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Proposal for Improvement in the Setting Process in the Broth Treatment of a Sugar and Ethanol Plant

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Abstract: In continuous processes, variability represents a significant challenge in achieving adequate performance, as standardization uncovers previously hidden profits at each stage. This article addresses the identification of an instability problem in the sedimentation process in the syrup treatment sector of a sugarcane energy plant. This problem compromises the quality of the final product and exceeds the established targets for input consumption, leading to the implementation of an automatically operated equipment to solve it. The objective of the proposal is to reduce process instability and, consequently, achieve input savings. To accomplish this, two quality tools were used, such as the Ishikawa Diagram, to identify the root cause, and the PDCA cycle, for the clear, effective, and efficient application of the new equipment. This project resulted in numerous benefits, as the achievement of stability promoted increased standardization in processes, including product specification and operations. Therefore, it can be concluded that this work had a positive impact on other sectors, such as finance, due to savings in product dosage, and logistics, due to two factors: the creation of a consumption pattern that facilitates predicting the appropriate time to acquire each input and the reduction of inventory movement resulting from a stable quality process.

Keywords: Quality, Stability, Economy, PDCA Cycle, Ishikawa Diagram

1. Introduction

The production of sugar and ethanol has been standing out in our country through the sugarcane industry. "The Brazilian sugarcane sector represented 2% of the national Gross Domestic Product (GDP) in 2019" [9].

With exponential growth, organizations are increasingly concerned with developing quality management [8]. Through quality tools, the inefficiency of polymer preparation in the sugarcane juice treatment process, specifically in the decantation stage, is identified. Therefore, the need arises for the implementation of an automated preparation system for this solution, as stated by Lima [17], "proper preparation increases process efficiency."

In a sugar and ethanol production plant, decantation is one of the most important stages [1]. Araújo [2], highlights that "decantation is a natural process where the force of gravity acts on particles with a density higher than water, dragging them to the bottom of the container." Thus, the activities carried out in juice treatment and the justification for implementing this automated system are emphasized. The need for a new system is important, and automation contributes to its development.

According to Prominent [23], the automatic polymer homogenizer is configured by the user through the control panel with integrated Siemens PLC, float-type level switch (3 stages), and a rotameter flow meter, which makes the system more economical. Thus, the path taken to prove and highlight the weaknesses and deficiencies of the processes in question is mentioned, where the quality tools are used to expose these needs and their respective concepts.

The steps for applying quality tools identify the root causes of deficiencies and the implementation of the equipment. Therefore, the importance of each quality tool in the post-implementation phase presents the beneficial factors that this system generates.

Therefore, this article aims to implement an automatic flocculant polymer homogenizer in order to achieve consistency, stability, and standardization in the decantation process.

2. Theoretical Framework

In sugarcane and sugar-alcohol mills, the juice treatment process is the stage that attracts the most attention from leaders and supervisors. The goal of juice treatment is to eliminate the highest concentration of impurities possible, such as soil, bagasse, and other materials [13]. The correct dosage of chemicals such as hydrated lime, flocculant polymer, and phosphoric acid (when necessary) are the main contributing factors to successful decantation. They require extremely precise dosing in terms of quantity because mild dosing directly impacts decantation efficiency.

Regarding the flocculant polymer specifically, using a dosage below the ideal parameters will result in weak and slow precipitation. Conversely, if the dosage is excessive, repulsion instead of flocculation occurs. However, if the dosage is within the recommended parameters, successful precipitation with improved efficiency is achieved [15]. Considering these facts, when proposing an improvement, it is necessary to have broad and solid knowledge to explore all paths toward improvement. Thus, the starting point should be the identification of all problems within the process at hand. Guedes [12] emphasizes that the identification process begins with recognizing the existence of the problem, and for that, understanding the process is essential to pinpoint the exact cause of the problem.

In this case, all possible problems causing poor decantation were identified using a quality tool called the Ishikawa diagram. It highlighted the deficiency in the preparation and homogenization of the flocculant polymer as the main cause for the instability in decantation. By observing the chemical dosing operator, it was also possible to identify that the homogenization process of the flocculant polymer is entirely manual, resulting in a lack of standardization and stability in the product's concentration. In terms of improvement procedures, a quality tool called the PDCA cycle was chosen, which allows us to determine the starting point and guide the entire process's development.

There are several sectors that contribute to the extraction of the final product, including Crushing (juice extraction from sugarcane), Boiler (steam production for heating and turbine operation), Fermentation (juice fermentation using yeast), Distillation (centrifuged wine distillation), Juice Treatment, and Sugar Manufacturing [19]. All sectors require careful attention and rigor in the process, but the juice treatment process, particularly decantation, requires even greater attention. The success of all other sectors involved in extracting the final product depends on a good and stable juice treatment. There are several processes within juice treatment, but this article will focus on decantation.

2.1. The Process

After the juice is pumped from the crushing mill to the treatment process, it undergoes the sulfitation process. This involves the introduction of sulfur dioxide (SO_2) gas into the juice, initiating a chemical process that leads to the coagulation of colloidal matter. This coagulation helps in the sedimentation and disinfection processes, allowing impurities to be carried away [19]. Hydrated lime is then injected to control the pH, neutralizing acidity and initiating the formation of insoluble substances that precipitate, resulting in primary flocculation [14].

Next, the juice is passed through heaters to reach a temperature of approximately 105°C. It then undergoes flash evaporation before entering the decanter [5]. Finally, a specific amount of high molecular weight flocculant polymer is dosed into the juice. This polymer helps improve flocculation, enabling rapid decantation and reducing the volume of settled sludge [22].

2.2. Automation

Automation, derived from the Latin word "Automatus," meaning self-moving, refers to the application of techniques, software, and/or specific equipment in a particular machine or industrial process with the aim of increasing its efficiency, maximizing production with minimal energy and/or raw material consumption, reducing waste emissions of any kind, improving safety conditions (material, human, or information-related to the process), or reducing human effort or interference in the process or machine [20].

This new technology will play a crucial role in the development of this improvement proposal as it will address the gaps needed for a stable process, including improved process quality, increased flexibility, and reduced losses [7].

According to Márcio Venturelli, technical coordinator at the SENAI Technology Institute and expert in Digitalization and Industry 4.0.

The Sugar-Energy sector has also evolved in terms of Industrial Automation. In the early 1980s, pneumatic control panels were replaced by electronic ones, followed by industrial networks in the 1990s. In the early 21st century, we see plants with Operations Centers commanding the entire facility using technologies such as Programmable Logic Controllers (PLCs), all connected in information and control networks [27].

2.3. Flocculant Polymer

Polymers used in fluid treatment activities, whether synthetic or natural, are commercially available in powder form to improve solubility. According to Cunha [6], "since the natural sedimentation of fine particles is slow, flocculant polymers are used to destabilize charges and aggregate fine particles, thereby increasing the sedimentation rate of solids." Consequently, the aggregated particles gain weight and settle.

According to Quevedo [24], natural polymers are those found in nature, meaning they are not synthesized by humans through transformation processes. Some well-known natural polymers include starch, natural rubber (latex), cellulose, chitin, among others.

On the other hand, synthetic polymers, as described by Quevedo [24], are produced through industrial procedures, artificially synthesized by humans. There are numerous synthetic polymers available in the market, such as polyethylene (PE), epoxy resin, synthetic rubber (SBR), and many more.

In the sugar-energy sector, particularly in the clarification stage of the juice, the most commonly used polymers are synthetic polymers called polyacrylamides, which have a high molecular weight and are soluble in water [18]. According to Lima, Esteves Junior, and Castilho [18], the polymer should be diluted in water within the range of 0.03% to 0.1% in the preparation tank. For example, for a tank with a volume of 10 m^3, 3 to 10 kg of polymer should be diluted.

2.4. Automatic Homogenizer

Polymer preparation systems are specifically designed and manufactured for powdered or solution-based polymers (emulsion). Polyelectrolytes are used as flocculation aids in a wide range of applications where colloidal solids or liquids need to be separated in an economical manner. The storage tank is subdivided into three independent chambers interconnected by an overflow system, preventing the transfer of unprepared polymer to the process [23].

2.5. Ishikawa Diagram

The Ishikawa Diagram is a tool that presents each step of a deficient process until it highlights the root cause of the problem. According to Miguel [21], it consists of a graphical form employed as an analysis methodology to represent factors that influence (causes) a specific problem (effect).

Due to the fact that the process of analyzing causes leading to the problem tends to be extensive, in this tool, all causes are divided into categories, which can be further divided into causes or families. According to Campos [4], these categories are: machinery, environment, measurements, materials, methods, and manpower.

2.6. PDCA Cycle

According to Arruda [11], in the 1920s, the quality tool PDCA was created, also known as the Shewhart cycle or the Deming cycle. It was conceived by Walter Shewhart and later popularized by the American William Edward Deming. According to Arruda [11], PDCA is a cycle that, when constantly implemented in a process, enables high levels of continuous performance improvement.

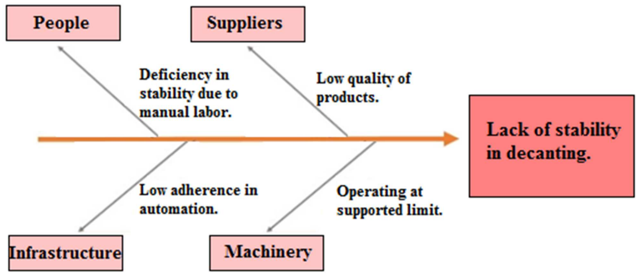
Known by the initials of its name, plan, do, check, and act, this tool holds great importance in a proposal for improvement, as through repeated iterations of this procedure in a given process, it is possible to achieve the success of continuous improvement.

3. Methodological Procedures

For the development of this article, a study was conducted on quality tools that facilitate the identification of the root cause of a problem, as well as another tool that could be used for implementing improvements. These tools were applied in a sugarcane and energy industry. Based on this study, two tools were implemented: the Ishikawa Diagram and the PDCA cycle.

3.1. Application Ishikawa Diagram

The Ishikawa Diagram starts by identifying the main causes of the problem in question, which are then categorized into people, suppliers, machinery, and infrastructure. By applying the data to the "fishbone" diagram and submerging the root causes by category, it was possible to identify the lack of stability in the sedimentation process, as shown in Figure 1.



Source: Own work (2021)

Figure 1. *Ishikawa Diagram Applied to the Lack of Stability in Decantation.*

3.2. PDCA Cycle Application

Even before understanding how to apply it, it is important to conceptualize the PDCA cycle. PDCA stands for plan, do, check, and act. According to a publication by the Brazilian Micro and Small Business Support Service [26], the PDCA cycle is defined as a quality tool that aims to facilitate decision-making and achieve previously established goals through cyclic actions.

Bueno et al. [3] provide a more assertive perspective on the PDCA cycle, as well as their view on its concept and implementation.

Each time a problem is identified and solved, the production system reaches a higher level of quality because problems are seen as opportunities to improve the process. The cycle can also be used to induce improvements, that is, to improve control guidelines. In this case, in the initial stage, a goal to be achieved and an action plan to reach it are planned, and the action is executed according to the new guideline. The effectiveness of meeting the goal is then verified. If the goal is achieved, this new action system is standardized. If the goal is not met, the process returns to the initial stage, and a new method must be planned [3].

Plan: To begin this planning, a thorough analysis of the recurring expenses associated with this acquisition is required, along with the identification of the financial advantages that the equipment will bring to the company. After this analysis, the practical aspect comes into play, organizing a location within the industrial plant where the equipment will be placed, prioritizing maximum accessibility for the operator and ensuring proper connection with the rest of the process and its corresponding instruments through pipeline installations. Once the installation is complete, training will be provided to each operator on how to operate the new equipment, along with their responsibilities regarding cleanliness and proper care of the company's assets.

Do: To start the equipment installation, follow all the details outlined in the planning phase regarding the appropriate location for installation, ensuring connectivity with the rest of the process and the installation of instruments. Proceed with the actual installation of the equipment and put it into operation.

Check: Perform a thorough inspection of the entire installation, ensuring that all installation details outlined in the planning phase are being met. After the equipment installation is completed, conduct a final check before it is operated for the first time. Once the equipment is in operation, begin checking and adjusting any settings that were not perceptible when the equipment was not in operation.

Action: In the event of any damage or issues during the installation process, it is necessary to intervene and correct the initially planned details to avoid material waste and rework. If any undesirable event is detected after the installation is completed, intervention is required to address and correct the issue before the equipment is put into operation for the first time. Once the equipment is operational, if any imperceptible problems are detected during operation, there should also be intervention to make final corrections to the equipment.

4. Results and Discussions

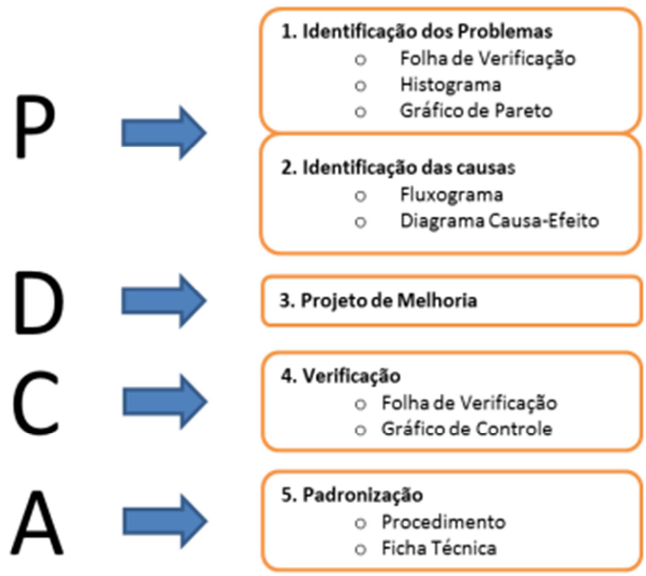
In an article presented by Junior [16], a serious environmental problem is addressed regarding the disposal of raw green coconut fruit waste. The author chooses to apply an Ishikawa Diagram with the purpose of determining the causes and effects of the problem. Structured into six categories: machine, manpower, measurement, method, material, and environment. Under the machine category, the cause "fruit sold in its natural state" is mentioned. Under manpower, the author discusses "lack of knowledge for reutilization." The measurement category is not specified. Under the method category, "unknowns" and "high demand" are mentioned. In the material category, "distrust" and "non-attractive residue for recycling" are identified. Under the environment category, the cause of "seven years to decompose" is presented. Thus, the presented effect is "Accumulation of green coconut waste." Therefore, as highlighted by Junior [16], through the Ishikawa Diagram, the main causes of the problem can be identified. It is understood that this tool had a considerably positive impact on our study as it was possible to identify the effect of lack of stability in sedimentation through the causes presented in each category.

Galvão [10] also presents, through a graduation thesis, the application of the Ishikawa Diagram and PDCA Cycle in the family agriculture sector in a vegetable garden in the municipality of Itinga - MA, aiming to eliminate unproductiveness in this sector. During the development of the Ishikawa Diagram, non-conformity information was identified in the processes of the vegetable garden. Therefore, through categories such as labor, measurement, raw materials, method, machinery, and environment, it was possible to systematically relate the causes to the problems found in this vegetable garden:

"Labor: when the necessary procedures are not followed by the farmer; materials: when there is improper use of inputs resulting in a lack for future work; methods: lack of formal methods; machinery: when there is a lack of equipment, gradual reduction, or breakage; measurements: when the distribution of activities is not done correctly; environment: when there is an intervention related to climate, humidity, and water, being the main causes of problems" [10].

In the construction of the PDCA Cycle, the author followed the four well-known stages of the method: Plan, Do, Check, and Act. In the Planning stage, the failures in the compost manufacturing process were recorded, and goals and objectives were defined accordingly. In the Do stage, training was provided to the farmers with the aim of correctly preparing the compost. In the Check stage, the progress was monitored and verified to ensure that the stages were flowing as expected, analyzing improvements and the final outcome of the activities. Finally, in the Act stage, the objective was achieved, and therefore, new goals should be established, as continuous improvement is necessary. However, by analyzing the performance of these tools, it is possible to identify the effectiveness of the results obtained when applied accurately in each stage, as in the case of our work where the installation of an automatic equipment solved our problems.

Ramires [25] presents in their study the application of the PDCA Cycle in an ethanol production plant, combining it with classical quality tools such as the Ishikawa Diagram explained in this work. Through this tool, Ramires [25] lists the causes of the main negative effects within the organization.



Source: Ramires (2012).

Figure 2. *PDCA Cycle/Quality Tools Used in a Case Study of an Ethanol Production Plant.*

5. Conclusion

At the end of this article, it was possible to identify the true importance of quality tools in an improvement process. The assistance that these tools provide from the very first moments when an improvement idea is born in our minds is clearly noticeable, giving us guidance for each step we need to take in order to implement the improvement.

After the installation and operation of the flocculant polymer homogenizer, the improvement in sedimentation stability was evident. There were considerable reductions in the sugar's color oscillation, improving the handling for homogenization and resulting in significant savings in the consumption of the product itself. Previously, the product was manually dosed using a measuring container, which could easily lead to inaccuracies, resulting in excessive consumption and poor concentration.

In addition to the process advantage, if we focus solely on the savings in polymer consumption, a positive financial return is clearly seen. Previously, approximately 18 bags of 25 kg were consumed per day, costing R$1,300.00 per unit, resulting in a monthly expense of R$702,000.00. With the installation of this automatic system, costing approximately R$300,000.00, there is a 5% monthly savings, resulting in an expense of R$666,900.00, and generating a monthly savings of R$35,100.00. Therefore, when calculating the payback period for this investment, the result is a return on investment in approximately eight months.

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