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DESIGN OF A GROUTLESS CLEAR COFFEE MACHINE USING DISTILLATION METHOD

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Abstract. Coffee is a plantation commodity that is made into a drink as one of the products that is popular with the public. Many coffee drink innovations have been made, one of which is a clear coffee drink without dregs. The process of making clear coffee can be done by the distillation method, namely the process of condensing the steam produced by a mixture of coffee powder and water. This study aims to obtain the design results of a clear coffee machine without dregs using the distillation method. The design is carried out based on the results of a patented study on making clear coffee. The coffee machine is made with a heating tube for a mixture of ground coffee and water, a steam collector tube and a distillation tube. The design results obtained a heating tube with a diameter of 25 cm and a height of 27 cm for a process capacity of 13.25 liters. Heating is performed using an LPG-fueled heater. The distillation process is carried out by cooling the water using a 15 watt aerator pump. The trial was carried out by processing 500 grams of fine coffee powder mixed with 2000 ml of water. The trial results obtained 500 ml of clear coffee with an average process time of ± 25 minutes.

Keywords: Design, Machine, Clear Coffee, Distillation.

1. INTRODUCTION

Coffee is one of the plantation commodities that plays a significant role in economic activities in Indonesia. Coffee production in 2020 was 762.38 thousand tons, in 2021 it was 786.19 thousand tons and in 2022 it was 774.96 thousand tons [1]. Indonesian coffee has different sizes, flavors, and characteristics according to the area of origin of the coffee so that the Indonesian nation is rich in coffee flavors [2]. The potential of coffee products is part of the utilization of appropriate technology, especially for mechanical technology in its processing. The application of appropriate technology has been widely used for post-harvest processing of coffee. This includes coffee bean sorting machines [3], coffee skin peelers [4][5][6], coffee bean washing machines [5], roasting machines [7][8][9][10], grinding machines [2][8][11], coffee powder sieving machines [12] and coffee powder packaging machines [13].

The majority of Indonesians like coffee drinks as a refreshing beverage enjoyed during leisure time [14]. Coffee is packaged with a distinctive taste and aroma so that connoisseurs always want to taste it again. As a result, coffee consumption in Indonesia increases by 6-8 percent per year [15]. Coffee drink products have been innovated, including palm sugar milk coffee products [16] and wine coffee [17]. Innovation has also been made for coffee making machines or devices. These innovations include the design of an automatic coffee maker using a conveyor [18], the design of an automatic coffee maker based on Arduino Uno with Android control [15], the design of a coffee water maker with a robotic system [14], the manufacture of an espresso coffee machine using a pneumatic system [19], the design of an automatic milk coffee machine based on Arduino [20].

Another innovation in coffee beverage products is clear coffee without dregs. This innovation was obtained from research results where the appropriate formulation was carried out with a roasting temperature of 195°C and a

ratio of ground coffee formulation to spring water of 10 g: 50 ml [21]. Characterization of clear coffee in testing pH levels, protein levels, water content, ash content, fat content, and caffeine levels resulted in the dark roasting treatment (195°C - 200°C) having the highest percentage value with low caffeine levels and the roasting temperature treatment of 195°C - 200°C had the highest level of preference [22].

This clear coffee product has been patented [23]. The manufacture of clear coffee uses the principle of condensation of coffee vapor or by the distillation method. The manufacturing process requires appropriate equipment or machines. For this reason, research is needed that aims to obtain the design results of a clear coffee machine without dregs using the distillation method.

2. METHODS

The design of the clear coffee machine refers to the steam distillation process of coffee. Clear coffee has been tested organoleptically and proximately for the characteristics of clear coffee with research that has been done. The patent for clear coffee is a series of processes for further production processes using the appropriate machine. The clear coffee machine is designed with the scheme in Figure 1.

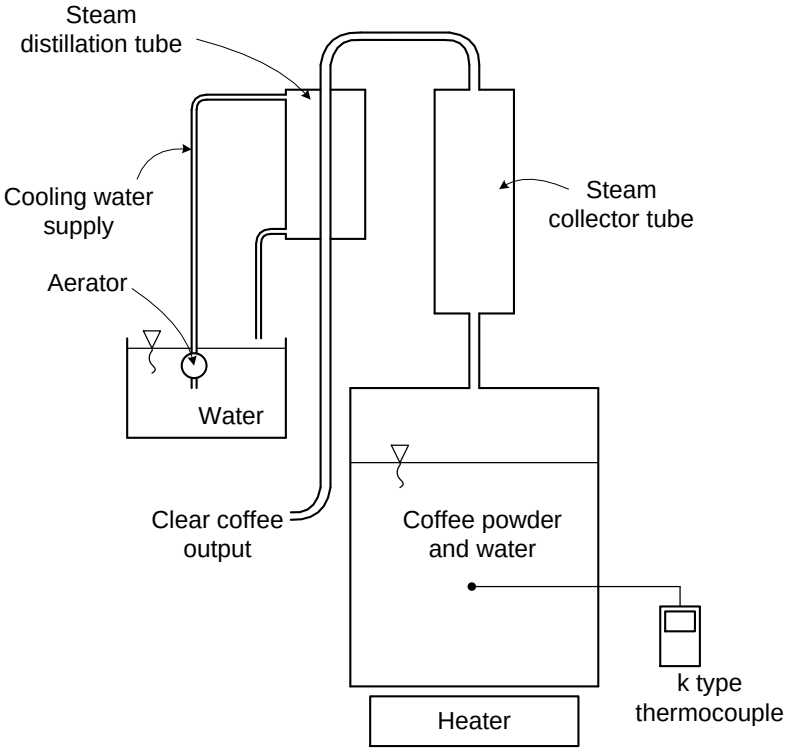

Figure 1. Schematic of clear coffee machine

Figure 1 shows a tube filled with finely ground and roasted coffee powder. Water is mixed into the tube and heated at the bottom of the tube. After a period of heating, coffee steam is produced. The pressurized coffee steam will move up into the steam collection tube. The collected coffee steam then flows into the distillation tube. Condensation occurs as cold water flows into the distillation tube, functioning like a heat exchanger. Cold water is circulated with an aerator or submersible pump. The coffee steam that interacts with the cold water will condense so that it drips into clear coffee liquid.

The design of the clear coffee machine was carried out with the design, manufacturing and testing stages of the tool. The machine trial was carried out by processing 500 grams of coffee powder mixed with 2000 ml of water. Heating was carried out using an LPG stove. The trial was carried out to obtain 500 ml of clear coffee. In the trial, data was recorded on the process time to produce 500 ml of clear coffee. Time measurements were taken using a stopwatch. Time measurements were taken after the water temperature in the tube reached 90°C where at this temperature, coffee steam production began. This temperature was monitored using a type K thermocouple. The thermocouple was submerged in the center of the tube. The trial was carried out five times.

3. RESULTS AND DISCUSSION

3.1. Design Result

The heating tube has a diameter of 25 cm and a height of 27 cm. With this size, the volume of the tube is 13,25 litre. The steam collector tube is designed with a diameter of 6 cm and a height of 30 cm so that the steam collector tube has a volume capacity of 0.85 liters. The distillation tube is made with a diameter of 6 cm and a height of 18 cm. An aerator pump with a power of 15 watts is used to supply cold water. For the distillation process, coffee steam is flowed through a copper tube positioned on the axis of the distillation tube. The copper pipe used is 20 mm in diameter and 2 mm thick. Copper is chosen because of its relatively good heat conductor properties so that it can optimize heat exchange between coffee steam and cooling water. All tubes are made of stainless steel. This is because the process of making clear coffee must not be contaminated with corrosion caused by the equipment material. While other accessories such as water hoses use plastic materials.

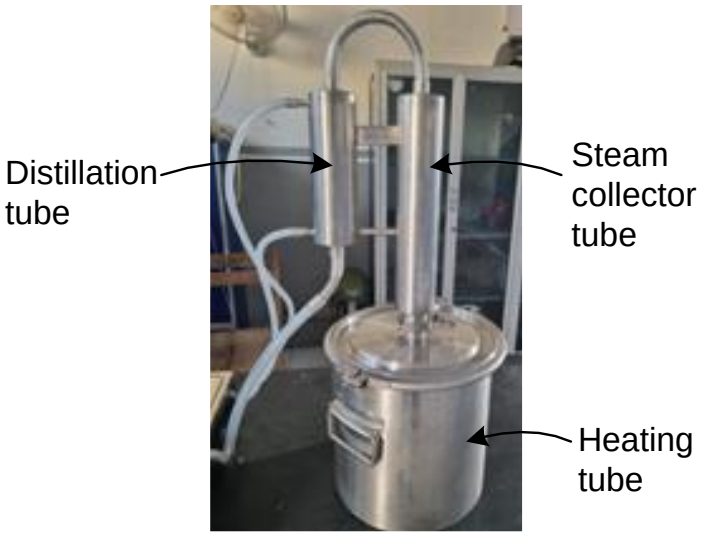

Figure 2. Results of the clear coffee machine design

3.2. Trial Result

The trial results are shown in the following table 1.

Table 1. Trial results

Number of trial	Processing time (second)	Processing time (minute)
1	1524,32	25,41
2	1511,74	25,20
3	1498,06	24,97
4	1492,13	24,87
5	1539,84	25,66
Average	1513,22	25,22

Table 1 shows that the average time required to produce 500 ml of clear coffee is 25.22 minutes. The photo of the clear coffee product is shown in Figure 3. The product photo shows that the coffee produced is relatively clear and without grout.

Figure 3. Photo of the product from the trial

The main target of this clear coffee machine design is that the equipment that is designed can produce clear coffee. This is done as a development of research results that have been carried out in the laboratory. The main drawback of this equipment is the relatively long process time so that further innovation needs to be done to optimize the process time.

3.3. Comparison With Similar Designs

In general, the design of the clear coffee machine has been able to produce the expected product. The energy requirements to produce 500 ml of clear coffee are:

a. LPG fuel.
   This fuel is used to heat the mixture of coffee powder and water. Heating is carried out for ± 26 minutes according to the test results. Based on the research results, LPG consumption for 10 minutes of combustion requires ± 0.135 kg of fuel [24]. So the consumption of LPG fuel for this heating is ± 0.3375 kg. The propane compound in LPG has a heating value of 50.35 MJ/kg or equal to 50350 kJ/kg so that the use of 0.3375 kg is equivalent to 16,993.13 kJ.
b. Electrical energy.
   Electrical energy is used to drive the aerator pump in the distillation process. The pump used has a power of 15 watts. The process time for 25 minutes requires 36 watts of electrical energy. This energy quantity is equivalent to 36 J/s.

Automatic coffee maker based on robotics or Arduino control uses a 12 Volt power supply as a source of electrical energy for its supporting components, including sensors, solenoids, servo motors and others. Assuming there are 5 supporting components, an electric current of 2 Ampere and an average process time of 5 seconds, the energy consumption is 120 watts per second or 120 J/s. Automatic coffee maker using a conveyor also requires similar supporting components so that its energy requirements are relatively the same. A coffee maker with a pneumatic principle requires a compressor as a source of compressed air. Assuming a compressor power of 0.25 HP and a process time of 5 seconds, the energy consumption is 932.125 J/s.

Table 2
Comparison of energy consumption with previous research

Design Topic	System	Energy Consumption
Automatic coffee machine	Robotic or Arduino control	120 J/s
Automatic coffee machine	Pneumatic	932,125 J/s
Clear coffee machine	Distilation	17,029.13 kJ/s

Table 2 shows that the energy consumption of clear coffee machines is very large compared to automatic coffee machines from previous studies. This difference occurs because making clear coffee requires LPG as a heating fuel. The large amount of energy required is a consequence of the heating value of the propane compound in LPG. On the other hand, automatic coffee machines are designed for coffee drinks that are consumed immediately so they only require hot water and stirring. The resulting drink is not a type of drink that is durable to store. In addition, automatic coffee machines produce coffee drinks with residue or dregs so that they are very different from clear coffee products. Water heating in the design of previous studies was not discussed explicitly.

3.4. Further Innovation Opportunities

The time required to produce 500 ml of clear coffee is an average of ± 25 minutes, which means 0.33 ml/sec is produced. The temperature of the heating tube must be maintained at more than 90ºC so that steam production can be sustainable. In this way, the distillation process can run optimally so that it will produce optimal products. Efforts to improve machine performance can be done by:

1. Increasing the amount of coffee steam production by increasing the diameter of the tube. A larger tube diameter is equipped with even heating so that more coffee water mixture is evaporated.
2. Optimizing the distillation process by flowing water at a lower temperature. Lower temperatures will accelerate the steam condensation process. The distillation tube device can also be equipped with barrier partitions to create vortices that will improve heat exchange performance.

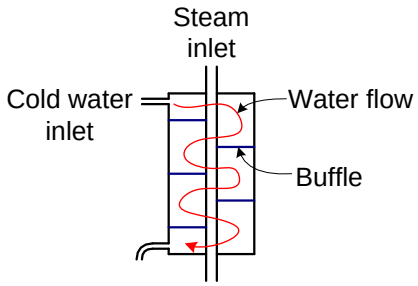

Figure 4. Schematic of adding a barrier partition in the distillation tube

Figure 4 shows a schematic of a distillation tube with the addition of barrier partitions. This innovation refers to the heat transfer model of a heat exchanger. The partitions will cause the water flow to meander so that the flow path becomes longer. The length of the path will provide more opportunities for the cooling water to exchange heat with the coffee steam. This increase in heat exchange performance will result in a more optimal condensation process.

The design results of the clear coffee machine have been tested well. For application on a production scale, it still requires feasibility in terms of production costs. Economic analysis is still needed so that the application of this clear coffee machine has the potential to be an alternative variant of the coffee drink business.

4. CONCLUSION

The design of a clear coffee machine without grounds using the distillation method has been carried out. The machine can produce 500 ml of clear coffee in about 25 minutes. Optimization of production can be done by changing the dimensions of the heating tube and distillation tube.

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