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PERFORMANCE OF FLUIDIZED BED DRYER USING HOT AIRFROM PYROLYSIS APPARATUS IN RICE DRYING

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ABSTRACT

Rice is one of the main foodstuffs in Indonesia. Freshly harvested rice usually contains 20-25% water (wet basis). The water content in rice needs to be removed up to 12-14% to avoid damage caused by microbes and fungi. One of the methods to remove the water content in rice is drying. In this study, rice drying was carried out using a fluidized bed dryer with a hot air source originating from the remaining heat of the pyrolysis apparatus. The operating conditions in this study were hot air velocities of 8 m/s, 9 m/s and 10 m/s, air temperatures of 50 ^{O}C, 60 ^{O}C and 70°C, and a bed height of 2 cm, 4 cm, 6 cm. This study aims to examine the effect of operating conditions on rice drying using a fluidized bed dryer. Drying was carried out with an initial moisture content of 26% of the rice. The results showed that drying air velocity of 10 m/s, drying air temperature of 70°C and bed height of 2 cm were the best-operating conditions in this study with a drying time of 40 minutes with the final moisture content of 5.92% and the highest drying rate of 0.0422 g/cm^2.min.

Keywords: rice, water content, drying, fluidized bed dryer, drying rate.

INTRODUCTION

Agriculture is an important sector in Indonesia's economic activities [1]. Rice is one of main algiculture products which is processed into rice [2]. In 2014, the amount of rice production in Indonesia was 70,846,465 tons and increased in 2018 to 83,037,150 tons [3]. The need for rice increases with the increase in population every year.

Freshly harvested rice has water content among 20-25% (wet base) [3]. In order to be store, water content in rice should be decreased to 12-14 % to avoid the damage caused by microbes and fungi [4]. One of the methods to decrease the moisture content in rice is by drying.

Drying is a process of heat transfer from medium and solid material, where solid material obtains heat convectionally and vaporizes the water contained in the material [5]. Currently, rice drying method uses two methods, namely drying by utilizing solar energy and drying with mechanical tools [6]. Mechanical dryers require energy to heat the dryer, heat the material, vaporize the material water, as well as move the heating air [7]. One of the most developed mechanical dryers is a dryer with fluidized bed type [8].

Fluidized bed dryer is used in various industries as mining, food, chemical and pharmaceutical industries [9], [10]. This dryer is widely used due to its several advantages such as a high drying rate which provides more contact of gas and solids and increases mass and heat transfer as well as shorten drying time [11-13].

Fluidized bed dryer requires high investment costs and operating costs due to considerable energy requirements. Previous research has used dryers with heat sources from the conversion of biomass and electricity, thus requiring relatively expensive operational costs. This study used fluidized bed dryers by utilizing heat from pyrolysis apparatuss which minimized the operational costs of energy sources. Performance testing of fluidized bed dryers such as dryer air speed, dryer air temperature and fluidized bed height is performed to obtain proper fluidized bed dryer operating conditions.

MATERIALS AND METHODS

Rice obtained from Martubung area, Medan Labuhan, Medan, Sumatera Utara. One unit of fluidized bed dryer integrated into pyrolysis apparatus was used in this study. In the process of drying rice, the equipment consists of three main components, such as drying chamber, pyrolysis apparatus and blower. Equipment set scheme in this study can be seen in Figure-1. Dryer chamber in dimensions of 50cm x30cmx100 cm equipped with cylinders where rice samples are placed. Pyrolysis apparatus with a stainless-steel tank diameter of 80 cm and height of 120 cm is used to produce charcoal and liquid smoke. Heat from biomass combustion process is flowed to fluidized bed dryer as a source of hot air in rice drying. Blowers with specifications of 220 volts, 650 watts and speed of 0-15,000 rpm equipped by air speed controllers are used to drain and variation of air speed to the dryer chamber. Other equipment for data collection tool consisting of hygrometer, anemometer, electronic balance, and oven.

Research Procedures

The rice sample is weighed with the bed height of 2 cm, 4 cm, and 6 cm and then put in the cylinders. Then the blower is turned on to drain hot air with temperatures variation of 50 ^{O}C, 60 ^{O}C and 70 ^{O}C and the variation in air speed is set at 8 m/s, 9 m/s, and 10 m/s then the cylinders containing rice is placed into the drying chamber. Hot air temperature comes in, hot air temperature comes out, relative humidity (RH) comes in and RH comes out of the cross section of the cylinders and rice weight is measured every 5 minutes. The data obtained is recorded and then processed to obtain moisture ratio and drying rate.

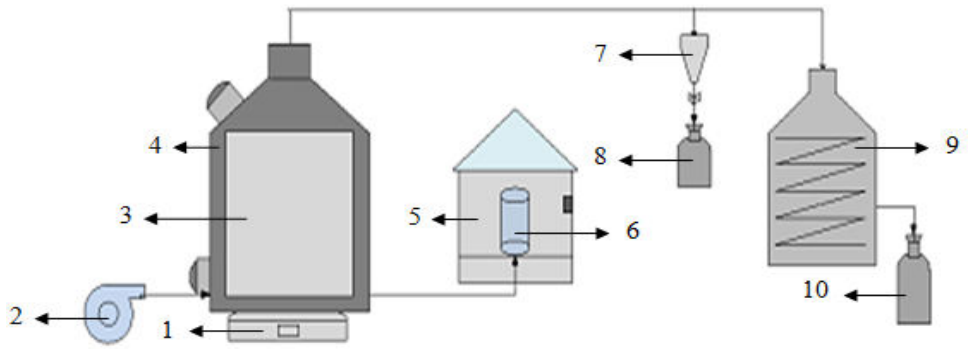

Figure-1. Fluidized bed dryer scheme by utilizing hot air from pyrolys is equipment in rice drying.

Note the picture:

1. Gas Heating Furnace
2. Blower
3. Pyrolysis apparatus
4. Hot Air Chamber
5. Drying Chamber
6. Cylindrical Bed
7. Trap
8. Tar Container Tank
9. Cooling Tank
10. Liquid Smoke Container Tank

RESULTS AND DISCUSSIONS

Minimum Fluidization Speed (Um_f) in Rice Drying

This study obtained a minimum fluidization speed (Um_f) at bed height of 2cm, 4cm; 6 cm are 0.382 m/s, 0.498 m/s, 0.573 m/s respectively. Therefore, the dryer air speed used was 14 times greater than the minimum fluidization rate. At a minimum speed (Umf), the driving force on the rice is approximately equal to the weight strength of the rice. The rice will begin to be fluidized because the minimum velocity (Um_f) is the lowest limit of air velocity required for the fluidization process [14]. At that speed, the fluidization process does not run perfectly because the rice is only slightly moved by the driving force of the dryer air so the rice requires higher air velocity than the minimum fluidization rate.

Effect of Operating Conditions on Moisture Ratio

Effect of Air Speed on Moisture Ratio

Figure-2 shows that with increasing the drying time the moisture ratio decreases until it reaches equilibrium. In high air velocity, the drying process is faster because the air with high velocity is easy to fluidize rice therefore the water on the surface of the rice can be carried by the dryer air immediately [12]. However, in Figure-2 it can be seen that the difference in the decrease in moisture ratio at air speed of 8m/s, 9m/s, and 10 m/s is not very noticeable because the small differences in air velocity hence hardly show the effect. At a speed of 8 m/s obtained final moisture content is 5.97% in the 45th minutes, at air velocity 9 m/s obtained final moisture content is 6.02% in the 40th minutes and at velocity 10 m/s obtained final water content is 5.92% in the 35th minutes.

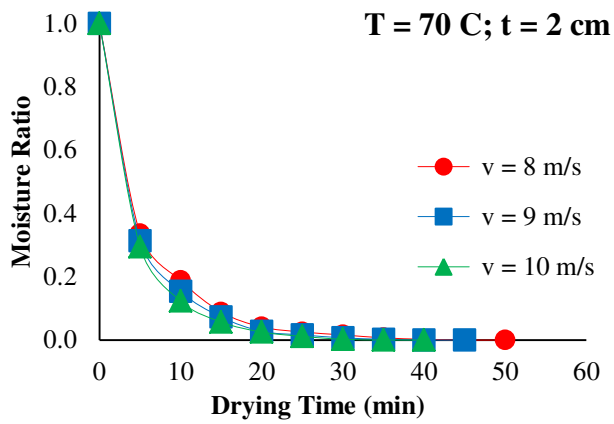

Figure-2. Effect of drying time on moisture ratio at air speed variationwith air temperature at 70 ^{0}C and bedheight at 2 cm.

Effect of Temperature on Moisture Ratio

Figure-3 shows that higher temperatures result in a faster decrease in moisture ratio than lower temperatures. At an air temperature of 70^{0}C the equilibrium water content is obtained in the 35th minutes with a final water content of 5.92% while at air temperatures of 60^{0}C and 50^{0}C the equilibrium water content is obtained at the 45th and 55th minutes with a final water content of 5.84% and 6.10%. At higher temperatures, heat is given by the dryer air to larger materials so that with the heating of the surface of the material, the water contained in the rice will reach out the surface of the rice in shorter time [12,15].

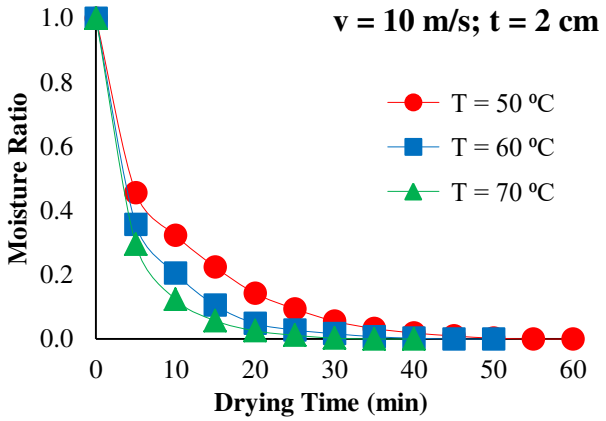

Figure-3. Effect of drying time on moisture ratio at air temperature variation with air velocity at 10 m/s and height at 2 cm.

Effect of Bed Height on Moisture Ratio

Figure-4 shows that the moisture ratio continues to decrease over time until finally the moisture content reaches equilibrium. At height bed 6 cm, the decrease in water content less than the height of 4 cm and 2 cm. At the height of the bed 6 cm obtained rice equilibrium water content in the 65th minutes with a water content of 6.77%, at the height of the bed 4 cm obtained rice equilibrium water content in the 45th minutes with a water content of 6.65% and at the height of the bed 2 cm obtained equilibrium water content at the 35th minutes with a water content of 5.92%. The thicker the dried bed, heat energy consumption in drying would be higher, while the drying condition on each bed is the same so that the decrease in water content in the thicker bed will be longer [16]. It is shown in Figure-4 that at the height of the bed 2 cm shorter drying time is 40 minutes than the height of the bed 4 cm and 6 cm that is 50minutes and 70 minutes.

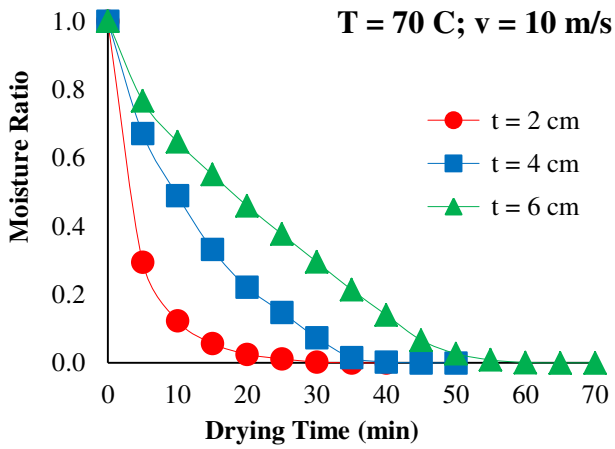

Figure-4. Effect of drying time on moisture ratio at bed heigh tvariation with air velocity at 10 m/s and the temperature at 70 ^{O}C.

Effect of Operating Conditions on Rice Drying Rate

Effect of air speed on Rice Drying Rate

Figure-5 shows that at the beginning of drying, the drying rate increases then decreases and eventually constants. The drying rate at the end of the drying process is slower due to the less amount of moisture remaining in the material. Figure-5 shows that the difference in drying rate is insignificant because the difference in air velocity of the dryer used is relatively small so it takes a considerable difference in the dryer's air speed to evaluate its effect on the drying rate. The highest drying rate was obtained in the 5th minutes at an air speed of 10 m/s is 4.22x 10^{-2} g/cm^2.min, while at air speeds of 8 m/s and 9 m/s the drying rate was 3.99 x 10^{-2} g/cm^2.min and 4.1 x 10^{-2} g/cm^2.min. The higher of the air velocity, the drying rate will increase due to the well fluidized material resulting in the process of mass transfer and heat evenly distributed throughout the dried material [11].

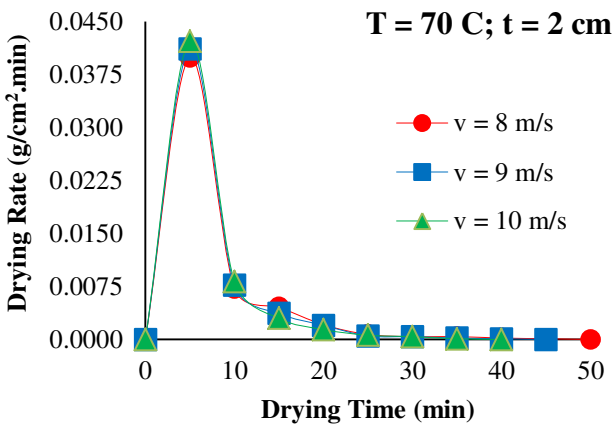

Figure-5. Effect of drying time on rice drying rate at air speed variation with temperature at 70 ^{0}c and bed height 2 cm.

Effect of Air Temperature on Rice Drying Rate

Figure-6 shows that the drying rate increases and then decreases and eventually constants. The drying rate at 70 °C is 4.22 x 10^{-2} g/cm^2.minwhileat60 ^{O}Cand50 ^{O}Care3.83x10^{-2} g/cm^2.min and 3.32 x 10^{-2} g/cm^2.min respectively. At a drying temperature of 70 ^{0}C the relative humidity (RH) value of the dryer air is 15%, lower than at 60°C and 50 ^{O}C by 17% and 20% respectively so that the air capacity in accommodating water vapor will be greater at the lowest RH. The higher the dryer air temperature, the RH of the air will be lower, thus increasing the process of mass transfer to eliminate the water content in the material [11, 17]. At 70°C the drying rate is higher and the shortest drying time is 40 minutes. Drying time require for temperatures 60 ^{0}C and 50 ^{0}C are50 minutes and 60 minutes.

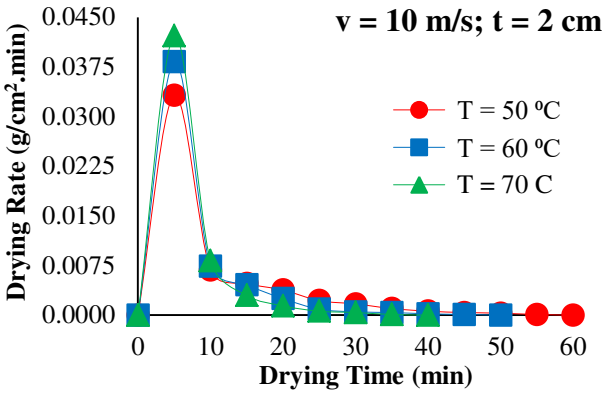

Figure-6. Effect of drying time on drying rate at air temperature variation with air velocity at 0 m/s and bed height at2 cm.

Effect of Various Bed Height on Rice Drying Rate

Figure-7 shows that the drying rate increases at the beginning of drying then tends to decrease and eventually constant. Drying rate at bed height 2 cm higher than bed height 4 cm and 6 cm. In a higher bed height obtained a lower drying rate at 5 minutes drying with the drying rate at the height of the bed 6cm is 3.99×10^{-2} g/cm^2.min,lower than the height of bed 4 cm and 2 cm are 4.13 x 10-2 g/ cm^2.min and 4.22 x 10^{-2} g/cm^2.min respectively.

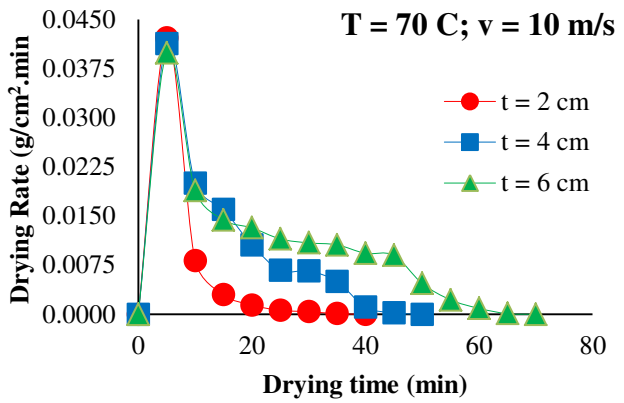

Figure-7. Effect of drying time and on drying rate at various bed height with air temperature at 70^{0}C and air velocity at 10 m/s.

Material mass is heavier causing the fluidization process is not maximized due to the particles in the drying space getting tighter so that the process of transferring mass from the dried material to the air becomes slower therefore the drying rate is lower and the drying time is getting longer[16]. At the height of the bed 2 cm higher drying rate and shorter drying time is 40 minutes while at the height of the bed 4 and 6 cm the drying time required is longer which are 50 and 70minutes.

Drying rice Characteristics using Fluidized Bed Dryer

Figures 8, 9 and 10 show that the rice drying process there are an increase in the drying rate at the beginning of the drying process and then the drying rate decreases rapidly and finally the drying rate decreases slowly along with the decrease in the moisture ratio in rice.

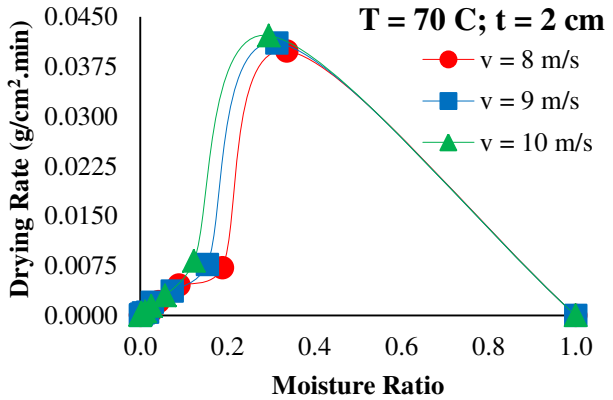

Figure-8. Effect of moisture ratio on drying rate at variations of air velocity with air temperature at 70^{0}C and bed height 2cm.

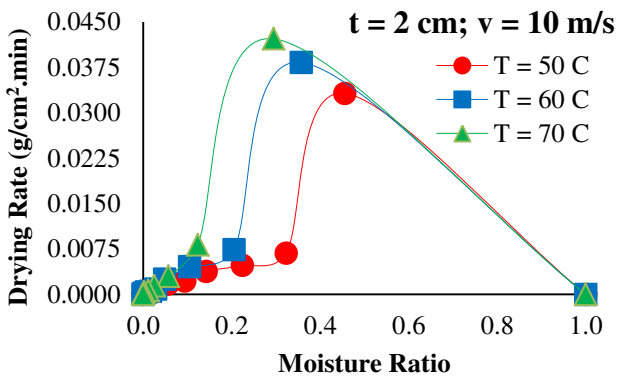

Figure-9. Effect of moisture ratio on drying rate at temperatures variations with air velocity 10 m/s and bed height 2 cm.

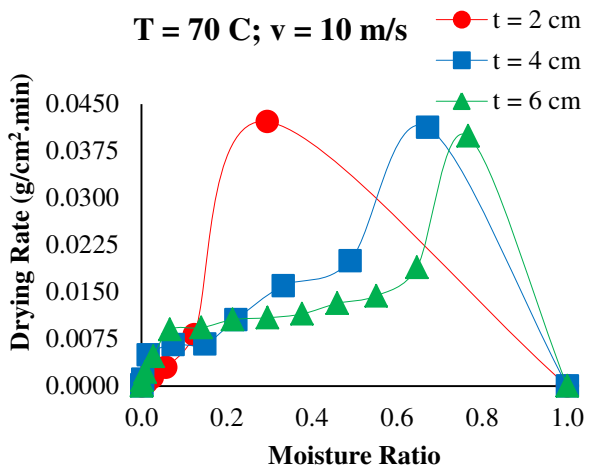

Figure-10. Effect of moisture ratio on drying rate at bed height variations with air velocity 10 m/s and air temperature 70^0C.

This research conducted at different air speeds of 8m/s, 9m/s, 10m/s (Figure-8), different air temperatures are 50^0C, 60^0C, 70^0C (Figure-9), and different bed heights of 2 cm, 4 cm, 6 cm (Figure-10) are obtained 2 periods of drying rate namely the drying rate period rises and the drying rate period decreases where the period of constant drying rate is insignificant. The period of constant drying rate does not indicate all heat energy is used for the removal of free moisture content on the surface of the material. It shows the existence of a period of increased drying rate and the release of moisture content tied to the dried material as seen by the existence of a period of decreased drying rate[18].

CONCLUSIONS

The conclusions obtained in this study are:

- Small differences in air velocity do not significantly affect the decrease in moisture ratio and drying rate in rice.
- Drying air temperature affects the decrease in moisture ratio and drying rate where the higher the dryer air temperature then the decrease in moisture ratio will be faster and increase the drying rate
- Bed height affects the decrease in moisture ratio and drying rate where the lower the height of the bed, the decrease in moisture ratio will be faster and increase the drying rate.
- The best drying process is at a temperature of 70^0C, bed height of 2 cm with a dryer air speedof10m/slasts with a drying time of 40 minutes with a final moisture contentof5.92 %.
- The characteristics of rice drying using Fluidized Bed Dryer have two drying periods, the drying rate period increases and the drying rate period decreases.

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