Research article

The Development of Rotating Rice Grain Dryer Prototype

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Abstract This research focused on the development of the rotating rice grain dryer prototype for Germinated Parboiled Brown Rice (GPBR) grains. The main GPBR producer in this study was Baan Dong Luang community enterprise, Bung Tawai Sub-District, Tao Ngoi District, Sakon Nakhon Province, Thailand. The producer needs to reduce paddy moistures from above 20% wb down to 15% wb as the packaging and buyer requirements. The original prototype was designed to utilize heat from only the sunlight. It consisted of the driving part, the base and frame and the dryer chamber, which was a smooth-inside-area stainless steel cylinder. In this work, five aluminum fins were installed inside the cylinder to increase the grain distributions. The grain-collecting tray and wheels were attached to the prototype. Experimental investigations were performed repeatedly; 3 times. From the experimental results, the grain distributions observed from the developed prototype were better those from the original prototype. The tray could facilitate the users in taking the dehumidified grains out. The wheels made the prototype movable, the developed prototype could be moved to take the sunlight more convenient. The noticeable experimental result was the drying performance of the developed prototype. The developed prototype took 3 hours to reduce the paddy moistures down to 15% wb while the original prototype could reduce the paddy moistures down within 4.5 hours. On the other hand, the fins could distribute the grains, the heat transfer inside the chamber was enhanced. The reduced drying period was about 33.33%. As the rice dryer is an important tool in household and community rice producers, this dryer prototype could be proved to reduce the drying areas, periods and labors which affects the net incomes of farmers. The famers satisfied with the developed prototype.

Keywords rotating rice grain dryer, germinated parboiled brown rice, GPBR, dehumidifying technology, heat transfer

INTRODUCTION

Nowadays many technologies play important roles in human daily life. One of the technologies, which takes a significant part in Agricultural society as in Thailand, is the post-harvest technology. One of main crops in Thailand is rice, in many post-harvest technologies relating to rice grains or paddies, rice-grain dryers or dehumidifiers are one of those. After paddies are harvested from rice fields, they must be reduced their moisture content. Otherwise, moist rice grains turn rotten faster than dry rice grains in storage containers. In Thailand, paddies are dehumidified traditionally by using heat from sunlight. In Thai communities, rice farmers spread paddies on ground in open wide areas. The reduced moist paddies can be kept in grain silos before the farmers sell or consume them.

The small-scale farmers must find wide areas to dehumidify their paddies, periods of the dehumidifying process rely on the sunlight intensity and ambient relative humidity. Often, the farmers let the moist paddies staying under the sunlight by days and labors are required. Even though, their paddy moistures cannot match acceptable or required levels of their buyers, the acceptable moistures are 15% wet basis (wb) and lower. As the labors are required in the drying process, the labor expenses are still existed, and they seem to be increased continuously. If the rice grain moistures cannot be reached at the acceptable levels, the initial rice production costs of the farmers are high while the selling prices are low, the profits decrease. As mentioned earlier about the important technology, the dehumidifying technology must take part in the small-scale rice farming to reduce the labor costs, processing times and areas. Many rice grain paddy dehumidifiers or dryers are available in world-wide markets. There are many commercial rice-grain dryers, they are big systems with high investment costs and required big amounts of the moist-rice-grain inputs. These commercial rice dryers are suitable for industrial levels more than small community and household levels.

In order to prevent paddies from their deterioration after harvesting, paddies must be dried down to the level of water activity that will enable safe storage by reducing respiration, inhibiting mound growth and preventing production of mycotoxins. These reasons correspond to a moisture content of about 13-14% wb, which is considered adequate for safe storage, milling and further storage as milled rice (Hall, 1970). Mechanical systems, especially those using hot air for rapid drying of high moist grain are becoming increasingly popular throughout the Asian-Australian region (Hung-Nguyen et al., 1999). Fluidized and spouted bed dryers are examples of high temperature dryers. Due to the high air temperatures used, residence time of grain in the dryer must be short to prevent heat damage (Juliano, 1971; Morey et al., 1981; Naewbanij, 1985; Soponronnarit et al., 1996).

There was a rotating rice grain dryer prototype (Bancheun et al. 2016) developed for the small community that produced Germinated Parboiled Brown Rice (GPBR) paddies. The main GPBR producer, who utilized the prototype, is Dong Luang community enterprise, Bung Tawai Sub-District, Tao Ngoi District, Sakon Nakhon Province, Thailand. The prototype was designed to dehumidify these specific paddies by using natural heat from the sunlight transferring to its rotating drying chamber or cylinder. Using the sunlight as the main heat source can reduce heating costs in the dehumidifying process. As the GPBR producer used the prototype, the moisture inside the paddies, which were placed in the chamber, was reduced as the initial objective. The average dehumidifying period, which was obtained from three repeating experiments, was 4.5 hours. However, there were problems occurred, as the enterprise members reviewed, such as its movable ability, an output correcting area and its drying period.

OBJECTIVES

In this current work, the development of the rotating rice grain dryer prototype was reported and discussed. The GPBR paddies so called Khao Hang Ngok in Thai language, were chosen to investigate the performance of the developed prototype since the GPBR producer must utilize the drying process two times. The first drying process is occurred after the paddies are harvested from the fields. The second process is occurred after the rice was germinated and parboiled, the GPBR paddies must be dehumidified before they were stored for any selling purposes. The operating conditions of the developed prototype could be concluded to inform the farmers. The GPBR products with the obtainable and suitable moisture contents could be performed, the low labor costs, short operating periods and smaller areas were concerned mainly.

METHODOLOGY

Since the rotating rice grain dryer prototype as shown in Fig. 1 was originally designed to use the natural sunlight to vaporize the moisture out of the paddies, no electric heater or other heat sources would be inserted into the prototype. The prototype design was reviewed to find simple ways to improve its movement and its performance in dehumidifying the GPBR grains. After the prototype problems were listed and the simple solutions were detailed. All solutions were evaluated for their suitability and possibilities. The development cost should not be increased; therefore, other communities can also utilize this dryer. After the prototype was modified according to the suitable solutions, then, the experiments were carried on finding its improved performance. The Dong Luang GPBR paddies were used in every experiment at Dong Luang community enterprise in this work. The experimental study processes consisted of these following steps.

(1) Measuring the initial moisture content of the grains,
(2) Putting the grains into the drying chamber, measuring the grains for its moisture content and measuring ambient temperature and sunlight intensity outside the drying chamber,
(3) Locating the dryer under the sun in the open area, measuring the ambient temperature and sunlight intensity outside the drying chamber,
(4) Turning on a motor to rotate the chamber for 30 minutes, and
(5) Turning off the prototype and measuring the final moisture content of the grains.

Fig. 1 The original rotating rice grain dryer prototype

RESULTS AND DISCUSSION

From reviewing the prototype in Fig 1, the prototype combined of 3 main parts as a driving part, a base and frame and a cylinder chamber. The dimensions of the prototype were 170x150x130 centimeters. The prototype frame was fabricated from steel bars. The chamber was made from the food grade stainless steel sheet, its dimension was 60 centimeters in diameter and 100 centimeters in length. The chamber was designed to take 100 kilograms of grains with 0.142 cubic meter. The driving part combined of the SAE 1045 steel bar with 3 centimeters in diameter and 152 centimeters in length, the chain system driven by a 1-hp motor (220VAC) with a 10-centimeter sprocket, and the reduction gear. The reduction gear adjusted the chamber rotating speed to be 2.8 revolutions per minute (rpm) from the motor speed of 1450 rpm. The prototype could also be rotated manually. The prototype was utilized by the potential users or farmers in the GPBR community enterprise, Dong Luang community enterprise. The operational information and comments were collected for the improvement in the current work. The first comment was about the grain distributions inside the chamber, there was no tool to distribute the grains inside the chamber as shown in Fig 2. There were some dehumidified grains left inside the chamber after the drying process because the users took the grain out by scooping them out as shown in Fig 3. The prototype movement to find the proper sunlight area was limited because there was no wheel attached on the prototype. After the problems were listed, the improvement plan based on the low budget was selected. Firstly, stainless-steel fins had to be installed along the cylinder length to improve the grain distributions. Secondly, the movable paddy tray had to be attached to collect the dehumidified grains. Heavy-duty wheels were attached to the bottom of the dryer frame for it movable capability. The developed prototype was shown in Fig 4. Six rectangular aluminum fins (right corner of Fig 4) with the dimensions of 100x10 centimeters were attached inside the chamber in the symmetrical distance among them. The dimension of the collecting tray was 90x140x30 centimeters. The 10-centimeter wheels were chosen according to their ability to support 70 kilograms on each wheel, all wheels could be locked for user safety during the dryer operation.

Fig. 2 A dehumidifying chamber

Fig. 3 An output correcting area of the prototype

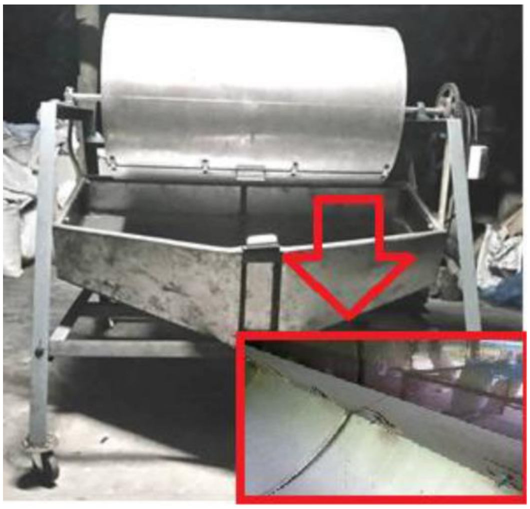

Fig. 4 The developed rotating rice grain dryer prototype

After the prototype was developed by attaching more parts, the experiments were carried out. To find the rice distribution after the fins were installed inside the chamber, 30 kilograms of white rice mixed with one cup of black sticky rice was placed inside the chamber. The developed prototype was turned on at the chamber speed of 2.8 rpm and operated for 30 minutes, 3 repeating experiments. From Fig 5, the black sticky rice was mixed or distributed better with the white rice after the fins were installed inside the chamber. The community members found that the attached tray and the wheels ease them in taking the paddies out and in moving the dryer to face the sunlight, respectively. Then, the community members chose to put 30 kilograms of the GPBR paddies into the chamber in each experiment because this was their normal batch amount. The developed prototype was investigated, the rotating speed was kept the same at 2.8 rpm. Moistures of the paddies in the chamber were measured in 5 different points every 30 minutes, and the aimed moisture was 15% wb. Three repeating experiments were performed for the same measurement conditions. The interesting result, which was found from the GPBR drying investigations, was the average dehumidifying period. The average dehumidifying period was reduced from 4.5 hours (the original prototype performance) to be 3 hours in this current work. This result could also imply that the fins played the important role in the grain distribution causing the better heat transfer to the paddies and the higher dehumidifying rate. The fin installation cost was less than that of the heater installation. Next, average moisture values of the paddies in different ambient conditions were shown in Table 1. The results revealed that the sunlight intensity still played the important role in dehumidifying process, the higher the intensity, the faster the drying process could be performed. The developed prototype could be used to dehumidify the paddies; from 21% wb moisture to 15% wb within 3 hours. Since there were rainy days during the investigation periods. The developed prototype was investigated its performance in this rainy condition while the original prototype was not investigated in this condition. The rainy weather affected the drying process, because of the high relative humidity of the ambient air; the slower the drying process could be carried out at average of 5 hours. We noticed that the developed prototype should be improved for its better performance in the high relative humidity conditions. An extra heating set may be attached to improve the developed performance in the rainy season.

Table 1 Information obtained from the experimental investigations of the prototype in different operating conditions

Ambient conditions	Prototype	Average moisture (%wb)	Sunlight intensity (W/ m^2)	Operating time (hrs.)
No rain 26 ºC 26%RH	original	from 21% to 15%	532	4.5
No rain 29 ºC 24%RH	developed	from 21% to 15%	507	3.0
Rain 30 ºC 85%RH	developed	from 21% to 15%	311	5.0

Fig. 5 Rice distributions in 30 minutes of the prototype operation observed by dark grain distributions among the white grains

CONCLUSION

The household GPBR grain dryer prototype was developed to be suitable with the GPBR dehumidifying processes before the GPBR products could be sent to the buyer or be stored in their containers. There were three parts of the original prototype; the driving part, the drying chamber and the base and frame. The chamber was designed to hold 100 kilograms of rice grains and driven by the 1-hp-AC motor at 2.8 rpm (the chamber velocity) through the sprocket and chain system. The developed parts, which were installed on the prototype, consisted of 1) the tray for collecting the grains outside the chamber, 2) four wheels to make the prototype movable and to take the proper sunlight and 3) 5 fins attached inside the chamber to increase grain distributions during the drying process. The experimental results of the developed prototype showed that the developed prototype could dehumidify the GPBR grains from 21% wb down to 15% wb. Apparently, the fins helped the dehumidifying process shortened by 33.33%. The ambient relative humidity also affected the dehumidifying period, the higher relative humidity the longer drying period. The developed household dryer prototype was proved to be practical for the GPBR drying process. The dryer users were satisfied with the improved performance.

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