

Performance Study of STR Dryer for Paddy

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Abstract

The study was conducted with a view to evaluate technical performance of a STR dryer in Bangladesh and to assess adaptability of the dryer at small paddy traders and large farmers' levels in Bangladesh. The experiment was conducted during December 05-07, 2014 at the workshop of the Department of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh. The capacity of the STR dryer was about 300 kg per batch. The study was conducted with two kinds of samples. Firstly in experiment- 1 and 2, the dryer removed moisture content of paddy from about 18.2% to 12% on an average 3 hrs time. Secondly, in experiments 2, 3 and 4, it removed moisture 14.1 to 10.9% (wb) on an average 2 hrs of time. The ambient air temperature and relative humidity were about 18.36°C-28.95°C and 55.4%-91.8%, respectively. The drying temperature of STR dryer for paddy drying was in the range of 38°C to 42°C. 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. Considering the level of technology and the capacity, STR dryer meets the requirements of small paddy traders and large farmers of Bangladesh and recommended for adaptation in Bangladesh conditions.

Key words: STR dryer, Drying temperature, Relative humidity, Dryer capacity, Drying efficiency, Paddy.

1. Introduction

Bangladesh is a predominantly agricultural country in which majority of the people earn their livelihoods from farming and agriculture-related activities. Paddy is the most important cereal crop in Bangladesh. Mainly three seasons exist for paddy cultivation in Bangladesh – Aus, Aman and Boro. The most common problem is that during harvesting of major cultivation period Boro and Aman, sky remains cloudy; hence sun drying which is common method of drying paddy in Bangladesh is extremely difficult.

Drying of paddy is the critical first step for post-harvest operation which permits better quality of seed, long term storage and minimizes fungal growth and infestation to safe moisture content. In Bangladesh, Sun-drying is the most common method used in our country and dependent on weather conditions. This is very time consuming due to rain, fogs 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 paddy. In addition, the solar radiation

change with the season and even with the time of the day, and the worst is in the rainy season (CIGR, 2003).

During the harvesting period of Boro and Aus, humidity of the air is very high (often 80-90%), and the harvested paddy containing 18-20% moisture. However, because of rain and cloud, the availability of sunshine hrs is not enough to dry paddy in this season. Under this condition, sun drying cannot be used to reduce the moisture content to 12% (w.b.), required by the reputed paddy millers and seed dealers. Moreover, delay in drying decreases the quality of paddy and sometimes it make large amount of loss in quality. A key problem inhibiting the supply of quality paddy during the Aus and Boro seasons is the lack of proper drying technologies available in the country. There are few mechanical paddy dryers available in the country for large-scale paddy drying and especially suitable for large paddy mills. However, majority of the paddy mills purchase dry paddy (about 12% w.b. moisture content) through large paddy traders. However, the large paddy traders do not involve small paddy traders

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and farmers in drying of paddy. The existing mechanical dryers available in the country are not suitable for themselves. Therefore, appropriate drying technology is needed to reduce drying losses and improve the quality of paddy for long-term storage.

Besides in the peak harvesting season, there are a great lack of labors to perform the drying operation. Sometimes, it becomes more hazardous when sudden rain occurs. Day by day labor is decreasing due to mechanization and exporting manpower in the abroad. Therefore, it is urgent to initiate and disseminate low cost dryer for drying paddy which is technically viable for mid-level traders and farmers.

The PETTRA implemented a project entitled "Test and Modification of IRRI-BRRI Seed Dryer".

It was reported that the dryer is suitable to dry seed paddy in adverse weather condition (Rahman, 2003). It was reported that the dryer is suitable to dry seed paddy in adverse weather condition (Rahman, 2003). The time required to dry 1 ton was 60 hrs and electrical energy required was 59.5 kWh for un-parboiled paddy (Baqui, 1996). SRR-1 dryer was fabricated and tested for both unparboiled and parboiled paddy and head paddy recovery was higher in dryer dried paddy compared to that of sun dried (Baqui, 1996).

BRRI conducted field demonstration of SRR-1 at Chunarughat of Habiganj district and every respondent (50) felt necessity of the dryer for their paddy drying at places where heavy rainfall occurs during the harvesting seasons. Therefore, the objective of the study was to conduct performance evaluation of a STR dryer for small paddy traders and large farmers.

2. Materials and Methods

2.1 Materials

The study of evaluating the technical performance of STR Dryer was done with local materials. There were 5 experiments performed. 1500 kg paddy grains (BRRI Dhan-49) used in the experiment to assess the performance of the dryer, were collected from Bangladesh Agricultural University Farm.

2.1.1 Components of STR dryer

A set of inner frame, perforated bamboo woven sheet, a stove and a flat bar mesh were constructed in the Department of Farm Power And Machinery workshop, Bangladesh Agricultural University, Mymensingh for experiment purpose. The performance evaluation of the STR dryer had been implemented during December 5-7, 2014 in accordance with the objectives of the study. Locally available materials were used in the experiment were Bamboo woven sheet, Stove, Fuel (Paddy husk briquette), Electric power source, Steel duct, Polythene cover mat, Weighing pot, Binding rope.

2.1.2 Apparatus required for measuring technical parameters

Technical parameters of the study were measured to use the apparatus were Thermocouples, Digital moisture meter, Digital anemometer, Thermostat, Auger, Electric balance, Desiccator and Oven. Other necessary materials for transportation and storage were a tractor of Department of Farm Power And Machinery Workshop and 25 bags of 60 kg capacity were used to carry the paddy from Bangladesh Agricultural University Farm to Department of Farm Power and Machinery and vice versa.

2.2 Description of the STR dryer

STR dryer is a low cost batch dryer developed by the Centre for Agricultural Energy and Machinery, Nong Lam University, Vietnam and Japan International Research Center for Agricultural Sciences (JIRCAS). The specifications of the dryer are given in table 2.1. This dryer consists of two perforated concentric cylinders with grains inside the annular space and air is passed from the inner cylinder through walls with bottom and top closed to dry the grains. An axial flow blower is used to suck the hot air from the stove (*Chula*) and force the air radially through perforated bins and paddy husk briquette is used as fuel in a portable locally made stove (*Chula*). The capacity of the dryer per batch is about 300 kg and requires 2 to 3 hrs to remove moisture from about 18% to 11% w.b.

2.3 Installation of the STR dryer

2.3.1 Installation of inner and outer bins

In the first step, the frame of the inner drying bin was installed by fixing the nuts and the bolts properly.

Then a piece of perforated bamboo woven sheet was stretched around the inner bin frame and tied it with GI wire. Similarly, the outer bin was constructed by making another cylinder with perforated bamboo woven sheet and ties it with GI wire.

2.3.2 Installation of thermocouples

There were eight thermocouples set up in various positions of the dryer to get the temperature response over time. These thermocouples were used to get the corresponding temperature during drying. Where, Inner middle = Middle height of inner bin; Bottom middle = Temperature at 5 cm from the bottom and middle position (11 cm) of the outer bin; Top middle = Temperature at 5 cm from the top and middle position (11 cm) of the outer bin; T_0 = Temperature at 2 cm from inner bin and middle height of the outer bin; T_1 = Temperature at 5.5 cm from inner bin and middle height of the outer bin; T_2 = Temperature at 11 cm from inner bin and middle height of the outer bin; T_3 = Temperature at 26.5 cm from inner bin and middle height of the outer bin; T_4 = Temperature at 20 cm from inner bin and middle height of the outer bin.

2.3.3 Pouring of paddy grains

Paddy grains were collected from the Bangladesh Agricultural University farm and these were weighed and poured in the annular space of the dryer. That was done in such a way so that equal paddy grains contained in all sides and the blower was set up. A polythene cover mat was used to cover the top of the dryer to protect leaking air and bricks were used to keep the mat with grain rigidity.

2.4 Calculation procedures for measuring technical performance

The dryer was installed in the Department of Farm Power and Machinery Workshop, Bangladesh Agricultural University, Mymensingh for detail evaluation of technical performance of the dryer. The following technical parameters were measured with appropriate instrumentation. Heat sensors were used for measuring temperature gradient in the drying front along with sensible drying and ambient temperatures during drying.

A moisture meter was used for instant measuring of moisture of paddy grain during drying. Drying airflow

and relative humidity were measured by an anemometer and respectively. Subsequently, samples were taken and paddy grain moisture was determined by oven dry method.

2.4.1 Evaporation rate

Evaporation rate is the amount of moisture evaporated from the paddy during drying per unit time. The evaporation rate was calculated by following expression:

$$E = W_d (M_i - M_f); E = \frac{E}{t_d}$$

Where, E = Evaporation (kg/batch), E = Evaporation rate (kg/hr), W_d = Mass flow rate (kg/batch), M_i = Initial moisture content, d.b (%), M_f = Final moisture content, d.b (%), t_d = Drying duration (hr).

2.4.2 Bone dry weight of paddy

Bone dry weight of paddy is the weight of dry matter present in the paddy after drying. It was calculated by the following expression:

$$W_d = \frac{W_t}{1 + M_i}$$

Where W_t = Weight of total grain (kg/batch), M_i = Initial moisture content, d.b (%), W_d = Bone dry weight of paddy.

2.4.3. Drying capacity

The ratio of the weight of total dried grain (whole and damage) in bin and time required to dry each bin is called drying capacity. The drying capacity was calculated from the following expression:

$$DC = \frac{W_t}{t}$$

Where, DC = Drying capacity, (ton/hr) W_t = Weight of total grain, ton, t = Recorded time (hr)

2.4.4. Energy consumption during drying

Total energy for the system in operation is the summation of equivalent fuel and electrical energy, and calculated with following expression:

$$ECT = 10^{-3} \times (FH + EE)$$

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

N: B: Net calorific value of fuel (briquette) = 10655 kJ/kg

Table 2.1 Specifications of the STR dryer

Items	Specification	Items	Specification
Blower		Stove (Chula)	
Diameter, cm	39 ± 0.05	Diameter, cm	36
Height, cm	39 ± 0.05	Length, cm	40
Motor size, kW	0.746	Placement of the wire mesh, cm	11.5
Operating voltage, Volt	220-240	Opening for air flow at the bottom H×W, cm	8 × 11
Frequency, Hz	50	Capacity of the dryer per batch, kg	300
RPM	2874	Drying time per batch, hr	2 ~ 3
Air velocity, m/s	21.6	Paddy of the dryer, Tk	21000
Inner bin			
Diameter, cm	40		
Length, cm	113		
Outer bin			
Diameter, cm	85		
Length, cm	113		

2.4.5 Hot air conveyer pipe efficiency

Energy supplied from hot air for the system is the actual energy supplied to the paddy grain. Following expression was used to determine it:

$$ES_a = \dot{a} \times A_p \times \rho_{air} \times S_{heat} \times t \times T_{avg}$$

Where, ES_a = Energy supplied by air (kJ), $\dot{a}$ = Air flow through the pipe (m³/hr), A_p = Area of the pipe opening (m²), ρ_{air} = Density of air (kg/m³), S_{heat} = Specific heat capacity of air, kJ/kg°C

t = Recorded time (hr), T_{avg} = Dryer temperature-Ambient temperature (°C)

N: B: Specific heat capacity of air = 1.055 kJ/kg°C, Density of air = 1.127 kg/m³.

Heat conveying efficiency through pipe, $\eta_{pipe} = \frac{ES_a}{EC_T}$

2.4.6 Drying efficiency

The drying efficiency is defined as the ratio of energy output of the drying section to energy input to drying section.

The output of the dryer in terms of energy is

$$Output_{dryer} = 10^{-3} \times mr \times L_g$$

Where, $output_{dryer}$ = Output of the dryer (MJ), mr = Moisture removed (kg), L_g = Latent heat of vaporization of moisture(kJ/kg).

mr = (Weight of grain before drying, kg – weight of grain after drying (kg))

Drying efficiency of the system is

$$\eta_{drying} = \frac{Output_{dryer}}{ES_a}$$

The overall drying efficiency is defined as the ratio of energy output of the dryer to total energy input.

3. Results and Discussion

3.1 Technical Performance of the STR dryer

The technical performance which is a major concern of overall performance of the dryer, is mostly depends on the type of dryer, its design and workmanship; however, other important factors are initial moisture content of the paddy and its maturity, drying temperature, ambient air temperature and relative humidity.

There were two types of sample dried; one sample was relatively higher moisture content about 18.1-18.0% (wet basis) and dried to 11.9-12.0% (wet basis). Another sample was lower moisture content about 14.1-14.0% (wet basis) and dried to 10.8-10.9% (wet basis). During all five experiments,

the ambient temperature varied between 18.36°-28.95°C with a relative humidity of around 55.38-91.79% (Fig. 1a, b, c, d, and e). The maximum ambient air temperature has found during 11:00 AM to 2:00 PM. The relative humidity increases with the

decreasing of ambient temperature which directly affect the drying time of paddy. During experiment-1 there was a load shedding of 55 minutes which showed corresponding changes in graphs.

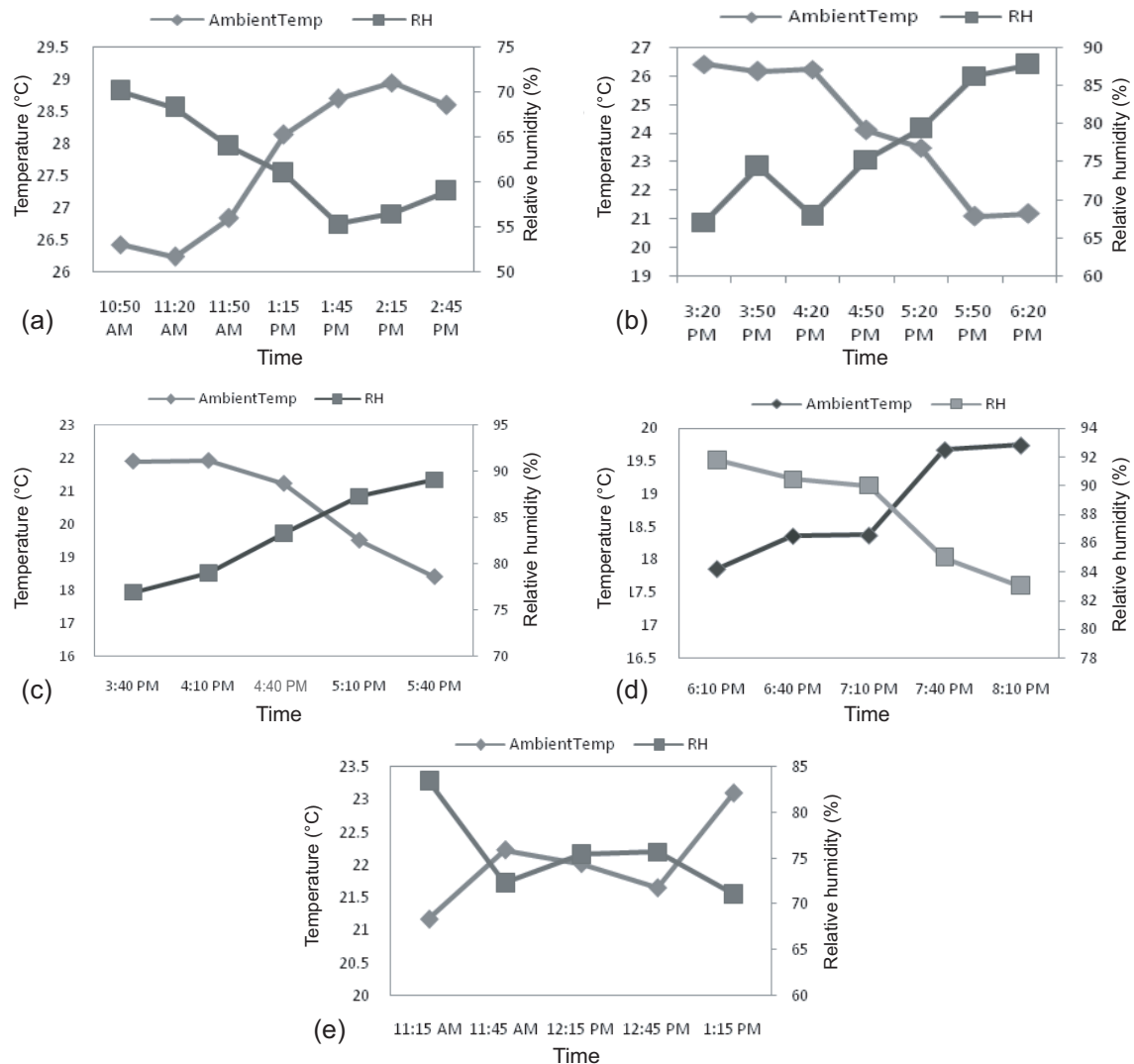


Fig. 1: Ambient air temperature and relative humidity (a) Experiment 1, (b) Experiment 2, (c) Experiment 3, (d) Experiment 4, (e) Experiment 5

3.1.1 Moisture profile of paddy during drying

Figure 2 show the gradient of moisture content in the grain during drying. It is evident from the figures that initially the moisture content of the paddy grain was about 18.2% (wb). 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. In this experiment, the final moisture content of the paddy grain was 11.0% (wb).

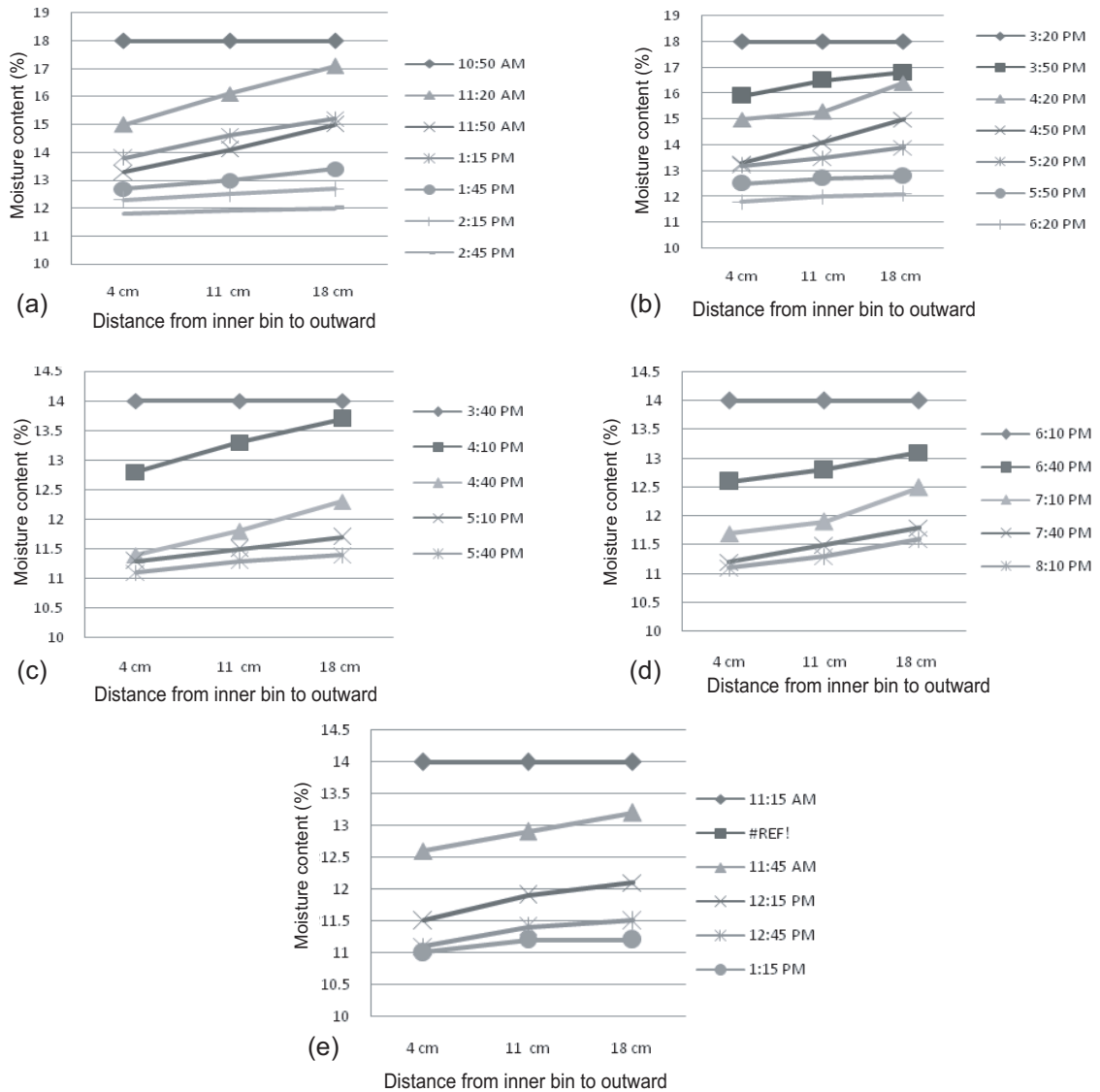


Fig. 2: Moisture gradient of paddy in drying bin

(a) Experiment 1, (b) Experiment 2, (c) Experiment 3, (d) Experiment 4, (e) Experiment 5. Where, 4 cm means (4 cm from inner bin and middle height of the outer bin); 11 cm means (11 cm from inner bin and middle height of the outer bin); 18 cm means (18 cm from inner bin and middle height of the outer bin)

Figure 3 shows moisture removal profile of paddy grain during drying. The figures show that at initial hrs, the moisture removal rate is higher and it slows down as the drying progresses and become very small. During the period, the initial moisture content of 18.2% (wb) reduced to a moisture content less than 12 % (wb). In this experiment, the paddy grain

moisture content was less 12% because of higher relative humidity in the ambient air. At storage, the paddy will gain moisture to the equilibrium moisture content of the ambient and during selling moisture content of paddy must be below 12% that is the requirement of the paddy miller.

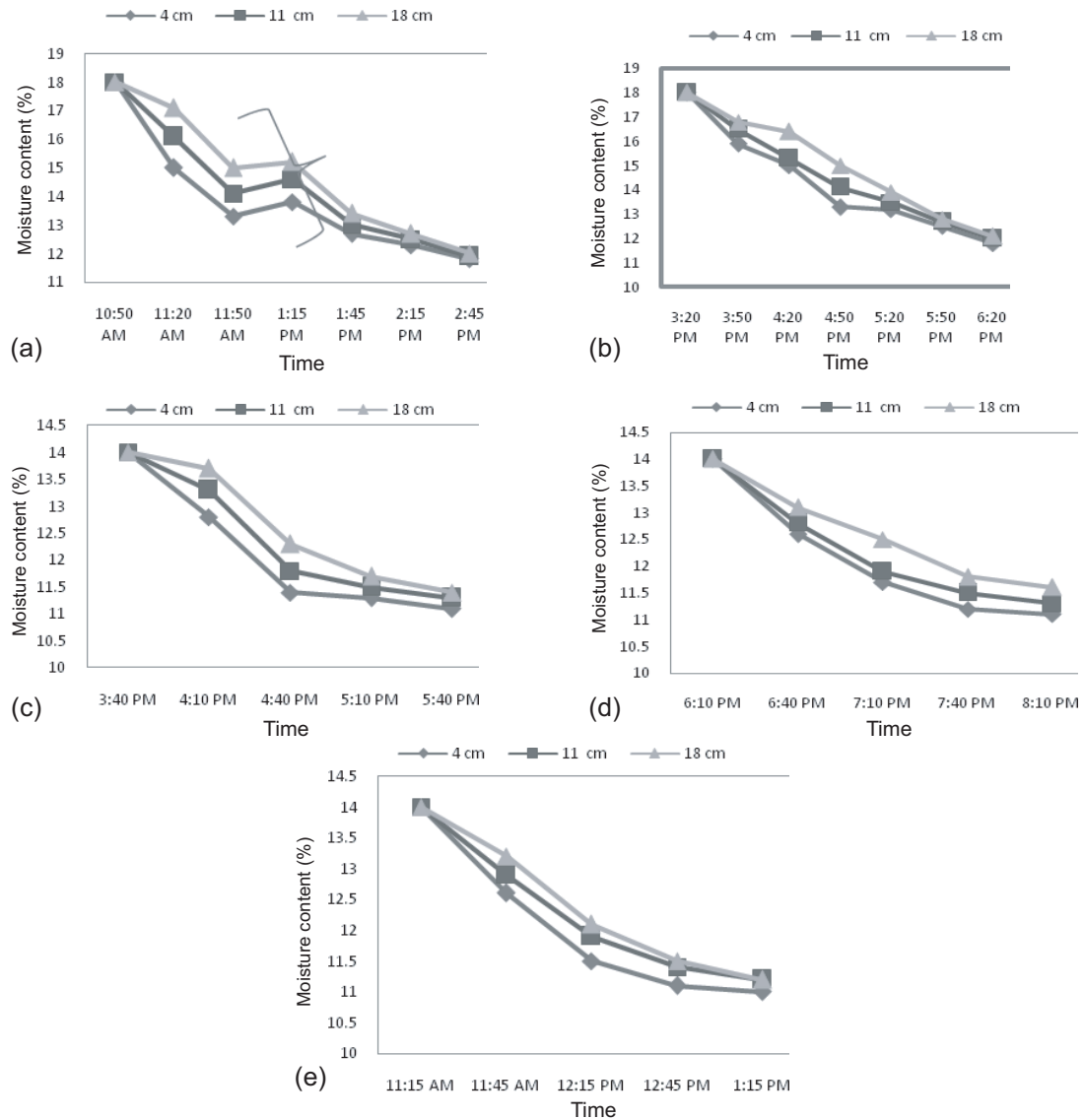


Fig. 3: Moisture removal profile of paddy during drying

(a) Experiment 1, (b) Experiment 2, (c) Experiment 3, (d) Experiment 4, (e) Experiment 5. Where, 4 cm means (4 cm from inner bin and middle height of the outer bin); 11 cm means (11 cm from inner bin and middle height of the outer bin); 18 cm means (18 cm from inner bin and middle height of the outer bin)

3.2 Technical Parameters of the STR Dryer

Table 1 shows the technical performance of the STR dryer during drying of paddy. The average initial moisture content was about 15.76 % and it was reduced to a final moisture content of about 11.5% during drying. The time required for drying was 2.4 hrs (Fig. 3). The drying efficiency of the STR dryer was found about 31.2%. The heat conveying

efficiency of the conveyer pipe assembly was found about 19.91%. Therefore, the overall dryer efficiency was found about 22.7% (Table 1). The overall efficiency of the dryer can be further improved by increasing the heat conveying efficiency of the conveyer pipe assembly by using insulator on the heat-conveying pipe.

Table 1: Technical performance of the dryer

Description	Values					Average
Experiment	1	2	3	4	5	
Initial moisture content, % (w.b.)	18.2	18	14.5	14.1	14	15.76
Final moisture content, % (w.b.)	12.1	12	11.3	11.1	11	11.5
Conveyer pipe efficiency, %	24.26	21.28	17.09	20.64	16.30	19.91
Drying efficiency, %	32	34.2	33	29	28	31.2
Overall dryer efficiency, %	24.2	22.2	23.4	21.6	22.1	22.7

The drying efficiency of 31.2% is very satisfactory with the prevailing ambient air temperature and relative humidity and these natural conditions are expected during major harvest of Aus and Boro Paddy. The capacity of the dryer is about 300 kg of paddy and 12 hrs requires operation to dry about 1.5 ton of paddy. The capacity is also suitable for small paddy traders and large farmers. Therefore, the STR dryer is technically recommended for the small paddy traders and large farmers of Bangladesh

4. Conclusion

The construction of the imported STR dryer from Vietnam is very simple in design and easily be fabricated in Bangladesh using locally available materials in local workshops. The operation of the STR dryer is very simple and local operators and laborers can easily operate the dryer with simple training. Locally available paddy husk briquette can be used as fuel and it which provides heat without smoking and keep the quality of paddy intact for marketing. The STR dryer maneuvers excellent drying ability of paddy in adverse conditions, especially in depressions, heavy rain and cloudy days with low ambient air temperature and very high relative humidity. Temperature and moisture profiles during drying are found as per proper design of well-accepted dryers available for drying of paddy. The dryer removes moisture content of paddy from about 18.2% (wb) to 11.0% (wb) on an average 2 to 3 hrs time of 300 kg of paddy, which is very encouraging in terms of technical analyses and suitable for Bangladesh conditions. The capacity of the STR dryer is about 300 kg per batch and 1.5 ton per 12 working hrs a day is suitable for small traders and large farmers of Bangladesh. The drying efficiency of the STR dryer is found about 22.7%,

which satisfy the standard batch dryer. There are further scopes for improving the overall dryer efficiency by using insulation on heat conveying pipe assembly. The STR dryer is environmental friendly and characteristics of reducing health hazard of laborers working on drying floor (*Chatal*). Considering the level of technology and the capacity, STR dryer meets the requirements of small paddy traders and large farmers of Bangladesh and recommended for adaptation in Bangladesh conditions.

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