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Design of Portable Coffee Roaster for Home Industry

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Abstract. At present, the availability of an appropriate roaster for home coffee processing industry is very limited. This study aims to design a portable coffee roaster with a maximum capacity of 2 kg per batch. The roasting machine is designed with six main parts, namely as a roasting cylinder, an outer cylinder equipped with an inlet-outlet funnel, a main frame, a heat source with the LPG fuel, a cooling unit, and a temperature control system. The roasting machine has been tested to roast an amount of green bean at a constant temperature of 225 °C with three targets of roasted degree, namely as light, medium and dark. The test result shows that the roasting machine can work properly. The temperature control system is able to regulate the roasting temperature as same as the temperature target during the process. With the stable temperature, the machine can roast the green coffee sample to reach the target roasted degree with good result. The test shows that the roaster can roast the sample of 1 kg of green bean at light roast degree with an average time of 13.2 minutes and an energy consumption of 4708.92 kJ. For the same amount of sample, the coffee roaster can work properly for the roast degree target of medium with an average time of 16.9 minutes and an energy consumption of 4708.92 kJ. Meanwhile, for dark roasted target, the roaster requires an average time of 28.59 minutes and consume an energy of 9417.85 kJ.

Keywords—design, coffee roaster, portable, home industry, performance.

1. Background

Secondary coffee processing is a series of operation to process coffee beans (green coffee bean) as the main raw material into ground coffee (ground coffee powder) and its derivative products. This processing includes a series of stages, starting from the preparation of raw materials, followed by the roasting, mixing, grinding process, and ending with the development process of coffee derivative products. Roasting is the most crucial stage on the coffee processing because the flavor formation process occurs therein. The coffee flavor is produced through a series of physical and chemical changes in the flavor candidates substance inside coffee [1] [2]. Roasting is a heat treatment process that aims to form the flavor and aroma of coffee [3] [4]. Coffee roasting is a very important process to form some organoleptic parameters (taste, aroma, and color) that underlie coffee quality and guarantee the quality of drinks [5]; [6]. The process takes place at high temperatures (> 200 °C).



In practice, coffee roasting equipment in the community is quite diverse. Traditional people generally use a pan that is burned from the bottom side. The heat will be transferred into the upper side where the coffee beans are placed. The beans will be heated directly with such conduction and convection procedure. Such roasting process is considered unhealthy, besides being wasteful of energy due to the very low absorption efficiency of heat. In its development, several roaster machines were later developed. Unfortunately, commonly roaster is originally developed to support medium and medium scale coffee processing industries. Today, some coffee roaster machines for the small scale are available even though they are generally very simple. Besides it often yields the unsatisfactory results, commercial roaster is very wasteful of energy and is considered less practical. The considerable demand for small coffee roaster machines and the limitations of the commercially available coffee roaster machines have encouraged researchers to develop these roasted machines in the last two years. This study aims to design and construct make small-scale of portable coffee roaster with high efficiency of energy for home coffee industry.

2. Material and Method

2.1. Tools and material

This research used material for roaster construction and material for testing. The construction material included plate of stainless steel, perforated plate of stainless steel, L-profile of steel for frame, shaft of stainless steel, bearing, motor and corresponding driver, controller components (thermocouple, thermo-control, display, power supply, solenoid valve, servo motor), and a heating element; while material for testing included coffee bean sample and LPG gases. Besides, it also applied some equipment for construction such as welding machines, lathes, roller machines, milling machines, drilling machines, sewing machines, grinding machines, bending machines, etc. In addition to construction equipment, several test apparatuses were also used such as multimeters, oscilloscopes, meters, scales, stop watch, etc.

2.2. Research sites

The research was conducted in the Lab. of Energy & Agricultural Machinery, Department of Agricultural and Biosystems Engineering, Faculty of Agricultural Technology, Universitas Gadjah Mada. This work was done in nine months, starting on March until November 2018.

2.3. Research procedure

This research was conducted in three stages, namely designing, manufacturing, and testing. The design phase aims to realize the design in the form of technical drawings that are ready to be realized or realized at the manufacturing stage. The manufacturing phase is a process to construct a roasting machine in accordance with the technical drawings that have been made in the previous stage. The manufacturing phase begins with determining the construction material requirements, purchasing these materials, and making roasted machine parts. After all the parts are constructed, the parts are combined with one another so that it becomes a roasting machine as a predetermined design. After the construction phase, the research continues with the testing phase. Tests are carried out in two stages, namely functional tests that aim to ensure that all engine components can work as their functions, and performance tests that aim to evaluate the work ability of the engine based on the function that has been set.

2.4. Roaster design

This research aimed primarily to design and construct a prototype of a small-scale portable coffee roaster with high energy-efficiency for the home coffee industry. Developing of the roasted machine has actually begun through a series of previous works. Our initial work was concentrated on designing a hygienic roasting machine. In this work, we focused on improving tool of pan in traditional roasting process. For hygiene purpose, the primary roaster was constructed with stainless steel material. The

initial design had a capacity of 0.5 kg / batch, which was consisted of two main parts, namely as a roasting cylinder and outer cylinder (cover). This first-generation roaster machine was operated manually with a gas stove as heating source. The manual roaster had been tested. The result showed that it could work well with good performance. One of the roaster disadvantages was the unsatisfactory roasted coffee, especially when it is viewed from the color uniformity of the roasted coffee. The manual stirring process was suspected to be the cause of the roast maturity level. Therefore, at the next development work, a roasting machine with the same capacity was designed by adding an electric motor to rotate the roasting cylinder continuously. The test results showed that the roaster prototype worked better than previously design. It was able to roast the sample of green coffee with uniform roasting level. The second prototype was kept to develop such roaster for the next experiment. On the third roasting generation, we focused on improving the second design, especially by adding the capacity up to 2 kg per batch and improving the heating source using special burner for LPG fuel. Design of this roaster is presented in Figure 1.



Figure 1. Design of Portable Coffee Roaster for Home Industry

3. Results and Discussion

3.1. Prototype of portable roaster

The roaster (as shown in Fig. 1) has six main parts, namely roasting cylinder, an outer cylinder equipped with an inlet-outlet funnel, a main frame, a heat source with the LPG fuel, a cooling unit, and a temperature control system. Besides, it is also equipped with supporting parts such as dirty-storage, supporting wheel, and small window for monitoring purpose. The roasting cylinder is designed by perforated plates with the hole diameter of 3 mm. Besides to accelerates the roasting process, the perforated tube is selected to improve the quality of roasted coffee, especially that relates to the cleaning aspect. Hopefully, the dirty component of roasting, such as pericarp, silver skin usually peels during roasting will release through to the perforate. The roaster cylinder is driven by a DC motor. The rotation of cylinder functions as a stirrer which will guarantee the quality of the roasted beans. While, the cover tube (cylinder) serves to maintain heat energy inside the roaster. With the cover, the speed of heat transfer from roaster to environment can be minimized. The cover is also equipped with an input funnel that functions to hold the coffee beans (raw materials) temporarily before being put into the roasting cylinder. The cover is also supported with an output funnel which can be opened and closed as necessary. The unit of heating serves to supply the heat source for roasting. In this design, a special stove model is constructed to optimize the roaster. To guarantee that the roasting process is stable, the heating unit is equipped with a control unit. The control functions to regulate the supply of fuel injected to the heating element. The control unit consists of a thermocouple, solenoid valves and a

thermo-control unit. While the cooling unit consists of a tube with a device made of perforated stainless plate. This part is also equipped with a blower unit which serves to suck heat when the cooling process takes place. The main frame part is designed from elbow-profile iron, functions to install all components of the roaster.

After the final design of the roasting prototype is completed, the next step is calculating the construction materials. Based on the design, necessary construction materials can be estimated. After determined, the next step is buying the materials. In this procurement, materials are purchased in stages based on the level of urgency. A number of prioritized materials include stainless steel plate, perforated stainless steel plate, and elbow iron. After all materials have been received, the next activity is manufacturing. The manufacturing activity begins with preparing of construction equipment that will be used to construct the roaster. The production machines used for manufacturing activities include cutting machines, grinders, lathes, milling machines, bending machines, roller machines, and welding machines. Constructing the roaster starts with part by part. Starting with six main parts construction, the activities is then continued to create other supporting parts. After all parts are manufactured, then they are assembled. The results of the portable roaster is presented in Figure 2.



Figure 2. Portable coffee roaster machine for home industry scale

3.2. Test result

After the roaster machine is assembled, the next stage is functional and performance testing. Functional test is carried out to ensure that the roaster can work properly. This work is carried out to test all of the roaster parts and ensures that all components can work as expected. After the roaster works properly, performance testing is then conducted. In this test, the roaster is used to roast the prepared coffee beans. There are three targets of roast level, i.e. light, medium and dark. A number of parameters are measured during the process. The parameters include roasting time, energy consumption, water content of beans (before and after roasting), roasted coffee bean colour, uniformity of roasted bean, percentage of grain cracking, and density of beans. The performance test results is presented on Table 1. Based on the result, it can be inferred that the roaster can work properly, especially when it is viewed from the parameter of uniformity of roasted bean.

Table 1. Result of performance test of the portable coffee roaster

| No | Parameter | Light | Medium | Dark |
|----|--------------------------------|--------|--------|--------|
| 1. | Roasting time (min) | 13.20 | 16.90 | 28.59 |
| 2. | Energy consumption (gr of LPG) | 100 | 100 | 200 |
| 3. | Moisture content (% wb) | 7,15 | 4.07 | 1.09 |
| 4. | Roasted bean color L*ab | | | |
| | L | 14.994 | 9.664 | 6.204 |
| | a | 6.893 | 4.789 | 3.372 |
| | b | 2.966 | -4.044 | -7.987 |
| 5. | Uniformity of roasted bean (%) | 92.22 | 94.44 | 98.56 |

| No | Parameter | Light | Medium | Dark |
|----|----------------------------------|-------|--------|------|
| 7. | Percentage of grain cracking (%) | 17 | 39 | 88 |
| 8. | Density (kg/liter) | 0.54 | 0.42 | 0.31 |

4. Conclusion

Research on design and construction have been carried out, resulted a prototype of small-scale portable coffee roaster for home industry of coffee. The prototype was operated with LPG gas, using perforated roaster cylinder, and had a capacity of 2.5 kg per batch. The roaster consisted of six main parts, i.e. namely as a roasting cylinder, an outer cylinder equipped with an inlet-outlet funnel, a main frame, a heat source with the LPG fuel, a cooling unit, and a temperature control system. This roaster could be operated easily. The material of green coffee was inserted through the input funnel and was channelled to the roasting cylinder after the roast temperature was reached. The roasting temperature could be adjusted easily, making it possible to roast the green coffee according to the desired temperature condition. The performance test showed that the portable roaster machines worked well. With a green coffee sample of 1 kg per batch, the machine was able to roast the sample till to the target of light, medium, and dark with a roasting time of 13.2; 16.9; and 28.59 minutes respectively.

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