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Study on Must-Flow Paddy Drying System Using Liquefied Petroleum Gas Energy Source

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***Abstract*— This research studies the performance of a liquefied petroleum gas powered Must-flow paddy drying system in drying a RD 6 variety rice paddy. Hot air velocity and paddy flow rate are investigated to determine their effect on reducing the moisture content of RD 6 rice with an initial moisture content of approximately 21 to 23% (w.b). Drying experiments were carried out with the following parameters: Paddy flow rates of 49, 75 and 130 kg/h, hot air speeds of 1.0, 1.5 and 2.0 m/s, 130 °C drying temperature, and drying chamber speed at 110 rpm. From the experiment, it was found that the paddy can be dehumidified to a final moisture content of 14 % (w.b) (desired level) with a paddy flow rate of 49 kg/h, hot air velocity of 2.0 m/s and specific energy consumption of 14.72 MJ/kg water removed. The hulling was 92.3% and the measurement of whiteness percentage of milled rice after drying was 61.9%.**

***Keywords*— Liquefied Petroleum Gas, Must flow Dryer, Paddy Dryer.**

I. INTRODUCTION

Rice is considered the staple food of people in Asia. During the harvest period when the rice (paddy) is d [1]. ue, the moisture content of the rice will be quite high. Initial humidity is approximately 21 to 23% (w.b) depending on the climate and season. Therefore, it is necessary to have a proper post-harvest process by reducing the humidity of the paddy seeds (paddy dehydration) to reduce the respiration rate and growth of fungus which causes deterioration of the quality of the rice paddy. A reduction in humidity of up to 14% (w.b) is optimal as the seeds can be stored in a controlled environment or temperature for 2 to 3 months. If sold to a local mill, the reduction in moisture content will not exceed 14%. (w.b) because this weight is not deducted from the total weight of the paddy. This makes it possible to sell the paddy at a better price or add value (value-added) to agricultural products. In the case where there is no moisture reduction operation, when the paddy is brought for sale, the weight of the paddy must be deducted in proportion to the increased moisture content.

When developing the automatic control system of the Must-flow paddy dryer for the drying test, the average hot air temperature was 130 ºC, the rotational speed of the drying chamber shaker unit was 110 rpm, and the velocity of the air flowing out of the dryer was 2.0, 2.5, and 3.0 m/s at the rotary valve speeds of 2.0, 4.0 and 6.0 m/s. A rotary valve rotation speed of 2.0 m/s can reduce the moisture content of paddy, from the initial humidity range of 20 to 21% (w.b), to a final moisture content of 14.8% (w.b). The specific energy consumption was 18.2 MJ/Kg water removed. In addition, the rice shelling rate after drying was 94.8% and the control system could reduce the specific energy consumption by 33.2 MJ/kg water removed [2].

This research studied a 2 ton/hr Must-flow paddy dryer to investigate the possible parameters affecting paddy drying. The parameters studied are as follows: air flow rate, rotational speed of drying chamber lift distance, and bed height. The test was performed at air flow rates of 0.05, 0.10, 0.15, 0.20, 0.25 and 0.3 m/s, drying chamber lifting speeds of 100, 120 and 140 RPM, bed heights of 1, 2 and 3 cm and drying chamber lifting distance of 4.6 cm. The experiment results showed that as the air flow rate increased the rice grains moved faster. At an air flow rate of 0.10 m/s, the movement of paddy grains within the drying chamber decreased accordingly, but at air flow rates of 0.15 to 0.3 m/s the values are similar. As the air flow rate increases, the density of the paddy in the drying chamber will decrease, but the porosity of the rice in the drying room will increase. It was found that with a bed height of 3cm and a drying chamber lift speed of 120 RPM the rice grains took the slowest time to move within the drying chamber. The production capacity of the must flow dryer is about 1,000 to 4,000 kg/hr, but at bed heights of 1, 2, and 3 cm, the speed of the drying room lift distance is 100 RPM and this condition cannot dry Must-flow rice. The conditions must be altered to a bed height of 3 cm and the speed of the drying chamber lift stage to 120 RPM in order to dry the paddy further [3].

The evaluation of the reference sample preparation process was studied. For rice moisture meters, resistance and capacitance types are commonly used to check the moisture percentage of paddy in trading. In this research, rice varieties of Jasmine 105 and Suphanburi 60 had moisture levels of 12%, 16%, 20%, 24% and 28% on a wet basis (Wet basis). It was found that rice at the target moisture levels of 12%, 16%, 20% 24 % and 28% took 2, 3, 4, 6 and 7 days to have a Rewetting Index at the level of 95%. Storage at room temperature found that paddy rice at humidity levels of 12% and 16% could be stored without quality deterioration for a period of 14 days, while paddy at humidity levels of 20%, 24% and 28% cannot be stored for more than 3 days due to mold growth. When testing the accuracy of the moisture measurement of the paddy with a moisture meter it was found that a capacitance meter was able to read moisture values with a percentage error [4].

The modification of rocket and shower type venturi burner devices used in ceramic kilns was also studied. Compressed bio methane gas (CBG) can be used in place of liquefied petroleum gas (LPG) by adjusting the gas nozzle size from 0.8 to 2.0 millimeters, adjusting the gas pressure from 1 to 10 psi and air conditioning vents. Ignition must be observed since flame color and flame characteristics must be stable and similar to liquefied petroleum gas. It was found that a rocket venturi burner with a nozzle adjustment of 1.4 mm. at a pressure of 5 psi and an air space within approximately 45% of the air space that caused the fire to ignite. And a shower-type venturi burner with a nozzle adjustment of 1.4 mm. at a pressure of 5 psi and an air space within approximately 50% of the air space that causes the fire to ignite. Visually the flame has a similar color to that of liquefied petroleum gas. The glaze was tested on ceramic products inside a 0.1 cubic meter shuttle kiln. After changing the fuel from liquefied petroleum gas to compressed bio methane gas in both the rocket and venturi type burners, the shower type was found to save the cost of coating the product per time by approximately 27.92% and 29.73%. The fuel consumption rate of compressed bio methane gas of the rocket and shower venturi burners went from 0.333 to 0.003 kg/hr. and 0.330 per 0.010 kg/hr., respectively. The thermal efficiency of both types of burners was tested with liquefied petroleum gas and compressed bio methane gas that had been adjusted to compare the thermal efficiency according to EN 2032 standards. It was found that the thermal efficiency of the rocket and shower venturi burners when using compressed bio methane gas as fuel was 55.76/1.31% and 52.87/1.20% compared to when using liquefied petroleum gas as fuel which were 52.48/0.16% and 53.48/53.48/. 2.04% respectively [5].

The influence of the hole size of the air diffuser and the height of the paddy bed on the pressure drop in the Must Flow dryer was also studied. This experiment was conducted using a test drying chamber measuring 20 cm. width x 95 cm. length x 30 cm high, with diffuser hole sizes varying from 1.1 mm, 1.5 mm, and 2.0 mm. Stainless steel mesh with varying heights of the paddy bed ranged from 1 to 5 cm and the hot air flow rate ranged from 0.05 to 0.30 m/s. The results showed that the 1.5 mm diffuser hole had a pressure drop that was 1.1 mm lower than the 2.0 mm diffuser hole and stainless steel. The pressure decreases accordingly with the air flow rate and the height of the paddy bed [6].

Therefore, rice with high moisture content that is sold to a mill will tend to be of lower quality and will be cheaper in price than rice with low moisture content. The dehumidification process is mainly performed with various types of dryers, using hot air to move through the grain layers. The heat from the hot air is transferred to the seeds causing a simultaneous heat and mass transfer process. From this principle of moisture reduction, dryers can be divided into two main types: stationary grain dryers and flowing or moving grain dryers. Mobile grain dryers can also be divided according to the hot air flow and grain flow characteristics: hot air flows parallel to the grain (parallel flow) or hot air flows perpendicular to the grain (cross flow).

For this study, the researcher will utilize Must flow rice drying technology to reduce moisture. Liquefied petroleum gas (LPG) will be the energy source for drying the rice since it is a fuel that is easily available on the market and provides good heat energy. For an energy efficient rice drying process the hot air flow control system and how it affects paddy drying will also be studied.

II. EQUIPMENT AND METHODSE

A. Materials

The experiment selected local fresh rice paddy in the central region of Thailand, RD6 variety rice paddy.

B. Cross-flow paddy dryer

This research uses a must-flow paddy dryer using liquefied petroleum gas as the fuel source. The dryer structure is made of 2-inch x 2-inch box steel while the drying chamber area is 150 x 1000 millimeters (width x length). The specifications of the dryer consist of various equipment as shown in Figure 1.

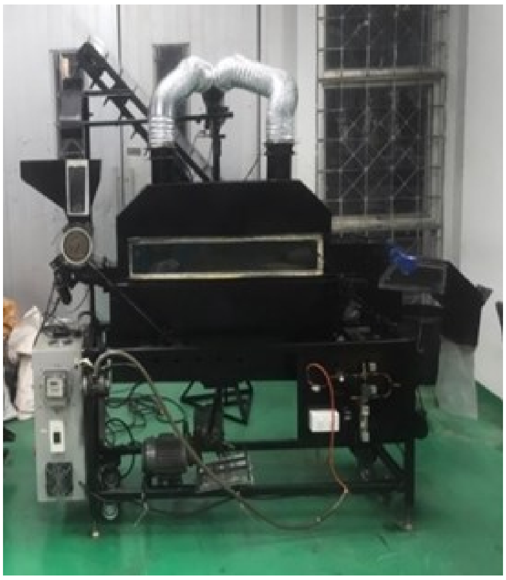

Figure 1. Must flow dryer.

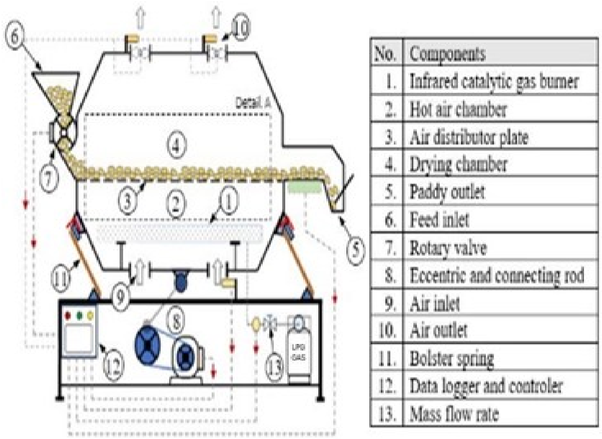

Figure 2. Must flow dryer components

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The operation of drying rice is powered by liquefied petroleum gas. To reduce the humidity of RD 6 rice variety which has an initial moisture content of approximately 21 to 23% (w.b), drying was carried out at a temperature of 1 3 0 °C, drying chamber lift stage speed of 110 RPM, hot air flow rates of 1.0, 1.5, and 2.0. m/s, rotary valve rotation speeds of 2.0, 4.0 and 6.0 rpm or paddy flow rates of 49, 75 and 130 kg/h, respectively. For this experiment moisture of the paddy is measured before drying. Parameters of the dryer are adjusted while controlling the operation of the liquefied petroleum gas fuel flow measurement unit. The paddy feeding rate can be used to calculate the amount of water that evaporates from the grain. The humidity after drying can be evaluated for the specific energy consumption in the must flow drying process of paddy. The electric energy consumption in the drying process was calculated. The SEC value, which shows the energy used to evaporate water from 1 kg of rice paddy, can be calculated. As the following equation.

$$SEC=\frac{E_{electric}+E_{thermal}}{M_w} \qquad (1)$$

when $E_{electric}$ = amount of electrical energy, MJ

$E_{thermal}$ = amount of heat energy, MJ

M_w = amount of evaporated water, kg

The electric and thermal energy consumption values can be collected directly from the electrical energy measurement and the amount of water that evaporates from the rice grains can be estimated from the difference between the weight of the rice before drying and the weight of the rice after drying. You can calculate the evaporated weight as in Equation 2 and calculate the weight of paddy after drying as in Equation 3.

$$M_d=\frac{w-d}{d}(100\%)=(\%db) \qquad (2)$$

when w = wet weight, %wb

d = dry weight, %db

M = moisture content, %

$$W_f=W_i\frac{(100-M_i)}{(100-M_f)} \qquad (3)$$

when = weight of paddy before drying, kg

= weight of paddy after drying, kg

= Initial humidity, %wb

= final humidity, %db

Measuring tools and equipment in the experiment were conducted on a paddy dryer using a dark measuring device. In order to bring the values of various variables to analyze and calculate further the following measuring tools are used.

C. Data analysis measurement tools

equipment	brand	model
1. Paddy moisture meter	Kett	PM-450
2. Anemometer	UNI-T	UT363
3. Measuring device for measuring the whiteness of rice	MILLMNIG METER	MM 1D
4. Moisture meter	TSI	7565-X
5. Digital scale	TCS-100	Series scsle
6. Gas flow meter	OEM	BIGHJ0215
7. Temperature recorder	GRAPHTEC	MT100

III. RESEARCH RESULTS AND DISCUSSION

A. Temperature and relative humidity measurements

After experimenting at various conditions, the results obtained are analyzed and compared resulting in the following graph. Comparison of hot air flow rates in the must flow paddy drying process using liquefied petroleum gas as an energy source. The experimental must flow drying process of paddy using liquefied petroleum gas as the energy source has many variables that affect the drying process. The flow rate of hot air flowing through the rice grains is one variable that affects the

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change in moisture content in the rice grains and results in the rice grains drying quickly. It was found that a hot air flow rate of 2.0 m/s was able to reduce the paddy moisture the most at a paddy grain feed rate of 49 kg/h. The humidity can be reduced from the initial levels of approximately 21 to 23% (w.b) to the final moisture content of approximately 14% (w.b). Additionally, it was observed that during a period of 35 minutes, the humidity will decrease rapidly and will gradually decrease slowly according to the drying room distance.

Figure 3 is the graph of the relationship between the outlet air temperature and the drying time using liquefied petroleum gas with a rotary valve rotation speed of 2.0 rpm when the hot air speed is 1.0 m/s, 1.5 m/s, and 2.0 m/s at a drying temperature of 130 ºC. The rotation of the rotary valve at 2.0 rpm takes the drying process 45 minutes. The hot air speed is 2.0 m/s. The temperature inside the drying chamber will gradually decrease due to heat transfer and moisture mass is better than hot air at a velocity of 1.0 m/s and 1.5 m/s.

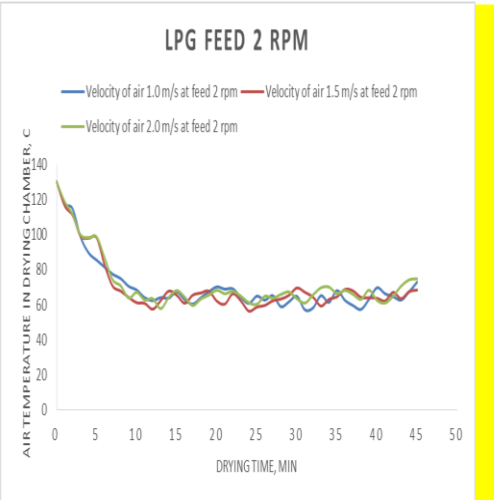

Figure 3 LPG FEED 2 RPM or rice grain feed rate 49 kg/h

Figure 4 is the graph of the relationship between the outlet air temperature and the drying time using liquefied petroleum gas with a rotary valve rotation speed of 4.0 rpm when the hot air speed is 1.0, 1.5, and 2.0 m/s at a drying temperature of 130 ºC. By rotating the rotary valve at 4.0 rpm, the temperature inside the drying chamber will gradually decrease to a temperature of 50 - 60 ºC because the amount of paddy rice inside the chamber is very dry and there is little space between the rice grains. Heat transfer and moisture mass are less as well and takes 50 minutes for the drying process.

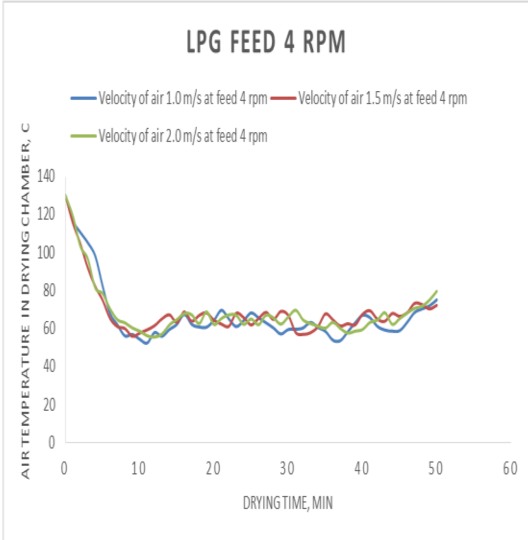

Figure 4 LPG FEED 4 RPM or rice grain feed rate 75 kg/h

Figure 5 is the graph of the relationship between the outlet air temperature and the drying time using liquefied petroleum gas with a rotary valve rotation speed of 6.0 rpm when the hot air speed is 1, 1.5, and 2 m/s at a drying temperature of 130 ºC. By rotating the rotary valve at 6.0 rpm, the temperature inside the drying chamber will gradually decrease to a temperature of 50 - 60 ºC because the amount of paddy rice inside the chamber is very dry and there is little space between the rice grains. Heat transfer and moisture mass are also low and the drying process time is 58 minutes.

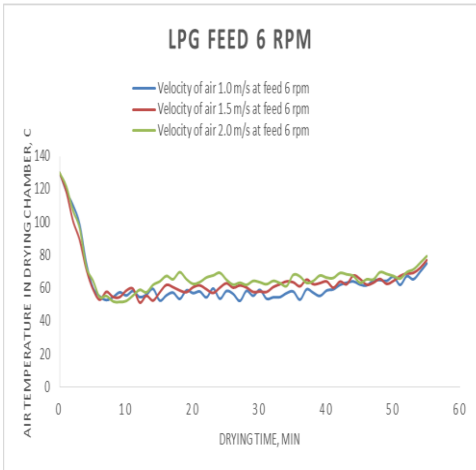

Figure 5 LPG FEED 6 RPM or rice grain feed rate 130 kg/h

Figure 6 is the graph of the relationship between the influence of the hot air flow velocity on the percentage of paddy moisture. Hot air velocity at 1.0, 1.5 and 2.0 m/s while rotary valve rotation is 2.0 rpm at a drying temperature of 130 ºC. It can be seen that rotary valve rotation at 2.0 rpm can reduce humidity the most. The drying process takes approximately 45 minutes.

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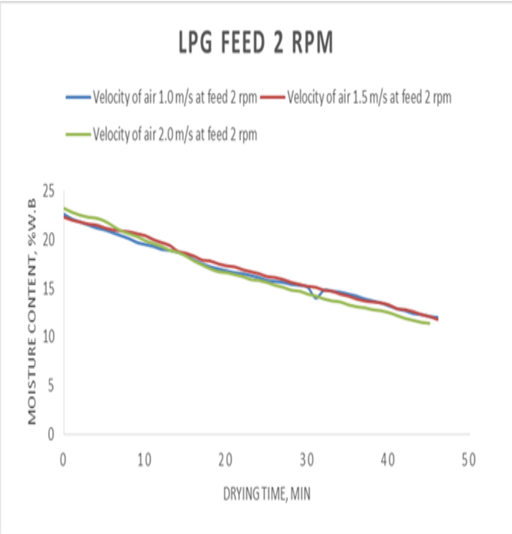

Figure 6. Influence of the flow rate of hot air flowing through the drying chamber on the final moisture content of paddy at a rotary valve rotation speed of 2.0 rpm.

B. Estimation of final moisture content

Comparison of paddy grain feeding rate and influence of hot air flow rate. Comparing the rice grain feed rates of 49, 75, and 130 kg/h and the hot air flow rate of 2.0 m/s in the must flow paddy drying process using liquefied petroleum gas as energy. From Figure 6, it is found that the paddy flow rate has an effect on paddy moisture reduction and drying times. At paddy flow rates of 75, and 130 kg/h and hot air flow rates of 1.0, and 1.5 m/s, the humidity can be reduced a little. This is because the amount of rice grains in the drying room is very large. This results in less space between the rice grains in the drying room. Hot air is therefore less able to flow through, causing less heat and moisture transfer as well. The rice flow rate of 49 kg/h and hot air flow rate of 2.0 m/s can reduce humidity the most. The drying process takes approximately 40 to 45 minutes. The energy consumption in the must flow paddy drying process is the lowest.

C. energy consumption in the must flow drying process of paddy rice.

Table 2 shows the energy consumption in the must flow drying process of paddy including electrical energy and heat energy. From the information it was found that the average electricity consumption is 0.37 MJ/hr and the average heat energy consumption is 4.50 MJ/hr, with the highest specific energy consumption in the drying process (SEC) being 21.74 MJ/kg water removed and the lowest being 11.68 MJ/kg water removed. When considering the paddy flow rates of 49, 75 and 130 kg/h, it was found that the hot air flow rates of 1.0 and 1.5 m/s had the highest energy consumption at paddy flow rates of 75 and 130 kg/h due to the slow flow rate of hot air. Therefore, only a small amount can pass through the space between the rice grains which affects the transfer of heat and moisture mass. The amount that evaporates is therefore small. It was found that the rice flow rate of 49 kg/h and the hot air flow rate of 2.0 m/s were able to reduce the humidity the most while having an average specific energy consumption (SEC) of 14.72 MJ/kg water removed.

Table 2 Energy consumption in the must flow drying process of paddy rice.

Paddy feeding rate kg/hr	Hot air flow rate m^3/s	Hot air °C	Initial humidity $\%w.b$	final humidity $\%w.b$	Amount of evaporated water kg/h	Amount of heat energy MJ/h	amount of electrical energy MJ/h	Specific energy consumption MJ/Kg water evap
49	1.0	130	21.6	14.10	0.20	1.98	0.178	11.79
	1.5	130	21.3	13.40	0.20	1.98	0.188	11.84
	2.0	130	21.9	11.20	0.17	1.95	0.173	12.48
75	1.0	130	21.4	10.60	0.20	4.02	0.328	21.74
	1.5	130	22.5	11.30	0.32	3.52	0.299	11.93
	2.0	130	21.8	12.40	0.37	4.02	0.302	11.68
130	1.0	130	21.3	15.00	0.41	6.53	0.547	17.26
	1.5	130	22	13.00	0.49	8.04	0.587	17.60
	2.0	130	21.7	11.00	0.56	8.54	0.522	16.18

IV. CONCLUSION

Study of must flow paddy drying system using liquefied petroleum gas as an energy source. To study the drying process and influence of paddy flow rate, hot air speed, and drying temperature on reducing the moisture content of Pathumthani 1 paddy rice with an initial moisture content of approximately 21 to 23% (w.b). The experiment was performed with the rotational speed of the drying chamber at 110 rpm, the drying temperature at 130 °C, and the rice flow rate at 49, 75, and 130 kg/h. When testing the rice flow rate of 49 kg/h with the hot air velocity at 1.0, 1.5, and 2.0 m/s, it was found that hot air flow at a rate of 2.0 m/s would reduce humidity form the initial moisture content of approximately 21 to 23% (w.b) to the final moisture content of approximately 14% (w.b). The

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Thank you to the Faculty of Engineering of Mechanical Engineering Department and Graduate School of Srinakharinwirot University, Nakornping Energy Research paddy rice spent time in the drying room for approximately 4 5 minutes and has a specific energy consumption (SEC) value of 1 4 .7 2 MJ/kg water evap. The rice shelling rate after drying was 9 2 .3 % and the results of the measurement of the percentage of whiteness of the rice after drying is at 61.9%. and Development Institute of Chiang Mai University and Pathumthani Rice Research Center who have supported the conducting of this research.

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