Testing coffee roasting machine with electric heater as energy source

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Abstract. The roasting process is the process of frying something without using oil. The roasting processes raw materials into cooked or ready-to-eat ingredients. The purpose of the roasting is to get a certain taste using heat transfer methods either without media or using sand. When the roasting process occurs, the coffee beans undergo physical changes, one of which is the water content due to heat transfer from the roasting medium to the material. During the roasting process, evaporation of water content occurs and the coffee beans will experience a decrease in mass. Coffee bean roasting machines with stove heat sources from gas fuel are currently being developed. The use of gas fuel is sometimes difficult to regulate a constant temperature because it depends on the valve setting to exit the gas flow on the stove. On the other hand if incomplete combustion occurs it will affect the flavour of the roasted coffee beans. The purpose of this study was to test a coffee roasting machine with an electric element heat source. Roasting machine testing with a time of 50 minutes produces an average temperature of 196.64 °C with a final moisture content of 3.61%.

1. Introduction
The roasting process is the process of forming the taste and aroma of coffee beans. If the coffee beans have uniformity in size, specific gravity, texture, moisture content and chemical structure, the roasting process will be relatively easier to control [1]. Thus, it is necessary to roast coffee that is appropriate or appropriate to the temperature and duration of roasting [2].

Roasting is usually carried out at temperatures above 200 °C which aims to get roasted coffee that is dark brown in color. Roasting greatly determines the color and taste of the coffee to be consumed, changes in the color of the beans can be used as the basis for simple classification [3, 4]. In the roasting process, the coffee will also experience a color change, which is successively from green or light brown to cinnamon brown, then to black with an oily surface. When the coffee is blackish in color and easily cracked (cracked) then the roasting is immediately stopped, the coffee is immediately removed and cooled.

Coffee roasting is influenced by 2 main factors, namely temperature and time. Roasting levels consist of light roast, medium roast and dark roast. These different roasting methods affect the taste, aroma and color of the coffee beans produced. Roasting in a closed way will produce coffee beans that taste slightly sour due to the retention of water and several types of volatile acids in the coffee beans. However, the distinctive aroma of coffee will be sharper and coffee will be protected from odor pollution from outside such as fuel or incomplete combustion gases [5].

The degree of roasting affects the flavor characteristics of the coffee extract produced. The degree of qualitative roasting is seen from the color of the coffee that has been roasted. The color of the roasted coffee also affects the percent loss (rate of loss) of the ingredients in the coffee, light roast is about 3-
5% loss, medium roast is about 5-8% loss, and dark roast is about 8-14% loss (including the level of roasting). water in rice coffee). This clearly shows that the chemical composition of both volatile and non-volatile coffee is influenced by the degree of roasting [6,7]. The roaster can be an oven that operates continuously. Heating is carried out at atmospheric pressure with hot media or combustion gases. Heating can also be accomplished by making contact with a heated surface, and in some heater designs this is a determining factor in heating. The most common design that can be adapted for continuous roasting is a rotating horizontal drum. Generally, coffee beans are poured out in parallel with hot air through this drum, except in some roasters where it is possible to cross flow with hot air [8,9].

When the roasting process takes place, it causes a change in the mass of water from the coffee beans, this is due to the transfer of heat to evaporation. The change in water mass occurs when the water content in the coffee beans has reached a saturated condition, causing the water contained in the coffee beans to change from the liquid phase to steam. These changes are evident in the decrease in water content with time. Roasting rate serves to determine changes in water content and weight of coffee during the roasting process. According to [6], in the early stages of the roasting process, heat energy in the roasting medium is used to evaporate water. The moisture content of coffee beans drops rapidly at the beginning of roasting and then will take place relatively slowly at the end of roasting.

The water content of coffee beans tends to decrease when the temperature and roasting time increase. The longer the roasting process, the more water content of the coffee beans will be affected. According to the statement of, that the greater the temperature difference between the heating medium and the food, the faster the heat transfers to the food and the faster the evaporation of water from the food. Roasted coffee beans vary from 1-5% depending on the ingredients used, roast level, temperature conditions and roasting time, and cooling method [10,11].

However, over time with the development of increasingly sophisticated technology, coffee roasting equipment continues to be developed to be able to produce coffee of the same quality as coffee using the manual roasting method. The roasting process is carried out using different times and temperatures, it all depends on the type of equipment used. Horizontal cylinder type coffee bean roaster with a heat source from LPG Gas fuel in the roasting process takes between 20 to 30 minutes [12]. The roasting process with a rotating cylinder type engine with a fuel source requires a roasting time of 12.3 kg/hour. This tool is very suitable and affordable to be applied by small entrepreneurs, both technologically and economically. The source of electrical energy is one that can be used as a heat source. Therefore, the purpose of this study was to test a coffee roaster using an electric heating element as a heat source.

2. Material and Methods
This study was conducted to test a coffee roaster machine with an electric heat source, as shown in figure 1. This machine consists of a perforated cylindrical tube with stainless steel plate material in which there are several stirring inserts as a place for roasting coffee where on the upper side there is a hopper for entering coffee beans and on the bottom side there is a bean output hopper. The cylindrical tube rotates with a reduced rotation speed using a gear box and pulley with an electric motor power source. The electric heating element used is 1800 Watt and is placed at the bottom of the cylinder tube where hot air will flow into the tube through the holes around the tube wall. The roasting temperature is set on the control panel using a thermostat above 205 °C [13,14]
Coffee bean material used is dry robusta coffee beans with a moisture content of > 12% which is roasted at a temperature of > 200 °C (dark roast). The data observed were the temperature of the roasting process, the need for electrical energy, water content and color uniformity.

3. Result and Discussion

3.1. Roasting process temperature

In this study, the temperature used for dark roasting is 205 °C. This roasting process uses an electric heating source so that it takes a long time to raise the temperature in the cylindrical tube chamber to 205 °C before the coffee beans are inserted. Temperature data were collected every 4 minutes until the coffee beans were roasted [15]. Temperature is an important part of the roasting process and can also affect the quality of the product produced. The roasting process requires a high enough temperature to be able to roast the coffee beans until they are cooked, which is above 200 °C. The higher the temperature, the faster the roasting rate.

![Figure 1. Electric heat source roasting machine](image)

![Figure 2. Roasting Process temperature graph](image)

Based on Figure 2, it is shown that the roasting process of coffee beans from the beginning of raising the temperature in the tube chamber until the coffee beans are ripe takes 90 minutes. The process of raising the initial temperature from 36 °C to a temperature of 205 °C before adding the coffee beans
takes 40 minutes or with a temperature rise rate of 4.24 °C /minute. After the temperature reaches 205 °C the coffee beans are put into the roasting tube chamber through the hopper. This roasting process takes 50 minutes so that the water content reaches below 4%. This roasting process is longer when compared to using gas fuel which takes about 20-30 minutes [16]. During the process of inserting the coffee beans into the roasting tube, the temperature decreased from 205 °C to 188 °C for 12 minutes. The decrease in temperature in the roasting tube space occurs due to the influence of the temperature on the coffee beans which is lower than the tube space. The roasting process continues until the coffee beans are ripe. The coffee bean roasting process starts from the introduction of beans at an initial temperature of 205 °C and a temperature decrease of 188 °C then increases again until the end of the roasting process for 50 minutes and the coffee beans have matured with the final roasting temperature being 202 °C. During the 50 minutes roasting process, the average roasting temperature was 196.64 °C.

3.2. Electrical energy

The process of roasting coffee beans uses an electrical energy source. There are two tools that use electrical energy, the first is used for electric heating as a heat source and the second is used an electric motor as a driving force for stirring coffee beans.

![Electric Heater Graph](image)

**Figure 3.** Graph of electrical energy requirements for electric heaters

Figure 3 shows the electrical energy required for electric heating varies but is not much different. The lowest electrical energy requirement is 2.83 kwh at 68 minutes and the highest is 2.91 kwh at 12, 28 and 36 minutes. During the coffee bean roasting process for 90 minutes, from the beginning, raising the temperature in the tube chamber until the coffee is ripe, it requires an average of electrical energy used is 2.88 kwh.
Figure 4 shows the electrical energy required for the electric motor to drive the coffee bean stirrer starting at the 40th minute. This is because when the process of raising the roaster temperature in the tube chamber reaches 205, the electric motor is not turned on [17,18]. When the condition of the electric motor is not turned on, the electrical energy requirement is only used for the components of the voltmeter and ammeter so that the energy requirement is 0.26 kwh. The process of stirring the coffee beans begins when the room temperature of the roasting tube reaches 205 °C and the coffee beans are fed through the hopper. The stirring process using an electric motor requires an average of 1.16 kwh of electrical energy.

3.3. Water content
In this study, the water content of Robusta coffee beans before roasting was 12.05% which was roasted using a temperature of 205 °C until the coffee beans turned black and reached a crack (popping sound). The results of the roasting water content analysis were taken every 5 minutes.

Figure 5. Graph of Decrease in roasting water content
In Figure 5, it can be explained that the shrinkage of the water content of the coffee beans from 12.05% to 10.06% in the 5th minute until it continues to shrink for 50 minutes of the roasting process the water content of the coffee is 3.61%. According to [4], the water content decreases at high temperatures because the higher the temperature, the higher the energy will move to the material so that the increase in temperature in the material also accelerates the evaporation of water in the material. The roasting process for 50 minutes causes a decrease in the moisture content of the coffee beans by 8.44% and this is according to [7], after roasting coffee beans will experience a decrease in water content of 8-14% from the initial water content for dark roast levels.

3.4. Color uniformity
Roasting can affect different coffee qualities including color uniformity. The color of the coffee beans is blackish brown. According to [5], the level of maturity in dark roasts is characterized by a blackish brown color, a taste that tends to be bitter and a more smoke smell.

The results of the research carried out are shown in Figure 6 that the level of color uniformity in the coffee beans produced is uniform color is 99.13% while for non-uniform color is 0.87%. The color uniformity result is quite high, namely 99.13% due to the long roasting process of about 50 minutes so that the ripening process is not forced and runs slowly according to the roasting time.

4. Conclusions
The test results show a coffee bean roaster with an electric heat source of 1800 watts is able to roast coffee beans at a temperature of 205 °C (dark roast) with a time to raise the temperature in the tube chamber for 40 minutes and the roasting process for 50 minutes where the average electrical energy used is 2.88 kwh for electric heating elements and 1.16 kwh for electric motors. The water content produced is 3.61% and the color uniformity is 99.13%.

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