Characteristic of Unhulled Rice Drying on Swirling Fluidized Bed Dryer

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Abstract. The most important thing of drying is removing moisture from materials towards the equilibrium moisture with normal ambient air. One of the drying ways is to use Swirling Fluidized Bed Dryer (SFBD) for drying materials in the form of granules or seeds. The experiment of Swirling Fluidized Bed to dry out unhulled rice was carried out. This research aims to find the characteristics of unhulled rice after the drying process and performance of SFBD. Swirling fluidized bed dryer with 15° angles of blade inclination, 650 mm of plenum chamber depths, and 30 blades were used to dry out unhulled rice 1 kg, 2 kg and 3 kg. In this study, 16.2 m/s hot air velocity and 55 °C were used to dryer out unhulled rice as long as 45 minutes. Initial moisture content of unhulled rice are 24.1% for 1 kg, 23.6% for 2 kg and 23.7% for 3 kg and final moisture content were 11.68%, 13.13% and 12.13% respectively. The evaporated mass of water was 123.2 gr, 217.5 gr, and 356.1 gr. The plenum pressure on the capacity unhulled rice of 1, 2, and 3 kg are 59.6 mmH₂O and 16.7 mmH₂O, 78.5 mmH₂O, respectively. The drying chamber pressure on the capacity unhulled rice of 1, 2, and 3 kg are 35.1 mmH₂O, 79.9 mmH₂O, and 37.5 mmH₂O, respectively.

1. Introduction
Drying is a common method used to obtain a longer shelf life of material from an agricultural product such as grains. Drying is the process of vaporizing the water content of an ingredient into the air. [1]. The drying process to reduce the moisture content of seeds or agricultural products is very important [2] because it determines the next result of an ingredient. Parameters that affect the drying process are hot air flow speed, temperature, pressure, and relative humidity [3]. Levy et al. [4] report that increasing superficial velocity and dry air temperature would increase the drying rate on coal drying process by the fluidized bed method. Simanjuntak et al. [5] mention that higher temperature and fluidization velocity will increase the drying rate on coal drying process by using the swirl fluidized bed. Hot air flow towards drying chamber has a dominant effect on removing surface moisture of material [6]. The less the amount of moisture in the air causes the lower relative humidity, consequently, more and more water from the grain is evaporated into the air, [7]. [8] explain that increasing the humidity ratio would decrease the drying rate.

Drying performance is strongly dependent on the drying methods and conditions used [9]. Various types of dryers and methods to decrease moisture on the material, traditional method till artificial drying methods by using a dryer. But both of these methods have advantages and disadvantages of each. The open sun drying is very simple and cheap but this method has many limitations namely low quality products, low drying rates and constrained by the weather, [10][11]. Chokphoemphun and Suriya
Chokphoemphun [2] stated that field drying is the easiest way. However, this method is also the most difficult to control environmental factors. The grain drying system in a natural way has many disadvantages such as depending on the weather and needing a long time. While used artificial dryer anytime the drying process can be carried out with a drying capacity that can be adjusted to the needs, but requires greater costs than manual drying because it requires energy to heat the drying chamber [12]. Yahya [10] stated that the mechanical dryer has the disadvantage that energy is used to heat the drying air for drying operation still depends on fossil fuels and consumes much energy, while the fossil fuels are expensive and steadily increasing, as well as their sources are limited.

The drying process can be done by exhaling hot air into or over the dried material [1]. One method of drying in this procedure is fluidization. Fluidization is a process whereby the pile of solid particles placed on the top of the grid or hollow plate starts to lift upward because of the flow of gas or fluid exhaled from below [13]. The gas velocity has a dominant influence on the process of surface water vaporization or on removing surface moisture. However, the gas velocity does not affect the particles that have high internal resistance to moisture displacement [6,14].

In the fluidization system, high-speed hot air comes in direct contact with the material to be dried, so the particles have a very high contact surface area with hot air, which makes the fluidized bed dryer provide heat and very high mass transfer [2]. This fluidization drying method includes the direct way process. The fluidized drying method has several advantages namely (i) the rate of heat and mass transfer is quite high because of the contact between the hot water and the dried material, (ii) uniform temperature and moisture, (iii) simple construction, (iv) high dryer capacity, (v) easy material transport inside the dryer, (vi) easy of control and (vii) low maintenance cost [6,15,17].

In drying with the swirling fluidization method, hot air comes in direct contact with the material, exhaled hot air flow also lifts and flies the object while spinning around the center body in the drying chamber. Drainage of fluidization systems has been done a lot for grains such as pepper or other materials such as coal and oil palm bunches. Yahya et al. [16] has designed, made, and evaluated a solar-assisted fluidized bed dryer connected to a biomass furnace. This drying system can reduce the water content from 20% to 14% (w.b.) within 796 s with an average temperature of 78 °C. Prabowo et al. [8] use SFBD to dry coal with variations in the angle of guide vane (AGV) or directional angle. Angles of 10° produce faster drying and produce less moisture content than vane guides with angles of 20° and 30°, namely 12.5%, 14.66%, and 18.01%, respectively. Ozbey and Soylemez [18] reported that drying was increased up to 38% compared to the non-swirling fluidized bed.

2. Methodology

2.1. Experimental set-up

This research was conducted by experimenting with unhulled rice drying using SFBD. Drying capacity consists of 1 kg, 2 kg, and 3 kg. The drying time is 45 minutes. Schematic diagrams of a laboratory-scale swirling fluidized-bed dryer (SFBD) system are shown in Figure 1. The experimental setup consisted of a swirling fluidized bed dryer with 1000 mm of height, 300 mm of diameter with acrylic material, 15° angles of blade inclination of annular blade distributor, 650 mm of plenum chamber depths with cone center body, 30 blades, two centrifugal blowers 3.7 kW, 6 kW electrical fin heater, and two hot air inlet. Drying air velocity on the annular distributor is 16.2 m/s. 55°C temperature was used to dryer out unhulled rice for 45 minutes.

Air from the blower is exhaled through the connecting pipe and passes through the heater so that the air temperature rises before entering the plenum chamber. The distributor directs hot air in the plenum chamber to the drying chamber with a tilt angle of 15°. The distributor angle slope forms the airflow that will surround the cone center body in the drying chamber. This airflow blows the rice that is fed through the inlet. The trial material was prepared as many as ten samples for each capacity and assumed the grain's initial moisture content for each variation of the same samples. The moisture content, relative humidity, and pressure are measure at times 1, 2, 3, 4, 5, 10, 15, 25, 35, and 45 minutes. Pressure measurement points consisting of points a, b, c, and d are shown in Figure 1.
Figure 1. Schematic diagrams of a laboratory scale swirling fluidized-bed dryer (SFBD)

Figure 2. Unhulled rice in drying chamber

Table 1. Measurement instruments

| Instrument    | Measured parameter | Range          | Resolution | Accuracy and tolerance |
|---------------|--------------------|----------------|------------|------------------------|
| Moisture analyzer | Moisture content | -              | -           | 0.001%                 |
| DHT22        | DHT22              | -40 – 80 °C    | 0.1 °C     | ±0.5 °C                |
|               |                    | 0 – 100% RH    | 0.1% RH    | ±2% RH                 |
### 3. Result and Discussion

Drying analysis is conducted from three sides namely from particle side, air dryer side and from device side. Decreasing the moisture for bed weight variation during every minute measurement is particle side analysis. Temperature and relative humidity are analyses for air dryer side. In the side of device, pressure drop analysis has been carried out on the bed distributor. Figure 2 shows that moisture content drops significantly until 5 minutes because of the amount of water in the material is large and then slower due to a decrease of moisture inside the particle. It can be said that the first five minutes is the early drying stage. According to Taib et al. [19] is called the period of drying rate constant. During the first stage of drying, mostly surface moisture is removed from the paddy [20]. After nine minutes, moisture content saw relatively consistent due to lower moisture inside of the particle. The stage can be said as the second drying stage, which is called the period of drying rate decreases [19]. The drying process with a larger mass evaporates more water than the smaller one. Increasing unhulled rice weight means enlarging the amount of water that should be removed [1]. The evaporated water mass in this study on various drying capacities (1, 2, 3 kg) is 123.2 gr, 217.5 gr and 356.1 gr respectively.

![Figure 3. Moisture content of unhulled rice during drying process](image)

#### 3.1 Effect of bed loading on temperature and relative humidity

The drying temperature is set at 55 °C for the start of feeding grain into the drying chamber while the average humidity in the drying chamber is measured 30%. These two variables are inversely proportional during the drying process. Figures 4, 5, and 6 show the effects of variations in the material fed into the drying chamber on temperature and humidity for 45 minutes of drying. Significant changes in temperature and humidity occur in the first 5 minutes of drying. The temperature for the drying load...
1 and 2 kg, the first 3 minutes decreased from 55 °C to 51 °C and 50 °C, respectively, and then tended to rise until the end of drying. Humidity increases from 30% to 35% and 40%, respectively, and then tends to decrease to the initial drying conditions. Whereas at the drying capacity of 3 kg, the temperature decrease occurred during 5 minutes of drying, namely from the setting of 55 °C to 47 °C, and the humidity of the drying room air increased from 30% to 42%. The decrease in temperature caused by the absorption of heat by the material to release water from the material into the surrounding air. While the increase in air humidity during the drying process shows the increase in water vapor contained in the air coming from the dried material, after 5 minutes of drying, the temperature tends to increase, and the relative humidity drops. When the particle's water content has begun to decrease, the chamber's temperature will back up. The relative humidity will return to the initial conditions of drying as a result of rising temperatures. Figures 4 and 5 for capacities 1 and 2 kg, temperature, and humidity depend respectively on the 45 minute. In contrast to the 3 kg capacity of the 35 minute temperature, and relative humidity still increased and decreased for each of them until the minute to 45.

![Figure 4](image.png)

**Figure 4.** Temperature and relative humidity in the drying chamber during the drying process for 1 kg of mass
Figure 5. Temperature and relative humidity in the drying chamber during the drying process for 2 kg of mass

Figure 6. Temperature and relative humidity in the drying chamber during the drying process for 3 kg of mass

3.2 Effect of bed loading on pressure in the plenum and drying chamber

The experimental results show that increasing the mass of the unhulled rice causes increased pressure on the plenum and the drying chamber due to the height of the bed will be greater along with the increasing mass of the unhulled rice. The higher expanse height of the bed will inhibit the air through the gap between the unhulled rice. The blower performance will decrease if the pressure increases, which causes reduced air discharge in the plenum chamber and affects the reduced air velocity through the bed. In Figure 7, showing the relationship between load and pressure in the plenum and drying chamber. Figure 7 shows that the addition of a load from 1 kg to 2 kg results in the increased pressure greater than load 2 kg to 3 kg, this occurs in the plenum and drying chamber. On the other hand, the pressure drop
differences (plenum chamber - drying chamber) is not significant that are 43 mmH2O, 43.4 mmH2O, and 42.5 mmH2O for loads of 1 kg, 2 kg, and 3 kg respectively.

![Figure 7. Relationship between load and pressure in the plenum and drying chamber](image)

4. Conclusion
Unhulled rice drying using laboratory-scale SFBD has been carried out and able to produce good grain for storage. A decrease in significant moisture occurs in the first 5 minutes of drying due to the moisture that is still much in the unhulled rice. Drying unhulled rice with each capacity of 1, 2, and 3 kg has an average initial moisture content of 24% and dried for 45 minutes with a final moisture content of 11.68%, 13.13% and 12.13% for capacities of 1, 2 and 3 kg respectively. Drying with a capacity of 3 kg evaporates water which is greater by 356.1 gr compared to 2 kg capacity of 217.5 gr and 1 kg capacity by 123.2 gr respectively. However the largest percentage of water evaporation occurs at a capacity of 1 kg which is 12.3% while mass 2 and 1 kg of 10.875% and 11.87%. The relative humidity of the drying chamber is greatly influenced by the mass of water that is evaporated from the dried material and also the relative humidity of the surrounding environment. The relative humidity in the drying chamber rises as the unhulled rice begins to be fed, and the temperature decreases.

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