Performance Evaluation of Paddy Rice Pneumatic Dryer

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Abstract
This research was carried out to study the drying of paddy rice by using the developed pneumatic dryer with and without the outlet air cyclone installation on the dryer. In this study, Thai jasmine rice 105 variety was selected as a sample in the experiment. The characteristic of drying behavior, specific energy consumption (SEC), drying rate (DR) and percent of head rice yield were evaluated as the performance of dryer. For the drying experiments, a 40 kg of paddy rice was dried by the hot air temperature of $80^{O}C$ with the proper of a terminal air velocity for paddy rice. The result shown that the drying system without cyclone gives a higher rate of moisture extraction than the system with cyclone installation. Based only on energy utilization during the process, the highest SEC of 7.25 MJ/kg_{water} occurs on the drying at the airflow rate of 0.0512 m^3/s by without cyclone. For the dried product quality, the highest head rice yield of 36.84% on the drying at airflow rate of 0.0631 m^3/s. The breakeven point of the developed dryer is 1.6 ton/year of a paddy rice drying.

Keywords: Paddy rice, pneumatic dryer, drying, head rice yield

Introduction

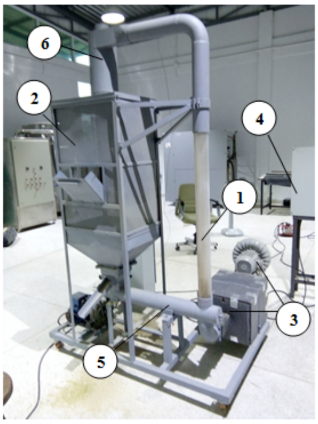
Rice is a kind of grain, which is a staple food in Thailand and Asia such as China, Japan and Malaysia. After the paddy harvesting, the moisture content (MC) in a paddy rice is height especially in a rainy season and it can cause the low quality of rice after the milling process. Therefore, the moisture reduction in paddy rice is a very important post-harvest process and the right moisture content of paddy rice for a long storage life is around 14%db (dry basis) [1]. At this moisture, the rice after milled are less in grain damage and high in head rice yield percentage. There are many methods to reduce the moisture of paddy. In Thailand, the traditional way is sun drying. This naturally method is easy and save the cost of heat energy. However, this way has a localization because the problems of labor and drying area intensive, long drying period, seasons and cannot control the final moisture content of the paddy rice. Another method to reduce the moisture of paddy rice is using of the dryer. It is a favorite method because it can operate in year round, faster than sun drying and able to control the desired paddy moisture. Notwithstanding the advantage of the dryer, the energy consume, drying capacity and the rice quality is a major problems in the moisture reduction by the dryer. There are a lot of currently research about how to reduce the moisture of paddy and also develop the system of dryer machines in order to use low energy consume but give a high capacity such as developing solar air heaters by modifying the roof of building [2], using stream dryers [3], designing inclined bed dryers [4] and using spouted bed [5].

The well known artificial drying for the paddy rice are LSU and fluidized bed dryer. They can reduce moisture by the less time, high capacity and have a well moisture distribution in paddy. There have been attempts to develop LSU and fluidized bed dryers with other drying techniques such as using Far-infrared (FIR) [6] to reduce moisture and using hot air and superheated steam for drying system [7], However, both LSU and fluidized bed still use relatively high energy when compared to other drying systems. Therefore, pneumatic dryers are the interest technique to researcher because the dryers can be operated with low hot air temperature and have low initial cost.

Accordingly, this research aim to evaluate the performance of pneumatic dryer, quality of milled rice after drying and discover the appropriate operating condition of the dryer. In the future, the result of this study will use as a guideline for the application of efficiently drying energy.

Experimental detail and methods

The developed pneumatic dryer shown in figure 1. The paddy rice was contained within the bin (No.2) with a dimension of 500 mm (W) x 400 mm (L) x 800 mm (H). The drying process begins by the feed auger (No.5) at the bottom of the bin conveyed the paddy rice to the drying column (No.1) that was made from an acrylic cylinder with a diameter of 76 mm and 1,000 mm in height. At the same time, the $80^{O}C$ of hot air produced by 3 kW of electric heater (No.3) charged to the drying column (No. 1) by the 3 HP of air blower and carried the paddy grains by the terminal velocity of the air. The moisture from paddy grain was removed by the hot air during paddy grain-hot air mixing and blow pass the drying column. Finally, the mixer flow into the cyclone (No.6) to separate the dried paddy and send it to the bin. This process continue circulatory runs until the paddy rice was dried.



(a)


(b)

Figure 1. (a) The developed pneumatic dryer (b) the paddy bin wall.

Testing in this experiment, Thai jasmine rice 105 variety was used to be the samples. For the drying experiment, a 40 kg of paddy was dried at 80°C of hot air drying temperature. The air volume flow rate and their related paddy feed rate were varied to 3 levels (set by the frequency on the blower motor invertor). The effect of cyclone installation are compared investigation. The drying behavior, specific energy consumption (SEC) by eq.1 (in MJ/kg_{water}), drying rate (DR) by eq.2 (in kg_{water}/hr) and percent of head rice yield (%) by eq.3 were evaluated as the performance.

$$SEC = \frac{Q_A}{(W_i - W_f)} \quad (1)$$

Where SEC = Specific Energy Consumption (MJ/kg_{water})
Q_A = Apply electric energy (MJ)
W_i = Initial weight of paddy (kg)
W_f = Final weight of paddy (kg)

$$DR = \frac{(W_i - W_f)}{hr} \quad (2)$$

Where DR = Drying Rate (kg_{water}/hr)
hr = Drying time (hr)

$$\text{Percent of head rice yield} = \frac{\text{weight of only full grain rice (kg)}}{\text{weight of paddy rice (kg)}} x100 \quad (3)$$

Results and Discussions

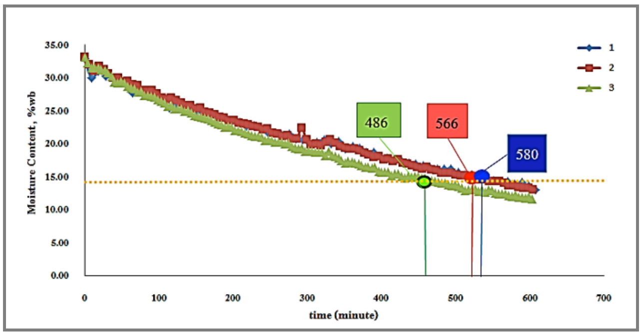
The drying behavior.

At the airflow rate of 0.0512 m^3/s, the system without cyclone uses a 377 minutes (around 6 hours) in the drying period. It is the fastest times in the moisture reducing from initial paddy rice to the finishing of moisture at around 14%wb (Table 1.). For the system with cyclone, the results showed that the airflow rate of 0.0631 m^3/s gives a fastest time in the reducing of moisture content of paddy rice. It uses a 486 minutes (around 8 hours) in drying time (Table 1.). Therefore, the drying by pneumatic dryer without the cyclone installed on the system can reduce the moisture of paddy rice faster than the system with cyclone.

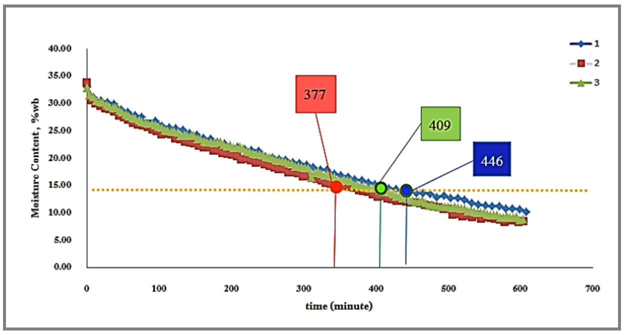
Table 1. The result of a pneumatic dryer without cyclone.

Flow rate level	**Air flow rate (m^3/s)**	**Paddy feed rate (kg/min)**	**Condition**	**Initial paddy MC (%wb)**	**Final paddy MC (%wb)**	**Drying time (min)**
1	0.0451	4.10	With cyclone	32.89 ± 0.13	13.88 ± 5.19	579.50
			Without cyclone	32.96 ± 0.39	13.96 ± 6.28	446.50
2	0.0512	6.35	With cyclone	33.21 ± 0.07	14.00± 5.47	565.50
			Without cyclone	33.68 ± 0.06	14.06 ± 6.60	377.00
3	0.0631	8.45	With cyclone	33.09 ± 0.65	14.00± 5.91	486.00
			Without cyclone	32.88 ± 0.03	13.86 ± 6.61	409.50

From both conditions, it was coincided that high airflow rates can well reduce moisture content of paddy rice because it generates the turbulence flow in the drying column. This situation leads the paddy rice well diffused within the hot air too and cause the high moisture extraction together and the drying behavior were shown in figure 2.



(a)



(b)

Figure 2. Behavior of paddy drying system (a) with cyclone (b) without cyclone

Specific energy consumption

In Figure 3, the results of the specific energy consumption of pneumatic dryer without cyclone showed that the airflow rate of 0.0512 m^3/s yielded the best specific energy consumption (7.25 MJ / kg $_{water}$). For the dryer system with cyclone, it was found that the airflow rate of 0.0631 m^3/s have the best specific energy consumption (10.41 MJ/kg_{water}).

Drying Rates

The drying rates of the pneumatic dryer without cyclone showed that the airflow rate of 0.0512 m^3/s generated the best drying rate (1.10 kg_{water}/hr) (Figure 3). For the dryer system with cyclone, it was found that the airflow rate of 0.0631 m^3/s yielded better drying rate (0.82 kg_{water}/hr).

From the results, the pneumatic dryer without cyclone provided the better drying rates than those of the dryer with cyclone. Because after the drying process in the drying column, it can make a secondary drying on the surface of paddy rice in the bin during the hot air from drying column was released to the bin with paddy rice.

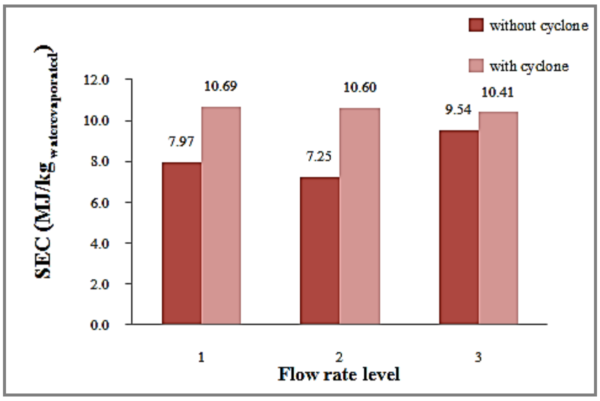


Figure 2. Comparison of specific energy consumption by cyclone and without cyclone installation.

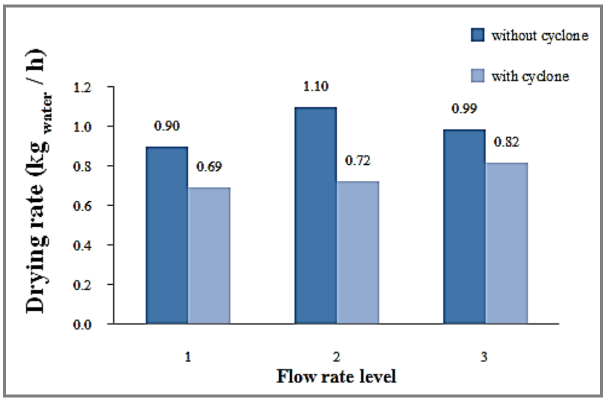


Figure 3. Comparison of drying rate by cyclone and without cyclone installation.

Head rice yield

The percent of head rice yield was used as a quality index of dried paddy rice (Figure 4). However, because the long experiment time (30 days in overall experiments), the quality of paddy rice sample must decrease and take an effect to the percent of head rice yield too. For the system with the cyclone, the higher airflow rate level might reduce the head rice yield of paddy because the high speed of airflow can make more damage on the paddy too. Especially when the paddy rice hits to the cyclone in the system with cyclone. It was found that the airflow rate of 0.0451 m^3/s yielded better head rice yield percentage of 33.91%.

For the system without cyclone, the higher airflow rate level might increases the head rice yield of paddy because the shortest time in drying and it have no mechanical damage by the cyclone and the airflow rate of 0.0631 m^3/s generated the best head rice yield of 36.84%

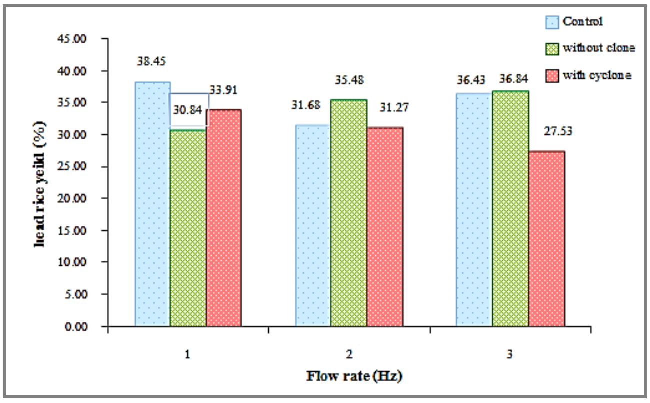


Figure 4. Comparison of head rice yield by sun drying, cyclone and without cyclone installation.

Conclusion

The drying system without cyclone gives a higher rate of moisture extraction than the system with cyclone installation. Based only on energy utilization during the process, the highest SEC of 7.25 MJ/kg_{water} occurs on the drying at the airflow rate of 0.0512 m^3/s by without cyclone. For the dried product quality, the highest head rice yield of

36.84% on the drying at airflow rate of 0.0631 m^3/s. The breakeven point of the developed dryer is 1.6 ton/year of a paddy rice drying.

Acknowledgement

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