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Analysis of Drying Air Temperature on Moisture Content in Coffee Beans Using a Fluidized Bed Dryer with Perforated Plates

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ABSTRACT

Fluidized Bed Dryer with perforated plate bed is used as drying for coffee processing. This study succeeded in reducing the water content of coffee beans by 0.11% within 30 minutes of drying more evenly with fluidization on coffee beans. The level of maturity of coffee beans can be achieved at a control set temperature of 200°C the coffee beans undergo a light roasting process with the center of the coffee beans receiving 83.8°C, at a temperature of 250°C the coffee beans undergo a medium roasting process with the center of the coffee beans receiving 130°C, and at the control set temperature of 300°C the coffee beans underwent a dark roasting process with the center of the coffee beans receiving a temperature of 107.6°C. The advantage of this Fluidized Bed Dryer with perforated plate bed compared to other mechanical dryers lies in its low energy requirements, which depend on the heater and blower power as its main components.

Keywords: *Coffee Bean; Drying; Fluidized Bed Dryer; Moisture Content; Perforated Plate*

INTRODUCTION

Coffee is a drink that is very easy to find in sachet form or some in kilograms (Afriliana, 2018). Domestic coffee production has been recorded to have reached 600.000 tons per year and more than 80% of the production comes from smallholder plantations (Direktorat Jendral Perkebunan, 2011). Significantly coffee bean production in Indonesia continues to increase, but the quality of the resulting coffee processing is generally still low (Rahardjo, 2012). Traditionally, the process of drying foodstuffs utilizes heat from the sun by drying them directly in the sun. This drying process depends on the weather conditions. In addition, the traditional drying process is also susceptible to contamination by insects, dust and things that cause the quality of coffee beans to decrease.

Drying is a way to remove some of water from a food material by evaporating some of the water contained in the food using heat energy (Hariyadi, 2018). Drying is generally defined as dry heat treatment. The drying process causes changes in texture, color, aroma of food ingredients and causes the substances contained in food ingredients, such as protein, fat, carbohydrates and minerals to become more concentrated (Makhsud and Riswandi, 2021). Drying is done to reduce water content of material, so that it can inhibit development of destroying organisms (Ruhyat, Nanang, 2019). The moisture content of a material affects the amount of water that is evaporated and the length of the drying process (Lahming and Risnawati, 2017). Dry air acts as a solvent medium to extract solutes, namely the water content of the wet material (Yogendrasasidhar and Pydi, 2018). Most drying processes only focus on the hydrodynamic level, including particle separation (Singh, Mahanta and Kalita, 2020). Thus, monitoring the moisture and hydrodynamics of the granules during drying is important to ensure the quality of the final product (Rimpilainen, Heikkinen and Vaukonen, 2012). The water content contained in materials, especially agricultural products, is divided into three conditions,

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namely: (1) water contained in free water conditions above the surface of the material (free water); (2) water contained in a bound state above the surface of the material (bound water); and (3) water that is bound and contained in the interior of the material (hydration water) (Ruhyat, Nanang, et al., 2019). Currently, the use of drying with the Fluidized Bed Dryer (FBD) model for granular materials has been widely operated in food and chemical processing (Hovemand, 2020). FBD has become one of the most prominent dryers in the industry (Yogendrasasidhar and Setty, 2019), generally used in the pharmaceutical and food industries to remove water in materials by continuously flowing hot air, thereby forcing mass transfer of water vapor in the material (Oliver et al., 2020); (Gagnon et al., 2021); (Wu et al., 2018); (Miranda et al., 2016); (Zhu et al., 2021). FBD can dry wet particles quickly and effectively (Poos and Szabo, 2017) and was developed commercially (Chuwattanakul and Ard, 2019). In the coffee drying process, the general term in the coffee industry is roasting. The treatment of temperature and roasting time has a very significant effect on the yield of coffee beans and the acidity of steeping coffee (Purnamayanti et al, 2017) as well as the mechanical physical properties of coffee beans (Nugroho et al, 2009).

Increasing the speed of drying air (3.15 m/s to 3.75 m/s) for coffee beans with the same length of time (4 hours), was able to reduce the water content of coffee beans by 36% (Sary, Ratna, 2016). Meanwhile, the standard temperature and roasting time are 200^{o}C/10 minutes (Edvan et al, 2016), 205^{o}C/44.7 minutes and 250^{o}C/29.6 minutes (Bambang Marhaenanto, et al, 2015). Analysis of the drying air temperature on the moisture content of coffee beans with a perforated plate fluidized bed dryer has been successfully carried out in this study. The duration of drying time with standard temperatures at 200 to 300 ^{o}C is carried out up to 30 minutes. The ability of a perforated plate fluidized bed dryer with an electric air heater to dry coffee beans, makes this tool a tool that speeds up the drying process, is practical in operation and is still able to maintain material quality, and can be used for a home industry scale, to be used by professionals.

METHODS

Fluidized bed dryers are one of the dryers that can be used more specifically, make coffee beans dark coffee, flavorful and make the coffee beans have a porous texture that is ready to be ground and extracted by adjusting the temperature according to the desired result. Coffee bean processing has a general condition that is judged by its quality level. Coffee beans which does not meet the requirement could not be included in coffee grading.

Table 1. shows the quality of the coffee beans and Table 2. shows the standard of coffee that has been dried or in terms of roasted coffee.

Table 1. General quality characteristics of coffee beans (rahardjo, 2012)

Characteristics	Quality Standards (%)
Seeds smell bad and smell bad	-
Water content	< 12.5
Dirt Content	< 0.5
Live Insects	None

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Table 2. General terms of roast coffee (SNI 01-298-1992)

Criterion	Unit	Condition
Condition (smell, taste)	-	Normal
Water content	% w/w	Max 4
Ash Level	% w/w	7-14
Ash Level	1 N NaOH/ 100 g	80 – 140
Caffeine Level	% w/w	2 – 8
Metal Contamination (Pb, Cu)	mg/kg	Max 30
Solids are not soluble in water	% w/w	Max 0.25
Bacterial count	Colony/ g	Max 300

The technical specifications of the Fluidized Bed Dryer with the type of perforated plate bed are shown in Table 3.

Tabel 3. Fluidized bed dryer specification

Description	Specification
Blower effisiensi	85%
Blower motor	186.5 Watt
Blower rotation speed	1420 rpm
Blower blade thickness	1 mm
Cyclone tank	None
Drying tank material	SUS and Aluminium
Function	Drying and Roasting
Electric coil heater	500 Watt
Temperature gauge	Digital type
Heater	Up to 300^{O}C
Bed Type	Perforated Plate Bed
Bed Diameter	0.15 m
Bed Area	0.018 m^2
Hole Bed Are	0.150 x 0,400 mm
Temperature digital	Thermocouple Type K
Timer Scale	Stopwacth

Based on the specifications of the blower in the test, the flow rate of the air flowing into the drying chamber is 5.44 m^3/s. The heat flow rate that occurs in the heater with a heater length of 0.3 m, a heater diameter of 0.011 m is 17.546; 630.17 W/m^3.These results are obtained based on the amount of heater power that works along the entire volume of the tubular heater, so in units of Watt / m^3.

Environmental air around the dryer is used as a medium for drying air to be flowed into the heater room by a blower with environmental air conditions in Table 4, as follows:

Table 4. Conditions of drying air media

Ambient Air Temperature			Dew point temperature	Saturation Vapor Pressure	Partial Vapor Pressure	Specific humidity	Enthalpy	Specific Volume	Enthalpy specific
Db	Wb	RH	Tdp	Psat	Pv	ω	H	v	h
^{0}C	^{0}C	%	^{0}C	mBar	mBar	kg/kg	kJ/kg	m^3/kg	kJ/kg
30	24	60	21	42	25.48	0.016	71.15	0.8799	40929.41

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Fluidization of coffee beans is desired to reduce or even eliminate the moisture content contained in them. The Fluidized Bed Dryer schematic in the drying system can be seen in Figure 1.

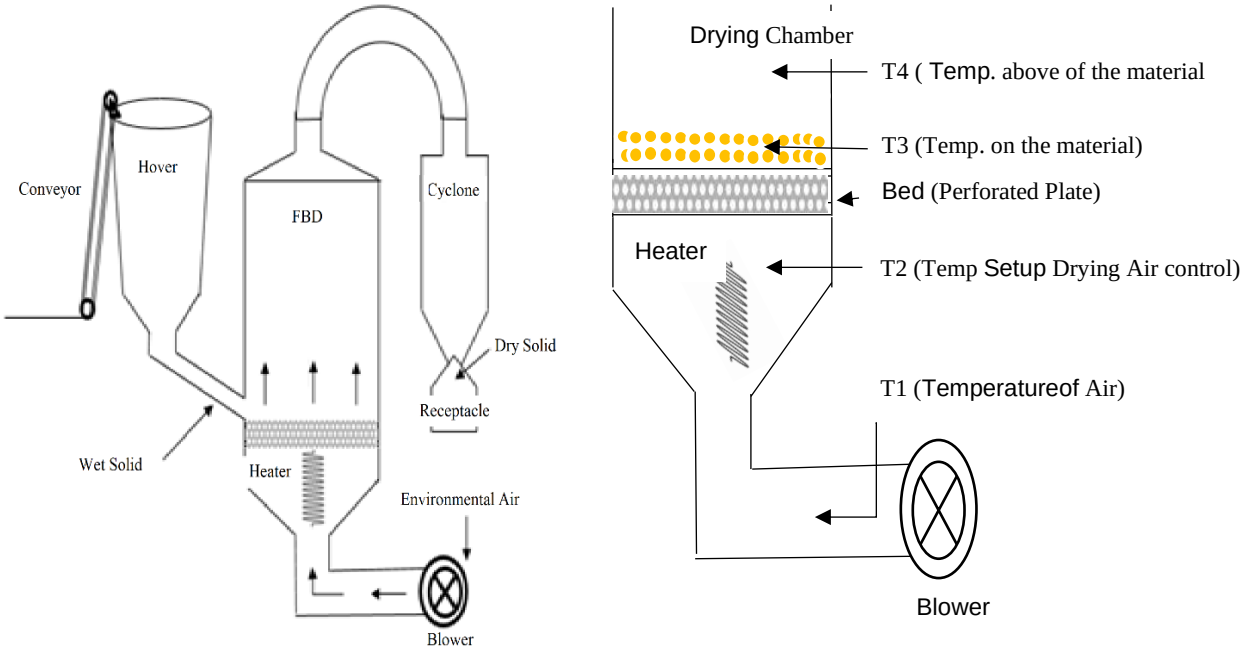

Figure 1. Schematic of drying process in Fluidized Bed Dryer

Figure 1 explains that Thermometer 2 (T2) is used to determine the temperature of the heater control air to heat the drying air supplied by the blower. Meanwhile, T1 is as described in table 3. Thermometer 3 (T3) is used to measure the temperature of the coffee beans during the drying process. The test uses 100 grams of coffee beans in each test, to find out how long it takes and how much water content is reduced by setting the heating temperature at 200, 250 and 300 ^{o}C in each test period of 30 minutes.

In the mechanical drying process, fresh air in the surrounding environment (T1) is sucked in and flowed by the blower fan, then through the air heater that has been set up at the control heater temperature (T2). Hot air moves to the bottom of the bed and penetrates the holes in the bed, then the coffee beans undergo a fluidization process. Coffee beans move due to the pressure of hot air currents. Fluidized bed requires relatively high air velocity to produce buoyancy. Air enters the bottom of the drying chamber, perforated plate with holes, from this chamber can be used to create a vortex of airflow. The hot air evaporates the water contained in the coffee beans (T3). This process is used as the drying process. At the end of the drying process, the hot air exits from the top of the drying chamber to the cyclone (T4). The cyclone separates the drying air from the coffee beans, the air exits the drying system, into the surrounding air where the dryer is located. But the coffee beans is still in the dryer chamber

The test results obtained in the form of water content of coffee beans at the beginning and end of drying by weighing the mass of coffee beans. The test data obtained were drying air temperature, coffee bean mass at the beginning and at the end of drying. The time required in the specified time range, while paying attention to physical phenomena, aromas and other things that occur during the drying process. The water content test uses the calculation of water content on a dry basis, the equation in determining the water content (Brooker D.B., F.W. Bakker-Arkema & C. W. Hall, 1974):

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$$M_{db} = \frac{Wt-Wd}{Wd} \times 100\% \quad (1)$$

Where:
M_{db} = dry base moisture content (%)
w_t= initial weight (kg)
w_d= final weight (kg)

The drying test process on the material is carried out with the following conditions:

a. Prepare the Fluidized Bed Dryer by performing function tests and ensuring the components can function properly.
b. Carry out the Running process on the Fluidized Bed Dryer by conducting a drying test without materials. The running process is carried out by an air drying process with a set temperature calibration starting at temperatures of 50, 100, 150, 200, 250, 300˚C with a time of 10 minutes for each increase in the set temperature.
c. The test uses coffee beans to find out how long it takes and how much water content is reduced with a set heater temperature of 200, 250 and 300ºC and a time of 30 minutes in each test.

RESULT AND DISCUSSIONS

Based on the tests carried out, the data is calculated how much power, air flow, enthalpy and flow rate that occur in the drying process with temperature. Drying research with Fluidized Bed Dryer using coffee beans tested are robusta from the Temanggung area, Indonesia. The following is the result of drying coffee beans for 30 minutes, as shown in Table 5.

Table 5. Coffee bean drying results for 30 minutes

Heater Set Temperature (ºC)	Coffee Bean Mass (g)	Temp. in the Coffee Bean (ºC)	Coffee bean water content (%)	Drying Capacity (kg/hour)	Amount of water vapor that moves (kg/hour)
0	0.1	31.5	14	0	0
200	0.094	83.8	13.94	0.012	0.0278967
250	0.093	130.0	13.93	0.014	0.0278795
300	0.089	140.5	13.89	0.022	0.0278106

Table 5 shows the drying capacity resulting from the drying process with this fluidized bed perforated plate bed. In testing using 100 g of material using temperatures set at 200, 250 and 300°C, it was able to reduce the moisture content of coffee beans caused by the specified drying temperature. Drying coffee beans with a Perforated Plate Fluidized Bed Dryer does not cause the coffee beans to be damaged or burnt, because the dry air received by the coffee beans is not as large as that provided by the heater. However, for 30 minutes, the coffee beans can be dried and reach a crack. Meanwhile, conventional tools require a longer time even with the same drying air temperature. Drying Capacity referred to in the table is the capacity of the coffee beans that can be dried by the dryer. While the amount of fluidized water vapor or water vapor that can be transferred from coffee beans.

The amount of drying air flow that occurs in the drying process can be shown in Table 6.

The rate of airflow through the pile of coffee beans with the temperature received by the coffee beans. while the rate of air flow after going through it, the air temperature above the pile

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of coffee beans is as large as that shown in Table 4. Changes in water content are not seen significantly in Table 5, but it can be seen that there is a change in the structure of the coffee beans, namely the coffee beans experience the first crack. The first crack event can be shown in Table 7. The remaining water content of coffee beans in this study was 13.89% as shown in Table 5. While in general the standard water content of SNI 01-2907-2008, which is 12.5%. However, the coffee beans in this test had the first crack.

Table 6. Presentation of air flow rate at heater set temperature

Heater Set Temperature (ºC)	Minute Drying	Temp. in the material (ºC)	Air Temp. above the material (ºC)	Air Flow Rate in the material (kJ/kg.m^2. ºC)	Air Flow Rate above the material (kJ/kg.m^2. ºC)
200	30	83.8	75.6	0.507	0.543
250	30	130.0	86.0	0.524	0.716
300	30	140.5	102.5	0.478	0.644

Table 7. Presentation of first crack

Heater Set Temperature (ºC)	Minutes First Crack	Temp. in the material (ºC)	Photo
200	30	83.8	
250	30	130.0	
300	20	107.6	

First crack is characterized by the sound of breaking or the first cracking stage of raw coffee beans that are still green (coffee beans), which are usually identical with color changes, starting from green coffee beans, then yellow and then brownish black or even dark black. Depending on the temperature and time used during the coffee drying process. When the coffee beans begin to turn brown in the yellowing process, there is a kind of mixing of carbon dioxide gas and water that both evaporate in the coffee beans. When the pressure of these two elements reaches its peak, the coffee beans will begin to open and it is at this time that the coffee beans will crack. This process is usually recognized by a crunchy sound, such as the sound of a nut cracking. After cracking coffee beans, it tends to be softer on the surface, but not overall. At this stage too, all familiar characters and flavors of coffee beans will begin to form (Masdakaty, 2015), (Feriyanto, etc., 2020), (Feriyanto etc., 2021)

With this fluidized bed perforated plate bed, the change in color of the coffee beans occurs at the temperature of the control heater set at 200°C, namely the light roast level, at a

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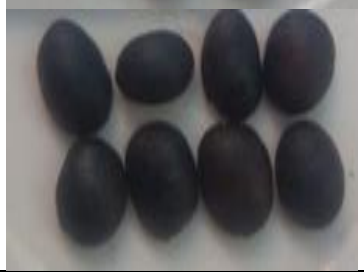
temperature of 250°C, which is the medium roast level, and at a temperature of 300°C, which is the dark roast level. As shown in Table 8.

Table 8. Presentation of coffee bean maturity level

Heater Set Temperature (ºC)	**Temp. in the material (ºC)**	**Drying Result**	**Maturity level**
200	83.8		*ligth roast*
250	130.0		*medium roast*
300	107.6		*dark roast*

The difference in dry air temperature from the heater to the temperature of the coffee beans occurs due to the air pressure from the blower to create fluidization conditions in the coffee beans, so that the heater heat temperature received by the coffee beans can be absorbed evenly.

Drying air discharge is 5.44 m^3/s, within 30 minutes and with a normal drying temperature (200 to 300 ºC), this fluidized bed perforated plate bed can be equivalent to a drying machine for industrial products. The relatively short time can cut the drying time which is 4 hours (Sary, Ratna, 2016), or other mechanical drying which reaches 20-24 hours of drying (Natawidjaya, 2012). Generally, the time required for the coffee drying or roasting process takes about 15 – 30 minutes with a high-energy machine, namely 1.000 to 2.500 Watts, which aims to maintain the quality of coffee in terms of coffee color and most importantly in terms of the desired taste. However, the water content achieved has not yet reached the standard water content of SNI 01-2907-2008, which is 12.5%.

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CONCLUSION

The level of maturity of coffee beans is achieved by reducing the water content of coffee beans by 0.11%. These results indicate that the drying capacity is 0.022 kg/hour, which is 0.0278106 kg/hour of water vapor transferred within 30 minutes of drying. The difference in temperature between the coffee beans and the control heater temperature occurs more because of the air flow coming out of the blower, making the difference in the drying temperature of the coffee beans. This is used to make the drying process happen more evenly on the coffee beans. First crack as the stage of changing the structure and color of the coffee beans, obtained in the drying process using a Fluidized Bed Dryer with a perforated plate bed, at a control set temperature of 200°C (83.8°C for coffee beans) for light roast, at a temperature of 250 °C (130°C for coffee beans) for medium roast, and at a control set temperature of 300°C (107.6°C for coffee beans) for dark roast.

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