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## Performance Study of Fluidized Bed Dryer with Immersed Heater for Paddy Drying

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**Abstract.** This paper investigated the performance of fluidized bed dryer with immersed heater for paddy drying. The influence of drying temperature and the temperature of immersed heater on drying curve, thermal efficiency, and quality of paddy was investigated. The fixed operating conditions are drying time of 60 minutes, paddy weight of 200 grams and the air velocity of 0.4 m/s. The variables are drying temperature and the temperature immersed heater namely 50, 60, 70, 80, 90 ( $^{\circ}\text{C}$ ). The results show addition immersed heater will increase drying rates. No constant drying rate was found. Increasing the temperature will decrease the utilized energy. The thermal efficiency decreases with increasing temperature. The increasing temperature and use immersed heater will decrease the residual moisture content, increase damaged and yellow paddy grain, and increase red paddy grain.

### 1. The first section in your paper

Paddy is main food for Indonesian people. Normally, paddy is harvested with high moisture content 32% (db., dry base). Then paddy is predisposed to deteriorate rapidly. For tropical countries, it is an extremely serious problem due to high humid air condition can accelerate an excessive mould growth, and yellowing of grains [1]. Therefore, paddy has to be dried to maximum 16% for storage.

Many researches were conducted to get the best method drying for paddy. Mainly Fluid Bed Dryer (FBD) was chosen, in which other dryer methods are Spouted Bed Dryer (SBD), Pneumatic Dryer, Tray Dryer, Inclined Bed Dryer, Impinging Stream Dryer, and Heat Pump Dryer. Paddy drying consumes huge energy and is sensitive to product quality [2-3]. Mainly, drying paddy is performed by a fluidized bed dryer for due to (1) uniform product quality due to complete mixing, (2) high drying capacity due to high ratio of air mass to mass of product [4-5]. The drying rate of paddy in fluidized bed dryer was affected by drying air temperature and bed thickness [6]. The maximum drying temperature in fluidized bed was suggested as 115  $^{\circ}\text{C}$  to reduce moisture to 24-25% (db) for ensuring rice quality [4]. The drying temperature in pulsed fluidized bed should be less than 145  $^{\circ}\text{C}$  for initial paddy moisture content of 28% (db) to maintain rice quality [7]. A new model of rough rice drying in fluidized bed was successfully developed [8]. The energy consumption of commercial fluidized bed dryer decreased with increasing paddy moisture content and drying temperature [9]. Paddy drying is a highly energy-intensive process and sensitive to the quality of rice [10]. They recommend that the maximum drying temperature to reduce paddy moisture down become 22% (db) in a single pass is 150  $^{\circ}\text{C}$  to achieve acceptable quality of product. No impact of air velocity on drying characteristics, and employing the tempering stages substantially reduces the energy consumption [3]. Intermittent drying



of paddy was investigated to saving energy [11]. The moisture effective diffusivity and glass transition temperature changed during paddy drying [12]. Energy and quality aspects for fixed deep bed drying of paddy also were investigated [13].

However, the main feature of paddy drying is mainly paddy drying is only in the second-stage drying phase, namely the diffusion phase. So the effort for energy efficiency is more directed at the acceleration of drying time. This has been attempted by some previous researchers with recycling air drying [4], intermittent drying method [11], and tempering method [3]. Meanwhile, other researchers tried to accelerate the drying rate on fluidized bed drying using the method of addition of immersed heater [14]. Therefore, this paper investigated drying paddy in fluid bed dryer with immersed heater. The drying kinetics, thermal efficiency and the product quality was measured. The variable is temperatures of drying.

## 2. Method

Paddy firstly is prepared by soaking in water and keeps in a refrigerator at a lower temperature to obtain the initial grain moisture content, i.e. 21.1% (wet base). The initial paddy moisture content was analyzed by oven for 24 hours at a temperature of 105°C. Figure 1 shows the apparatus set-up of lab scale batch fluid bed dryer with immersed heater in column of fluidization zone. The experiment starts by measuring the minimum fluidization velocity. Then, the intake air velocity is set 2 times above the minimum fluidization velocity. Inlet air temperature ( $T_{gi}$ ) varied namely 50, 60, 70, 80 and 90°C. The process starts with an experiment that will turn on the blower air. Furthermore, air heater is positioned as desired, e.g. 50 °C. After drying air temperature reaches the temperature desired, 200 g paddy material is inserted into the bed. The temperature controller TIC (below distributor) maintains inlet air temperature at the desired level. During the experiment, inlet air temperature, inlet air humidity, outlet air temperature, and outlet air humidity is measured each 5 minutes. Finally, the drying process is stopped for 60 minutes. At the end of the experiment, samples were taken again for measuring the moisture content using oven. Furthermore, after the drying operation, the quality of dry paddy were analyzed with the manual method (physically election) by weighed the hollow grains, red and broken grains and percentage it to the sample weight so that the figures obtained percent grain of hollow, broken and red.



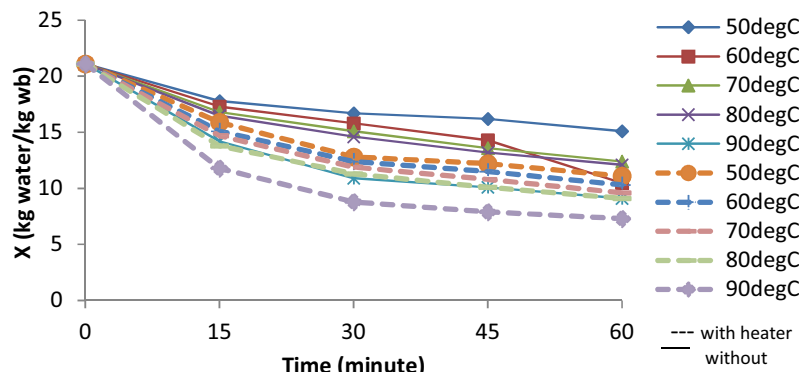
Figure 1. Experimental apparatus set up

## 3. Results and Discussion

### 3.1. Drying Curve

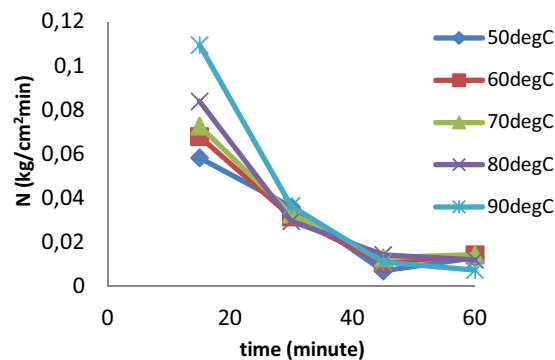
Figure 2 shows the profile of moisture content of paddy in fluid bed dryer in the variable with and without immersed heater. FBD with immersed heater give more drying rate, due to the additional heat from immersed heater. This additional heat from immersed heater will make the temperature in

fluidizing column higher, then the diffusion of water vapor inside paddy higher. Furthermore, increase drying temperature will decrease drying time. This is due to increase drying temperature will increase diffusion rate of moisture inside particle, then the drying speed will be more faster. Similar results have been previously reported that increasing temperature will increase drying rates of paddy [11-13].



**Figure 2.** The influence of drying temperature on profile of moisture content of paddy in fluid bed dryer within variable with and without immersed heater

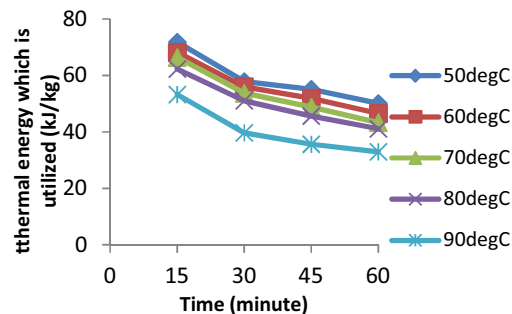
Figure 3 shows the profile the drying rate during the drying process. The absence of a constant drying rate indicates that in drying the paddy only has a second drying phase ie the rate of drying diffusion. The drying rate decrease by the time due to the moisture content inside of particle also decrease by the time. Therefore, the driving force from the center to the surface of particle decrease due to the moisture content in the center and the surface of particle became bigger. This results are similar that diffusivities of moisture inside particle paddy decreases during drying process (Midilli, 2002; Xing-jun, 2016).



**Figure 3.** The influence of temperature on drying rate

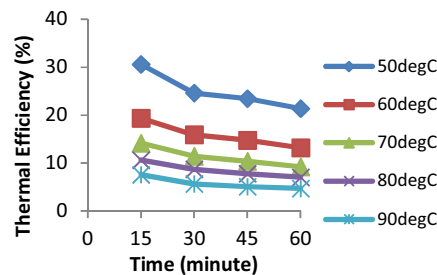
### 3.2. Thermal Efficiency

Figure 4 shows the influence of temperature on utilized energy for evaporated moisture from paddy. Increasing the temperature will decrease the utilized energy. This is because, with the rise in dryer temperature, the supply rate of energy is getting bigger. Meanwhile, this increase is not proportional to the energy consumption for drying. As a result temperature rise decreases utilized energy. These results are similar that by increasing temperature, the total utilized energy is decrease [13]. Furthermore, by the time, the utilized energy decrease. It is caused, by the time, the sum of moisture inside particle decrease, then drying rate decrease. Therefore, the energy utilized for evaporation of moisture becomes lower.



**Figure 4.** The influence of temperature on utilized thermal energy

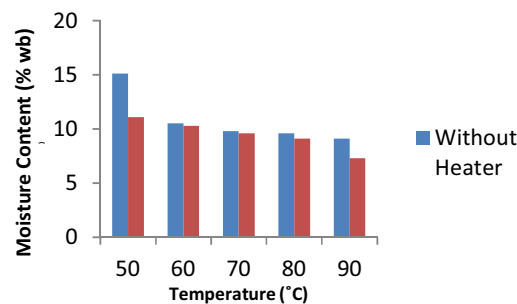
Figures 5 show the thermal efficiency drying for different drying air temperature. The higher of drying temperature, the thermal efficiency decreases. It means, by increase drying temperature, the energy loss by carried air out of dryer become larger, then thermal efficiency decreases. Drying efficiency values in this study is less than 70%. The low value is due to the efficiency of the design of fluidized bed dryer is used less than optimal where the absence of insulation caused the loss of heat from the dryer. Furthermore, the thermal efficiency decreases with drying time. This is proportional with the profile of utilized energy, due to the supply energy for heating of drying air is constant. It can be concluded that the longer time of the drying, the energy utilized decrease, then the thermal efficiency decreases.



**Figure 5.** The influence of temperature on profile of thermal efficiency

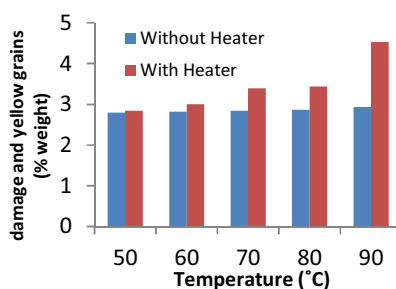
### 3.3. Product Quality

Figure 6 shown the residual moisture content of each variable without or with immersed immersed heater has decreased along with increasing temperatures. The higher the drying air temperature, the lower relative humidity of air, then capacity of drying air to capture water from the paddy is greater. Therefore, the residual moisture content becomes lower. Furthermore, with the immersed heater will increase the temperature again, so the relative humidity will also lower air, and residual moisture content is lower. These results are consistent with the results of [6].



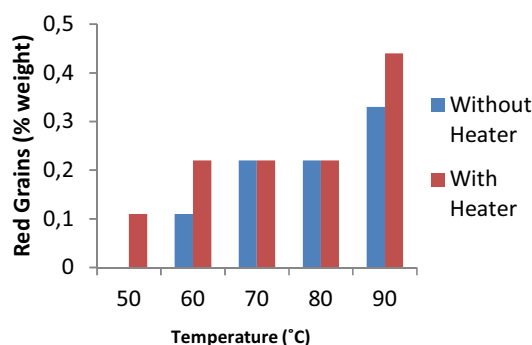
**Figure 6.** The influences of temperature on the residual moisture content

Figure 7 shows the influences of temperatures on the damaged grains and yellow grains. It can be seen by increasing temperature, the broken grains and yellow grains increased due to the skin of paddy will be burnt. These results are consistent with [2-3]. Furthermore, the use of immersed heater causes the damaged grain and yellowed grain more higher due to contact between the surfaces of grain with the coil of immersed heater.



**Figure 7.** The influences of temperatures on the damaged grains and yellow grains

Figure 8 shows the influences of temperatures on the red grains. It can be seen increasing of temperature will increase the red grains. The use of immersed heater causes the damaged grain and yellowed grain higher. The reason is similar with the phenomenon of the damaged grains and yellow grains and consistent with results of [2-3].



**Figure 8.** The influences of temperatures on the red grains

#### 4. Conclusion

Fluid bed dryer with immersed heater was successfully drying of paddy. Addition immersed heater will increase drying rates. No constant drying rate was found. Increasing the temperature will decrease the utilized energy. The thermal efficiency decreases with increasing temperature. The increasing temperature and use immersed heater will decrease the residual moisture content, increase damaged and yellow paddy grain, and increase red paddy grain.

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