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Effects of temperature improvement rate on the results of coffee seeds in a coffee roasting machine with internal warming system

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Abstract

The technology used to make coffee in Bangli Regency, which is a means that varies greatly from traditional to modern. Technology which is one of the same goals that is producing quality coffee. To get good quality coffee is the roasting process. The coffee roaster machine in coffee is mostly using an external heating system that is heating from outside the cylinder. Coffee or roasting time becomes less efficient because much heat is wasted. This study covers the development of coffee roaster machines with an internal heating system that uses heating elements in the cylinder, to regulate the temperature using digital thermocouples that can be adjusted according to need. The results of the test of the coffee component on the degree of light maturity result in a test value of taste above 80 which means that it is included in a special category. The productivity of the external heating system roasting is 0.41% and the internal heating system of 0.67% means that there is a difference of 0.26%. And an internal heating system that provides electricity with a usage time of 1.25 hours of Rp. 285,239 /month.

Keywords: Coffee roaster machine; internal heater; temperature improvement; productivity; product quality

1. Introduction

Coffee production in Bangli Regency, with Arabica coffee, has a unique aroma and has been accepted in international markets such as Japan, the United States, the Netherlands and France. Unfortunately, most of the coffee exported is still in the form of processed coffee (rice coffee) [1]. It is a challenge for farmers and the district government to increase the selling value of coffee production through further processing into roasted coffee or ground coffee which is currently advanced processed coffee, only able to penetrate traditional markets. In the roasting process the coffee beans will experience two important process stages, namely evaporation of water at temperatures below 160 °C and roasting at higher temperatures up to 225 °C. At a temperature of 180 °C – 225 °C the pyrolysis process occurs, the coffee will experience chemical changes such as the authoring of crude fiber, the formation of volatile compounds, the evaporation of acidic substances, and the formation of coffee-scented substances [2].

The results of a survey conducted in several coffee production centers in Bangli Regency found problems that severely hampered the production process of roasted coffee or ground coffee, namely at the stage of roasting coffee into coffee which is ready to be ground. While this stage is the stage that most determines the aroma and taste of coffee [3]. As a result, production is relatively low and of poor quality. The cause of the emergence of these problems is the use of a roaster that is not equipped with a temperature and time regulator. To ensure consistency in the quality of roasted products and the quality demands of ground coffee by consumers, the use of this machine has problems that are sufficient to hamper the production process. The machine operator must have a keen sense of smell and a high taste for the aroma of the roasted coffee. Just a little negligence causes the coffee to be scorched and of poor quality [4].

Another obstacle found in the use of this machine is the use of external heaters from gas fuel. This type of heating system is widely applied to roasting machines currently available. The external heating system, which is good heating with gas and heater, is given from outside the roasting cylinder. This system has a disadvantage that is the difficulty of controlling the temperature so that overheating often occurs due to direct contact between coffee and a cylinder plate which causes the coffee beans to burn and can reduce the quality of coffee produced. In addition, gas supply must be guaranteed to maintain the stability of the process and also the effects of gas odor that can contaminate the aroma of coffee.

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Roasting presents an important process step. The influence of roasting on coffee bean and cup quality was put in research focus only since several years. In our work, we were focusing on the influence of the roasting process on changes of microstructure and on the mechanisms involved in volume expansion. In the work of Geiger (2004), the influence of structure resistance forces and driving forces on volume expansion was studied in detail. Dynamic mechanical thermal analysis DMTA was applied for the identification of transition phenomena of polymeric cell wall compounds. With DMTA texture modifications such as 452 softening and hardening of materials can be identified and related to the changes of the physical state of materials. For the analysis coffee beans of different moisture content were cross-sectioned to slices of3mm thickness and mounted on a DMTA Solids Analyzer RSA II with plate-plate configuration. Then, the specimens were heated linearly from 30°C to 250°C with a heating rate of 5°C/min. Therein, the storage modulus G’ is shown. The fast drop of storage modulus G’ between 130 and 170°C represents a transition of polymers from the glassy to the rubbery state, the coffee bean texture is softening. The storage modulus G’ increase between 200 and 230°C represents the reversion of the transition, interrupted by a melting phenomenon of a compound between 212 and 217°C. The coffee bean texture is hardening again [6].

DMTA-thermogram of a coffee bean. There is a strong relationship between initial moisture content and the temperature range of the glass transition. Because DMTA analysis was performed under non-moisture-controlled conditions, the moisture content as determined immediately at the beginning of the transition was taken into account. By variation of the initial moisture content a state diagram for coffee beans was developed. Because no sharp and pronounced transition was found in DMTA, the on- and offset of the transition was used to describe the state transition. In order to identify the compounds involved in the state modifications in green coffee beans an adapted DMTA method was applied to analyze the behavior of pure amorphous or semi-crystalline polymers prevailing in coffee bean cell walls, namely cellulose, arabinogalactan and mannan. The observed state diagram of coffee beans correlates to cellulose and mannan, whereas arabinogalactan melted completely above 210°C. Probably, the melting phenomenon observed in DMTA analysis was caused by arabinogalactan. Finally, a mixture of cell wall compounds representing the approximate composition of coffee beans was analyzed [7].

2. Methods

This research is a type of experimental research through testing prototypes of internal heating roaster machines. The roasted coffee is tested for moisture and moisture in the laboratory. Besides testing the roasted coffee from the color side using a comparison chart, and the taste or aroma of coffee was tested by a coffee tester (panelist). The parameters studied include temperature or temperature and roast time to the aroma, taste, and level of coffee dryness.

The tests conducted include: (a) Testing the productivity of the machine to determine the ability of the roaster machine with an internal heating system; (b) Testing Water Content, that is to find out the water content in certain coffee beans; (c) Organoleptic Test or Test Cup which is a quality assessment system for commodities that uses human sensory instruments as measuring instruments, such as the hands, tongue, nose, ears and eyes. People who conduct organoleptic tests are called panelists. Test results data are analyzed using the statistical program.

3. Results and Discussion

3.1 Prototype of Internal Heating Roaster Machine

This roasting process is a process where heating is carried out directly from the coffee cylinder, where the heater (heater) will immediately heat the coffee without passing through other materials so that the coffee will get even heat. But in this process it has a disadvantage where the heater used can only be an electric heater. The following is a schematic picture of the difference in the external heating process by heating in as shown in Figure 1

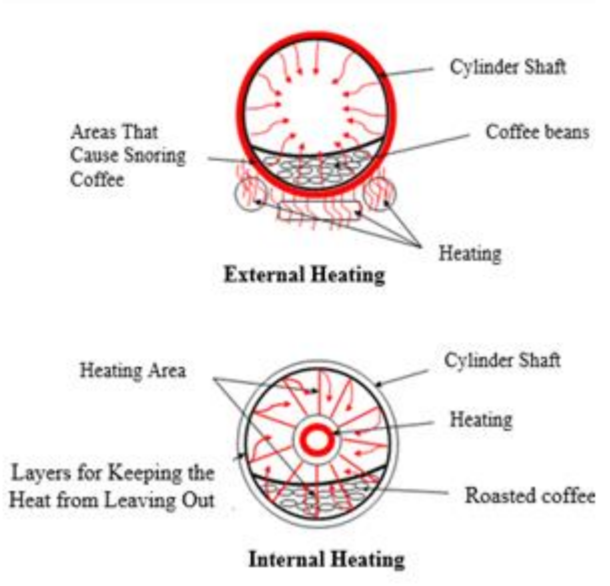

Figure 1. Differences in concepts between external and internal heating systems [5]

The results that have been achieved in this study are in the form of component design and roasting machine construction, which includes component images and dimensions, overall machine construction drawings. The design and determination of the dimensions and ingredients of the roasting machine are carried out by considering product cleanliness, energy consumption, operator safety and ease of operation and maintenance. The design process uses the Autodesk Inventor 2015 program. The roasted machine construction design can be seen in Figure 2.

3.2 Roast Machine performance testing

The test includes the function of the machine without load which consists of: the cylinder rotation mechanism, ignition system, control function of the control panel, cylinder rotation in accordance with operational modes and temperature settings. No-load machine functions can be known by visually observing all components tested after the engine is run by not directly burdening with roasting. From the results of the observation, all machine components are functioning properly. The drive and transmission motors are easily turned on and can quickly reach a stable rotation. The roasted cylinder rotation is obtained by 13 rpm in accordance with the final design. Likewise, the internal heating system using heating elements can be operated properly [6], [7]. Setting the heating settings on the digital display settings.

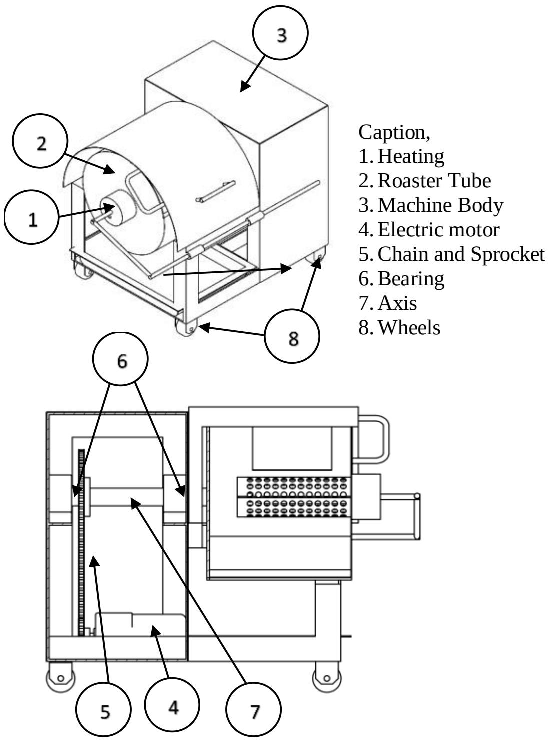

Figure 2. Design of 3D construction of coffee roasting machines through the Autodesk Inventor program

Testing the performance of roasted machines with loads carried out through the roasting process directly on the appliance. The parameters measured and the instruments used can be seen in Figure 3. Tests are carried out in stages, and repeated with the same roasting load until the total production time, relationship of roasting time, heating settings and temperature to the quality of roasted coffee are obtained for each equal load. Data retrieval in this test is done every 5-10 minutes from the beginning until the coffee is almost burnt. Part of the testing process is presented in Figure 3, while the test data is presented in graphical form in Figure 4.

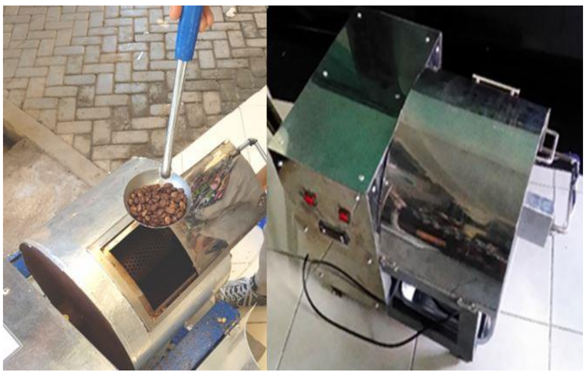

Figure 3. Roasted processes and measurement of coffee blend

Comparison of heating time in the roasting process is done by heating the coffee from outside the cylinder, where the heater in this case the heater or gas is on the outside of the cylinder wall. The heat transfer that occurs is the convection of outside air into the outer wall of the cylinder then conduction passes through the cylinder plate and finally convection from the inner wall to the surface of the coffee bean. The system requires more complicated procedures and controls, as well as more energy use, namely electricity and gas. While the internal heating system is carried out directly from the coffee cylinder, where the heater (heater) will immediately heat the coffee without passing through other materials so that the coffee will get even heat. But in this process it has a disadvantage where the heater used can only be an electric heater (heater) [8], [9]. Results Testing the rate of heat increase in the cylinder tube is the ratio of heating time as in Figure 4.

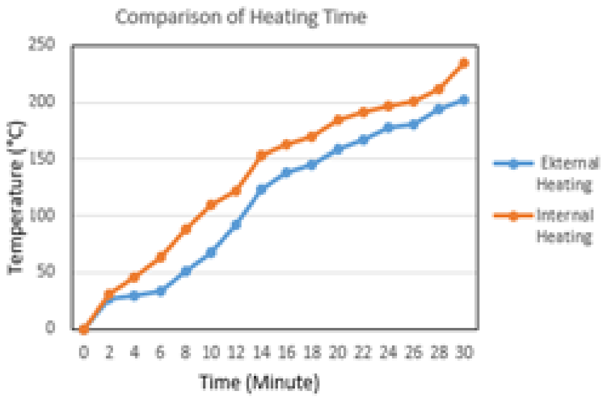

Figure 4. Comparison of time of external heating and internal heating

Machine productivity testing to determine the ability of roasting machines with an internal heating system. The following is a diagram of the temperature rise that occurs when the machine is working. As in Figure 5,

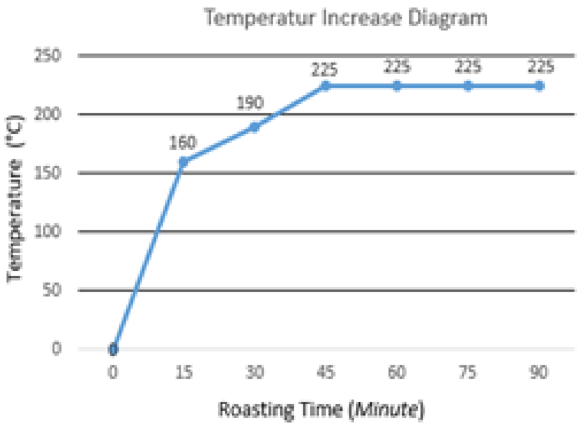

Figure 5. Temperature increase diagram

It can be concluded that it takes 15 minutes for the engine to reach a temperature of 160 ° C where at this temperature the coffee has passed the evaporation phase of the water. further testing can be conducted starting from 30 minutes, 45 minutes, 60 minutes, 75 minutes, up to 90 minutes. The test results from the coffee roaster machine, the most appropriate time to use is roasting for 75 minutes or equal to 60 minutes after a temperature of 160 °C. The color texture of the coffee beans after heating on the roasting machine with an internal heating system as shown in Figure 6.

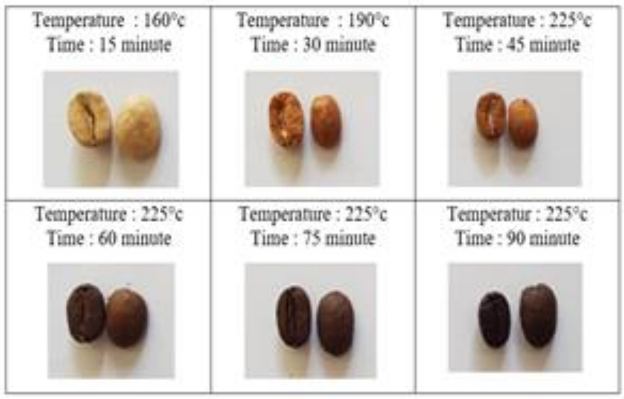

Figure 6. Texture result for Arabica coffee testing

During the roasting process takes place there is heat transfer from the heater tube (roasting media) to the material and also the mass transfer of water. The heat that causes changes in the water mass of the material due to the latent heat of evaporation [10]. This change in water mass occurs when the water content in the material has reached saturated conditions, causing the water contained in the material to change from the liquid phase to steam. Water content testing was carried out on coffee roasters for external heating systems with an internal heating system with the same loading and Arabica coffee type from the Kintamani coffee plantation in Bangli Regency, as shown in Figure 7**.**

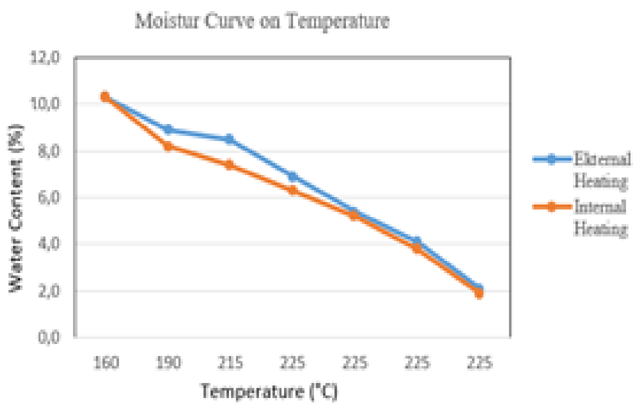

Figure 7. Moisture curve on temperature

Based on the curve of changes in coffee water content to temperature it is seen that the coffee water content will decrease with increasing roasting time. Organoleptic Test or Test Cup, a quality assessment system for commodities that uses the human sensory instruments as a measuring tool, such as the hands, tongue, nose, ears and eyes. People who conduct organoleptic tests are called panellists. The panellist acts as a measuring tool (cupper) covering sensitivity to recognize, differentiate and compare. Coffee roasting results after an assessment by the Investigator in Figure 8.

Figure 8. Results of Arabica Coffee Roast

Table 1. Results of Arabica Coffee Roasting Test

Testing Time	Test result		
	Enjoy	No favors	Uneven (%)
30 Minute	0%	100%	0%
45 Minute	0%	100%	0%
60 Minute	60%	40%	5%
75 Minute	**80%**	20%	15%
90 Minute	50%	50%	20%

From the test results obtained from the coffee roaster internal heating system, the most appropriate time to use is roasting for 75 minutes or equal to 60 minutes after a temperature of 160 °C.

Calculation of productivity is based on the process of roasting coffee because heating elements greatly affect roasting time [11]. Productivity uses external heating methods:

$$P = \frac{Output}{Input \cdot time} \times 100\%$$

$$P = \frac{0,5}{1 \cdot 120} \times 100\%$$

$$P = 0,41\%$$

Productivity uses internal heating roasting machines

$$P = \frac{Output}{Input \cdot time} \times 100\%$$

$$P = \frac{0,5}{1 \cdot 75} \times 100\%$$

$$P = 0,67\%$$

Based on the above calculations it is known that there is an increase in productivity from 0.41% to 0.67%. So it can be said that the coffee roasting machine for internal heating can increase the productivity of home industry coffee farmer producers by 0.26%.

Based on economic considerations, the roasting system of the internal heating system can increase the productivity of Arabica coffee farmers in terms of operating costs, calculation of consumption of electricity consumption in roasted machines,

The price of electricity per kWh = Rp. 1467.28 / kWh
Engine power = 540 watts = 0.54 kW
Operating time = 75 minutes = 1.25 hours
So that the costs incurred in a single machine:
Cost = engine power x operating time x electricity price
= 0.54 kW x 1.25 hours x 1467.28 / kWh
= Rp. 990,414

If calculated within a month, then:
Monthly fee =(12 hour/1.25hour x Rp 990,414) x 30 day
Monthly fee = Rp. 285,239,232 / month

4. Conclusions

The coffee roaster internal heating system results from the development of this study shows that this type of machine is able to provide a solution to the problems faced by small industries of Arabica coffee processing in increasing productivity and maintaining the quality of powdered coffee production. This roasting machine can also be operated and maintained easily, cleaner and can save production costs of more than 26% compared to an external heating system roasting machine.

Although this roasting machine has many advantages over previous roaster machines, this machine still needs to be refined and further developed in certain parts that can improve engine performance. One component that needs to be improved is the temperature control system and the heat-dampening system from the cylinder tube. Further studies on this roaster cylinder need to be done so that a more efficient roaster machine can be obtained with components that can be made entirely (locally) and at affordable prices for coffee farmers or small industries.

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