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The effect of heat, air mass flow rate and temperature on paddy drying time using rotary type dryer

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Abstract. In this study a heat exchanger was manufactured and utilised as paddy dryer. Diesel engine exhaust gas was used to heat the air and supplied to the heat exchanger. A shell and multi tube helical coil heat exchanger was employed with shell length and diameter of 1,050 mm and 152.4 mm, respectively. Furthermore, a tube with twenty coil and 3,250 mm length was attached inside the shell where coil diameter and helical coil number are 58.8 mm and 4, correspondingly. Besides, Heat source was generated from the diesel engine exhaust gas. The engine can generate 54 kW of power and maximum speed of 3600 rpm. The aim of this research is to analyse the paddy drying time using rotary type dryer equipped with heat exchanger. This study based on experimental work, the data retrieval procedure is the way in which to obtain the necessary data to be analyzed, where the procedure is initially the water is loaded into the tank and the valves are all open, then the pump switch is switched on so that water flows in the drains of the appliance heat exchanger and then diesel engine turned on so that hot gas flow in the gas line. This is done to dispose of the air contained in the heat exchanger, let it last for a while until the exhaust gas temperature goes into the heat exchanger in steady state. The result revealed that in order to obtain 14% of paddy moisture content, it took 8 hr and 33 minutes of drying time at 46.7 °C of air temperature with the rate of air mass flow of 0,057383 kg/s. Whereas, it was 8 hr and 37 minutes long to get the same moisture content when the air temperature and air mass flow were maintained at 70.4 °C and 0,082788 kg/s, accordingly. The energy needed to dry the paddy at 46.7 °C was 19374.89 kJ. In contrast, it was required 18932.03 kJ of energy at 70.4 °C. If it is seen from the explanation then the main conclusions of this research that by using this rotary type drying tool the drying process can be done and can save cost and time, besides that also this finding provide recommendation information related to the utilization of alternative energy for drying.

1. Introduction

Drying process is one of most important aspect to produce high quality of paddy. Weather change and season shift are obstacles to farmers start from planting stage until post-harvest. Harvesting in rainy season cause difficulties for the farmers to dry paddy where during the rainy season paddy will get wet and also, there is lack of sunlight. When picked paddy get damp, it will last for two days only until become damaged [1, 2]. Observation was done on moisture content and drying time. Dehydrating was stopped when the moisture content of paddy reach 14% of moisture content. The fastest drying could be acquired with zeolite to paddy ratio 60:40 at 600 °C. This method could save time up to 73.07 minutes compare to the one without zeolite [3, 4, 5].

Sun dry technique is a conventional method which is widely practiced by Indonesian farmers. It is all because this system is very simple and cost-effective. Unfortunately, it closely depend on the weather, the need of extensive land, long drying time, inconsistent product quality and easy to get contaminated by unwanted substances. Basically, it needs three days to dry paddy but in rainy season, the time required could be one week. Christopher et al [6], concluded that in order to acquire paddy with 14.12% of moisture content, it took 54 hr of drying time. However, other evidence showed that it needed three to four days [7].

Drying, as a part of crop processing, is a procedure to decrease moisture content by applying heat. Drying is performed to maintain paddy quality during storage by preventing bacteria and mould growth and inhibiting insect and mite presence. Safe moisture content is about 12 to 14% for fresh cereal [8].

To decrease moisture content of paddy by sunshine was more popular method in Indonesia than using drying machine. Simplicity and profitable were the main motivation of applying sun dry method. This simple desiccating can simply be performed by means of plastic rug, tarpaulin even bamboo webbing as drying mat [9]. This was a popular technique but unfortunately, there were some disadvantages such as product lost level was about 1.78% which was reasonably high, varied sunshine and temperature, the thickness level of paddy stack, flipping frequency and raining. Consequently, drying process could not be performed. As a result, degradation or mould was performed and drying time took longer [10].

Paddy is also known in scientific name as *Oryza Sativa*. It is family of *Gramineae* and become one of the oldest food source from grains and most consuming in the world including Indonesia. Paddy drying was one of challenging factor in paddy production cycle which was known as dried paddy. Moisture content of fresh post-harvest paddy was 20% to 27 % in general [11]. On the other hand, recommended moisture content is 14%. The decrease of moisture content could be done either conventionally by applying sunlight as well as using drier machine [12].

Environment relative humidity (RH) also affected moisture content of paddy. In environment with RH 20% to 60%, moisture content of paddy was about 10% to 13%, a safe and good dryer air temperature was in between 45 °C to 75 °C [13]. The increase of dryer air temperature produced the more heat energy. As the result, the amount of evaporated moisture mass from paddy became escalated. Also, the higher air flow rate the faster vapour mass removed from substance [14].

Utilization of exhaust gas thermal for heat exchanger to heat the air up in drying paddy was need to be considered in order to limit the use of petroleum. Exhaust gas thermal of Diesel engine was applied to heat the air up in heat exchanger. Heated air supplied to rotary type dryer equipped with fin which was used to flip paddy in drying chamber to distribute drying process evenly and to shorten drying time [15]. Rotary dryer is a cylinder shape dryer apparatus and moving in circular motion to reduce moisture content from solid substance by expose the substance to dry air. The substance that needs to be dried was fed to upper inlet, due to rotating of the dryer, the substance will move out slowly to lower outlet [16]. Heat source of the dryer was hot air which flew inside dryer that was so called direct-heated dryer. When the heat source supplied from outside of shell dryer, then it was known as indirect-heated dryer [17].

The aim of this study was to acquire paddy properties after drying with rotary type dryer equipped with heat exchanger. In the results of this research is expected to be one way to support the Indonesia government's policy in addition to developing alternative energy sources as well by making energy savings by utilization of heat exhaust from diesel engines as a dryer.

2. Method

This study was experimentally work based. Helical coil lay out and experiment apparatus of the helical coil heat exchanger was depicted in figure.1 and 2, respectively. The data retrieval procedure is the way in which to obtain the necessary data to be analyzed, where the procedure is initially the water is loaded into the tank and the valves are all open, then the pump switch is switched on so that water flows in the drains of the appliance heat exchanger and then diesel engine turned on so that hot gas flows in the gas line. This is done to dispose of the air contained in the heat exchanger, let it last for a while until the exhaust gas temperature goes into the heat exchanger in steady state. To facilitate the experiment both at the time of making the tool and until the data collection then made and presented the flow chart of the research process shown in figure 3.

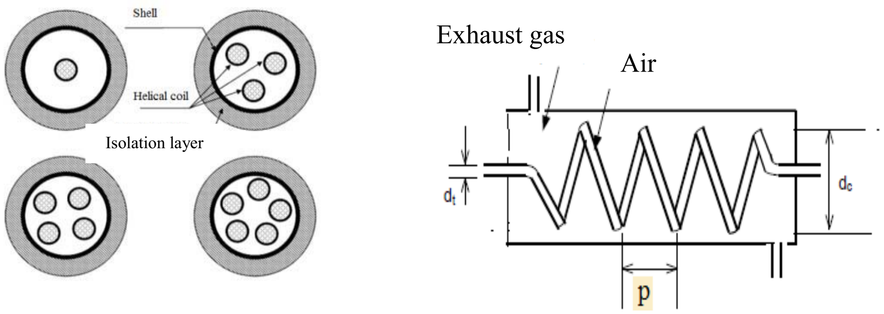

Figure 1. Helical coil

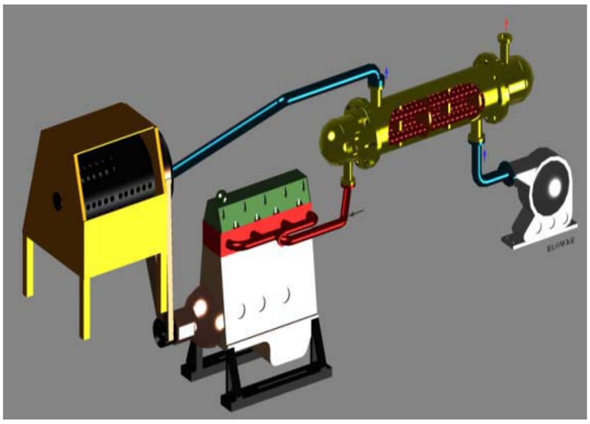

Figure 2. Experiment apparatus

Table 1. Dimension of Helical coil

PARAMETER	DIMENSION
Shell diameter	**Article I. 0,1524 m**
Coil diameter	0.011 m
Pitch length	0.03 m
Thick tube coil	0.001 m
coil diameter	0.0504 m
Helical coil number	4 number
HE length	1.046 m
Helical coil material (Copper)	396 W/m.ºC

Table 2. Dryer chamber dimension

Parameter	Dimension
Dryer diameter	0.70 m
Length	1.0 m
Fin width	0.15 m
Fin thick	0.01 m

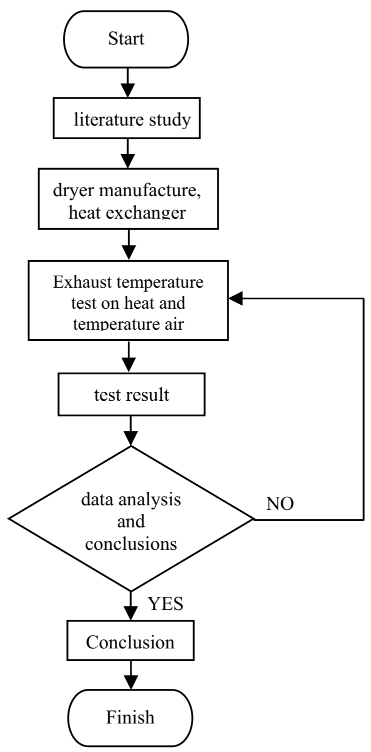

Figure 3. Flow Chart

3. Results and discussions.

In this experiment the observed variable is the air temperature in the rotary drying chamber. Temperature effects can be seen in figure 4. In figure 4, the graph relation between time (hr) and moisture content of wet basis (%) indicates that at 43.3 °C drying temperature with available heat rate 4811.24 kJ/hr takes longer 2.9 hr drying with hot air heat flow rate available 4811.24 kJ/hr obtained from a helical coil heat exchanger which serves as an air heater to achieve a moisture content of 14%.

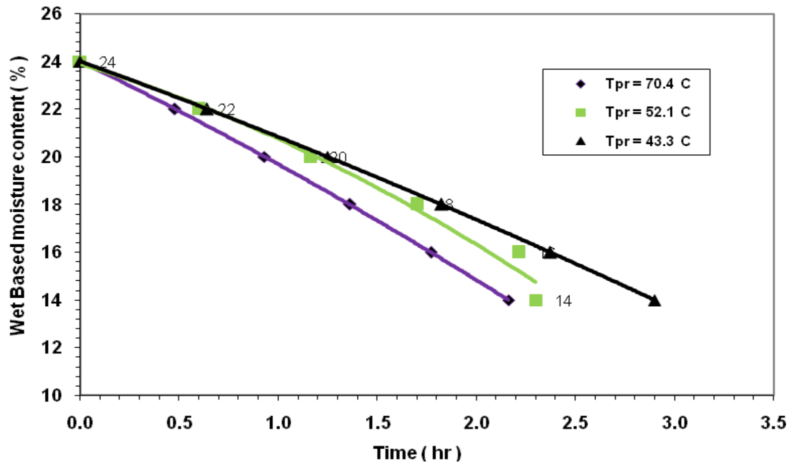

Figure 4. Moisture content -vs- drying time

Air temperature in rotary drying chamber was the examined in this work. Figure 4 explained the relation between time (hr) and moisture content of wet based (%). It can be seen that it acquired 2.9 hr at 43.3 °C with the heat rate 4811.24 kJ/hr to gain 14% of paddy moisture content.

Temperature was varied i.e. 43.3 °C, 52.1°C and 70.4 °C. The fastest drying was at 70.4 °C with heat rate 6280.99 kJ/kg and 2.16 hr long. Wet based weight was 50 kg with moisture content of 24%. Drying process is heat and mass transfer occurred simultaneously. The product that needed to be dried was exposed directly to hot air and subsequently heat transfer performed from the hot air to the product. At the end, the moisture evaporated into the dried air.

Figure 5 explained the amount of heat which was transferred to dryer chamber in order to vaporise moisture in the product. This process reduced product mass as depicted in figure 5. with three different temperature. It also can be realised that the decrease of product mass was affected by heat flow rate which flew to dryer chamber. Initial weight was 50 kg and became 44.19 kg at the end with the amount of heat was 4811.24 kJ/hr and drying time was 2.9 hr at 43.4 °C. Furthermore, it spent 2.3 hr at 52.1 °C temperature and 6011.24 kJ/hr of heat. Fastest drying time was 2.16 hr at 70.4 °C of temperature with the amount of heat was 6280.99 kJ/hr.

Temperature change compared to moisture ratio (MR) can be observed on Figure 6. With the intention of how strong the influence of shrinkage to drying characteristic, therefore relationship between time and MR was formed. Figure 6 showed that the connection between time and MR was changing in each experiment. At 43.3 °C of drying time, MR = 1 became as low as MR = 0.38, while for temperature of 52.11 °C, it was obtained that MR = 1 went down to MR = 0.36. Likewise, MR = 1 reduced to MR = 0.25 at 70.4 °C. All were caused by the fact that relative humidity (RH) at 70.4 °C was lower than RH at 52.1 °C and 43.3 °C. As a result, time needed was shorter. Next observed variable was air mass flow rate which flew into the dryer chamber. Hot air needed to speed up drying time and to reduce moisture content from 24% to 14%. This condition is also almost the same that has been obtained by Zainuddin, at all using heat exchanger multi tube. The type of Diesel machine to use in the testing is 4FB1 Isuzu Diesel engine. The machine has the maximum machine power and rotation of 54 kW and 3.600 rpm. The performance testing of heat exchanger has been conducted in some variations of Diesel machine rotations of 1.500 rpm, 1.750 rpm, 2.000 rpm, 2.250 rpm and 2.500 rpm. The testing result shows a maximum effectiveness to happen at the machine rotation of 1.500 rpm. The maximum effectiveness to get is 67.8% and then it goes down drastically in accordance with the increase of air mass flow rate. The hot air temperature created is from 47.1°C to 52.3°C so that it can be used for the purpose of drying up the unhulled rice [18].

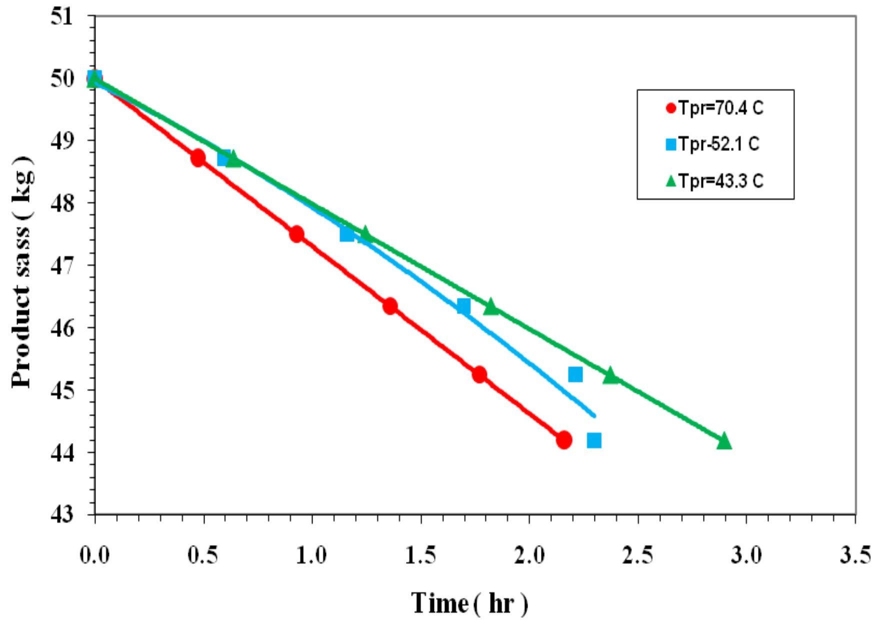

Figure 5. Effect of temperature and mass flow rate of drying air from mass product on drying time

As a comparison of the results of this study on the other side of the study Amirhossein Akbaria altogether at all (2018) explain that hot air of inlet temperature has the most significant influence, this is done with rotary type heat exchanger. The parameter of inlet hot flow temperature was the most effective parameter on the regeneration temperature and the efficiency. In addition, by increasing the temperature of the inlet hot flow, the regeneration temperature and the efficiency were increased nonlinearly. It was observed that by increasing the efficiency, the number of heat transfer units was increased too. The efficiency of the heat exchanger was 38.8% in average and 42.2% at maximum state [19]. Similarly, the air and moisture content obtained by Luanfang Duan at all (2017), namely using coal as a particle object used in the drying process Then, based on the experimental results two empirical correlations were regressed by least square method, both of the two correlations were valid under most of the conditions and the mean deviations in MRT prediction were 8.1% and 8.0% respectively [20].

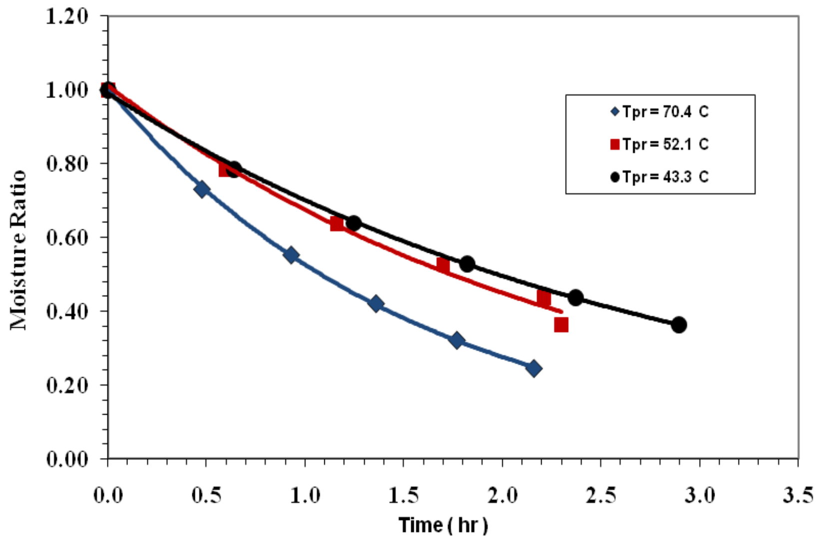

Figure 6. Effect of temperature and mass flow rate of dryer air from moisture ratio to drying time

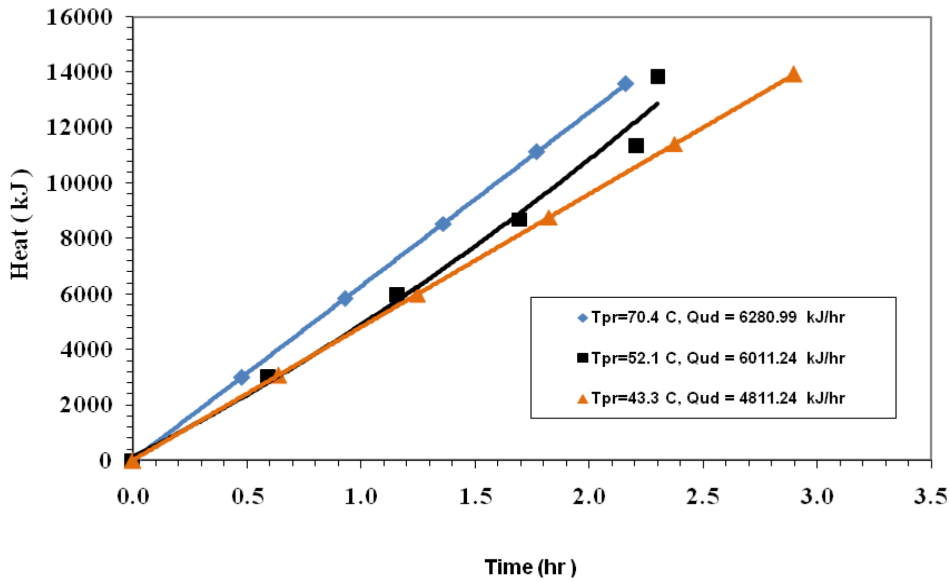

Figure 7. Effect of temperature and available air heat from acquired heat on paddy dryer to drying time.

Figure 7 indicated the trend of operational time length of heat exchanger which produced hot air for rotary dryer chamber as paddy dryer. Heat required to get moisture content of 14% at temperature 43.3 °C was 1393.46 kJ. Hot air flow rate was 0.29 kg/s with drying time 2.9 hr and available heat was 4811.24 kJ/hr. Heat generated at temperature of 52.1 °C was 13819 kJ with hot air flow rate of 0.27 kg/s and drying time was 2.3 hr with available heat 6022.24 kJ/hr. At temperature of 70.4 °C, heat was generated in 13575.30 kJ with air flow rate of 0.16 kg/s, drying time and available heat were 2.16 hr and 6280.99 kJ/hr respectively.

4. Conclusions

Results revealed that in order to get 14% moisture content, it was required 8 hr and 37 minutes of drying time at 46.7 °C and air mass flow rate of 0.057383 kg/s. In addition, it took 1 hr and 33 minutes to obtain the same amount of moisture content at 70.4 °C with mass flow rate of 0.082788 kg/s. Heat generated were 19374.89 kJ and 18932.03 kJ at temperature of 46.7 °C and 70.4 °C, accordingly. The fastest drying time to acquire moisture content of 14% was at 70.4 °C with heat rate was 6280.99 kJ/kg and drying time of 2.16 hr.

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