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Performance Evaluation of Low-cost Grain Dryer

Abhishek Anand*[1, 2], Saurabh Sid[1], Mukesh Shrivastva[1], Dinesh Rajak[1], Aminul Islam[2] and Monika Jain[2]

[1]College of Agricultural Engineering and Technology, Dr. Rajendra Prasad Central Agricultural University, Samastipur, Pusa, Bihar, India
[2]School of Agriculture and Allied Sciences, The Neotia University, Kolkata, W.B., India

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ABSTRACT

Paddy is India's most significant agricultural crop, accounting for more than 40% of the nation's overall production of food grains. The moisture content of 10.0 to 12.0 %, which is suitable for safe storage, must be achieved after the drying of paddy. Drying of materials having high moisture content is complicated process, involving simultaneous heat and mass transfer. In this study the performance of grain dryer was evaluated for paddy grains for two different paddy varieties, Rajshree weighed 372 kg and Rajendra Kasturi weighed 366 kg with Initial Moisture Content IMC of Rajshree 14.00 % w.b. (V1) and of Rajendra Kasturi 13.40 % w.b. (V2). Initial Moisture Content (all in w.b.) of variety V1 was 14.00 % and of variety V2 was 13.40 %. It was reduced to the Final Moisture Content (all in w.b.) of 10.10 % for variety V1 and 9.60 % for variety V2. It was found that 1000 grains weight of paddy grains was reduced due to loss of moisture. It is also observed that average length and average breadth of grains decreases with decrease in moisture content for both the varieties of paddy grains. It was found that the bulk density of paddy grains after drying was 578.9 kg/m ^{3} and 555.58 kg/m^3 V1 and V2. Decrease in bulk density is natural phenomenon during drying which was also observed here. It was observed that percent moisture reduction was lower at initial stage of drying for variety V1, which became higher at later stage of drying. However, the percent moisture reduction was higher at initial stage of drying for variety V2, which became lower at later stage of drying. Paddy was dried up to 10.10 % and 9.60 % for variety V1 and V2 respectively during this time. The drying efficiency for both varieties V1 and V2 was found as 35.36 % and 36.85 % respectively. The heat utilization factor and coefficient of performance was found as 0.948 and 0.052 for variety V1 and 0.960 and 0.040 for V2. Grain dryer is capable of drying paddy grains within reasonable time. Temperature and moisture profiles during paddy drying are found well accepted for drying of paddy. The quality of dried paddy grains was reasonably good and acceptable. Considering the level of technology and the capacity, the dryer meets the requirements of paddy traders and farmers of Bihar.

Key words: *Bulk density, Drying, Heat utilization factor, Moisture content, Temperature*

Introduction

Drying of grains is the first critical step for post-harvest operations which permits better quality of grains, long term storage and minimizes fungal growth and infestation to store at safe moisture content. The most popular method in our country is sun drying, although it is reliant on the weather (Doymaz, 2005). This is very time consuming due to adverse weather condition like rain, fog etc. These result in delayed drying, re-wetted grains and quality deterioration. This leads to a damage that reduces the quality and market value of grains (Alam *et al.*, 2020). Due to the rainy season (June to August), short days, and foggy weather (November - January), drying of grains is a significant issue in Bihar. Besides in the peak harvesting season, there is a great lack of labours to perform the drying operation. Sometimes, it becomes more hazardous when sudden rain occurs. Day by day labour is decreasing due to mechanization and exporting manpower abroad. Therefore, it is urgent to initiate and disseminate low cost dryer for drying grains which is technically viable for mid-level traders and farmers.

Paddy (Botanical name *Oryza sativa*, Grains family - *Poaceae*), commonly known as Asian rice, is the plant species most commonly referred as rice in English (Gnanamanickam, 2009). For a large portion of the global population, particularly in Asia, it is the most widely consumed staple food as a cereal grain (Awika, 2011). Paddy is the most important agricultural crop in India, contributing to more than 40 % of the country's total food grain production. Currently, most of India's top paddy suppliers and paddy exporters are mainly based in region such as West Bengal, Uttar Pradesh, Andhra Pradesh, Punjab, Tamil Nadu, Bihar and Chhattisgarh. These largest paddy producing states hold about 72 % of the total paddy growing area in India and contribute more than 75 % of the total paddy production in the country. India followed on rank 2^{nd} with a paddy production volume of approximately 166.5 million tonnes in 2018. West Bengal is the largest paddy producing state in India. Bihar ranks 6^{th} amongst the main agricultural states in India. Over 33 lakh ha of area is used for paddy production in Bihar. Bihar produced 72.68 lakh tonne of paddy in its last financial year 2017-18 (Sinha, 2017). When paddy is harvested, it has a high moisture content, which results in heat build-up from the respiration of the grain's microorganisms (Dillahunty *et al.,* 2000). Low thermal diffusivity of grain and increased temperature accelerate mould growth, loss of nutrition and flavour which is not suitable for storage. In order to increase shelf life of perishable foods, drying plays important role. Drying of materials having high moisture content is complicated process, involving simultaneous heat and mass transfer. Sun/Solar drying and mechanical drying are the two methods for the drying of grains.

Drying is the process of removing moisture from a porous media by evaporation, in which hot air is passed through a thin layer of the material until equilibrium moisture content (EMC) is achieved. Moisture removal from an agricultural product depends on drying air temperature, velocity, relative humidity, variety and maturity. Hence, various isolated and combined methods are involved in moisture removal from a grain.

The concept, which focused on small-scale farmers who cultivate less than 0.5 ha but live in an area with access to electricity, was based on the idea of low-temperature drying (a few degrees above ambient air). As per original design, this dryer consisted of two perforated concentric bins made of bamboo (later modified of wire mesh) with grains inside the annular space. To dry the grains inside the annular space, air is fed from the inner bins through walls with the bottom and top closed. The hot air from the stove (chulha) is forced radially through perforated bins with the aid of an axial flow blower (Joshi *et al*., 2012). The cost for this modified dryer has been calculated about 20,000/- with drying capacity of 0.5 tonne. Grain dryer is able to remove moisture at the rate of 2.30 % to 2.85 % (w.b.) for Maize crop (Rajak *et al*., 2015).

Hence grain dryer can be used for the quality drying of the grains (Stephen *et al*., 2009). It is cost effective and due to low cost it can be adopted by small and marginal Indian farmers very easily. There is a need to popularize this grain dryer among farmers/processors. But before popularization, dryer needs to be tested and evaluated for its suitability to dry farm crops like maize, paddy, etc. The current study was undertaken with the following objectives to evaluate the performance of low cost grain dryer: i) Evaluation of relevant engineering properties of selected paddy grains before and after drying, ii) To test and evaluate the grain dryer with respect to effect of drying and varieties of paddy on different dependent variables and iii) To determine cost of drying for drying of paddy grains in grain dryer.

Materials and Methods

In this section, the description of the grain dryer, the working principle of the grain dryer, sample preparation, the experimental plan and experimental methodology are discussed. The modified dryer (Fig. 1) consists of the following components:

Blower: Blower is one of the most important components of the grain dryer. It is used to suck the hot air from the stove (*chulha*) through mild steel pipe and force the air radially through perforated bins. It has diameter of 37.0 cm and height of 26.0 cm. It can be operated with the help of an electric motor.

Motor: Electric motor of 1.0 HP, single phase, 2800 rpm, 220 - 240 V was used as a power source to operate blower. As a modification, motor was mounted on the outer periphery of dryer bin with the help of supporting frames. Power was transmitted to blower with the help of pulleys of diameter of 10 cm and 15 cm and belt drive (A 1306 LP/A 50).

Inner and outer bins: Both inner and outer bins are

Table 1. Shows Past studies on different drying

Author name	Study details	Outcome
Kolling *et al.,* 2006	Tested the behaviour of fixed bed corn dryer during the operation of drying, on the basis of commercial scale with different variables i.e. product temperature, airflow, fuel consumption (corn cobs) and ambient and drying air conditions.	Resulted that the average drying air temperature was 41.7°C, and also maximum drying air temperature was found to be 42°C inside the dryer. When the moisture content is above 18 %, the 85 % of the total time for exhaustive drying was effectively consumed.
Kaaya and Yamuhangire, 2010	Studied drying of grains of maize with the help of two methods, first is drying on the bare ground and second was by the help of biomass dryer.	The biomass dryer is more effective than the bare ground drying, as bare ground drying took 5 days to dry the maize to 14 % moisture content, but biomass dryer took only 6 h for drying up to same moisture level. There was no effect on the germination of maize from drying in the biomass dryer.
Bola *et al.,* 2013	Designed and developed a batch in-bin maize grain dryer and studied different properties of maize (moisture content, bulk density) and properties of dryer (drying chamber dimension, amount of removal of moisture, quantity of air, volume of air, capacity of blower, heat quantity and actual heat required to effect drying).	Resulted with a locally fabricated dryer was affordable with a total cost of sixty thousand Naira (N60, 000 = 375 USD).
Rajak *et al.,* 2015	Studied grain dryer with to improve its drying efficiency, reduce the drying time, and produce hygienic and quality dried wheat and maize.	Resulted that the modified dryers was able to remove moisture at the rate of 2.15 to 2.66 % (w.b.) per hour for wheat crop and at the rate of 2.30 to 2.85 % (w.b.) per hour for maize grains.
Aktar *et al.,* 2016	Evaluated technical performance of STR dryer and assessed adaptability of for small paddy traders and large farmers' levels (300 kg per batch) in Bangladesh.	Resulted that the drying and the heat conveying efficiencies of the STR dryer were found about 31.2 % and 19.91 %, respectively. The overall dryer efficiency was found about 22.7 %, which satisfy the standard batch dryer performance.
Dev and Kumar, 2017	Evaluated grain dryer andengineering properties before and after drying for drying of Maize at three different loadings (200kg, 250kg, 300kg) and three levels of initial moisture content of about (20 %, 22 %, 24 %) w.b by maintaining at average air temperature of 45°C.	Reported that total drying time increased with increasing moisture content.
Kumar *et al.,* 2018	Studied and evaluated technical performance of a low modified STR dryer (500 kg per batch) with four different air velocities such as 1.5, 2.0, 2.5 and 3.0 m/s were used for drying with temperature of 50°C.	The results showed that the temperature and moisture distributions in STR dryer were quite uniform. Duration of drying of paddy from 24.78 % to 8.5 % moisture content (w.b.) was 3.5 - 7 h depending upon the source of energy used. At all the air velocities, the lowest value of lightness was observed at air velocity of 3.0 m/s and the highest values were recorded at air velocity 2.0 m/s.

made of wire mesh stainless steel. Diameter and length for inner bin is 37 cm and 91 cm respectively and for outer bin diameter is 101 cm and length is 100 cm. Grains are put in the annular space between inner and outer bins.

Stove *(chulha):* Stove is placed in one side of the grain bin and firing was done using biomass briquette/coal. It has diameter of 38 cm and length of 33 cm.

Heat Conveyance Pipe: Heat conveyance pipe having diameter 8.5 cm and length 153.5 cm is used to convey the hot air from *chulha* to the dryer.

Inlet funnel at *chulha:* The inlet funnel having diameter 43 cm and height 42 cm is connected with the heat conveyance pipe. It covers the *chulha* and makes the path for hot air to the dryer through the heat conveyance pipe.

Inlet funnel at dryer: The inlet funnel at dryer having diameter 37 cm and height 26 cm consist of fan and is used to convey hot air into inner bin.

Working principle of grain dryer

When grains are dried in a deep bed, they are not all completely exposed to the same drying air conditions. The state of the drying air fluctuates with time and with the depth of the grain bed at any given time in the grain mass. In addition, thin layer drying of grain uses a much smaller amount of air flow per unit quantity of grain. Every static bed batch drier used on farms is built using the deep bed drying technique. Grain drying in a deep bin can be thought of as the accumulation of numerous thin layers. The humidity and temperature of air entering and leaving each layer vary with time depending upon the stage of drying, moisture removed from the dry layer until the E.M.C is reached. Little moisture is removed rather a small amount may be added to the wet zone until the drying zone reaches it. The temperature, humidity, grain M.C. and air movement speed all had an impact on the drying zone's volume. When the product and air are in equilibrium, drying will end (Chakraverty, 1995).

The grain dryer's design, which targets small-scale farmers who cultivate less than 0.5 ha yet live in an area with access to electricity, is based on the idea of low-temperature drying. The investment for this dryer was only about 20,000/- with the drying capacity of 0.5 tonne in 8 hours. The two bamboo (later converted to wire mesh) perforated concentric cylinders used in this dryer have grains inside the annular gap. The two bamboo (later converted to wire mesh) perforated concentric cylinders used in this dryer have grains inside the annular gap. The hot air from the stove (chulha) is forced radially through perforated bins using an axial flow blower to draw it through mild steel tubing.

Sample preparation

Fresh and healthy paddy grains of two varieties *Rajshree* and *Rajendra Kasturi* were taken for experimental work. After winnowing of grains with the help of winnower, paddy grains were weighed using electronic weighing balance (GLOBUZ, 300kg capacity and 50g readability) and placed in the dryer. 372 & 366 kg paddy grains of two varieties

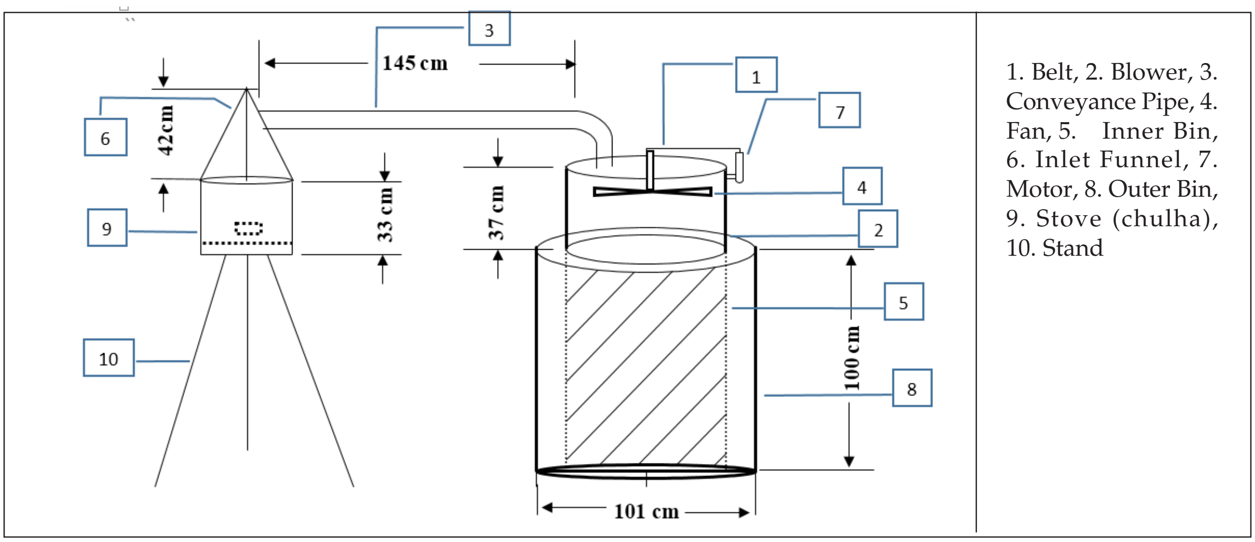


Fig. 1. Schematic diagram of the modified grain dryer.

Table 2. Dryer dimensions/specifications

	Items	Specification
	Batch capacity	300-500 kg depending on grain type
I	**Blower**	
	Diameter	37.0 cm
	Height	26.0 cm
	Fan sweep	12.0 cm
II	**Motor**	
	Motor power	1.0 HP
	Operating voltage	220 – 240 V
	Frequency	50 Hz
	Speed	2800 RPM
III	**Motor Frame**	
	Horizontal supporting frames (5 nos.)	1.5 × 1.5 × 0.15 cm
	Vertical supporting frame	3.0 × 1.5 × 0.15 cm
IV	**Inner bin**	
	Material	Wire mesh, stainless steel
	Diameter	37 cm
	Length	91 cm
V	**Outer bin**	
	Material	Wire mesh, stainless steel
	Diameter	101 cm
	Length	100 cm
VI	**Stove *(chulha)***	
	Diameter	38.00 cm
	Length	33.00 cm
	Placement of the iron rods for holding fuels	21.00 cm
	Opening for air flow at the bottom H × W	9 × 11 cm
	Stand height for *chulha*	84.00 cm
VII	**Conveyance pipe**	
	Total length of pipe for hot air movement from *chulha* to Dryer	153.50 cm
	Diameter of conveyance pipe	8.50 cm
VIII	**Inlet Funnel at *Chulha***	
	Height	42.00 cm
	Diameter	43.00 cm
IX	**Inlet Funnel at dryer**	
	Height	26.00 cm
	Diameter	37.00 cm
X	**Stand height at the bottom of dryer**	7.00 cm

were used for testing with an initial moisture content of 14.00 % w.b. and 13.40 % w.b. respectively, which was determined by standard hot air oven method. Table 3. Shows the equipment/instruments used during the experimentation.

Determination/measurement of variables

Moisture Content: Initial and final moisture content of the paddy was determined for finding the dry matter as well as moisture content of the raw sample. The moisture content of sample was determined by standard hot air oven method. The samples were dried in the hot air oven at 105 ± 2°C for 24 hours. The total dry materials or the initial/final moisture content of sample was determined in accordance with AOAC method (Chen, C. 2003) and Moisture Content (MC) was calculated using following formula:

$$\text{M.C. (\% w.b.)} = \frac{Wm}{Wm + Wd} \times 100 \qquad ..\ 1$$

Where, M.C. = Moisture content (% w. b.), W_m = Weight of moisture, W_d = Weight of bone dry material

1000 Grains Weight: 1000 grains weight was measured with the help of digital pocket scale balance available in the laboratory of Department of PFE.

1000 grains from each IMCs and FMCs of paddy samples were randomly taken and weighed using digital balance of 0.01 g sensitivity.

Grain size: Grain size of paddy is defined by its length and breadth of grains. To determine average length and average breadth, 20 grains from each variety V_1 and V_2 were randomly taken before and after drying and with the help of electronic digital caliper of 0.01 mm resolution with ± 0.02 accuracy, the length (l) and breadth (b) were measured. After the measurement of length and breadth, the Average length and Average breadth were calculated.

Bulk density: It is the ratio of total mass of grains and total volume of grains. To determine the bulk density, measuring cylinder of 1000 cc was filled with paddy grains from each IMCs and FMCs. These grains were weighed with the help of digital electronic balance available in the Department of PFE laboratory and weights were converted into kilogram from gram. After that the bulk density of the paddy grains was calculated by using the formula given below.

$$B.D. = \frac{\text{Total mass of grains (kg)}}{\text{Total volume of grains } (m^3)} \quad .. (2)$$

Moisture reduction (%): It is the amount of moisture removed from the grains during entire drying process. IMCs and FMCs were measured with the help of digital moisture meter for both the varieties of the paddy grain and after that moisture reduction is calculated by the formulae given below.

$$\text{Moisture reduction (\%)} = \frac{\text{IMCs} - \text{FMCs}}{\text{IMCs}} \times 100 \quad .. (3)$$

Average drying temperature (!): It is defined as the ratio of sum of all the observation of recorded inlet air temperature to the total number of observations. Inlet air temperatures were recorded with the help of multi-thermometer at an interval of half an hour and after that the mean value of recorded temperature was calculated for both the varieties.

$$\text{Average drying temperature } (^oC) = \frac{\sum_{i=1}^{n} T_i}{n} \quad .. (4)$$

Where, T_i is the recorded temperature, n is the number of observations.

Hot air conveyer pipe efficiency (%): Energy supplied from hot air for the system is the actual energy supplied to the paddy grain. Air flow rate and ambient air temperature were recorded by digital anemometer, dryer temperature was recorded by multi-thermometer and the total dryer running time was taken as recorded time for both the varieties of grains. Following expression was used to determine it:

$$ES_a = å \times A_p \times \rho_{air} \times S_{heat} \times t \times T_{avg} \quad .. (5)$$

Where, ES_a = Energy supplied by air (kJ), å = Air flow through the pipe (m/h), A_p = Area of the pipe opening (m^2), ρ_{air} = Density of air (kg/m^3), S_{heat} = Specific heat capacity of air, kJ/kg°C, t = Recorded time (h), T_{avg} = Dryer temperature - Ambient temperature (°C)

Total energy for the system in operation is the summation of equivalent fuel and electrical energy. Electrical energy used was calculated by energy meter and the amount of fuel (coal) used was recorded and then energy consumption was calculated with following expression:

$$EC_t = (F \times H + EE) \quad .... 6$$

Where, EC_t = Energy consumption (kJ),F = Amount of fuel used (kg), H = Net calorific value of fuel (kJ/kg), EE = Electrical energy used (kJ).

After calculating the value of Energy supplied by air and Energy consumption, hot air conveyer pipe efficiency was determined.

$$´_{pipe} = \frac{ES_a}{EC_t} \times 100 \quad .... 7$$

Drying efficiency (%): The drying efficiency is defined as the ratio of energy output of the drying section to energy input to drying section.

$$\hat{}_{drying} = \frac{\text{Output energy of dryer}}{ES_a} \quad .... 8$$

Output energy of dryer = $\mathbf{M_r \times L_g}$

Where, M_r = Moisture removed (kg),L_g = Latent heat of vaporization of moisture (kJ/kg).

Heat Utilization Factor (HUF) and Coefficient of Performance (COP): The utilization factor of a drying system is the ratio of drop in temperature of drying air by drying process and the increase in temperature of ambient air by heating.

$$HUF = \frac{\text{Drop in dry bulb temperature of drying air, } ^oC}{\text{Increase in dry bulb temperature of ambient air, } ^oC} = \frac{t_2 - t_3}{t_2 - t_1}$$

Where, $\mathbf{t_1}$ = Average dry bulb temperature of ambient air, $\mathbf{t_2}$ = Average dry bulb temperature of heated air, $\mathbf{t_3}$ = Average dry bulb temperature of exit air.

COP = 1 – HUF …. 10

Cost of drying

Cost of drying was calculated by determining the fixed cost and variable cost for the entire working period by straight line method.

Results and Discussion

The performance of grain dryer was evaluated for paddy grains for two different paddy varieties, *Rajshree* weighed 372 kg and *Rajendra Kasturi* weighed 366 kg with Initial Moisture Content (IMC) of *Rajshree* 14.00 % w.b. (V_1) and of *Rajendra Kasturi* 13.40 % w.b. (V_2). To study the factors affecting the performance of the dryer, various parameters were recorded during experimentation at certain time interval.

Variation in engineering properties of paddy grains: Variation in different engineering properties of paddy grains was observed just before and after completion of each drying experiment. Table 4. Shows this variation in different engineering properties.

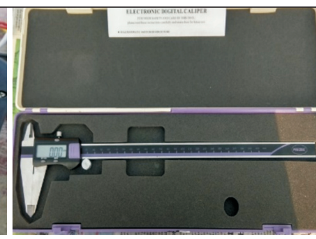
Moisture Content: From Table 4. It is clear that Initial Moisture Content (all in w. b.)of variety V_1 was 14.00 % and of variety V_2 was 13.40 %. It was reduced to the Final Moisture Content (all in w. b.) of 10.10 % for variety V_1 and 9.60 % for variety V_2.

1000 Grains Weight: It is evident from Table 4 that the weight of 1000 grains before drying was 22.20 g and 14.83 g for V_1 and V_2 respectively which was reduced to 21.14 g and 14.18 g for V_1 and V_2 after drying. It was found that 1000 grains weight of paddy grains was reduced due to loss of moisture.

Table 3. Equipment/Instruments used during experimentation

Hot air oven

Universal handy moisture meter



Electronic digital caliper

Humidity/temperature data logger

Digital pocket scale balance

Anemometer

Multi-thermometer

Sample collector

Variety - *Rajshree*

Variety – Rajendra Kasturi

Average length and average breadth: From Table 4. It is clear that average length and average breadth of different paddy varieties was reduced during drying experimentation. The average length and average breadth of the paddy grains before drying was 7.63 and 2.62 mm respectively for V_1 and 5.92 and 2.17 mm respectively for V_2. Average length and average breadth of grains after drying was 7.45 and 2.47 mm for V_1 and 5.61 and 2.06 mm for V_2. It is also observed that average length and average breadth of grains decreases with decrease in moisture content for both the varieties of paddy grains.

Bulk Density: Table 4. shows the variation in bulk density during experimentation. The bulk density of the paddy grains before drying was 600.00 kg/m^3 and 580.00 kg/m^3 for varieties V1 and V_2. It was found that the bulk density of paddy grains after drying was 578.98 kg/m^3 and 555.58 kg/m^3 V_1 and V_2. Decrease in bulk density is natural phenomenon during drying which was also observed here.

Variation in ambient air temperature & R.H. and drying air temperature: Table 5 and Fig. 2 show the

Table 4. Variation in engineering properties for paddy grains before and after drying.

S. No.	Parameter	*Rajshree* (V_1)		*Rajendra Kasturi*(V_2)	
		Before drying	After drying	Before drying	After drying
1	Moisture Content (% w.b.)	14.00	10.10	13.40	9.60
2	1000 Grains Weight (g)	22.20	21.14	14.83	14.18
3	Average length (mm)	7.63	7.45	5.92	5.61
4	Average breadth (mm)	2.62	2.47	2.17	2.06
5	Bulk Density (kg/m^3)	600	578.98	580	555.58

Table 5. Variation in ambient temperature/R. H. and drying air temperature with drying time during experimentation.

Drying Time (min)	Variety (V_1) *Rajshree*			Variety (V_2) *Rajendra Kasturi*		
	Ambient air temp.(°C)	Ambient R. H.(%)	Dryingair temp.(°C)	Ambient air temp.(°C)	Ambient R. H.(%)	Dryingair temp. (°C)
0	25.2	41.7	42.9	22.2	49.4	45.2
30	24.8	44.2	40.5	22.3	52.5	50.8
60	24.2	55.9	52.2	23.4	57.9	52.4
90	25.3	60.9	52.3	24.2	69.4	58.8
120	27.2	62.9	55.5	25.8	71.9	60.2
150	28.6	70.5	58.4	26.2	73.5	58.2
180	30.2	71.3	60.5	27.2	70.5	55.9
210	29.2	80.4	65.2	26.9	82.5	62.2
240	27.9	82.3	59.2	25.3	83.3	60.3
270	25.2	79.4	58.4	25.4	76.6	54.2
Average	26.78	64.95	54.51	24.89	68.75	55.82

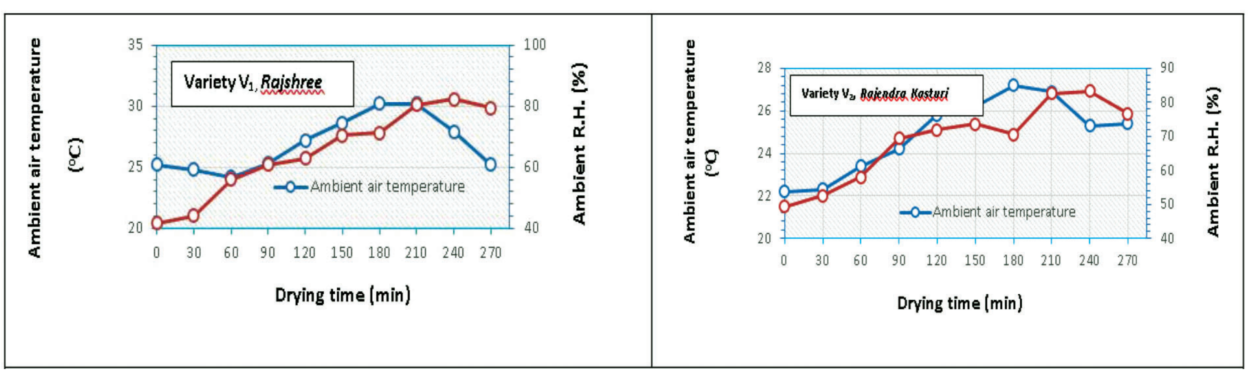


Fig. 2. Variation in ambient air temperature and ambient R.H. with drying time (a) Variety V_1, *Rajshree* , *(b)* Variety V_2, *Rajendra Kasturi*

variation in ambient air temperature and ambient R.H. with drying time during experimentation for both the varieties of grains. It was observed that the ambient temperature varied within overall range of 24.2 °C to 30.2 °C with an average value of 26.78 °C during experiment with variety V_1. However, it varied between 22.2 °C to 27.2 °C with an average value of 24.89 °C during experiment with variety V_2. Similarly R.H. varied within the overall range of 41.7 % to 82.3 % with average value of 64.95 % for V_1 experiment and within the overall range of 49.4 % to

Table 6. Variation in moisture content of paddy grains with drying time

Drying Time (min)	Moisture Content (% w. b.) Variety (V_1) *Rajshree*	Variety (V_2) *Rajendra Kasturi*
0	14.00	13.40
30	13.70	12.50
60	13.50	11.70
90	13.20	11.20
120	12.80	10.90
150	12.20	10.50
180	11.70	10.20
210	11.20	10.00
240	10.60	9.90
270	10.10	9.60

Table 7. Variation in percent moisture reduction of paddy grains with drying time

Drying Time (min)	Percent moisture reduction Variety (V_1) *Rajshree* IMC - 14.00% w.b.	Variety (V_2) *Rajendra Kasturi* IMC – 13.40 % w.b.
30	2.14	6.72
60	1.46	6.40
90	2.22	4.27
120	3.03	2.68
150	4.69	3.67
180	4.10	2.85
210	4.27	1.96
240	5.36	1.00
270	4.72	3.03

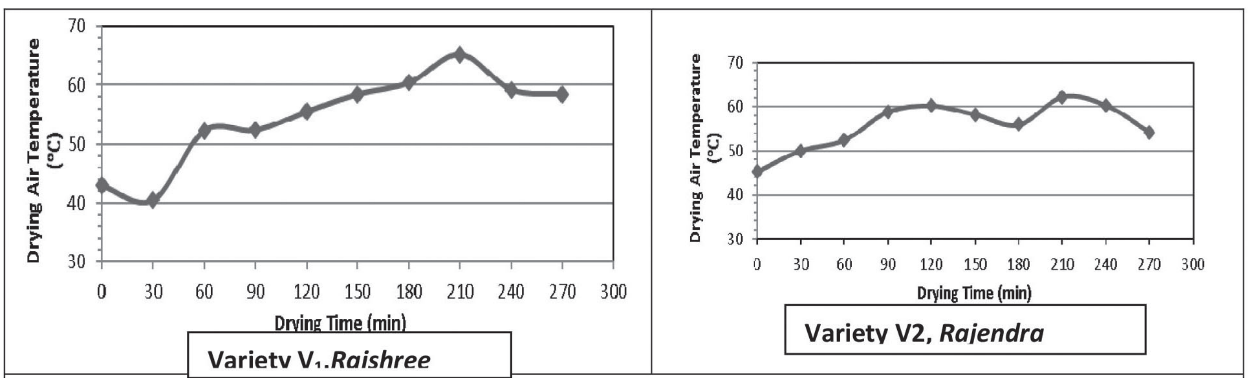


Fig. 3. Variation in drying air temperature of paddy grains with drying time

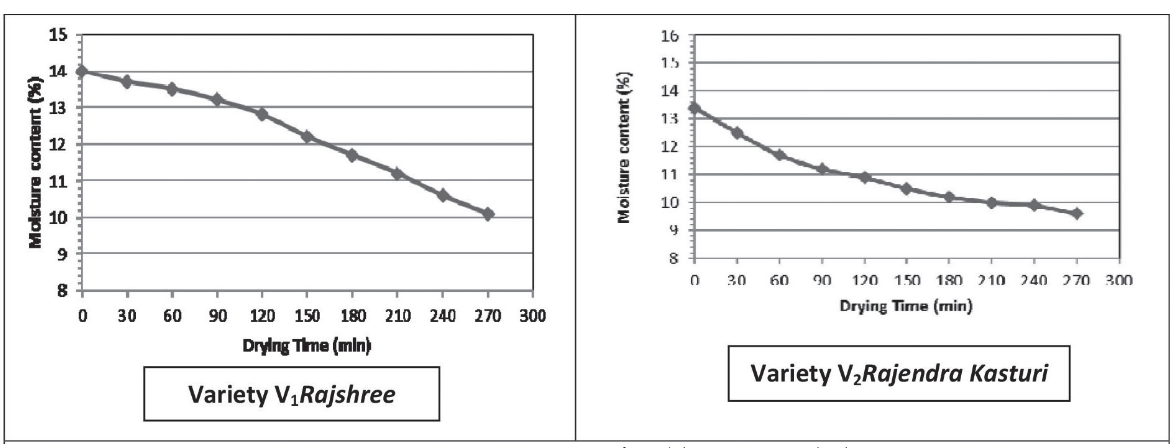


Fig. 4. Variation in moisture content of paddy grains with drying time

83.3 % with average value of about 68.75 % for V_2 experiment.

Table 4.2 and Fig. 3 show the variation in drying air temperature with drying time during experimentation for both the varieties of grains. The overall variation in drying air temperature was observed in the range of 40.5 ºC to 65.2 ºC with average of 54.51 ºC for V_1 experiment and in the range of 45.2 ºC to 62.2 ºC with average of 55.82ºC for V_2 experiment.

Effect of drying on moisture content: Table 6 and Fig. 4 show the effect of drying on moisture content with drying time of two different varieties of paddy full capacity of grain dryer. It is obvious that the M.C. of grains reduced with increasing drying time. It was observed that moisture content of variety V_1 was reduced from 14.00 to 10.10 % (w.b.) in 270 minutes drying time as compared to variety V_2 to reduce moisture content from 13.40 to 9.60 % (w.b.) in same time. As the drying of paddy grain progresses, the grains near to the inner bin dry rapidly and the moisture concentrated slowly at the far side of the outer bin grain. The moisture removed from the grain near to the inner bin passes through the grain at far side cause slow removal of moisture. However, as drying front progresses, the moisture content of paddy grains at all position become almost equal.

Effect of drying on percent moisture reduction: Table 7 shows the variation in percent moisture reduction of selected varieties of grains. It was observed that percent moisture reduction was lower at initial stage of drying for variety V_1, which became higher at later stage of drying. However, the percent moisture reduction was higher at initial stage of drying for variety V_2, which became lower at later stage of drying. The drying time of 270 minutes yielded 27.85 % moisture reduction for variety V_1 as compared to 28.35 % for variety V_2. This difference may be due to the difference in size and bulk density of grains of two varieties, variation in drying air temperature and grain bed depth.

Variation in drying parameters: Table 8 shows the variation in drying parameters of both paddy varieties. Parameters included final moisture content (% w.b.), overall moisture reduction (%), total drying time (min), average drying air flow rate, total fuel consumption (kg), and average fuel consumption (kg/h). Following major observations/results emerged during experimentation:

- The total drying time to reach the final moisture content (FMC) of about 10 % (w.b.) was 270 minutes (4.5 hours). Paddy was dried up to 10.10 % and 9.60 % for variety V1 and V_2 respectively during this time. The overall percent moisture reduction for V_1 was 27.85 % and 28.36 % for V_2.
- Total fuel consumption is 18 kg and 22 kg for two selected varieties of grains V_1 and V_2 during whole experiments.
- The average fuel consumption rate for variety V_1 was 4.00 kg/h and for V_2 was 4.89 kg/h.

The average air velocity was measured as 2.6 m/s and 2.7 m/s for experiments with variety V_1 and V_2 respectively.

Hot air conveyor pipe efficiency: The hot air conveyor pipe efficiency for both

Varieties at its own grain loading has been calculated which is presented under Appendix – (B). The Hot air conveyor pipe efficiency for both varieties at its own grain loading was found as below:

For 372 kg grain loading of *Rajshree* variety 21.44 %

For 366 kg grain loading of *Rajendra Kasturi* variety 15.34 %

Drying efficiency: The Drying efficiency for both varieties has been calculated which is presented

Table 8. Variation in drying parameters

Drying Parameter	Variety (V_1), *Rajshree* Grain Loading (372kg)	Variety (V_2), *Rajendra Kasturi* Grain Loading (366kg)
Initial Moisture Content (% w.b.)	14.00	13.40
Final Moisture Content (% w. b.)	10.10	9.60
Overall Moisture Reduction (%)	27.85	28.36
Total Drying Time (min)	270	270
Average drying air velocity (m/s)	2.6	2.7
Average air flow rate (m^3/h)	13284	13788
Total Fuel Consumption (kg)	18	22
Average Fuel Consumption Rate (kg/h)	4.00	4.89
Final Dried Weight (kg)	355.50	351.00

under Appendix – (C). The drying efficiency for both varieties at its own grain loading was found as below:

For 372 kg grain loading of *Rajshree* variety 35.36 %

For 366 kg grain loading of *Rajendra Kasturi* variety 36.85 %

Heat Utilization Factor (HUF) and Coefficient of Performance (COP): The heat Utilization Factor (HUF) and Coefficient of Performance (COP) for both varieties has been calculated which is presented under Appendix – (D). The HUF & COP for both varieties was found as below**:**

Particulars	Variety (V_1), *Rajshree* Grain Loading (372kg)	Variety (V_2), *Rajendra Kasturi* Grain Loading (366kg)
HUF	0.948	0.960
COP	0.052	0.040

Cost of drying: The cost of drying for both varieties has been carried out which is presented under Appendix – (E). The drying cost for both varieties at its own grain loading was found as below:

For 372 kg grain loading of *Rajshree* variety 1.26 /kg 104.88 /h 0.28 /kg/h

For 366 kg grain loading of *Rajendra Kasturi* variety 1.44 /kg 118.21 /h 0.32 /kg/h

Conclusion

From the present study, we may conclude that the operation of the dryer is very simple and local operators and labourers can easily operate the dryer with simple training. Grain dryer is capable of drying paddy grains within reasonable time. Temperature and moisture profiles during paddy drying are found well accepted for drying of paddy. Its design has to be improved for its maximum and efficient/ economical utilization. The quality of dried paddy grains was reasonably good and acceptable. Considering the level of technology and the capacity, the dryer meets the requirements of paddy traders and farmers of Bihar.

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