in the form of root, which reproduces through the planting of the bulbs, that is, the teeth (BATATINHA et al., 2005 apud LEONEZ, 2008). The literature indicates that the emergence of garlic is something uncertain causing controversies about its true origin, because it may have arisen in Mediterranean Europe or on the Asian continent, most studies point out that the eye originated in Asia and arrived in Europe through the old negotiations (LEONEZ, 2008).

There are basically two types of garlic grown in Brazil, one known as noble garlic, characterized by the size and uniformity of the bulbs, consisting of a few bulbs per bulb and cultivated by large farmers, whose production is intended for the formal market. The other type is the semi-noble, characterized by the small size of the bulb, in which are inserted numerous bulbs, arranged without uniformity and narrow, known as "stick bulbs". It is cultivated by small farmers and its production is often destined for subsistence and the local market (MELO et al., 2011).

Its bulb is popularly known as the head, it is composed of teeth and it is these teeth that are used worldwide as an essential item in cooking and as a medicine due to its antimicrobial and therapeutic properties against cardiovascular diseases, intestinal and pulmonary pathologies (QUINTAES, 2001). This condiment has an energy value of 113 kcal per 100 g. It is a food full of minerals, especially phosphorus, potassium, calcium and magnesium (BOTREL; OLIVEIRA, 2012). Among other compounds already called garlic, organosulfurs stand out, among them aliin, allicin and ajoene that have proven beneficial biological activities (BUTT et al., 2009) cited by (CHAGAS et al., 2012; PEAR TREE; SAINTS, 2013).

In garlic, about 30 substances with potential therapeutic effect have been identified. Its bulb has a yield of 0.1 to 0.2% (v: p) of volatile oil, standing out in its chemical composition diethyl disulfide, allyl disulfide, diallyl disulfide, allyl trisulfide, diallyl polysulfide, S-allyl cysteine, S-allyl cysteine, S-allylmercaptocysteine, among other constituents. The sulfur compounds present in garlic are in quantities three times higher than those of other vegetables also rich in these compounds, such as onions and broccoli (MILNER, 2001). The type and concentration of compounds extracted from garlic depend on its stage of maturation, cultivation practices, location in the plant, conditions of processing, storage and handling (MARCHIORI, 2003).

According to the National Association of Garlic Producers (ANAPA), the country should reach in the year 2022, 250 thousand tons of garlic produced in a plantation area of 18 thousand hectares. The figures represent an increase compared to 2021, when the harvest reached 220,000 tons and 16,000 hectares (ANAPA, 2022). The positive result of this harvest is mainly due to the performance of the "cerrado", where the production area reached 14,500 hectares and the harvest continues at full steam in the states of Minas Gerais, Goiás and Bahia, in the period of July and September (ANAPA, 2022).

In June 2022, the import of fresh or chilled garlic except for sowing presented, in terms of quantity, an increase of 2.3% compared to the previous month and a reduction of 14.9%, compared to the same month of the previous year, standing at 13.7 thousand tons. In value, there was an increase of 2.0% in comparison with the previous month and a reduction of 21.1% in comparison with the same month of the previous month, representing an expense with imports of US$ 16.5 million, at an average price of US$ 1,198.6/t, FOB countries of origin, in the month.

The main origin of imports in June was Argentina, representing 72.2% of the total value imported in the month (US$ 11.8 million) and 68.5% of the quantity (9.4 thousand tons), at an average price of US$ 1,263.1/t FOB. The FOB import price in June of garlic originating in Argentina increased by 0.2% compared to the previous month and decreased by 17.6% compared to the same month of the previous year (CONAB, 2022).

2.2 GARLIC PASTE

With the advancement of modernization and the development of technology, nowadays consumers are increasingly looking for ready-made products that bring agility of handling and facilitate their day-to-day. Garlic paste is a product that meets these prerequisites (BERBARI et al., 2003).

The development of a paste processed with garlic in natura ready for consumption boosted the use of garlic, thus increasing its consumption by society, because many people were afraid to make its manipulation due to the organosulfur compounds present in this food, especially the allicin that makes the eye have as a predominant characteristic the strong smell which hindered the use of this horticultural (JUSWIAK, 1999).

When analyzing the industrialization of garlic, the paste is the product with the highest regular rate of use, and for the production of garlic paste certain precautions must be followed, among these we can mention the fact that the sooner the harvested garlic is processed, managed and industrialized the clearer the paste will be due to the physiological processes that lead to sprouting. Another important factor when it comes to the time interval between the harvest of garlic and the manufacture of garlic paste is that the shorter this interval, the higher the yield, due to the lower loss of moisture of the bulbs (Prati et al., 2010).

Citric acid has high solubility and a great ion sequestering power, which prevents undesirable reactions of color and aroma oxidation. Its versatility has made it one of the most used options by the industry in controlling the oxidation of products. Thus, its use is summarized in a safe and simple alternative for the processing of garlic paste (BERBARI et al, 2003).

On May 18, 2022, the Ministry of Agriculture and Livestock (MAPA) published MAPA ORDINANCE No. 435 that incorporates the MERCOSUR Technical Regulation of Garlic Identity and Quality, but it deals only with garlic *in natura and* does not define physico-chemical parameters such as acidity, moisture and ashes. There is also no specific legislation for garlic processed in paste, and it is necessary to rely on other works already published to compare with the results obtained.

Acidification to pH 4.0 using citric acid is efficient to control the enzymatic browning of garlic paste stored at room temperature for 3 months (BERBARI et al, 2003). The browning of garlic paste is directly linked to the storage time (BERBARI et al, 2003).

2.3 MINIMALLY PROCESSED FOODS

Minimally processed foods (AMP) are foods that are subjected to simple operations in the food industry, equivalent in cleaning, washing, selection, cutting, packaging and storage, operations that must maintain all the natural characteristics of the product (CHITARRA, 2000).

The main objective of minimally processed foods is to provide the consumer with the feeling of consuming a fresh food with a longer shelf life and at the same time, ensure its nutritional values and sensory characteristics (OLIVEIRA et al., 2006).

According to Lima et al. (2005) the minimum processing consists of the removal of what is not normally consumed in food, such as shells, stalks and seeds. However, even with the changes made in the food, the natural characteristics of the product must be maintained. Minimally processed foods were first used in hotels, restaurants and fast food franchises, in current times have expanded to the entire population especially those who have little time to prepare their food.

Minimally processed fruits and vegetables are part of a class of foods that are developing rapidly and essentially. Most studies referring to this area are being developed in Europe, Japan and the United States of America (USA), where the growing demand is noteworthy both individual and institutional (KOHATSU et al, 2009).

The legalized sale of minimally processed foods began in the United States, around the 70's, in Brazil the MPAs had a delay to enter the taste of Brazilians entering the market only in the last decades. Nowadays this food group has great expression in the supply and economy of the country where the large supermarket chains are responsible for 10% to 13% of the total percentage of sales (OLIVEIRA et al, 2011).

Due to the new eating habits, the consumer is becoming more demanding in relation to the quality of the food, the concern with the well-being and health grows day by day. This change in behavior awakens the search for healthier products that offer a high nutritional value, characteristics that refer to the natural as freshness and purity. In addition, the consumer tends to analyze with more caution the cost/benefit of the product (GERALDINE, 2000).

Minimally processed foods, because they are handled manually and by equipment, are subject to biochemical, physiological changes and microbiological deterioration that contribute to the change of texture, color and flavor, this happens due to peeling and cutting operations. (PEREIRA et al., 2003).

The mechanical damages necessary to process the food such as cutting, cause increased respiratory activity and ethylene production, this ends up causing some biochemical effects, such as enzymatic discoloration and decreased nutritional aroma, texture and quality, so the sharper the instruments and equipment, the less damage caused to tissues favoring the shelf life of these products (DEL CARO et Al., 2004).

That is why it is important to use quality control tools, which aims to save expenses, reduce cross-contamination, solve problems, actions that aim to ensure quality and increase the shelf life of these products (PEREIRA et al., 2003).

2.4 QUALITY MANAGEMENT

According to the Ministry of Agriculture, Livestock and Supply (MAPA) (2022), quality is defined as the set of parameters or extrinsic or intrinsic characteristics of a product that allow to determine its quantitative-qualitative specifications through aspects related to the tolerance of defects, measurement or content of essential factors of composition, sensory characteristics, hygienic-sanitary or technological factors or any other aspect that may influence the use of the product.

As a consequence of an increasingly competitive market and growing appreciation of customer needs, many companies are implementing quality management policies aimed at ensuring the satisfaction of their customers and stakeholders (stakeholders) (NOGUEIRA and DAMASCENO, 2016).

In the food industry the importance of quality management is evidenced, since in addition to the main focus on the satisfaction that the product provides to its customers, quality is directly related to health and food safety. In addition, efficient quality management directly impacts costs and, consequently, the profitability of companies (NOGUEIRA and DAMASCENO, 2016). The adverse public attention on food toxinfections associated with the food industries leads to consumer distrust and extensive financial losses (NOGUEIRA and DAMASCENO, 2016).

Quality Management consists of the set of coordinated activities to direct and control an organization with respect to quality, encompassing from planning, control, assurance and quality improvement, and at all stages can be present the improvement of quality. From this concept arises the concept of Total Quality Management (TQM – Total Quality Control) (NOGUEIRA and DAMASCENO, 2016). The application of TQM within organizations is strongly associated with continuous improvement, which is understood as a process of cultural and behavioral changes that can be put into practice through management and/or operational systems, methods or techniques, which result in the improvement of the organization and add value. To transform theory into practice and ensure the full viability of the conceptual structure of the basic guidelines of quality management, management tools and programs are used. The association of tools and employee involvement with quality results in the success of the management system (NOGUEIRA and DAMASCENO, 2016).

2.5 STATISTICAL PROCESS CONTROL

Controlling the quality of products and services offered is an age-old necessity. The historical records indicate that the great civilizations, such as the Egyptian, the Greek and the Roman, had a quality control system, in their own molds and distinct from those currently employed where the artisans themselves were responsible for the conference of the manufactured products. Over time, the growing demand for products made it impossible to inspect all manufactured products, so this process began to be carried out by sampling. The statistical sampling process provided sufficient information on the quality of the products, without, however, increasing costs (SPOHR, 2014).

The quality of the products and services consumed is a factor that increasingly characterizes a competitive factor in the market, enabling organizations to have advantages over others. Under this aspect, the Statistical Process Control (SPC) presents itself as a tool capable of enabling the monitoring of the process for the defined control variables, so that the control graphs help in the visualization of the behavior of the process. The basic foundation of the CEP is based on the concepts of variability. Quality is defined as compliance to specifications. If variability is high and specifications are not met, quality is an increasingly distant target. The use of the CEP, therefore, allows to evaluate the process and ensure greater reliability in the final product obtained, in addition to enabling the improvement of the process, since the problems that are identified generate action plans that aim to eliminate or reduce important causes of variability in the process (MUCIDAS, 2010).

For many years, the separation of defective from non-defective products occurred at the end of the production process, making it difficult for factory supervisors to take corrective action. At the moment when the focus of this inspection ceased to be the product and began to be centered on the process, continuous improvement actions could be implemented more easily. Consequently, the products manufactured have reached higher levels of quality, with a view to a rigorous and preventive online monitoring. In addition, the costs generated by rework and scrapping of non-conforming items were reduced (SPOHR, 2014).

According to Lins (1993), to put a process under control, it is necessary to analyze all significant deviations of behavior that may occur in it, clearly identify their causes and solve them whenever possible. When the process is under control, these problems will have been eliminated and only a few occasional variations, not systematic or random, in their behavior will occur. Only then does it become appropriate to establish a cycle in which this process is observed and compared with a desired standard of performance. The study of process behavior is developed with the support of Statistical Process Control (SPC), which is based on two premises:

a) every process undergoes small random variations that occur within certain limits, without a systematic cause that can be eliminated — the behavior is statistical: most variations are very small and large variations are extremely rare.

b) when the process presents a systematic deviation or a variation outside its limits of behavior, there will be one or more causes for this occurrence. Such causes, called special causes, can be identified and eliminated.

The main objective of the CEP is to quickly detect the cause that is affecting the quality of the process, through the control charts, among other tools, and with this to be able to reduce the variability of the same, and then produce a product with greater quality assurance and lower cost. Despite all the care in the processing, still, there are as a result some products with defects, and they can be separated into two categories: chronic defects where they are inherent to the process and are always present until the problem is detected and resolved and sporadic defects that are represented by deviations from what the process is able to do, They are detectable more easily and can affect the process for a short period of time, with this they can disappear and appear in the future. These defects or failures during the process generate high production costs, non-standard products, thus causing a reduction in competitiveness (CAMPOS, 2018).

2.6 CONTROL CHART

Alencar et al. (2004) states that control charts or charts are tools used in Statistical Process Control (SPC) and aims to identify deviations in the pre-defined parameters for the process and standardize the production line reducing costs and ensuring product quality. The use of the control chart presupposes that the process is statistically stable, that is, that there are no special causes of variation.

Control charts are a useful quality tool in monitoring and applying improvements in production processes. This is because the monitoring of the variable at each stage of the process allows the identification of special causes of variation and immediate intervention at the point where the problem was diagnosed. However, although control charts are an easy-to-use tool, there are not many published works that report their application in the food industry (SPOHR, 2014).

According to Ramos (1995, p. 15), "the control graph is an efficient method for the study of the statistical stability of a process, from the observation of random sequences of small samples, collected at regular intervals". Its use does not determine the factors causing variation, but it is a tool capable of indicating when unusual sources are present (SPOHR, 2014).

The classical control charts (Shewhart) are temporal graphs that present the measurement values of the variable of interest on the vertical axis and the points in time at which the measurements are made on the horizontal axis and that are interpreted as a function of horizontal lines, called the upper limit of control (LSC), midline (LM) and lower limit of control (LIC) (ALENCAR et al, 2004).

The analysis of the control graphs allows to determine if a given process is stable, that is, if there is no presence of special causes of variation acting on it (RAMOS, 2000). If these points are all arranged within the limits of control, it can be considered that the process is "under control". But, if one or more points are outside the control limits, it can be said that the process is out of control, and that an investigation and corrective action is necessary to detect and eliminate the causes of the process (CAMPOS, 2018).

For a process to be considered statistically stable, the points on the control charts must be randomly distributed around the midline without there being strange patterns of the type, increasing or decreasing trends, cycles, stratifications or mixtures, points outside the control limits (RAMOS, 2000). Non-randomness tests serve to verify if a given process can be considered as subject only to the action of common causes of variation, a situation in which it is said to be stable (under control or predictable), or if points on the graph present some strange configuration (ALENCAR et al, 2004).

3 METHODOLOGY

3.1 PRODUCTION OF CRUSHED GARLIC

The company located in the south of Minas Gerais, initially buys garlic from small producers in the city and in the supply center (CEASA), located in Pouso Alegre MG, and the amount of garlic purchased depends on the company's garlic stock before being minimally processed and also on the amount of final product to be stored. The cultivar most acquired by the company is the cultivar Chonan. The storage is separated into two places, storage of raw material where the garlics are inside bags protected from light on top of pallets so as not to come into contact with the floor, another place stores the finished product in plastic drums with a capacity of up to 85 kg.

The garlic is received and placed in the storage sector, and then it is directed to a piece of equipment that separates the garlic cloves from the bulb. Continuing the work, the garlic is taken to a machine that has the function of removing the peels of the garlic clove, after peeling the garlic goes to the crusher, which has a capacity of 30 kg for each batch, which has knives that rotate at high speed processing the garlic by means of cuts in small pieces until it becomes paste. The final product is stored in plastic drums, forming a batch per drum where they are properly identified. The drums are stored on top of pallets protected from sunlight and the product is transferred to the final packaging - transparent plastic jars with a capacity of 200g, according to the demand of orders.

Samples were collected from different points of the drums containing crushed garlic to perform the analysis of colorimetric parameters, humidity, ash and pH. The collection was made in 10 distinct points in each drum, where in each point 20 grams were collected, the points were: 2 points on the surface, 2 points on the bottom, 2 points in the middle, 2 points on the side on the surface of the drum and 2 points on the side of the bottom of the drum.

The samples were analyzed in the bromatology laboratory of the Federal Institute of Education, Science and Technology of the South of Minas Gerais - Inconfidentes campus.

3.2 COLORIMETRIC PARAMETERS

The color of food is an important factor for the commercialization of these foods, and can be determined quantitatively, by colorimetry, with the use of equipment such as colorimeters and spectrophotometers. For analysis, 30 grams of each sample collected from crushed garlic were analyzed, the tests were performed on the Konica Minolta colorimeter (Model CM-2300).

The internationally recommended color specification system, defined by the Commission Internationale de l'Eclairage (CIE), uses the CIE L*, a*, b* scale, and is commonly referred to as the CIELAB system. The value L* represents the variations from white (L*=100) to black (L*=0). The value a* represents the variations from green (negative value) to red (positive value). The value b* represents the variations from yellow (positive value) to blue (negative value) (JHA, 2010, CALVO & DURAN, 1997, MELÉNDEZ-MARTÍNEZ et al., 2007, PÉREZ-LÓPEZ et al., 2006)

3.3 MOISTURE ANALYSIS

The evaluation of moisture loss by desiccation was done by direct drying in a FANEM oven at 105ºC by method 012/IV of the Adolfo Lutz Institute (1985).

3.4 PH ANALYSIS

The pH analysis of crushed garlic was performed with the aid of an Alfakit pHmeter, duly calibrated following the 017/IV method of the Adolfo Lutz Institute (1985), where the procedure consisted of weighing 10 grams of sample in a beaker using an analytical balance, then dilution in

100mL of distilled water, was stirred to homogenize the solution and then the pH was determined using the pH meter following the manufacturer's instructions for use.

3.5 ASH ANALYSIS

The ash analysis was performed by heating the sample at temperatures close to (550-570) ºC following the 018/IV method of the Adolfo Lutz Institute (1985), where ash analysis was combined with moisture analysis, incinerating the residue of the moisture analysis.

3.6 CONTROL CHART

For the construction of the graph or control chart, the control limits were defined following the Shewhart charts where three deviations (3σ) are placed above or below the central limit (OLIVEIRA et al., 2013). The following formulas were used to calculate the lower control limits (LIC), upper control limit (LSC) and control limit (LC):

$$LSC = \mu W + 3\sigma W$$

$$LC = \mu W$$

$$LIC = \mu W - 3\sigma W$$

Where μW is the average of the results obtained from the analyses and σ represents the standard deviation obtained. a control chart was constructed for each parameter analyzed, color, moisture, pH and ash were analyzed.

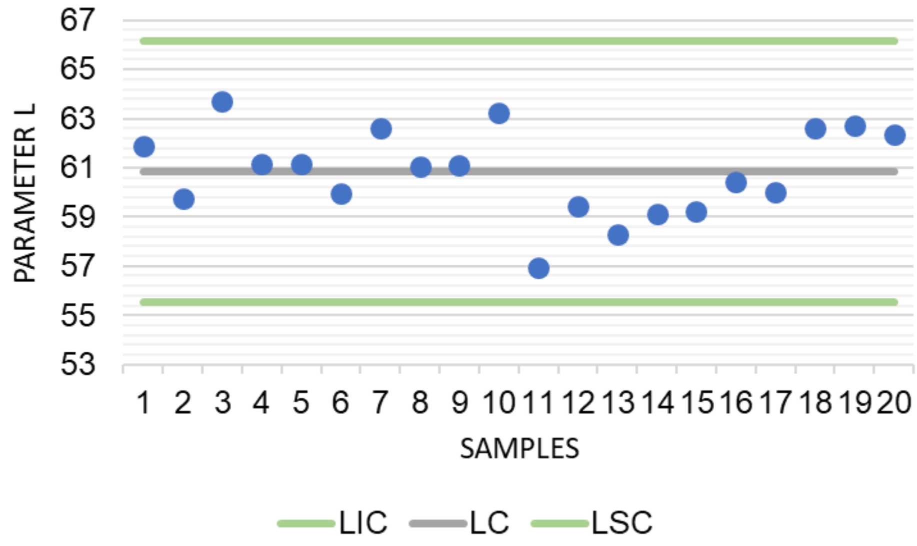
The type of control chart chosen was the one for variables, because variables were used for its construction. This type of card can be divided into four types and among these the Ẍ and s cards (mean and standard deviation) were chosen because the number of samples is greater than or equal to 10 (OLIVEIRA et al., 2013).

The data used were obtained through the analyses in the laboratory being tabulated in an Excel spreadsheet, from this were made the necessary accounts for the creation of the control charts also called control chart, through the Microsoft Office® Excel 2016 software.

4 RESULTS AND DISCUSSION

Figure 1 shows the control plot for the colorimetric parameter L (luminosity) of the garlic samples evaluated.

Figure 1 - Luminosity control chart (Parameter L).

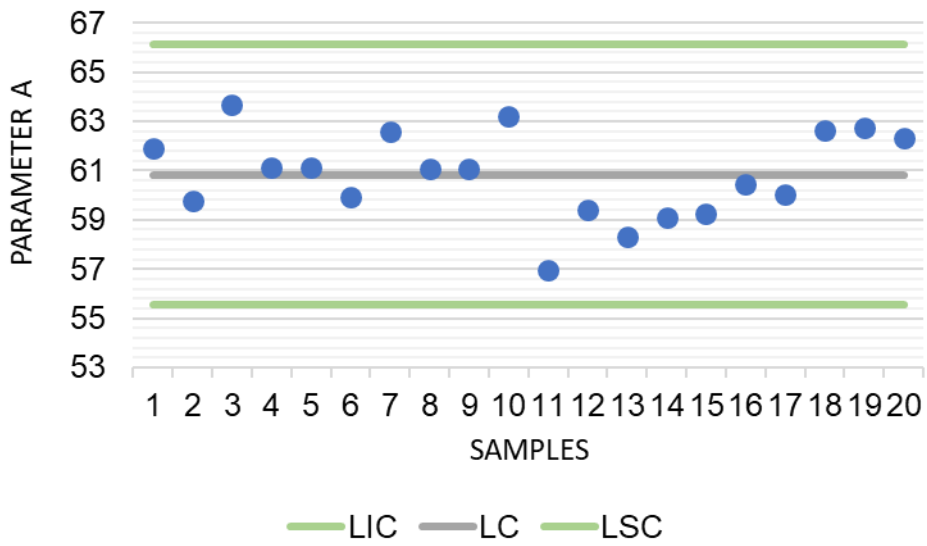


Source: Autoral , 2022.

It can be seen from Figure 1 that all samples are within the space delimited by the Lower Limit of Control and Upper Limit of Control and, therefore, the process is under control for the colorimetric parameter L (Luminosity).

Figure 2 shows the control plot for the colorimetric parameter *a (green to red) of the garlic samples evaluated.

Figure 2 - Control chart for colorimetric parameter *a.

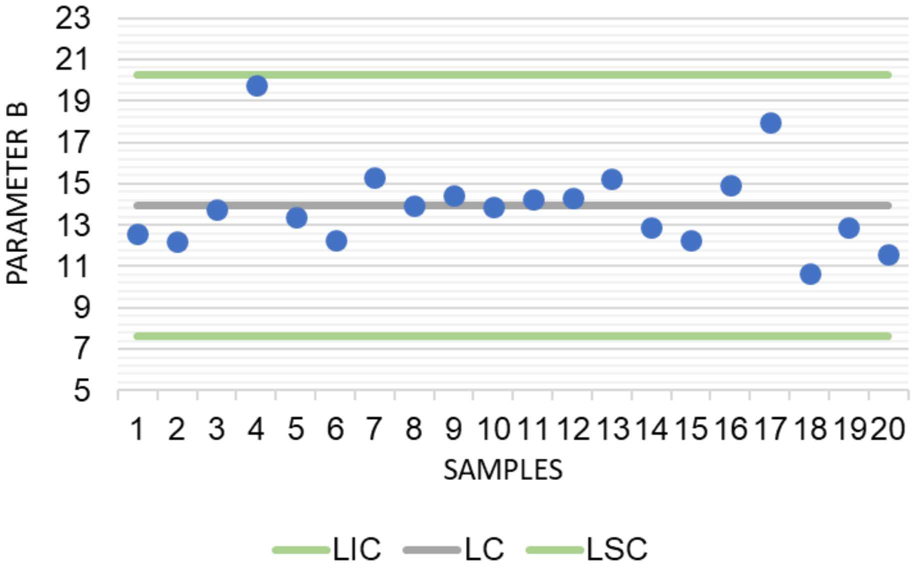


Source: Autoral , 2022.

In Figure 2, it can be observed that the points are well grouped close to the control limit, showing very homogeneous data. There is one point, i.e. a sample that differed from most and is above the upper limit of control. Considering that a sample exceeded the upper control limit, we can conclude that this process is out of control for the colorimetric parameter *a for the garlic samples evaluated.

Figure 3 shows the control plot for the colorimetric parameter *b (Yellow to Blue) of the garlic samples evaluated.

Figure 3 - Control chart for colorimetric parameter *b.



Source: Autoral , 2022.

When analyzing Figure 3, one can see a large concentration of data very close to the Control Limit (mean), showing great homogeneity of the data. In particular, two points call attention for having moved away from the control limit, and one came to overlap the upper line of control, but it did not exceed it. Therefore, we can conclude that the process is under control for the colorimetric parameter *b for the garlic samples evaluated.

The current Brazilian legislation does not provide legislation for processed garlic that defines acceptable limits and values to define quality on the color parameters, so it was not possible to compare the results obtained with those defined by law in order to determine if the process meets the same.

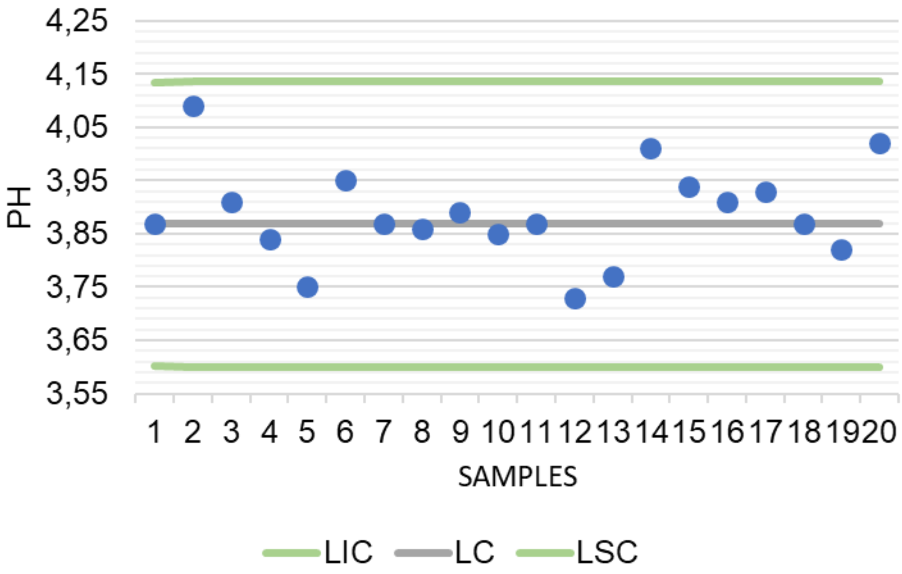
Through the analysis of the three colorimetric parameters (L, *a and *b), it is observed that only the parameter *a is out of control, because it has a point outside the established limits, evidencing that this process is not stable and predictable. For the other parameters, the process is stable and predictable.

The natural color of food represents an aspect of quality. However, during the processing steps of the food, changes in color are observed, which ends up impairing the quality condition. Foods of plant origin are the most affected by this type of modification, due to the action of enzymes that are intrinsically present in these foods. Situations of browning are quite common in fruits and vegetables, requiring greater care to these foods, so it is essential to use appropriate preservation methods so that the natural sensory characteristics can be maintained. The enzymatic browning reactions are due to the action of the enzyme polyphenoloxidase (PPO) and peroxidase, and usually occurs in the cutting or peeling processes of the food, at which time these enzymes come into contact with oxygen resulting in browning reactions in the vegetables, which are not desirable (MONTEIRO and CAVALCANTE, 2019).

Therefore, the non-compliance for parameter *a may be associated with the action of peroxidase and polyphenoloxidase from the processing activity, the absence of the execution of some conservation technique and the lack of control of the storage time.

Figure 4 shows the control graph for the pH parameter of the crushed garlic samples evaluated.

Figure 4 - pH parameter control chart.



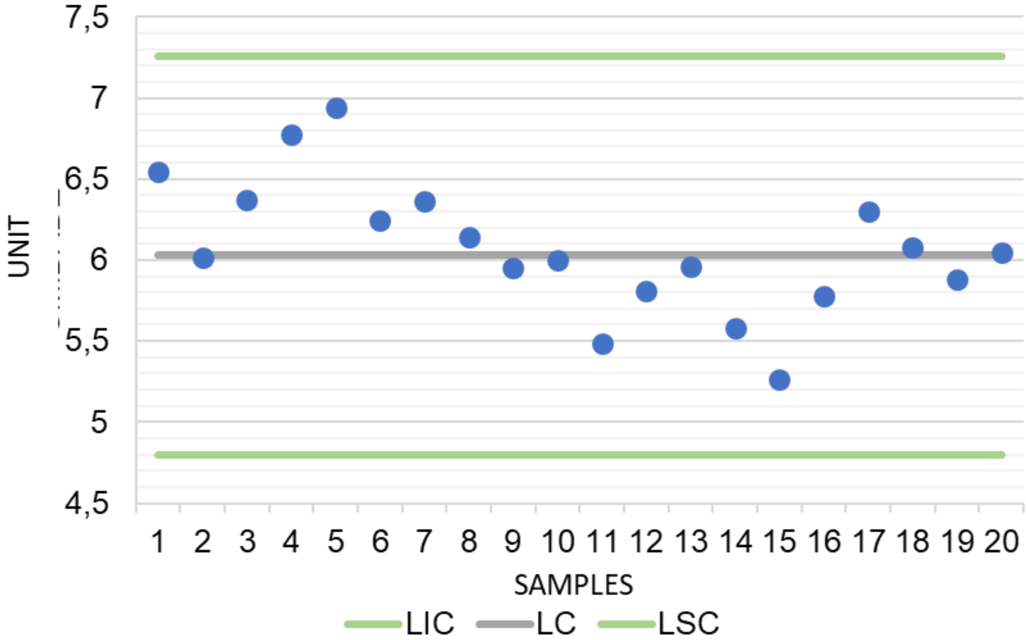
Source: Autoral , 2022.

According to Figure 4, it is observed that none of the analyzed samples exceeded the lower control limit and the upper control limit, however it is possible to observe that there is a large number of samples that are not close to the control limit (mean). Thus, it can be concluded that even though the samples are under control, there is a pH variance in the lots collected and analyzed by the authors.

Most of the pH of the samples collected is below 4.0 and the average among the samples is 3.87. According to Prat et al, (2010) the pH of garlic paste should be below 4.0 de novo to combat the growth of microorganisms and increase the shelf life of the product. Prat et al. (2010) also points out that over time over storage, the pH of the pastes may increase and consequently the acidity decreased, a fact that can be explained by microbial growth.

Figure 5 shows the control graph for the moisture parameter of the garlic samples evaluated.

Figure 5 - Humidity parameter control chart.



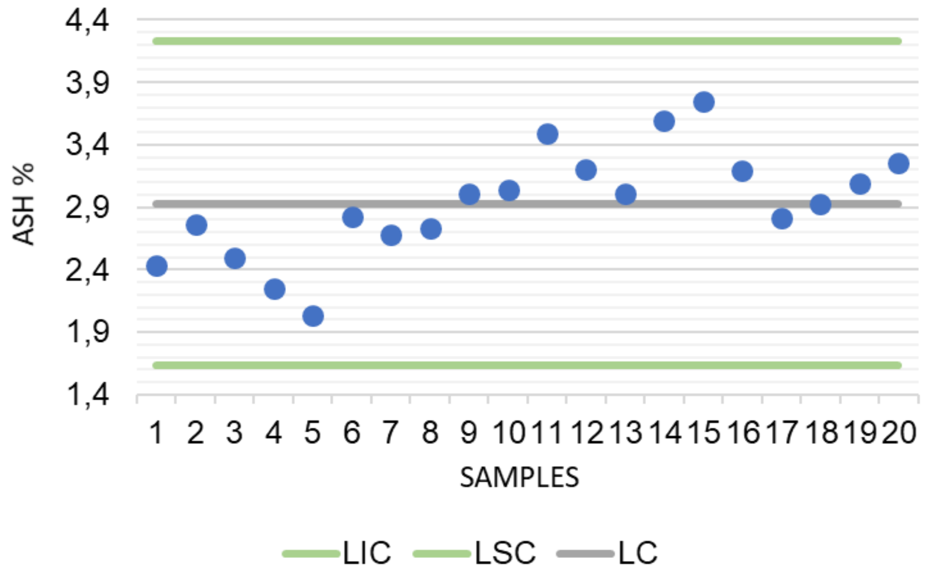
Source: Autoral , 2022.

According to Figure 5, it is possible to notice that most of the points are under the control limit (average) and that some points are closer to the upper limit of control and the lower limit of control. Even if some points are far apart, none of them has exceeded the determined limits, so the process is under control, it is predictable and stable.

The fact that the garlic paste is stored in vertical drums can be a factor that influences the moisture variation of the samples, because with the action of gravity, the existing moisture in the upper part tends to migrate to the lower part making the garlic paste of the upper part less humid and that of the lower part more humid. Therefore, the homogenization of the garlic paste before filling is very important to maintain the same moisture standard for all samples.

Figure 6 shows the control plot for the ash parameter of the garlic samples evaluated.

Figure 6 - Grays parameter control chart.



Source: Autoral , 2022.

In Figure 6, you can see that the gray parameter is under control by locating the placement of the analyzed garlic paste samples on the control chart. Even with the samples scattered throughout the chart, none exceeded the upper limit of control or the lower limit of control.

According to Montgomery (1997) it is only possible to interpret the statistical control charts of a process, as follows: considering it "under statistical control" or "out of statistical control, within this, we can evaluate that in the ash parameter occurs the existence only of natural variability of the process, that is, that it is under the action only of the so-called random causes, both for individual value charts and for moving amplitude cards.

According to Hessler, Camargo and Dorion (2009) a production process planned and carefully monitored will exist natural variation, resulting from common (random) causes, making sure the stability of the same.

In a study conducted by Souza (2002) that evaluated the implementation of a control letter in an alcoholic beverage company that worked with whiskies and vodkas, where the labels were not under control, the author concluded that the identification of a higher percentage of defects is due to the difficulty of gluing the label and back label which requires improvements in the production process. There was a change in the labels of the products, which leads to the need for further studies in this process.

In the work of Maciel et al. (2014) evaluated the chemical composition of wines produced in the same region of Italy, derived from three different cultivars, the actor analyzed color, alcohol level, flavonoid level, total phenols, anthocananines, among other variables. According to the study, wine production was considered totally out of statistical control, the authors suggest that production is out of control for reasons related to equipment mismatch, operators without proper training, poor quality of raw material, or even poorly performed setups and through this study he suggests a managerial intervention in the quality control of the company.

Campos (2011), used the control chart to study the percentage of moisture in equine rations, where it was observed that the humidity was not under control and it was found that the lots evaluated were influenced by high humidity due to rainfall during manufacturing. The sequences of points indicated a change in the level of the process that can occur due to factors such as: lack of maintenance of the dryer, high turnover of operators, lack of adequate training and failure in the process of pelletizing the feed.

In a work developed by Laros et al. (2014), shows the application of control chart in laboratory of physicochemical analysis of wheat, this work performed physicochemical analysis on wheat (humidity, number of fall, color and ashes). For the construction of the control charts, 30 analyses were performed for each parameter of a sample of wheat flour acquired for this purpose, where it was verified that all the analyzed parameters are out of control.

In another study by Silva et al (1999) the author applied the control chart in a dairy industry, the process steps chosen for the investigation of the quality level were pasteurization, skimming of milk and packing, the author collected samples of the steps studied for two months and analyzed the temperature of the milk, percentage of fat and the weight of the final product, it was observed that there was failure in all stages of the production process, concluding that production is completely out of control; The author states that dairy has fragility in the quality assurance of products and recommends new financial investments in the company.

Henrique (2019) followed the quality of cashew nut almond production, the author chose moisture as the controlled variable, the author compared the behavior of the raw product with the behavior of the roasted product. It was observed that for the raw samples in May there was a high variation, coming from special causes, since the humidity analyzed during this period was under climatic influences. In June the behavior of the raw product was similar to that presented in the month of May, already in the behavior of the roasted product, we have non-standard points, showing that the production is out of control, being explained by possible variation in temperature, acidity of the oil used in the roasting or nonconformities in the raw material used.

Santos et al, (2021) evaluated the quality of cassava flour, where they collected 63 samples of cassava flour. The samples were evaluated for acidity by titration; starch content by polarimetry and moisture, ash and total crude fiber contents, compared with the values of the legislation. It was observed by the control charts that the process is out of statistical control for the parameters moisture, ash, acidity, fibers and starch content.

Silva (2019) verified the variability of the manual process of filling guava of 500 grams in an industry of the food sector with the use of statistical process control tools. From the data collection, the control charts were elaborated that demonstrate that the process is under control, with the results the author observed the excess weight of the guava and then an analysis of the waste was made and then the main causes for this problem were identified.

Lima (2019) studied the production process of a biscuit factory by checking 250 packages of rolled biscuits through the quality tools, applying the control chart in order to identify the causes for the main problems of the product. However, it was observed that the process is out of control and then the author observed that the lack of standardization is due to the change of shifts, problems with the quality of flour and maladjusted equipment.

Campos (2018) who employed Statistical Process Control, from the chart or control chart in a pasteurized orange juice company evaluating the standardization of total acidity and soluble solids. It was observed that the control for titratable total acidity was under control. However, for total soluble solids, it is perceived that there is an out-of-control process. In the same work the author states that there may have been some error, which will be called a special cause, which happens a few times, but generates a disturbance in the process becoming out of control.

All these studies cited highlight the effectiveness of the control chart (control chart), concluding that the control charts are efficient in monitoring deviations from parameters representative of the production of various products and in different areas of production, the implementation of the control chart reduces the waste of raw material and unnecessary expenses.

5 CONCLUSION

By analyzing the results of the control charts, it is concluded that all processes for all analyzed parameters are under control, that is, they are predictable and stable. Except for the colorimetric parameter *a, which after the analysis of the control chart, it is noticed that one of the samples exceeds the value defined for the Upper Limit of Control, therefore, this process is out of control. Because it happened only once after all the analyses, we can determine what happened as a special cause, where an error occurred and it generated a disturbance to the process, but it is something sporadic.

It can be concluded that the use of control charts for the industry is of paramount importance to monitor the processes, identify causes of variation, optimize the processes, minimize waste and thus offer a standardized and quality product to the consumer.

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