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Mechanical drying of paddy using BAU-STR dryer for reducing drying losses in Bangladesh

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Abstract

Mechanical intervention in each stage of post-harvest operation of paddy is time demand due to increased cost of labour as well as shifting of labour from agriculture to non-agriculture sector. Mitigation of food demand of rapidly increasing population is becoming a major future challenge in agriculture sector. Drying of paddy is important for maintaining quality and long term storage of paddy. Among the drying methods, traditional sun drying is the most common practice in Bangladesh. Normally, farmers use yard in wet season (Boro & Aus) and field in dry season (Aman) to dry paddy. In this case, appropriate paddy drying technology could play a vital role to strengthen food security by reducing drying loss. Therefore, a study was conducted to investigate the drying loss of paddy both in traditional sun drying and mechanized drying method (BAU-STR dryer) at selected areas of Bangladesh. Popular and mega rice varieties cv. BRRI dhan28 and BRRI dhan49 were used as drying materials to evaluate the performance of BAU-STR dryer with different dryer capacity i.e. 300, 400, 500 and 600 kg of paddy per batch. Drying losses of BAU-STR dryer were examined during Boro and Aman season of 2015 and 2016 whereas drying losses under open sun drying method was measured during Aman season 2017 in the selected areas of Tangail, Mymensingh, Netrokona and Jessore districts of Bangladesh. The results showed that the average drying loss of paddy in BAU-STR dryer was found 0.48% and 0.36% during Boro and Aman seasons, respectively at 2015 and 2016 while sun drying loss at farmer's field level was found 3.95, 3.24, 2.98 2.41 and 3.04% in Tangail, Mymensingh (Phulpur), Mymensingh (BAU), Netrokona and Jessore districts, respectively. The low cost BAU-STR dryer would be an alternative and effective drying technology to save 1.4 MMT of paddy by reducing 2.7% losses of national production (51.87 MMT) for combating hunger and improving food security in Bangladesh.

Key words: Drying loss, BAU-STR dryer, paddy, food security, Bangladesh

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Introduction

Bangladesh is an agricultural country where agriculture contributes 16.33 % of the GDP to the Bangladesh economy. In Bangladesh rice covers about 61 % of the total agricultural area and 75 % of the cropped area. Rice farming is the main source of income and employment of the rural people. Average yield of rice under irrigation condition is 2.81 tons per ha which is low compared to the average yields obtained in other countries with similar agro-climatic conditions (Majumder S. et al., 2016). Bangladesh is now producing about 51.87 million ton of paddy (IRRI, 2016) to feed about 161 million people (UN, 2015). The population of Bangladesh is still growing and is expected to reach 200 million by 2050 (UN, 2012). On the other hand, the amount of cultivable land per capita is decreasing due to various non-agricultural activities like industrialization and urbanization. For this reason, rice production of Bangladesh need to increase to feed the growing population of the country. Therefore, post-harvest loss reduction in each stage of operation can play a vital role in enhancement of national food security as well in the world.

Paddy is usually harvested at grain moisture content between 22 to 28% (wet basis). Delayed drying, incomplete drying, or uneven drying will result in qualitative and quantitative losses. Improper drying of paddy (high moisture grain) will generate heat due to respiration of microorganisms and grain itself, low thermal diffusivity of grain and increased temperature accelerate development of mold which damage the grain. Some grain mold pathogens produce compounds (mycotoxins) that can be toxic to farm animals, wildlife, or humans. High moisture also reduces grain germination rate and vigor due to respiration of grain, mold and insects activities. It causes the loss of nutrition and flavor due to reduce starch and sugar content and increased fatty acid and finally, reduce head rice recovery (Pundlik DS, 2015). Therefore, drying of paddy is critical to prevent insect infestation and quality deterioration of rice grain and seed.

Drying is the most important part of post-harvest loss reduction. It is the process to reduce the moisture from grain to a safe level for storage and handling following harvest. It is a critical step for maintaining grain quality and minimizes storage and processing losses. Sun drying is a traditional and common practice in Bangladesh where paddy is exposed to sun and wind in the yard or field (Figure 1). But it is very dependent on weather conditions. Climate change makes weather very unpredictable and unexpected rainfall can result in delayed drying, re-wetted grains and quality deterioration which lead to damage that reduce the quality and market value of paddy. To reduce post-harvest loss especially in drying, low cost BAU-STR dryer would be an alternative to sun drying method of paddy in Bangladesh. Therefore, the objective of this research was to investigate drying loss of paddy in traditional sun drying method at farm level and compared with mechanized drying method using BAU-STR dryer.

Figure 1. Traditional paddy drying process (a) sun drying in yard, (b) sun drying in field and (c) sun drying in rice mill.

Materials and Methods

Drying loss of BAU-STR dryer was examined during Boro and Aman season of 2015 and 2016 at the workshop of the Farm Power and Machinery Department, Bangladesh Agricultural University, Mymensingh, Bangladesh whereas drying loss under open sun drying method was measured during Aman season 2017 in the selected areas of Tangail, Mymensingh, Netrokona and Jessore districts of Bangladesh. Freshly harvested paddy varieties BRRI dhan28 and BRRI dhan49 were collected from the Bangladesh Agricultural University farm in the Boro and Aman season respectively to evaluate the BAU-STR dryer with the different drying capacity of 300, 400, 500 and 600 kg per batch of paddy and three replications.

***Description of the dryer*:** The BAU-STR dryer consists of a perforated inner bin and a perforated outer bin with annular space for rice grains, a biomass stove, a hot air conveyance pipe and a blower to provide the heated air. A pictorial view, schematic view and experimental set up of BAU-STR dryer are shown Figure 2. The inner and outer bins are made of stainless steel wire (8 meshes). The diameter of inner bin is fixed (40 cm) while the diameter of the outer bin is adjustable to hold desired volume of rice. Heated air is forced from the inner bin through grains and perforated walls of the outer bin with bottom and top closed to dry the grains inside the annular space. An axial flow blower is used to suck the hot air from the biomass stove a through steel pipe and also the blower forces the air radially through the grains in the annular space between the perforated bins. A diesel generator is used as alternative source of power for running the blower in absence of electricity supply from the national grid. Locally available rice husk briquette is used as a fuel in a portable locally made stove.

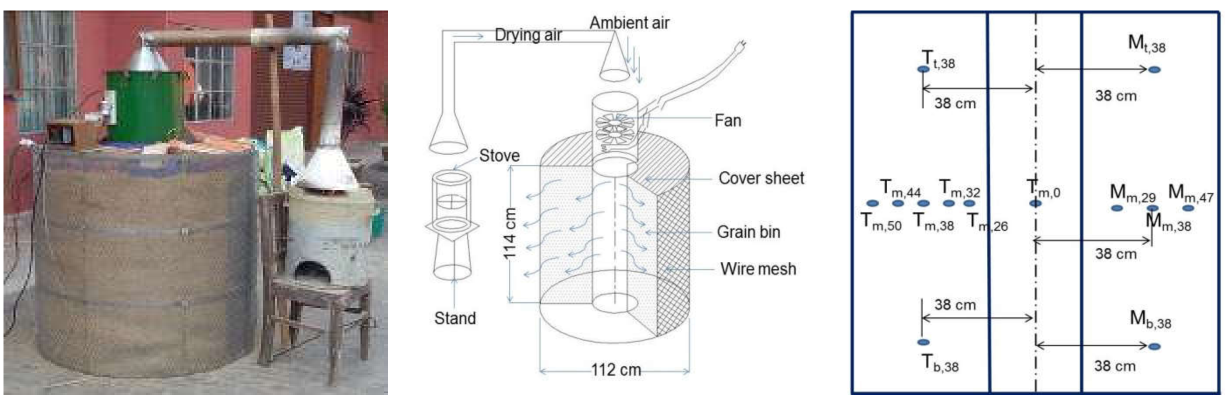

Figure 2. BAU-STR dryer (a) photographic view, (b) schematic view and (c) experimental set up (T-temperature sensors, M-moisture sensor, t-top, m-middle, b-bottom, Number in the subscript indicate distance from the center line in cm)

***Experimental procedure for BAU-STR dryer*:** The BAU-STR dryer was installed in the workshop of the Department of Farm Power and Machinery, Bangladesh Agricultural University. Fresh harvested paddy was collected from BAU farm. The collected samples were cleaned, weighed and recorded initial moisture content. Initial moisture content and weights were adjusted at 14% moisture content (wet basis) to calculate drying loss of paddy. The dryer was loaded with desired volume of paddy and drying operation continued till the desired moisture content of 12% (w.b.) was achieved. Final weights and moisture content were also measured and adjusted at 14% moisture content (wet basis) to calculate drying loss of paddy. Initial and final moisture content of paddy were determined in two ways: manually using digital moisture meter and an electric oven (105 °C for 24 hrs). Two electrical balances (Model- ES-HA precision balance scale) were used to weight paddy.

The drying air temperature was measured using nine *K*-type thermocouples which were attached to a data logger (Model-FLUKE 2635A Hydra series Data bucket). The data logger was connected with a computer to record and store temperature reading at one minute interval during drying operation. The ambient air temperature and relative humidity were measured by using a data logger (Model-TRH 1000, temperature accuracy: ±0.2°C and RH ±4%).

Moisture content was measured at the five locations in side of the grain bin named M_{m1}, M_{m2}, M_{m3}, M_t and M_b, respectively. A digital moisture meter was used to measure moisture content of paddy (Model-RiceterL, accuracy: ± 0.2% 105°C, measurement range 11-30% for paddy rice) after collection of sample with the help of steel made sample collector. Data were collected in every half an hour interval during drying operation.

***Experimental procedure for field drying*:** The experimental procedure to determine field drying loss was followed as mentioned by Jose et al. (1985). Existing farmer's practices in post-harvest operation were taken in consideration to investigate field drying loss which includes harvesting time, harvesting process and drying practice of paddy. For this purpose, 50 m² (5m X 10m) test area were marked randomly by staking the corner poles in the field. The test area was select about 1 m distance from the levee to avoid man-made shattering loss because of passing people. Harvesting loss was measured by marking 1 m along the length of test area from the 5 m side to cover an area of 5 m² (1m X 5m). All the grains lying on the field were picked up carefully from the selected 5 m² area after harvesting paddy by sickle. Collected paddy were cleaned and weighted. Moisture content was also measured at the same time. Weights are adjusted at 14% moisture content to calculate harvesting loss. Another 10 m² (2m X 5m) areas were selected randomly from the remaining 45 m² field to determine field drying loss. Harvested stalks with grains were spread over the test area for field drying as practiced by the farmers. Farmers collect paddy after 5 to 7 days sun drying. Fallen paddy was picked carefully from the test area which represent harvesting and field drying loss. Collected paddy were cleaned, weighted and adjusted weight at 14% moisture content. Harvesting loss was subtracted from total loss to determine field drying loss. The remaining 35 m² area were also harvested following same practice to determine the grain yield.

***Calculation procedure of drying loss in BAU-STR dryer*:** The obtained data from laboratory and field were used in calculating drying loss of paddy in BAU-STR dryer and at farmer's field, respectively. The following formulas were used to calculate drying loss of paddy in BAU-STR dryer (Jose et al., 1985).

$$\text{Moisture conversion factor (MCF)} = \frac{100 - M_i}{100 - 14} \quad (1)$$

$$\text{Area factor (AF)} = \frac{50\,m^2}{5\,m^2} = 10 \quad (2)$$

$$\text{Adjusted initial weight of paddy, } D_{2i} = D_{1i} \times MCF \times F_g \quad (3)$$

$$\text{Adjusted final weight of paddy, } D_{2f} = D_{1f} \times MCF \times F_g \quad (4)$$

$$\text{Drying Loss, (\%)} = \frac{D_{2i} - D_{2f}}{D_{2i}} \times 100 \quad (5)$$

Where,

M_i = Initial moisture content of paddy

MCF = Moisture conversion factor

F_g = Percentage of filled grains

D_{1i} = Initial weight of paddy before drying, (kg)

D_{2i} = Adjusted weight of paddy before drying at 14% moisture content, (kg)

D_{1f} = Final weight of paddy after drying, (kg)

D_{2f} = Adjusted weight of paddy after drying at 14% moisture content, (kg)

***Calculation procedure of field drying loss in open sun drying*:** Field drying and harvesting loss (pre-harvest and post-harvest) were measured considering obtained yield of paddy. The following formulas were used to calculate drying loss of paddy at field level (Jose et al., 1985).

Yield (OY): $Y_{ad} = Y_i \times MCF \times F_g$ (6)

Where,

Y_i = Weight of paddy of the tested area at field moisture content including filled and unfilled grain, (kg)

MCF = Moisture conversion factor

F_g = Percentage (%) of the filled grains

Y_{ad} =Adjusted weight of paddy of the tested area at 14% moisture content, (kg)

$$\text{Harvesting loss, (HL)} = \frac{P_2}{Y_{ad}} \times \frac{1}{10} \quad (7)$$

Where,

$P_2 = P_1 \times MCF \times AF$ (6)

P_1 = Harvesting loss of paddy (5 m^2) at field moisture content, (g)

P_2 = Harvesting loss of paddy (50 m^2) at 14% moisture content (kg)

HL =Harvesting loss of paddy in %

Field drying loss (FDL) = Total loss (TL) – Harvesting loss (HL)

$$FDL = \left[\frac{TL_2}{Y_{ad}} \times \frac{1}{10} \right] - HL \quad (8)$$

Where,

$TL_2 = TL_1 \times MCF \times AF$

TL_1 =Total loss of paddy in selected area (10 m^2) at field moisture content, (g)

TL_2 =Total loss of paddy in selected area (50 m^2) at 14% moisture content, (kg)

TL =Total loss of paddy in %

Results and Discussion

***Performance of BAU-STR dryer*:** The BAU-STR dryer was evaluated in the workshop of the department of Farm Power and Machinery, BAU during Boro season with different dryer capacity and Aman season with different paddy varieties. In Boro season, the range of drying air temperature was 42.5 to 46.0 °C to remove moisture content from 19.7 to 11.7% (average) for different sample size of paddy in between 3.3 to 3.7 hrs (Table 1). The drying time varies with drying air temperature and relative humidity of ambient air during drying. The drying rate varies from 1.7 to 2.9% per hr which depends on initial moisture content of paddy. Moisture removal rate was higher at high initial moisture content and lower at low initial moisture content.

The highest drying efficiency was observed at S_{500} (68.6%) compared to others treatments. The drying efficiency depends on higher supply energy use efficiency of dryer. It was observed that BAU-STR dryer is more suitable for 500 kg sample size of paddy (Table 1).

The efficiency of dryer increases with the increasing sample size up to 500 kg, then it was decreased with the increase of sample size. It may be occurred due to optimum grain bin size of dryer. Moisture removal rate was lower and required time was higher in treatment S_{600} compared to S_{500}. The resultant drying efficiency was higher in treatment S_{500} than that of other treatments.

In Aman season, the range of initial and final moisture content was 18.3 to 21.9% (wb) and 11.2 to 11.7% (wb), respectively. The paddy was dried to an average final moisture content of 11.5 from 20.6% (wb) in between 3.3 to 5.8 hrs. The higher ambient air temperature and lower relative humidity directly affected the drying time. The initial moisture content of sample is also important factor in drying period. The less initial moisture content required less drying time. The resulted drying time of first treatment is found less than that of other treatments. The drying rate was found to be varied between 1.8 to 2.2% in the dryer during drying for different paddy varieties. Grain size and shape (length-width ratio) is a varietal property of paddy. The drying time is shorter for BRRI dhan34 and longer for BRRI dhan49 and BRRI dhan62 which is due to having more resistant in outer layer. This cause's higher shell resistant for transferring heat to grains of this variety and for this reason moisture exchanging in this type is less (Habibian et al., 2006). The drying efficiency of the treatments more or less similar due to higher energy use efficiency.

The field performance of BAU-STR dryer was also evaluated in selected area of Jessore, Mymensingh and Netrokona districts during Boro and Aman season. The range of initial and final moisture content was 17.8 to 25.4% (wb) and 11.5 to 12.5% (wb) in Boro season whereas 19.4 to 27.1% and 13.3 to 13.7% in Aman season, respectively. The paddy was dried within the range of 2.5 to 4.8 hrs. Drying rate and drying efficiency of BAU-STR dryer at farmer's field follow similar trend of laboratory experiments.

Table 1. Performance of BAU-STR dryer during Boro and Aman season at laboratory and farmers field.

Season	Treatments	Drying air temp. °C mean ± std	Initial MC (%)	Final MC (%)	Drying time (hr)	Drying rate % mc/hr	Drying efficiency %
Boro (lab)	S_{300}	46.0±2.5	21.2	11.4	3.4	2.9	52.7
	S_{400}	45.2±4.0	18.6	11.4	3.3	2.2	61.9
	S_{500}	45.8±2.6	20.4	11.6	3.6	2.4	68.6
	S_{600}	42.5±4.9	18.5	12.3	3.7	1.7	46.0
Aman (lab)	BRRI dhan34	39.9±2.1	18.3	11.2	3.3	2.2	51.8
	BRRI dhan49	40.2±1.9	21.5	11.7	5.0	2.0	56.4
	BRRI dhan62	41.6±2.9	21.9	11.6	5.8	1.8	53.8
Boro (field)	BRRI dhan28	44.3±3.5	17.8	11.5	2.5	2.5	51.5
	BRRI dhan28	42.5±3.0	25.4	12.5	4.7	2.7	64.8
	BRRI dhan28	41.8±4.2	23.6	12.5	4.8	2.3	51.9
Aman (field)	BRRI dhan49	39.7±2.4	27.1	13.3	4.3	3.2	61.0
	BRRI dhan49	39.6±1.5	19.4	13.7	4.0	1.4	65.9
	BRRI dhan49	39.0±2.6	24.2	13.4	4.7	2.3	57.0

***Drying loss in BAU-STR dryer*:** Drying loss of paddy in BAU-STR dryer during Boro and Aman season at laboratory is shown in Figure 3, 4. Drying loss varied significantly with the dryer capacity in Boro season (Figure 3). The average loss was found to be varied between 0.32 to 0.59% during Boro season. Higher drying losses were observed in S_{300} (0.59%) whereas the lowest drying loss (0.32%) was observed in S_{600} compared to others sample size. It may be occurred due to different volume of paddy per batch as because paddy handling loss more or less similar in each batch. The effect of variety on drying loss was observed whereas BRRI dhan34, BRRI dhan49 and BRRI dhan62 were used as short, medium and long variety at laboratory (Figure 4). There was no significant variation among the paddy variety. The result showed that the highest loss was estimated in short variety compared to medium and long variety. Basically, drying loss in BAU-STR dryer was negligible/ minimum because of small area requirement for drying whereas limited scope to scattered paddy out of reach. This loss may be occurred due to sample collection for moisture measurement after half an hour interval. Therefore, drying time is one of the factors which affect drying loss during operation.

The BAU-STR dryer was also evaluated in the selected area at farmer's field in terms of drying loss during Boro and Aman season (Figure 5, 6). The range of drying loss was observed from 0.37 to 0.45% in Boro season whereas 0.32 to 0.43% in Aman season at farmer's field. There was no significant variation of drying loss in different locations and seasons because of same dryer capacity and variety.

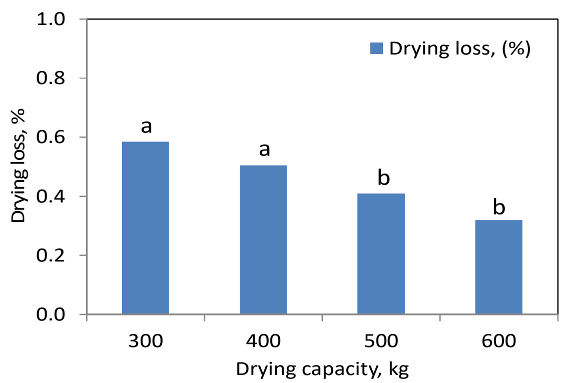

Figure 3. Drying losses of paddy in BAU-STR dryer during Boro season at laboratory, BAU, Note: Dryer capacity (dc)=**, cv%= 9.94

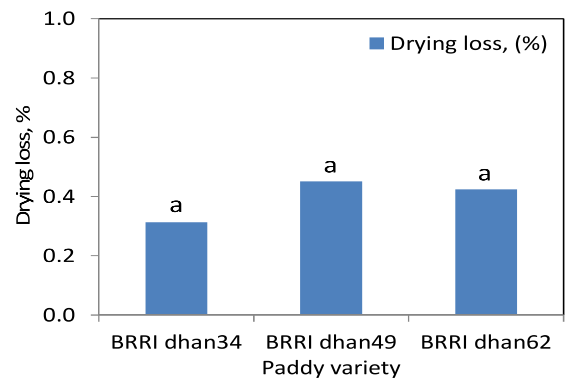

Figure 4. Drying losses of paddy in BAU-STR dryer during Aman season at laboratory, BAU, Note: Paddy variety (pv)=NS, cv%= 21.45

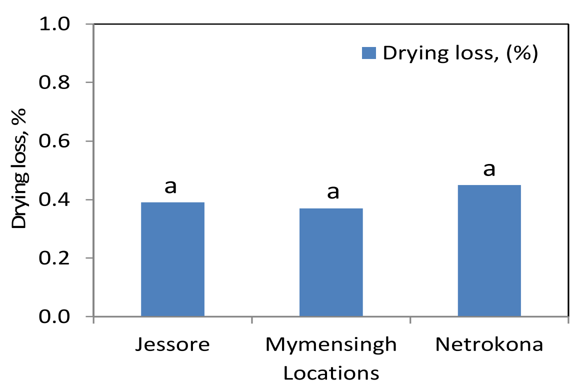

Figure 5. Drying losses of paddy in BAU-STR dryer during Boro season at field level, Note: Location (l)=NS, cv%= 26.13

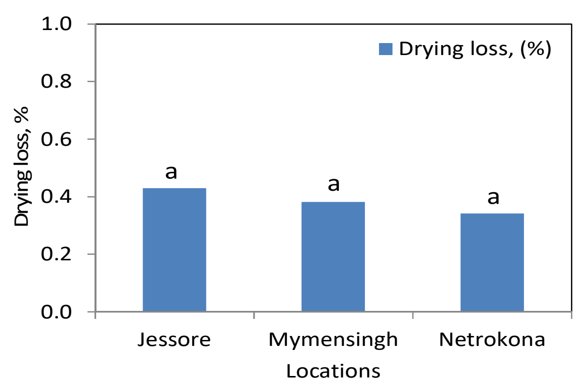

Figure 6. Drying losses of paddy in BAU-STR dryer during Aman season at field level, Note: Location (l)=NS, cv%= 19.06

Drying loss in open sun drying (field) method: Aman is harvested in dry season when grains are matured or over matured. Farmers usually dry paddy with straw in the paddy fields after harvesting. For this purpose, farmers keep paddy in the field for 3 to 7 days and in that time matured paddy has fallen down from the spikelet which in turn into more drying losses. Drying loss of paddy in open sun drying (field) at different locations is presented in Figure 7 and it was varied from 2.41 to 3.95%. The estimated drying losses varied significantly with the locations. Highest field drying loss was observed in Tangail (3.95%) which was due to rewetting by foggy weather whereas the lowest drying loss was observed in Netrokona (2.41%) which may be due to dry weather.

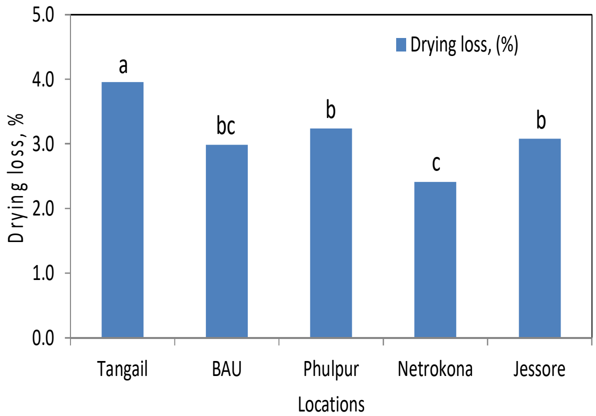

Figure 7. Drying losses of paddy in open sun drying method at farmers field during Aman season, Note: Location (l)=**, cv%= 11.04.

This losses occurred during field drying as a result of over maturity or over drying or attacks by insects at night time or rainfall after harvesting, eaten by birds or other animals, farmers' initiatives or paddy getting moldy due to poor sunlight intensity or shattering due to rewetting by foggy weather or rains and short duration of sunlight especially in winter season. Paddy variety, drying field or floor also influenced the drying losses. Nath et al. (2016) stated that the average post-harvest losses from harvesting to drying 10% in three rice growing seasons whereas the average pre-harvest, post-harvest, harvesting, field stacking, transportation, threshing, cleaning and drying loss was observed 0.43, 1.99, 0.83, 0.53, 3.16, 0.45 and 2.89%, respectively. Bala et al. (2010) reported that rice postharvest loss is approximately 14%. This loss include cutting loss 1.06 - 6.5%, handling and transport loss 0.63 to 6.0%, threshing loss 1.65 to 2%, drying loss 1.56 to 5% and storage loss 3.05 to 7.5%. In another study, it was observed that the post-harvest loss in each operation i.e threshing, cleaning, drying, parboiling and milling were 0.94, 0.83, 3.3, 3.5 and 3.2% with a total post-harvest loss from threshing to milling were 11.85% (Saha et al., 2001).

Conclusions

Bangladesh government has been increasingly interested in policy issues concerning national food security and has enforced programs for its improvement to reduce drying loss as well as post-harvest loss of paddy. Drying loss of paddy in BAU-STR dryer was found between 0.31 to 0.59% with an average 0.43% at laboratory level whereas it was found between 0.34 to 0.45% with an average 0.39% at farmer's field level. On the other hand, drying loss of paddy in open sun drying method at farmer's field was ranged from 2.41 to 3.95% with an average 3.1%. Therefore, mechanical intervention reduces drying loss of paddy significantly. The low cost BAU-STR dryer would be an alternative effective drying technology to save 1.4 MMT of paddy by reducing 2.7% losses of national production (51.87 MMT) to combat hunger and improve food security in Bangladesh. The knowledge of post-harvest losses of rice are useful to policy makers for intervention in national production, loss reduction process, existing storage structure and import rice towards attaining food security for the growing people of Bangladesh. In addition, the government should take initiative to introduce appropriate mechanical drying technology like BAU-STR dryer through government subsidy to the farmers and small traders for reducing post-harvest losses.

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References

Bala BK, Haque MA, Hossain, MA, Majumdar S (2010). Postharvest loss and technical efficiency of rice, wheat and maize production systems: Assessment and measures for strengthening food security. Final Report CF no. 6/08, National Food Policy Capacity Strengthening Programme (NFPCSP), Bangladesh.

Habibian M, Kazemi R, Shafiee SH (2006). Practical application of fluidized bed dryers for agricultural products. Paper presented at the 16th National Congress of Iran Food Industry, Gorgan University of Agricultural Sciences and Natural Resources. Gorgan, 12-13 April 2006.

Hodges RJ, Buzby JC, Bennett B (2011). Postharvest losses and waste in developed and less developed countries: opportunities to improve resource use. J. Agril. Sci. 149: 37–45.

IRRI (International Rice Research Institute) (2016). World Rice Statistics. http://ricestat.irri.org:8080/wrsv3/entrpoint.htm. Oct 04, 2017

Jose RA, Choudhury NH, Boxall RA (1985). Farm and village level post-harvest rice loss assessment, Bangladesh, Postharvest rice loss assessment manual. AG: GCPP/BGD/017/NET, Field Document1, Bangladesh Rice Research Institute, Ministry of Agriculture, Food and Agriculture Organization of the United Nations, Dhaka, July 1985.

Majumder S, Bala BK, Arshad FM, Haque MA, Hossain MA (2016). Food security through increasing technical efficiency and reducing postharvest losses of rice production systems in Bangladesh, Food Sec. 8: 361–374.

Nath BC, Hossen MA, Islam AKMS, Huda MD, Paul S, Rahman MA (2016). Postharvest loss assessment of rice at selected areas of Gazipur district. Bangladesh Rice J. 20(1): 23-32.

Saha CK, Sarker RI (2001). Postharvest losses and labour requirement of rice crop in two selected villages of Mymensingh district. Bangladesh J. Agri. Engg. 12(1&2): 1-10.

Pundlik DS (2015). Studies on Flexible Hermetic Storage System for Paddy. A thesis of Faculty of Post Graduate School, Indian Agricultural Research Institute, New Delhi, India.

UN (United Nations) 2012. World Population Prospects. http://www.un.org/en/development/desa/publications/world-population-prospects-the 2012-revision.html

UN (United Nations) (2015). World Population Prospects. The 2015 Revision: Key Findings and Advance Tables. Department of Economic and Social Affairs Population Division. The United Nations, New York. Retrieved from https://esa.un.org/unpd/wpp/publications/files/key_findings_wpp_2015.pdf.