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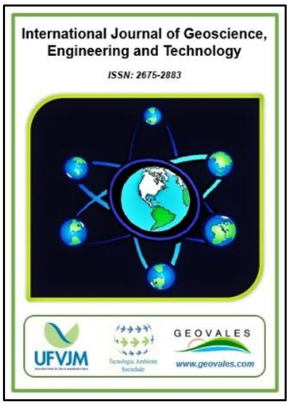

Automation of Brewing Pot with Arduino Microcontroller

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Abstract

In Brazil and in the world, beer is a popular and widely consumed drink. The optimization of some processes in the production of craft beers has been gaining prominence since it facilitates the process, providing more safety and quality in the final product. Therefore, the present work aims to increase the efficiency in the extraction of sugars, maintaining temperature stability during the process. For this, an adaptation of a brewing pot was carried out and the development of a controller that uses the Arduino platform together with different sensors. Furthermore, the man-machine interface was elaborated through the buttons, OLED display, buzzer and LEDS. The pot and the controller work together to control the entire process, keeping the wort temperature within the established ranges, during the time specified by the recipe. Throughout the development of the project, several tests were carried out to identify possible failures in the system. The controller was able to reach and control temperature steps, offering a viable and effective solution for beer production, in addition to being cost-effective.

Keywords: Brewing pot control, Arduino, Automation, Temperature control, Craft beer.

1. Introduction

In Brazil and in the world, beer is a popular and widely consumed beverage. Brazilian legislation[1] defines beer as a beverage obtained by fermentation, from brewer's yeast, malted barley wort or malt extract. In addition, that has been subjected to a cooking process with hops or hop extract added (Brasil, 2019). Thus, the basic ingredients of beer are: water, malt, hops and yeast.

The production of craft beer in Brazil presented in 2013 about 195 registered breweries. Subsequently, in 2018, 889 registrations were reached, demonstrating significant growth. That said, the states with the highest concentration in this sector are Rio Grande do Sul, São Paulo and Minas Gerais (Müller and Marcusso, 2019).

Hughes (2014, p.17) expresses that craft beer is produced by a small and independent brewery, with quality ingredients and traditional methods. There is an important difference between craft beer and the beer produced by larger companies. Even without having a high amount like the big industries, craft brewers have more freedom to produce batches of beer without chemicals and naturally carbonated.

The optimization of some processes in the production of craft beers has been gaining prominence and bringing benefits to producers. An important contribution with automation is the reduction of workload, since there is no need for monitoring in the mashing and boiling stages. As a result, more people want to start making it by hand.

Craft beer requires constant attention and care, especially in terms of time and temperature control. In order to facilitate the production process and reduce material losses, automation can be

[1] Art. 36 of Decree No. 9902/2019.

applied using the Arduino[2] associated with a brewing pot. Therefore, the process will be done more safely and there will be an increase in the quality level of the final product.

The Arduino is a microcontroller with functionality similar to a programmable logic controller (PLC), being an easy means of automation in smaller environments. In this course conclusion work, aiming at a lower cost benefit, the Arduino UNO will be used, together with sensors so that the pan performs the mashing and boiling processes with greater efficiency.

The controller developed in this work can be seen as an Internet of Things (IoT) application. For Santos and Gonçalves (2023, p.117), IoT is present in devices that have sensors capable of interacting with the environment where it is located. Through these, it is possible to transmit and receive data, in addition to interacting with the end user.

2. Objectives

2.1. General Objectives

Build an automated brewing pot using Arduino in order to keep the temperature as stable as possible, improving efficiency in the sugar extraction process.

2.2. Specific Objectives

- Understand the craft beer manufacturing processes and propose improvements;
- Build a pot using controllers, sensors and actuators compatible with the Arduino system that enables the automation of brewing production processes.

3. Literature Review

3.1. Beer history

According to Hughes (2014), the first evidence of beer production dates back to the years 7000 BC and 4300 BC due to some discoveries. For example, ceramics with traces of ingredients and recipes for alcoholic beverages made with cereals, an ingredient commonly used in the manufacture of craft beer, were found.

The commercialization of beer took place around 1040 at Weihenstephan Abbey in Bavaria, when monks turned beer production into a commercial enterprise. Gaining popularity for its safety, as it is boiled before fermentation (Hughes, 2014).

From 1100, hops began to be marketed in Germany, giving rise to the export of hopped beer. In 1516, the Reinheitsgebot, Beer Purity Act originated, which determined that only water, hops and barley would be the permitted ingredients in the manufacture of beer (Hughes, 2014).

3.2. Ingredients for crafting

3.2.1. Water

Water is an essential ingredient in beer production. According to Hughes (2014), the final product is directly influenced by the chemical characteristics and water quality due to the interference of its pH on the malt enzymes. It is worth mentioning that waters from different places on the planet produce different beers. Also, there can be a reaction between yeast and antibacterial chemicals (chlorine or chloramine) if these are in high concentrations.

3.2.2. Malt

Malt is the result of a technological process of germination (malting) of cereal grains, in which enzymes are created that convert starch into fermentable sugars. Barley, a cereal from the grass family, is widely used in the production of beer because it is rich in starch, contains enzymes, has a husk that protects the grain during malting and adds the characteristic aroma and flavor of the product. (Rosa and Afonso, 2015). Figure (1) illustrates whole and milled malt grains.

Figure 1 – Whole malt grains on the left and ground malt grains on the right.

[2] Available at: <https://www.arduino.cc/>. [Accessed 16 May 2023].

3.2.3. Hops

Hop is a conical flower of a vine originating in temperate climates, in which only the cones of the female plants are used in the manufacture of beer. In general, supplies are imported from Europe or the United States, as the climatic conditions in Brazil differ from those ideal for growing hops (Bellei et al., 2018). Figure (2) illustrates the most used form, the pellets, where the flowers are dehydrated and pressed, reducing the volume that helps in transport. This ingredient is added to the boil at different time intervals to add bitterness, aroma, flavor and prevent bacteria proliferation (Hughes, 2014).

Figure 2 – Hop Pellets.

3.2.1. Yeast

Yeasts, Figure (3), are a type of unicellular fungus that feed on the sugars and carbohydrates present in beer, transforming the sweet wort into beer and producing alcohol (Hughes, 2014). In brewing, yeasts are classified into:

- Bottom fermenting yeasts: used in the production of Lagers[3], they are activated at low temperatures (9 and 15°C) and accumulate in the lower part of the fermentation tank. The final product has a less fruity style or with less fermentation aromas, such as the well-known golden and light beers (Bellei et al., 2018).
- Top fermenting yeasts: used in the production of Ales, they are activated at high temperatures (15 and 25°C) and act close to the surface of the wort. These yeasts are generally denser, darker and more aromatic than lager yeasts (Bellei et al., 2018).

Figure 3 – Dry yeasts.

3.3. Brewing process

The brewing process can be divided into seven stages: milling, mashing, sparge, boiling, cooling, fermentation, maturation, and finally, priming or forced carbonation and bottling. Figure (4) shows a summary of the brewing process.

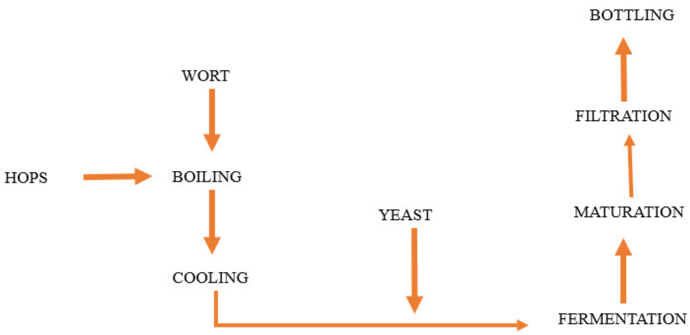

Figure 4 – Summary of the brewing process.

3.3.1. Milling Grain

The grains are milled in order to break up the malt husk so that the starch can be exposed (Hughes, 2014). It is worth mentioning the importance of preserving the skins, since they help in the must filtration/clarification process.

3.3.2. Mash

It consists of dissolving malt grains in hot water to convert the starch into fermentable sugar. Its final product is wort, a sugary liquid that is the basis for the beer.

3.3.3. Spark

It is made after infusing the grains in order to extract as much of the residual fermentable sugars as possible.

[3] The terms Lager and Ale indicate different types of beer.

3.3.4. Boiling

Hops are added to the boil in a specified time in each recipe[4]. At this stage, the wort is sterilized and the hops release bitterness, flavor, and aroma (Hughes, 2014).

3.3.5. Cooling

It performs cooling through heat exchangers introducing atmospheric O_2, in order to provide ideal conditions for yeast fermentation (Rosa and Afonso, 2014).

3.3.6. Fermentation

Yeasts are added to the wort and, subsequently, conditioned in fermenters. In this phase, the production of alcohol and CO_2 occurs by the yeasts that consume the fermentable sugars, in addition to defining the taste of the beer (Rosa and Afonso, 2014).

3.3.7. Maturation

After fermentation, the beer is cooled and matured where the flavor of the beer will be perfected. This process varies depending on the chosen beer, lasting from 6 to 30 days (Rosa and Afonso, 2014).

3.3.8. Bottling

After fermentation, priming sugar is added to generate gas and foam in the beer due to the action of the remaining yeasts. Then, the drink is transferred to bottles or barrels that, depending on the recipe, will pass for two weeks at a specific temperature to produce gas and foam. Thus, the beer will be ready for consumption (Hughes, 2014).

3.4. Temperature steps

Temperature steps play a fundamental role in the mashing stage. They consist of keeping the wort at a specific temperature, which can vary 2°C above or below, during a period of time. The number and duration of steps vary according to the recipe used. Each temperature range has the purpose of activating an enzyme that will bring specific characteristics to the beer.

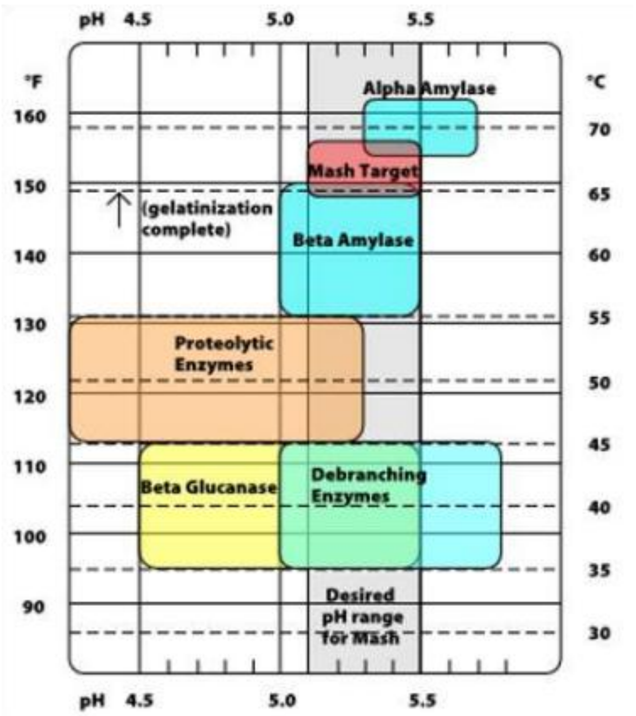

Figure 5 – Enzyme performance range (Palmer, 2006).

The Figure (5) shows the temperature range in which the enzymes work. As you can see, between 55°C and 65°C is the temperature range in which beta-amylase acts, responsible for transforming starch into maltose. Alpha-amylase acts in the temperature range of 65°C to 72°C, breaking down non-fermentable sugars and bringing *body* to the beer.

At temperatures above 75°C, the enzymes' activities are terminated, as they undergo changes known as denaturation. During manufacturing, enzyme inactivation is performed in the mash-out, which consists of raising the temperature of the wort to 75°C and remaining there for 10 min. After this process, the wort will be ready to go through the filtering and clarification process.

3.4.1. Recirculation pump

According to Vieira (2017, p. 32), when activating the heating system, the must contained in the lower part of the false bottom tends to heat up more than the must in the upper part, causing problems such as protein denaturation and caramelization of the liquid. To resolve such issues,

[4] Set of information necessary for beer production, such as the amount of water, malt, hops and yeast. The recipe also shows the boiling and mashing time.

a recirculation pump is used in the mashing stage, which also helps to standardize the temperature and clarify the must. In addition, this equipment is used to transfer liquids between the pans during the production process.

3.5. Tests carried out in the production process

3.5.1. Iodine test

The test is carried out during the temperature steps in order to verify that all the starch present in the malt has been transformed into sugar. As shown in Figure (6), when iodine reacts with starch, a change in its color occurs, resulting in shades of blue or black. If the color of the iodine does not change, it is observed that the enzymatic transformation process was satisfactory.

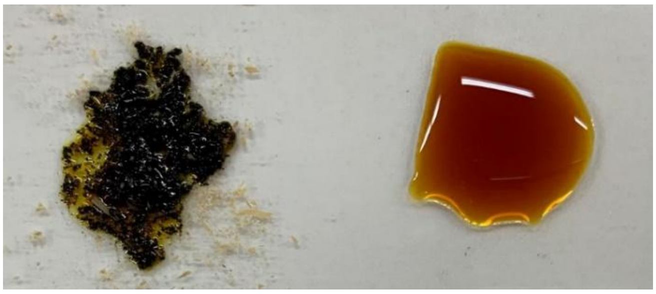

Figure 6 – Iodine test, on the left with reaction, on the right without reaction.

3.5.2. Wort density

Density measures the amount of sugar in the wort. It is directly related to fermentation time and alcohol content. Therefore, higher concentration of sugars, more time will be spent in fermentation and, consequently, the beer will have a higher alcohol content.

Hydrometers or refractometers can be used to measure density. The hydrometer, as shown in Figure (7), measures the concentration according to the fluctuation shown, and operates at temperatures from 20°C to 25°C. On the other hand, the refractometer uses the refraction of light in a small amount of beer, and may present some deviations in the measurement if it already contains alcohol.

3.6. Temperature control

Temperature is the main process variable and its monitoring is essential because it involves chemical and physical processes, and also the protection of equipment (Bega et al., 2006). It is associated with molecular activity, that is, the greater the agitation of molecules, the higher the temperature. To specify the system that will make your measurement, it is necessary to analyze factors such as: temperature range, accuracy, protection and response time. In this way, it will be possible to define which temperature and protection sensor is most appropriate for the system (Bega et al., 2006).

Figure 7 – Density test with the hydrometer.

3.6.1. Temperature range

Initially, it is necessary to choose a sensor that meets the specific temperature ranges for the project. Furthermore, it is important to analyze the possibility of future alterations in the ranges, as well as the need to modify the instruments after a certain period of time (Bega et al., 2006).

3.6.2. Accuracy

The sensor must be chosen that meets the needs of project, and not cause unnecessary expenses (Bega et al., 2006).

3.6.3. Protection

The sensors are protected by pipes that have low resistance when inserted in aggressive media. In this sense, it is extremely important to know the medium and the temperature in which the sensor will be placed, making it possible to specify the adequate protection, reducing the cost of replacing sensors (Bega et al., 2006).

3.6.4. Response time

Sensor protection should be considered, as it affects response time due to characteristics such as conductivity and thermal resistance. If the sensor has a protective housing, it will perform worse compared to what is directly exposed (Bega et al., 2006).

3.7. Automation and Arduino platform

Industrial automation can be defined as a set of techniques designed to make automatic tasks, replacing human physical effort by computable electromechanical elements (Silveira and Lima, 2003). It can be classified in three ways: rigid, programmable and flexible. Rigid automation is used in the production of a single product on a large scale. The programmable one is used when there is low production of different items, making use of programs in which the system interprets, facilitating the development of different products. And, finally, the flexible one, which is similar to the one mentioned above, but, in this case, the program has a limitation regarding the different characteristics that can be performed (Roggia and Fuentes, 2016).

Arduino is an open-source electronics prototyping platform, which has a microcontroller capable of reading inputs and transforming them into outputs. For this, the Arduino programming language is used, which is similar to the C language, and the Arduino Software (IDE - Integrated Development Environment) (Arduino, 2018). According to Arduino developers, some advantages of using it are: low cost; be cross-platform; has a simple and clear programming environment; in addition to featuring open source and extensible hardware and software. Therefore, the Arduino platform can be applied in conjunction with different sensors to automate the craft beer production process, adding efficiency and security. Figure (8) illustrates the Arduino software interface.

Figure 8 – Arduino IDE software interface.

4. Materials and methods

4.1. Technical visit

In this work, research was carried out in the literature about this subject, as well as technical visits in two micro-breweries in the Teófilo Otoni city: Platônica and Cia do Mucuri (Figure 9). The purpose of these visits was to improve understanding of the production of craft beer, in addition to observing improvements in the production line to be implemented in the controller.

Figure 9 – Technical visit at Cia do Mucuri.

During the visits, the importance of recirculating and clarifying the wort before proceeding with the boil was clear, in order to avoid the caramelization of the beer at the bottom of the pot and to ensure that the temperature of the fluid remains uniform during the process. Constant monitoring of temperature is essential, since when reaching high temperatures tannin is extracted, a substance common in wines, however, undesirable in beer, as it makes the drink astringent.

Analyzing production at Cia do Mucuri, two limitations in the system were identified. The equipment used makes only three temperature steps, therefore, if the manufacturer intends to produce a beer that has four or more temperature steps, it is necessary to make the changes manually. In addition, given that there is no automated control of the boiling time, the user needs to maintain constant monitoring, attentive to situations that require turning off the equipment to avoid loss of product.

4.2. Adaptation in the pot

In the development of the work, the adaptation of a brewing pot and the development of a controller that uses the Arduino platform in conjunction with different sensors were carried out. Thus, the pot and the controller work together to control the entire process, keeping the wort temperature within the established ranges, during the time specified by the recipe. The recipe provides all the information about the beer production process and will be detailed in the next sections.

4.2.1. Adaptation of the Brewing Pot

To build the mechanical part of the system, a 25L brewing pot with a false bottom was used, which was perforated to install the electrical resistance and the faucet. As it is an output device, the resistance is turned on or off according to the commands sent by the Arduino to heat the wort. The false bottom, together with the *bed* formed by the malt husks, is essential for the filtration process. Figure (10) shows the adaptation process.

Figure 10 – Adaptation process and already adapted pot.

4.3. Controller Development

Before designing the controller, a sketch was developed using the TinkerCad web application. As seen in Figure (11), the tool provides a variety of sensors and components that can be used in different projects. In addition, it is possible to carry out a simulation of the system in order to identify problems such as short circuits.

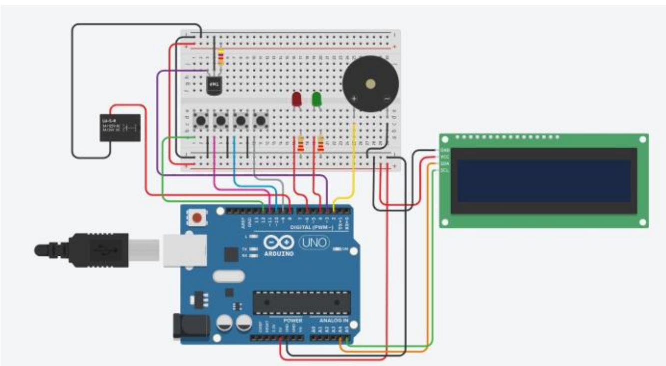

Figure 11 – Controller sketch in TinkerCad.

4.3.1. Arduino Uno Board

Microcontroller that has 14 digital input and output pins, in addition to 6 analog inputs. Its communication is done through a USB input, and also has a reset button. This board was chosen because it has a great cost/benefit ratio.

4.3.2. Button

The button or push button is a component frequently used in automation projects with Arduino. It acts as an input device, that is, it supplies information to the board. Thus, when pressed, mechanical energy is transformed into electrical energy. In the developed controller, four buttons were installed with different functions: cancel, confirm, increment and decrement.

4.3.3. Temperature sensor

To perform the temperature measurement, a kit consisting of a Type K Thermocouple together with the Max6675 Reading Module was used. This input device features a shielded tip end completely covered in stainless steel, reading temperatures from 0°C to 800°C, with an accuracy of approximately 1.5%.

The sensor calibration was performed with an analog mercury thermometer, in order to check if the reported temperature was consistent with the real one. Thus, it was possible to verify that the sensor has good accuracy.

4.3.4. OLED display

The OLED display (Organic Light Emitting Diodes) is an electroluminescent output device that operates through organic light emitting diodes whose operating principle consists of stirring molecules by electric current. The panel used has a resolution of 128x64 pixels, allowing the presentation of information in a clear and precise way.

4.3.5. LED

The LED (Light Emitting Diode) is an output device that emits a light signal. This component has polarity, therefore, so that it has proper functioning. The larger rod (anode) must be connected to the positive pole and the smaller rod (cathode) must be connected to the negative pole.

4.3.6. Buzzer

The buzzer is a component that converts the electrical signal sent by the Arduino into a sound wave, being then defined as an output device. It is used in the project to emit a sound signal and attract the user's attention at important moments, such as, for example, alerting the end of boiling. Like the LED, the buzzer has polarity, which can be seen through the "+" symbol on the top of the component.

4.3.7. Relay

The Relay Module is an output device used to control the activation of the electrical resistance. It was connected through the normally open contact (NO), so that it sends an electric current flow to the contactor at times when it is necessary to activate the electrical resistance. Using the relay module it is possible to control voltages of up to 220V and, in addition, the device contains a red LED that is always on when it is receiving adequate energy from the Arduino, and a green LED that lights up when the circuit is closed, indicating that there is passage of tension.

4.3.8. Contactor

A contactor consists of a set of contacts that are activated by means of an electromagnet. There are a variety of types of contactors and in the present work the normally open configuration contactor was chosen. Under such an arrangement, the contacts remain open and prevent the flow of electric current. However, when activated, they operate the closure and allow the passage of electric current through them.

4.4. Functioning of the code

Figure (12) illustrates a flowchart that was developed with the aid of the Lucidchart diagramming application. The objective is to facilitate the understanding of the structure of the source code and the operation of the automated system.

The flowchart shows all the functions that are performed during the process, in addition to the moments when the system waits for a confirmation from the manufacturer to start the next step. It is important to point out that the man-machine interface is made through buttons, display OLED, buzzer and LEDs, as shown in Figure (13).

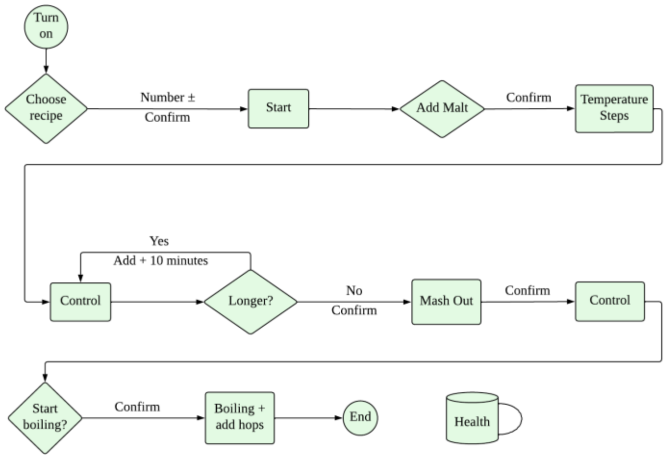

Figure 12 – Pot operation flowchart.

Figure 13 – Image of the assembled temperature controller.

The number of temperature steps and time for each one of them, as well as the boiling and mash-out time are already pre-programmed in the *recipes* function. There are currently 4 recipes available and it is possible to add new recipes to the source code, just by inserting all the necessary information, similar to what happens with the pre-existing ones.

When starting, the pot should already contain the water that will be used in the mashing process. There is then a welcome message on the display and the user is guided to use the increase or decrease buttons to choose the recipe.

Next, it is necessary to determine which recipe will be produced, using the buttons to choose a value from 1 to 4. The display is updated when the user changes these values and presses to confirm. The *recipes* function receives the chosen number and configures the parameters that will be essential for the later steps.

Next, the *start* function takes place, responsible for activating the relay and heating the water up to the initial temperature specified in the recipe. During the process, the temperature is continuously checked, shown on the display and compared with the set value. When the temperatures are equivalent, the resistance is turned off and the system emits a sound signal, indicating that the malt can now be added.

After confirmation, the temperature step begins, in which all the information necessary for the process is identified and transmitted by parameter to the *control* function. This, in turn, is responsible for heating the wort to the established temperature and starting the time count. Then, the temperature control occurs simultaneously with the time control, turning on or off the resistance activation relay, based on the values measured by the sensor. At the end of the last temperature step, the program allows the user to add another 10 minutes to this step, as many times as necessary, in case the iodine test is not satisfactory.

Before starting the mash-out stage, the system again waits for the user's confirmation. New parameters are passed to the *control* function so that the temperature is raised in order to pause the action of the beta-amylase molecules and alpha-amylase.

After finishing the mash-out and confirming the user, the boiling process begins. During this stage, sound signals are triggered to indicate when it is necessary to incorporate the hops into the wort and, in addition, the relay is on until the end of the time, considering that there is no temperature control. The end of the process is displayed on the OLED display, together with an audible signal. Finally, all components are turned off, indicating that mashing and boiling have been successfully completed.

5. Results and discussion

5.1. Comparison between controller prices

To carry out a cost-benefit analysis of the controller, a survey was made of all the parts used in the controller, in which Table (1) exemplifies the low cost. The prices of the pieces were taken from the Mercado Livre[5].

Table 1 – Cost of controller components.

Material	Price
Arduino Uno R3	BRL 62.00
OLED display	BRL 24.00
Contactor	BRL 62.30
Cables and connectors	BRL 25.00
Led	BRL 2.06
Jumpers	BRL 5.60
Buzzer	BRL 5.53
Temperature sensor	BRL 37.98
Button	BRL 20.00
Relay	BRL 14.00
Total	**BRL 196.67**

The Table (2) shows a comparison between the controller and a Beer Max controller. It is worth noting that the comparison microcontroller costs around R$809,37, a difference of R$612,7. Thus, due to the similarity of functions between the two products, the developed controller is cost-effective.

Table 2 – Comparison with Beer Max device.

Functions	This Controller	Beer Max
Revenue Capacity	20	20
Preheating	Yes	Yes
Pause for Adding Malt	Yes	Yes
Amount of Temperature stages	10	5
Hop Additions	15	5
Boil	Yes	Yes
Advancement of Stages	No	Yes
Extra time	Yes	Yes
Cooling control	No	Yes
Boiling detection	No	Yes

5.2. Comparison between pot prices

The survey of the costs related to the assembly of the brewing pot was elaborated in Table (3). When carrying out the feasibility analysis of the automation, considering the costs of the pot and the controller, it is verified that the total value would be R$1000,56. Prices were taken from the e-commerce “Cerveja da Casa”.

Table 3 – Cost of pan components.

Material	Price
Aluminum Pot (False bottom + register + Sparge) 27l	BRL 425.00
Recirculation pump	BRL 159.90
Immersion chiller + 2m non-toxic hose	BRL 100.00
Resistance 3.5 kW	BRL 118.99
Total	**BRL 803.89**

[5] Available at: <https://www.mercadolivre.com.br/>. [Accessed 16 May 2023].

In the market, there are pots available with all the components already integrated. When analyzing existing options that can meet the proposed objectives, the Beer Max brand microbrewery was found as an example. It should be noted that the product sold has an approximate cost of R$4347,00, while reproducing a similar pan, purchasing the materials separately enables an economy. Table (4) indicates the comparison between the two products.

Table 4 – Comparison with Beer Max's microbrewery.

Components	Automated pot	Beer Max
Level marker ruler	No	Yes
Filter basket	No	Yes
Recirculation pump	Yes	Yes
Immersion chiller	Yes	Yes
Automatic pump shutdown	No	Yes
Programmed preheating	No	Yes

5.3. Mashing results in the laboratory

The Figure (14) illustrates the temperature variation as a function of time during mashing and boiling. From 20 to 68°C, the start process takes place, which consists of raising the temperature so that, subsequently, the malt is added. Then, a drop in temperature is observed, and the beginning of the first ramp. The increasing segments of the graph indicate the temperature rise up to the established parameter. The constants represent the mashing and boiling stages in which there is no temperature variation.

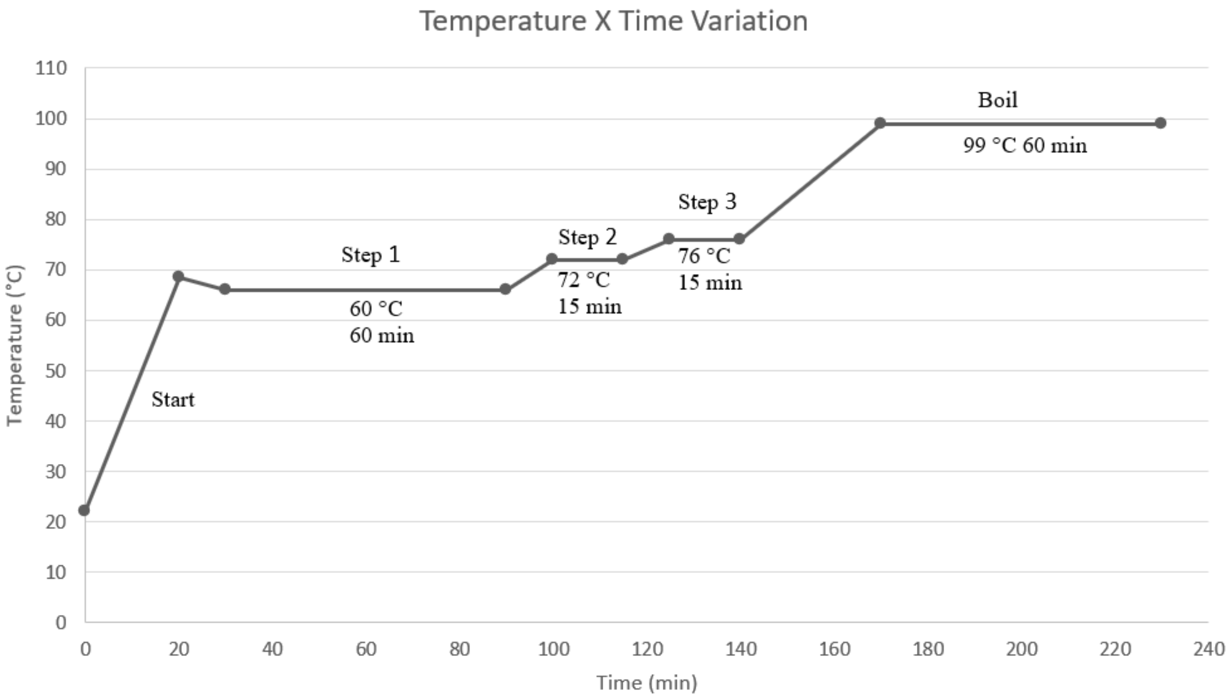

Figure 14 – Temperature range as a function of time.

During the entire course of the process, systematic monitoring of temperature and time was carried out, with the aim of ensuring proper functioning and identifying potential failures. At all stages, temperature control was performed with precision, and the standby functions proved to be effective. At no time was any significant deviation found in the temperature control process, thus verifying that the features were implemented correctly.

A relevant finding was the inefficiency of the temperature control in the absence of the recirculation pump, resulting in an increase of up to 3 degrees in relation to the established value. On the other hand, with the use of the pump, greater stability in temperature was observed, since the measurement became more uniform. It is worth mentioning that this instrument is used to prevent the wort from caramelizing, considering that recirculation is necessary.

The developed system is not restricted exclusively to the production of beer, since the controller can be used in any recipe that requires precise control of time and temperature. In addition, the Programmable Logic Controller (PLC) architecture, composed of relays and a display, has potential for application in several projects, requiring only adaptations in the programming logic.

6. Conclusion

During the development of the automation of the brewing pot, all the mentioned methodologies were applied, which helped in the execution of all the objectives of the work. Simultaneously, the learning acquired at the university was expanded to the community, through demonstrations open to the public, stimulating interest in the production of beer itself.

The developed system demonstrated the ability to successfully control mashing and boiling processes, offering a viable and effective solution for beer production. Therefore, through the implemented automation, a complete controller and an adapted pot with functions similar to those available on the market were developed.

6.1. Suggestions for future work

6.1.1. Related to the controller

Considering the safety features of the controller, some improvements can be implemented to enable automatic shutdown in emergency cases and protection against overheating or short circuit.

6.1.2. Related to the Software

Mobile application to control the system and record recipes, along with a tutorial on how to use it.

6.1.3. Pot related

Develop a thermal well to couple the temperature sensor. Also implement a removable basket to remove the malt without the need to transfer the liquid to another pot, saving time and materials, in addition to facilitating later cleaning. As well as an instruction manual to aid understanding.

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