RESEARCH ARTICLE

EFFECT OF TWO STAGE DRYING EMPLOYING FLUIDIZED BED DRYING, TEMPERING FOLLOWED BY FIXED BED DRYING ON HEAD RICE YIELD OF BRRI DHAN28 RICE VARIETY IN BANGLADESH

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ARTICLE DETAILS

ABSTRACT

Article History:

Received 18 February 2021

Accepted 21 March 2021

Available online 27 April 2021

Drying of high moisture paddy to achieve quality milled rice is an important issue in a paddy producing country like Bangladesh. This study has been conducted to investigate the impact of two stage drying technique namely, fluidized bed drying, tempering and followed by fixed bed drying method on quality of BRRI Dhan28 rice variety in terms of head rice yield (HRY). Moist paddy was dried in fluidized bed dryer (FBD) as first stage drying to reduce moisture from 25-27% to 18-19% using three drying temperatures of 120, 130, and 150°C at three bed thicknesses of 8, 10, and 12 cm. The first stage dried samples were immediately tempered for 30 minutes and dried in second stage drying by fixed bed dryer using $40 \pm 1^\circ\text{C}$ temperature maintaining bed thickness as 30 cm for the further reduction of moisture content to 13-14% (wb). Sun drying method was followed as complete drying of control sample. Control sample was used to compare the milling quality of rice dried in two stage drying technique. In addition, head rice yield was also compared to existing industrial paddy drying complexes. The results revealed that HRY of rice samples obtained from different drying methods was comparable. All the sets of drying parameters in two stage drying yielded better quality HRY than the control and even existing industrial drying method. The highest HRY (53.43%) of milled rice was obtained in the two-stage drying. On the other hand, the samples dried in the sun drying and industrial drying using Louisiana State University (LSU) dryer yielded 49.77% and 48.25% HRY, respectively. Therefore, the two-stage drying technique can be used for drying of high moisture paddy to obtain quality dried rice.

KEYWORDS

Two stage drying, Fluidized bed drying, Fixed bed drying, Sun drying, Head rice yield.

1. INTRODUCTION

Drying of paddy is a very important issue in all paddy-producing countries especially in humid tropical climates. Paddy is normally harvested with high moisture contents, approximately 20 to 35% on dry basis (db) (Khanali et al., 2012). A group researchers reported that harvested paddy contained high moisture between 20 and 25% on wet basis (wb) in tropical countries and during the rainy season it becomes as high as 22-26% (wb) (Inprasit and Noomhorm, 2001; Igathinathane et al., 2008). After harvesting, paddy needs to be dried in order to prevent quality reduction. High moisture content of paddy should be reduced to 12-14% (wb), which is considered as adequate for milling and safe storage and further storage as milled rice (Wisnet et al., 2001).

Besides, delay in drying or improper drying reduces grain quality and grain wastes become significant (Khodadadi et al., 2012). Post-harvest treatment such as drying is an important step to produce high quality rice. In Bangladesh, paddy drying problem is common during the peak

harvesting season of boro rice in the months of April to May. During this season, farmers get difficulty in drying their cereals due to large quantities of harvest within short time which has, in turn, led to reducing paddy quality and increasing post-harvest losses due to microbial infestation. Paddy drying is often a problem in Bangladesh due to sudden and irregular rain and cloudy weather in summer, and fog and short day in winter (Bala et al., 2010). Bala also reported that the post-harvest losses are the highest during storage followed by drying (Bala, 1978).

A study showed that the traditional and some commercial grain dryers consumed considerable time and energy in their operations and the available dryers are very expensive (Kunii and Levenspiel, 1991). Therefore, there is need to develop suitable drying technique that would lead to time reduction of grain drying without compromising efficiency and also give low operating cost (Kunii and Levenspiel, 1991). Post-harvest losses can be minimized and the quality of dried product can be improved by adopting the present two stage drying strategy for drying of high moisture paddy employing fluidized bed dryer followed by fixed bed

Quick Response Code

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DOI:

[10.26480/sfna.02.2021.74.78](https://doi.org/10.26480/sfna.02.2021.74.78)

dryer and sun drying method. Two stage drying concept is one of the techniques that consists of an initial rapid drying stage followed by a slow drying stage (Wisnet et al., 2001).

Usually, the fluidized bed, spouted bed, and Louisiana State University (LSU) dryers are used as the first-stage dryers for rapid moisture reduction from high-moisture paddy in Asian rice processing industries. Meanwhile, the in-store dryer or fixed bed dryer, ambient air ventilation or sun-drying methods are widely used for further or complete moisture reduction to 13-14% moisture content for safe storage of paddy (Sarker et al., 2013). Two stage grain drying strategy has been suggested by many researchers as one of the most successful drying techniques (Izadifar and Mowla, 2003). In two stage drying technique, high moisture of paddy grain is rapidly reduced to a more manageable level (around 13-14% wb) using fast drying rate (Bunyawanchakul et al., 2007). In the first stage of two stage drying system, high moisture paddy grain would be dried by air at high temperature and high velocity to medium moisture level (approximately 18-19% wb).

Subsequently, in the second stage of drying, ambient air temperature and low airflow would be used to reduce the grain moisture to the safe level (around 12-14% wb). Drying methods have direct effect on quality of dried paddy. Fluidized bed dryer (FBD) that has high drying rate, as the first stage drying has been suggested by many researchers in order to obtain high head rice yield (Poomsa-ad et al., 2001; Soponronnarit and Prachayawarakorn, 1994; Soponronnarit et al., 1996a; Sutherland and Ghaly, 1990; Poomsa-ad et al., 2005; Morey et al., 1978; Thakur and Gupta, 2006; Muhlbaauer et al., 1981; Jittanit et al., 2010; Prachayawarakorn et al., 2005b). However, drying with a fluidized bed dryer is recommended to reduce moisture level around 18-19% (wb) for acceptable head rice. Previous researchers asserted that the fluidized bed dryer is an efficient dryer for first-stage drying (Jittanit et al., 2010; Prachayawarakorn et al., 2005a). On the other hand, in terms of product quality, a group researcher suggested that the breakage of rice during milling could be considerably reduced if a two-stage drying process was applied (Bhattacharya et al., 1971).

In addition, a study reported that head rice yield was significantly affected by the drying method (Prachayawarakorn et al., 2005a). Even though two stage drying was reported employing FBD and LSU dryer yet this drying technique employing FBD as the first stage dryer followed by fixed bed dryer as second stage dryer was not found in the literature. Introducing FBD with fixed bed dryer might be an alternative drying method in Bangladesh condition. Therefore, this attempt was to assess the effect of two options of two stage drying on HRY. Thus, a suitable quick drying technique could be developed for quality dried rice.

2. MATERIALS AND METHODS

In this experiment, paddy sample of BRRI Dhan28 variety was used as the test material to dry in the fluidized bed dryer, fixed bed dryer, and sun drying method.

2.1 Field visit and data collection from existing industrial drying complexes

A baseline survey was carried out to collect data on head rice yield of existing paddy drying system so that performance of proposed two stage drying systems can be compared. Necessary data were collected from different rice processing complexes from Pulhat, Gobindopur and Bottoli areas of Dinajpur district. The respondents were mill owner, manager and technicians while most of the data were recorded based on their verbal reports.

2.2 Sample preparation for drying experiments

Dried paddy with moisture content 13-14% (wb) was purchased from local market of Dinajpur. These were manually cleaned removing impurities such as leaves, broken stalks, chaffs, immature and unfilled grains. Then, the paddy was remoistened by soaking in water at room temperature for 10-12 hours according to make the moist paddy of 25-27% (wb) initial moisture content (Khanali et al., 2012; Wisnet et al., 2001).

2.3 Experimental Procedure

The two-stage drying method was accomplished in this investigation: Fluidized bed drying, tempering and followed by fixed bed drying. A previously designed and fabricated lab scale fluidized bed dryer as shown in Fig. 1 was used to dry the paddy samples from a high moisture level of 25-27% (wb) to 18-19% (wb). The fixed bed dryer as shown in Figure 2

was used in the second stage drying for further reduction of moisture from 18-19% (wb) to 13-14% (wb). In addition, one sample was dried completely by sun drying method which was used as control sample. This control sample was used to compare the performance of the proposed drying technique with it and existing industrial drying.

2.3.1 First stage drying of paddy samples in Fluidized bed dryer (FBD)

Fluidized bed drying experiment was carried out using three temperatures of 120, 130 and 150°C at three bed thicknesses of 8, 10 and 12 cm. The air flow rate ranged from 0.061 to 0.087 m³/s and the corresponding bed air velocity was 1.9 to 2.7 m/s. Firstly, the blower was switched on 5-10 minutes before running the electric heater. The heater bank was so properly regulated to raise desired drying air temperature. Air temperature was measured by digital thermometer. The calculated amount of holdup paddy samples for 8, 10 and 12 cm bed thickness were then loaded into the fluidized-bed drying chamber by inlet port then drying was completed maintaining estimated drying time that was recorded by a stopwatch. The drying process was continued until the estimated drying time, which was found experimentally earlier by trial method for reducing paddy moisture from initial to desired final moisture content of 18-19% (wb). Paddy sample was then discharged from outlet port of drying chamber. Moisture content of dried paddy was determined by oven method. Fluidized bed dried sample was tempered at grain temperature in a plastic bucket for 30 minutes and then cooled to ambient temperature.

Figure 1: Photographic view of the experimental fluidized bed dryer

2.3.2 Second stage drying of fluidized bed dried samples in fixed bed dryer

The paddy samples that had been previously dried in the fluidized bed dryer were further dried using lab scale fixed bed dryer as second stage drying from 18-19% (wb) to around 13% (wb) moisture content. The dryer consist of a drying chamber was 20 cm×20 cm×100 cm with holding capacity of about 30 kg. Drying temperature and bed thickness were considered 40±1°C and 30cm, respectively based on previous researchers suggestions while the air flow rate was 0.025 m³/s and the corresponding bed air velocity was 0.63 m/s (Sarker et al., 2013; Elepano et al., 2005).

Figure 2: Photographic view of an experimental fixed bed dryer

The blower was switched on few minutes before running the electric heater until steady and constant drying air temperature of $40 \pm 1^\circ\text{C}$ was raised. Then the previously dried and tempered samples were fed into the drying chamber. The representative paddy samples were taken at 30 minutes interval from the sampling holes located at three different positions (top, middle and bottom) of the drying chamber and moisture content of sample was determined by using digital grain moisture meter (GMK-303RS, Korea). The drying process was continued until final moisture content of 13-14% (wb) was obtained. After that, the samples were collected from the top, middle and bottom layer and then mixed properly because industry level drying process usually concern with the quality of mixed paddy of all layers of fixed bed dryer. Finally, the dried samples were stored at ambient temperature packing in plastic bags.

2.3.3 Drying of control sample

Complete sun drying was carried out to dry the control paddy sample spreading on plastered pavement. Paddy layer thickness was maintained at 2-3 cm. Air temperature and relative humidity were $27-33^\circ\text{C}$ and the 56-70%, respectively during drying. During sun drying, the paddy was stirred at 20 minutes interval for uniform drying. The moisture content was determined at 30 minutes interval. The drying process was continued until the moisture content of the samples reduced to around 13% (wb). Control drying was carried out to compare the milling quality of rice with other drying methods.

2.4 Milling of dried sample

Milling of dried paddy samples was carried out at the Rice Milling Research Laboratory of Bangladesh Rice Research Institute (BRRI), Gazipur. The milling process involved dehushing, polishing and grading. Before starting milling test, the final moisture content of paddy samples were determined. The moisture content of the dried samples ranged between 13 to 14% (wb). 100g of dried and cleaned paddy was dehusked with a De-husker (JLG 2.5, Korea) while the bran was removed with a Rice Polisher (JNMS 15, Korea) running for 45 seconds for each amount of dehusked brown sample.

2.5 Assessment of quality of dried rice

2.5.1 Head rice yield (HRY)

The head rice yield was defined in this study as the ratio of head rice mass to dried paddy mass. Head rice yield was determined according to using the following equation (Sarker et al., 2013; Sarker et al., 2014; Tirawanichakul et al., 2012; Cnossen and Siebenmorgen, 2000; Islam et al., 2006):

$$\% \text{ Head rice yield} = \frac{\text{Weight of head rice}}{\text{Weight of dried paddy sample}} \times 100 \quad (1)$$

2.6 Statistical analysis of milling data

Two factor experiment in completely randomized design (CRD) was used to know the effect of drying parameters on milling quality in terms of HRY in each option of two stage drying. The first factor was temperature which has three levels such as 120°C , 130°C , 150°C and second factor was paddy bed thickness which has also three levels such as 8 cm, 10 cm, and 12 cm. Further, a single factor experiment in completely randomized design (CRD) was also used to compare the quality of milled rice obtained from the two stage drying techniques, control drying, and industrial drying method. Thus the only factor was drying method. The statistical software package SAS 9.3 version was used to calculate the mean values, standard error mean (SEM) and analysis of variance of obtained values on rice quality as head rice yield. Meanwhile, Duncan's Multiple Range Test (DMRT) analysis was employed to determine the differences in rice quality among the drying methods at $P \leq 0.05$.

3. RESULTS AND DISCUSSION

3.1 Milling quality in existing industrial drying complexes

Base line survey results on the status of drying and milling of rice in Dinajpur district of Bangladesh is given in Table 1. Both parboiled and raw rice are found to be processed in the visited rice mills. LSU dryer that was continuous mixing type dryer, found to be used in the mills. Total drying time varied from 8 to 12 hours in the LSU dryers having the capacity of 1.8-3.6 ton/hr. The average milling result in terms of head rice yield (HRY) was compared with HRY obtained from the proposed two stage drying technique and control drying (Sun drying method).

Table 1. Status of rice drying and milling of rice mills in Dinajpur district

Serial No.	Name and location of the mills	Capacity (ton/hr)	Drying time (hr)	Milling quality
				% HRY
1	Two Brothers Auto Rice Mills, Sadar, Dinajpur	3.6	8-10	51.15 ± 0.23
2	Nilufa Auto Rice Mill, Sadar, Dinajpur	1.8	9-10	50.07 ± 0.27
3	Friends Auto Rice Mills, Sadar, Dinajpur	2.2	10-12	52.15 ± 0.17
4	Tanjum Auto Rice Mills, Sadar, Dinajpur	2.0	8-10	53.10 ± 0.11
5	Raj Auto Rice Mills, Sadar, Dinajpur	3.0	9-10	49.85 ± 0.47
Average				51.25 ± 0.25

*Mean values $\pm$ standard error mean (SEM); HRY: Head rice yield

3.2 Quality evaluation of dried paddy

3.2.1 Head rice yield obtained from two stage drying (Fluidized bed drying, tempering and followed by fixed bed drying method)

Figure 3 shows the percentage of HRY for the paddy samples obtained from the two-stage drying using fluidized bed drying followed by fixed bed drying.

Figure 3: The effect of fluidized bed drying operating parameters on HRY during two stage drying of paddy

[1st stage in FBD: temperature 120, 130 and 150°C and paddy bed thickness 8, 10 and 12 cm; Air velocity: 1.9-2.7 m/s. 2nd stage infixed bed dryer: Temp- 40°C , Bed depth-30 cm and air velocity-0.63 m/s].

When paddy was dried in FBD using drying temperature of 150°C at 8 cm bed thickness, the highest HRY (54.54%) was achieved which was similar with the values as reported (Prachayawarakorn et al., 2011). Paddy with high moisture content (27%, wb) dried using higher temperatures by FBD and fixed bed dryer gave higher head rice yields. On contrary, the lowest HRY was obtained while using 130°C in fluidized bed drying at 8 cm bed thickness. This low HRY might be due to the non-uniformity of moisture content in the paddy bed and fluctuation of temperature and air velocity in the drying chamber. Besides, paddy with similar moisture content dried by fixed bed dryer as second stage using higher temperatures yielded lower HRY corresponding to similar results as mentioned (Sarker et al., 2013).

3.2.2 Comparison of the HRY of paddy dried by control drying, industrial dryer and the proposed two stage drying technique

Table 2: Comparison of the HRY of paddy dried by control, industrial and the best combination of two stage drying technique

Drying methods	Drying Parameters	HRY
Two stage drying (FBD + Fixed bed drying)	Bed thickness(cm) / Drying air temperature($^\circ\text{C}$)	
	8/120	54.54 ± 0.31^a
	10/130	51.04 ± 0.75^b
	8/150	53.04 ± 0.48^{ab}
Control drying	Temperature: $27-31^\circ\text{C}$, Relative humidity: 53-70% and air velocity: 0.05-0.1 m/s	49.77 ± 0.07^c
Industrial drying (LSU dryer)	Drying temperature: $60-70^\circ\text{C}$	48.25 ± 0.25^c

*Mean values $\pm$ standard error mean (SEM).

FBD: Fluidized bed dryer; Fixed bed drying temperature: $40 \pm 1^\circ\text{C}$, Bed thickness: 30cm and bed air velocity: 0.63m/s.

Table 2 displays the percentages of HRY obtained from the control, industrial and proposed two stage drying technique under the best combination of drying operation conditions (Drying air temperature and bed thickness). A comparison on HRY obtained from the three methods such as control, industrial and the two-stage drying method namely fluidized bed drying followed by fixed bed drying revealed that the head rice yield obtained from the two-stage drying technique was comparatively higher than that of control and industrial drying. The results were also similar to the milling characteristics observed (Pin et al., 2007; Takai and Barredo, 1981). It is also clear that the proposed two stage drying option yielded at least same quality of milled rice in comparison to existing industrial drying methods. Similarly, in some study reported that fluidization techniques had been producing increased HRY compared to conventional drying methods (Inprasit and Noomhorm, 2001; Tirawanichakul et al., 2004; Prachayawarakorn et al., 2005a). Nonetheless, the bed thickness and temperature combination of 10cm/130°C yielded lesser HRY compared to 8cm/120°C, which could be ignored due to higher standard error mean. Thus, the two stage drying options can be practiced for achieving quality rice. Practicing tempering after fluidized bed drying could increase head rice yield, as suggested by many researchers (Poomsa-ad et al., 2001; Poomsa-ad et al., 2005; Prachayawarakorn et al., 2005a).

However, this table has also indicated that quality grade varied from a to c, whereas two stage drying as 8 cm/120°C got quality grade a, which was similar to the previous findings (Taweerattanapanish et al., 1999). Even though a lower HRY was obtained by using the combination of 10 cm/130°C in the two-stage drying, which might be due to the non-uniformity of moisture content in the paddy bed, caused by a very low air flow used in fixed bed dryer. The HRY obtained from the sun drying was almost similar or lower than that of two stage drying methods, which indicated that the paddy dried with FBD and fixed bed dryer did not affect the HRY. Similar outcomes were also reported (Soponronnarit et al., 2001; Prachayawarakorn et al., 2005b). At industry level the amount of HRY obtained was lesser. Over polishing to make more fine rice might be the reason of lower HRY in the industry level. The previous researchers also reported that HRY decreased linearly as milling duration increased, or as more bran was removed (Reid et al., 1998). In conclusion, based on quality in terms of HRY, the proposed two stage drying technique can be used for drying of high moisture paddy. In depth study can be carried out to find out the best combination of drying temperature and bed thickness for drying of various initial moisture content paddy using FBD and fixed bed dryer for obtaining better quality rice.

4. CONCLUSION

The effect of two stage drying methods on HRY of BRRI Dhan28 rice variety has been investigated. In this paper, the two-stage drying of BRRI Dhan28 rice variety was carried out in a laboratory scale fluidized bed dryer (FBD) and fixed bed dryer used as first stage and second stage drying, respectively. All the first stage dried samples were tempered for 30 minutes in the plastic bucket as required to temper and balance paddy moisture content. A comparable HRY was found from the two-stage drying which was compared with the complete sun drying and industrial drying method using LSU dryer. The results also showed that at least 2% HRY can be increased by using fluidized bed drying followed by fixed bed drying method compared to existing commercial drying methods. Even though three fluidized bed drying temperatures of 120,130 and 150°C at any thickness of 8, 10 and 12 cm gave the acceptable quality of milled rice but 120°C at 8cm yielded the highest quality of rice thus this can be recommended temperature and bed thickness. Thus two-stage drying practice is found to be more suitable than the existing drying systems as it can raise the capacity of the drying complex and maintaining the quality of dried rice in terms of head rice yield. Therefore, two stage drying technique presented in this paper can be adopted as pilot scale for drying of high moisture paddy in Bangladesh.

ACKNOWLEDGEMENTS

The authors would like to express their sincere thanks to the Krishi Gobeshona Foundation (KGF), Ministry of Agriculture, The People's Republic of Bangladesh for providing fund (Project No. TF29 AM/15) in fabricating lab scale fluidized bed dryer and fixed bed dryer and to the Ministry of National Science and Technology (NST) for awarding the fellowship to the first author for conducting his Masters Research. Their heartfelt gratitude also goes to the Rice Milling Research Laboratory of Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh for facilitating the milling tests.

AUTHOR CONTRIBUTIONS

The corresponding author ensured that the descriptions are correct and that was agreed by all authors. Dr. Md. Sazzat Hossain Sarker was responsible for conceiving the idea, supervised the work and also corrected the manuscript; Md. Abdul Wazed has carried out the work and written the manuscript, while Dr. N. H. M. Rubel Mozumder co-supervised the work and also corrected the manuscript.

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