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Improving The Quality of Coffee Beans Using Electronic Fermenters to Increase the Economic Value of Coffee

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Abstract
Coffee is one of the most popular commodities, including in the international market. The process in developing the Robusta coffee commodity and increasing its economic value is to make fermented coffee into wine coffee. Coffee wine fermentation is traditionally placed in a closed place or container without temperature control and pH value checking. This study aims to create a fermentor system that can control temperature, detect pressure in the fermentor and determine the pH value in the fermentation process. Temperature control in the fermenter uses the PID (Proportional Integral Derivative) method. The PID controller determines the setpoint of 31oC. The actuators of the system are a series of thermocouples and TRIAC which control the light of an incandescent lamp which is a source of heat to raise the temperature in the fermenter. The fermentation process is complete when the pH value has touched 4. The results of this study produced fermented coffee which had a pH value of 4 using a fermenter for approximately 4 weeks, while for the traditional method without temperature control it took approximately 6 weeks. Testing the caffeine content in coffee before fermentation was 2.43% and the caffeine content after fermentation was 2.00%.

Keywords: Wine coffee, robusta coffee, fermenter, PID Controller.

1. Introduction

One of the most popular plantation commodities in Indonesia and has a high economic value is coffee. Coffee is one of the preferred plantation commodities and is widely traded in international markets. One of the coffee-producing countries is Indonesia, which is the fourth largest coffee producer after Brazil, Vietnam and Columbia, while Indonesia's export destinations are generally to America, Japan, the Netherlands and Italy [1]. In Indonesia, coffee plantations consist of 96% smallholder plantations, 2% private plantations, and 2% state plantations. Coffee is also a source of income for at least one and a half million coffee farmers in Indonesia [2]. Based on data that can be seen from the Central Statistics Agency (CSA), the total export value of coffee cherries from Indonesia and processed coffee in 2017 amounted to 1186.9 tons and decreased in 2018 by 31.25%. In addition, Arabica coffee prices fell by 7.6% and robusta fell by 13.24% in October 2020 when compared to October 2019 [3]. Therefore we need a solution that can increase the economic value of coffee commodities such as the quality of the coffee cherries produced. To improve the production quality and quality of coffee cherries, Robusta coffee farmers will usually sort the coffee cherries in terms of size and quality, such as the color of the coffee cherries [4]. The fermentation process in coffee is one part of the post-harvest processing process which is carried out using dry, semiwet or wet processing methods. This process is usually done to remove the slime layer that is still present in the coffee beans. Fermentation on coffee cherries will make the coffee that is formed has a distinctive taste. Fermentation if done too long will cause a bad taste and not formed because it is over fermented, whereas if fermentation is done in a short time it will cause a less formed taste. The most important factors when carrying out a fermentation are the temperature and the duration of the fermentation. The temperature used in the coffee fermentation process does not come from the coffee cherries themselves but rather the temperature in the environmental conditions. One of the efforts that can develop the coffee commodity industry is by detecting coffee aroma [5], selecting coffee [6], ripening coffee [7], making coffee [8] and by processing coffee into wine coffee [9].Set 1.60 cm left and right page margin, and set 1.20 cm top margin, and set 0.60 cm bottom margin.

2. Wine Coffee Process

Wine coffee is fermented coffee which has a unique taste and a delicious taste compared to coffee in general. This coffee is a product that is liked by the public because of its unique taste and aroma. Wine coffee is a product that adds to the diversity of processed coffee-based ingredients that are currently being found in the market. The coffee cherries to be fermented must be selected which are of good quality and red in color, therefore a classification of coffee cherries is needed [18], then the coffee cherries will be fermented. Traditionally, the coffee cherries will be fermented in a closed place for about 2 months to undergo the fermentation process. The container used can use plastic or a tightly closed barrel because the fermentation process is carried out anaerobically or without air. If the coffee cherries have turned brown and give off a wine-like aroma, they can then be dried in the sun. The monitoring process carried out by farmers is quite frequent because there is no technology that can monitor temperature or pH in coffee cherries. According to the farmers, the process of making wine coffee is quite long and quite difficult when compared to ordinary coffee which is directly dried in the sun and takes approximately 2 weeks, so the price of wine coffee is indeed higher than coffee in general. Currently there are many coffee wines on the market and have many connoisseurs and also have various types such as wine coffee robusta or arabica. Wine and coffee are two very different types of products, although wine is made from grapes and coffee comes from coffee cherries, wine coffee has the taste is similar to wine because it undergoes post-harvest processing, namely the fermentation process. Wine coffee can also be said as coffee fermentation that occurs after the harvest process and before it becomes coffee beans.

Figure 1. Coffee cherries during the fermentation process.

3. PID Method (Proportional Integral Derivative)

PID control (Proportional–Integral–Derivative controller) is one of the controllers for determining the precision of an instrumentation system by relying on feedback on system output. This control system has the goal of controlling the system by relying on the feedback provided so that errors do not occur. Controlled output includes stability, accuracy, and also dynamics. Proportional Integral Derivative (PID)

Controller is a controller consisting of several components, namely proportional (P), integral (I), and derivative (D). The characteristic of this controller is the existence of feedback that is generated and as a determinant to reduce the occurrence of errors. Each component of P, I, and D has its own advantages and disadvantages and each of these components can work alone or work simultaneously [22].

Each controller P, I, and D has different advantages, where the proportional control action has advantages that can make the rise time of the system faster. Integral control actions have the advantage of being able to minimize errors that occur in the system as well as the advantages of derivative control actions, namely minimizing errors and being able to reduce or anticipate overshot/undershot of the system. The control system is divided into two parts show in below.

a. Open Loop
   Open loop or open loop has the characteristic that is where the output or output value does not affect the control action.

Figure. 2. Open loop block diagram.

b. Close Loop
   Close loop is different from open loop because it has feedback or feedback on the system. Where the output value will influence the control action. This closed loop is considered more stable than the open loop

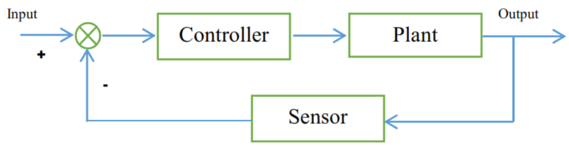

Figure. 3. Closed loop block diagram.

2. Experimental

The fermenter is designed to be closed and airtight because the fermentation process is carried out anaerobically, the fermenter also has several components and sensors to support the success of the fermentor in the coffee cherry fermentation process.

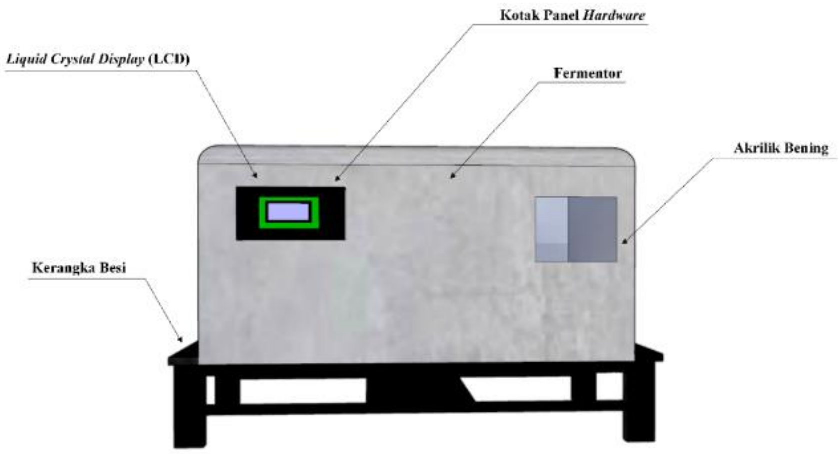

Figure. 4. Coffee cherry fermenter build design.

In the design of making this coffee wine cherry fermenter with dimensions of 40 cm high, 55 cm long and 35 cm wide. For coffee cherries shelters, this fermenter can hold up to 20kg capacity of coffee cherries.

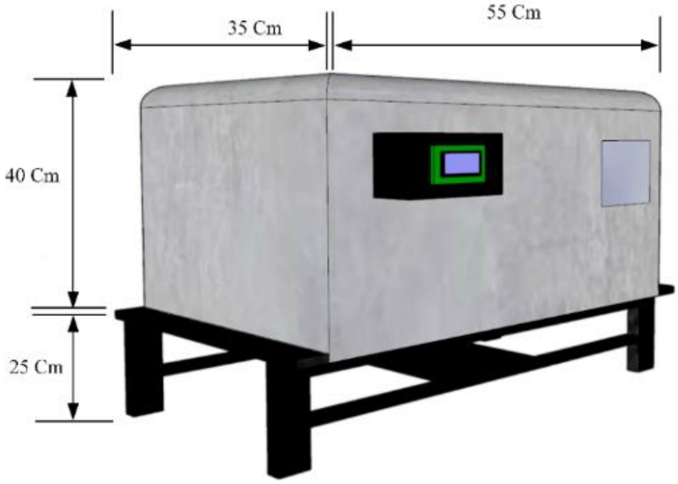

Figure. 5. Fermenter size design.

3. Result and Discussion

Testing the PID (Proportional Integral Derivative) constant on robusta coffee cherry fermentation in a fermenter with a temperature set point at 31oC with a manual tuning process using Ziegler-Nichols. The following is a graphical image of the results of the PID tuning test data.

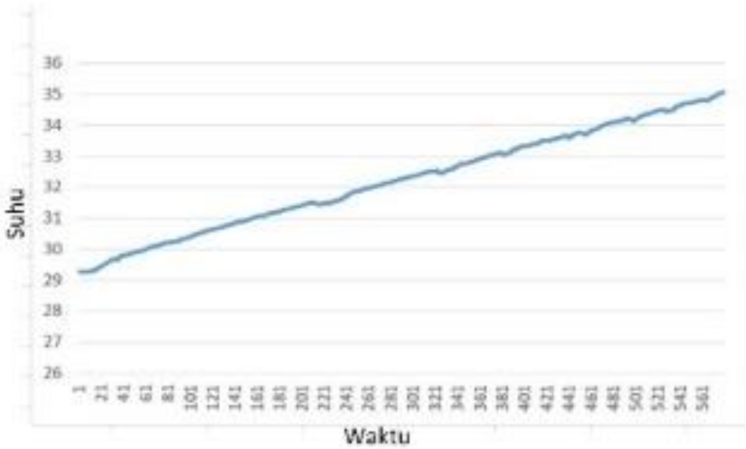

Figure. 6. Manually tuning PID.

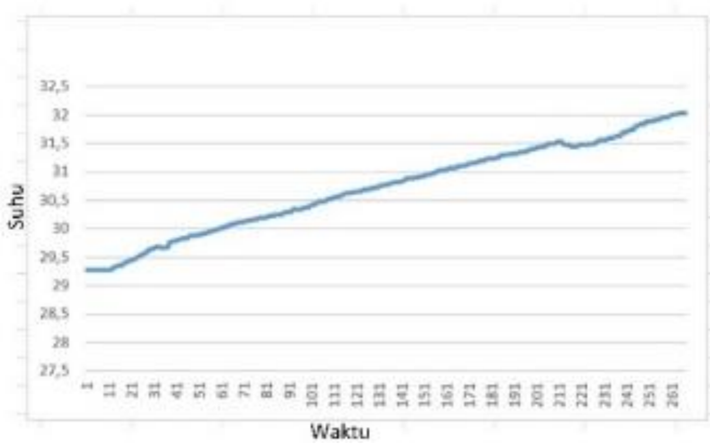

Figure. 7. PID tuning chart if detailed.

The design in the testing process has a heating source obtained from an incandescent lamp which requires a set point of 31 ^{0}C for the temperature in the fermenter. The initial temperature before the manual tuning process, namely in the fermenter, the temperature is ±29oC, the delay time (L) obtained is 12 seconds, while the time needed for the temperature to reach the set point of 31oC is 157 (T) seconds because the temperature set point is not too high. The values of the time delay (L) and time constant (T) are used as reference numbers to determine the values of Kp, Ki, and Kd. Here are the Ziegler-Nichols tuning rules.

Table 1. Table of tuning PID.

Control-ler	Kp	Ti	Td
P	$\frac{T}{L}$	∞	0
PI	$\frac{T}{L}$ 0,9	$\frac{L}{0,3}$	0
PID	$\frac{T}{L}$ 1,2	2L	0,5L

to find the value of Ki using the formula:

$$Ki = \frac{Kp}{Ti} \quad (1)$$

while to find the value of Kd using the formula:

$$Kd = Kp \; x \; Td \quad (2)$$

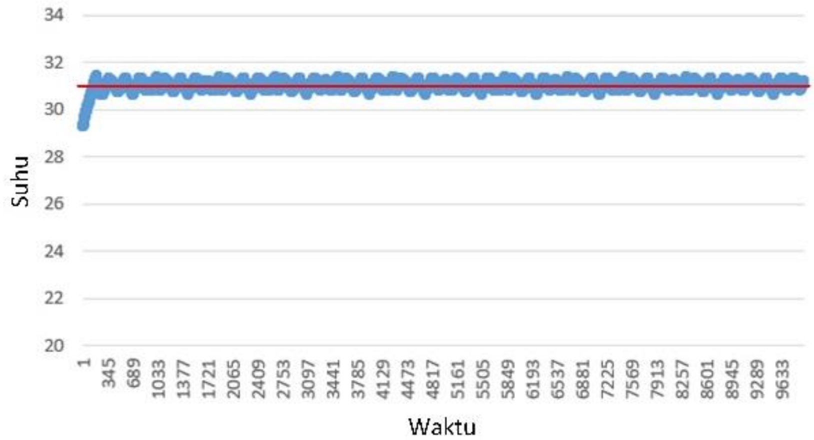

Figure. 8. Experimental results with the PID method.

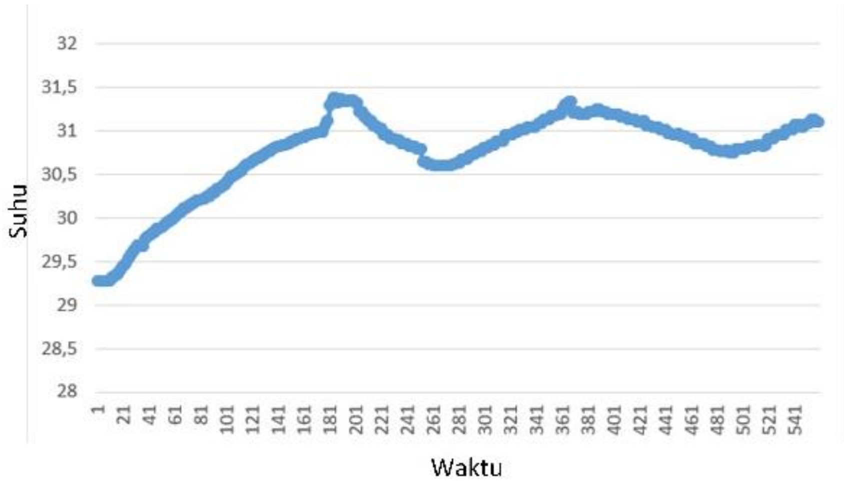

Figure. 9. Experimental results chart if detailed.

From the graph above, to find the error value using the formula:

$$\%ESS = \frac{Tc - Tx}{Tx}\, x\ 100\% \qquad (3)$$

While to find the maximum overshoot of the system using the formula:

$$Mp = \frac{C_{tp} - C_\infty}{C_\infty}\, x\ 100\% \qquad (4)$$

Where :

T_c = maximum peak temperature value
T_x = temperature set point
C_∞ = state at peak time
C_{tp} = condition at setpoint

The maximum overshoot (maximum overshoot) is the maximum peak value of the response curve measured from one, if the response steady state price is not equal to one, then the maximum percent over-shoot is usually used. Rise time is the time required for the response to rise from 10 to 90%. Settling time is the time required for the response curve to reach and settle in the area around the final price whose size is determined by an absolute percentage of the final price (5% or 2%), in the system a percentage of 2% of the setpoint value is used.

From the experimental results above, the steady state error value of the electronic fermentor system with a setpoint of 31^{o}C is 1.25%. Below fig. 10 show result of this experiment different fermentation with electronic fermenter and manually fermenter.

a) Fermentation with electronic fermenter.

b) Ferment manually.

Figure. 10. Placement of fermented coffee cherries in electronic fermenters and manually.

4. Conclusion

This journal shows an electronic fermenter that is used as a place to ferment coffee cherries with various supporting components in it that can simplify and speed up the fermentation process. An electronic fermenter is a tool that is integrated with various supporting components such as temperature sensors, pH sensors, pressure sensors, and gas sensors which are used as a coffee wine fermentation process. The electronic fermenter is designed to be closed and airtight because the fermentation is carried out anaerobically and without additional bacteria, so it only relies on the natural decay process of the

fermentation process. The setpoint used is 31oC using the PID method. PID control (Proportional–Integral–Derivative controller) is one of the controllers for determining the precision of an instrumentation system by relying on feedback on system output. This control system has the goal of controlling the system by relying on the feedback provided so that errors do not occur. Controlled output includes stability, accuracy, and also dynamics. The error rate in the electronic fermenter using the pid method is 1.25%.
Electronic fermenters can speed up the fermentation process until it reaches a pH value of approximately 4 weeks compared to manual fermentation which takes approximately 6 weeks to reach a pH value of 4. Based on the results of tests that have been carried out during the coffee cherry fermentation process no alcohol gas is produced, this is evidenced by no significant change in the detection of pressure sensors and alcohol gas sensors, namely the initial data is around 0.2 g/dl and the end of the fermentation process the highest value is 0.4 g/dl. and pressure is 0.07 psi while the highest value during the fermentation process is 0.09 psi. The post-fermentation process has several stages that are almost the same as in the direct coffee process, including the drying process, the coffee skin separation process, the coffee roasting process, and the grinding process into coffee powder. Previous research said that the fermentation process in coffee cherries can reduce the levels of cadein in it. Therefore testing for caffeine content is carried out in a laboratory with national accreditation using the HPLC method point 6.6 (SNI 01-3542-2004) in order to obtain accurate results. The caffeine content in coffee before fermentation is 2.43% and the caffeine content in coffee after the fermentation process is 2%, this proves that fermentation in coffee cherries can reduce the caffeine content in it.

5. Authors' Biography

Koko Joni is lecturer at University Of Trunojoyo Madura Indonesia Since 2002, Focus Research In Control Engineering.

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