Innovation Lab for Reduction of Postharvest Loss
BANGLADESH

TECHNICAL REPORT No. 1

TESTING AND EVALUATION OF FLATBED DRYER IN BANGLADESH
- APPLICATION FOR DRYING FRESHLY PARBOILED PADDY –

May 28 to June 2, 2014

Authors:

Nguyen Thanh Nghi, PhD
Center for Agricultural Energy and Machinery,
Nong Lam University-HCMC, Vietnam

Alfred Schmidley
Business Model and Value Chain Specialist,
International Rice Research Institute
Los Baños, Philippines

***Contributors**: Shanewaz Ali, Owner, Ali Seed Co.; Mobarak Choudhury, IRRI Project Coordinator, PH Innovations Lab; Latiful Bari, IRRI PH Engineer, PH Innovation Lab; Lito Diestro, IRRI Technical Consultant; Dr. M.A. Baqui, Visiting Professor, BSMRAU; Mozharul Islam, Coordinator, Monitoring and Evaluation, Practical Action-Bangladesh; Bidhan Chandra Nath, Senior Science Officer, Farm Machinery & Postharvest Division, BRRI; Abdul Momin, Associate Professor, Dept of Farm Power Machinery, BAU; Md Tazul Islam, Sr. Mechanic, DFPM, BAU; Md. Oli Ullah, Janata Engineering.*

Acknowledgements

We wish to thank US-AID for generous funding support for the Innovation Lab for Reduction of Postharvest Loss.

We also wish to thank Kansas State University and the ADMI Institute at the University of Illinois for ongoing project implementation support under the Innovation Lab for Reduction of Postharvest Loss in Bangladesh.

Lastly, we wish to thank all those who were involved in supporting technical assessment activities from May 28 to June 2, 2014, including CSISA-BD field staff, Ali Seed Company, Nong Lam University, Bangladesh Agricultural University, Bangladesh Rice Research Institute, Bangladesh Sheikh Mujibur Rahman Agricultural University, Practical Action-Bangladesh, the Janata Engineering Company, and the IRRI Innovation Lab Team.

Abbreviations

ADMI	Archer Daniels Midland Institute for the Prevention of Postharvest Loss
BAU	Bangladesh Agricultural University
BRRI	Bangladesh Rice Research Institute
BSMRAU	Bangladesh Sheikh Mujibur Rahman Agricultural University
CSISA-BD	Cereals Strategic Initiative for South Asia (Bangladesh)
FBD	Flatbed dryer
FtF	Feed the Future
FGD	Focus Group Discussion
GO	Government Organization
IRRI	International Rice Research Institute
KSU	Kansas State University
MC	Moisture content
NGO	Non-Government Organization
NLU	Nong Lam University (Viet Nam)
PAB	Practical Action Bangladesh
PH	Postharvest
PHL	Postharvest Loss
UoI	University of Illinois
USAID	United States Agency for International Development

Background

Drying capacity is deemed a major constraint and source of postharvest loss in rice for both rice seed and grain in Bangladesh. Mechanical drying, when technology and actor support are appropriately matched to local conditions, has been shown to reduce physical and quality losses and positively benefit farmers and PH actor incomes.

In 2013, IRRI and its partners began pursuing improved mechanical drying options under the USAID-funded Feed the Future initiative. The Cereals Systems Initiative for South Asia (hereafter CSISA-BD) began working with farmer seed growers, amongst others, and more recently, the newly announced Innovation Lab for Reduction of PH Loss began a broader assessment of postharvest opportunities in the US-AID FtF zone. While the former provides a multi-stakeholder platform for stakeholder learning and delivery, the newly announced Innovations Lab is uniquely placed to provide technical support for testing and verifying locally suited options and incorporating lessons from other countries where PH technoligies such as mechanical drying have been successfully adapted.

In 2013, CSISA-BD partners piloted a 4-ton flatbed dryer (of Vietnamese design) with a local seed processing entrepreneur in Jessore, Bangladesh, for technical evaluation and business model study. The entrepreneurial investor, a farmer himself, recovered the investment cost the first year when heavy rains and limited capacity to sun-dry crops threatened certain spoilage of seed grown by him and other fellow farmers joined to their farmer seed growing association. However, while saving farmers' seed, further technical study was deemed necessary in order to further evaluate and "fine-tune" the technology and explore optimal options for actors under local conditions using this pilot site for testing, training, and exposure visits. Several techincal problems remained and the potential of the application beyond its current owner's use had yet to be determined, especially for drying parboiled paddy and other crops (not just rice seed).

Hence, apart from seed drying, FBD's can be tested as a next step and potentially adapted for drying high moisture parboiled paddy common in Bangladesh and other South Asian countries. Currently famers have difficulties drying parboiled paddy at the household especially during rainy periods. (Rice is Bangladesh is now grown in three seasons, year-round). Many millers must also stop their rice mills during rainy season, which usually continues for about two to three months in a year. 8 Millers from Rajbari with 2 accompanying project staff (led by project partner Practical Action) made an exposure visit to the site in February, followed by a larger technical learning activity with multiple stakeholders in March (aided by CSISA-BD). Thus a dialogue with farmers and millers has been established who have seen the dryer operate but must be convinced of its benefits for drying parboiled paddy for milling.

Goals

Technical consultant, Dr Nguyen Thanh Nghi, joined our Team to evaluate the dryer and in the process help build capacities of others how to conduct a technical evaluation and troubleshooting "practicum" with instrumentation and defined research protocols at this pilot site (that also operates as a sustainable commercial business). Dr Nghi joins us from Nong Lam University in Viet Nam which has over many years conducted much research and design work on flatbed dryers and successfully transferred them to local private sector actors in Viet

Nam as well as other SE Asia countries. Hence, our goal was not only to improve the dryer's function and operator's abilities for drying seed, but also testing the capacity of the flatbed dryer for drying fresh parboiled paddy for milling – a new application for which little research and stakeholder understanding exists. (In Southeast Asia, flatbed dryers have only been used for fresh (non-parboiled) paddy due to cultural reasons and consumer preferences for rice.) This is deemed necessary before attempting to scale out additonal pilots for mechanical dryers elsewhere in Bangladesh and where CSISA-BD and the Innovation Lab can play a critical role.

The 4-ton flatbed dryer design was originally piloted based on an earlier design from Nong Lam University (NLU). It was installed under CSISA-BD at a pilot site in Jessore in 2013. As a next step, a technical consultant, Dr Nguyen Thanh Nghi, from NLU has been engaged to conduct further evaluation and technical work and make recommendations on mechanical drying technologies for Bangladesh, including new applications, such as high moisture parboiled paddy for milling, and potential other crops such as maize. (It should be noted drying capacity for maize in Bangladesh's rapidly gorwing feed and poultry industries is another major constraint to farmers and other industry actors.) Additional applications for mechanical drying technology woud make it more commercially viable and increase benefits to farmers and other PH stakeholders.

To achieve these goals, three trips for NLU researcher Dr Nghi have been agreed upon and funded by the Innovation Lab (with CSISA-BD contributing to local costs for fabricating materials, etc.) The exact dates for each trip will be adjusted depending on actual findings in Bangladesh and agreement among related local stakeholders how to proceed. During this first trip, Dr Nghi also attended the Innovation Lab Inception Meeting, June 3, to present initial test findings to a wider stakeholder group for planning next steps. This report details the test results and findings of Dr Nghi's first trip to Bangldesh from May 28 to June 4, 2014 with our multi-stakeholder Team.

Trip 1 Objectives

1. Train local stakeholders how to test and evalaute a flatbed dryer, including data collection methods and instrumentation used during testing;

2. Evaluate performance and troubleshoot 4-ton FBD pilot in Jessore adopted by a entrepreneurial seed processor last year as a first pilot site;

3. Test the FBD's capacity and performance for drying high moisture parboiled paddy for milling. Two batches (replications) of fresh wet parboiled paddy (for milling) were dried, including sun drying control test for milling quality comparison;

4. Introduce to local stakeholders additional mechanical drying options and designs in anticipation of further needs in rice and other crops such as maize;

5. Attend the US-AID funded Innovation Lab Inception Meeting in Dhaka to report test findings and engage wider stakeholders in discussion of possible next steps (for inclusion in the Project's current PH Assessment activities and recommendations).

Participants

The above objectives were pursued with support from the Innovation Lab Team, CSISA Bangladesh hub offices, and a number of organizations who participanted in the training and dryer practicum as follows:

- *Dr Nghi Nguyen*, Professor, Nong Lam University, Viet Nam (Innovation Lab trainer/consultant)
- *Mr. Shanewaz Ali*, Owner, Ali Seed Co. (along with 3 staff)
- *Mobarak Choudhury*, Project Coordinator, PH Innovations Lab
- *Latiful Bari*, PH Engineer, IRRI
- *Dr. M.A. Baqui*, Visiting Professor, BSMRAU, Dhaka
- *Mozharul Islam*, Coordinator, Monitoring and Evaluation, Practical Action-Bangladesh
- *Mr. Bidhan Chandra Nath*, Senior Science Officer, Farm Machinery & Postharvest Division, BRRI, Gazipur
- *Dr. Abdul Momin*, Associate Professor, Dept of Farm Power Machinery, BAU, Mymensingh
- *Md Tazul Islam*, Sr. Mechanic, DFPM, BAU, Mymensingh
- *Md. Oli Ullah*, Janata Engineering, Chuadanga (fabricator)
- *Lito Diestro*, IRRI, Technical Consultant
- *Alfred Schmidley*, Business Model and Value Chain Specialist, IRRI

Figure 1: Dr Nghi (center) with several participants in the training. 15 participants total took part in technical assessment activities.

Description of Materials and Methods

Dryer Specifications:

- Vietnamese Model: FBD, 4-ton
- Type: Conventional flatbed dryer (FBD)
- Design capacity: 4 ton/batch
- Rice husk comsumption: 25 kg/hr
- Motor power: 7.5 kW
  (actual power is 5.6 kW)
- Perforated screen area: 27 m^2
- Design air flow rate: 4 m^3/s

Figure 2: Conventional Flatbed Dryer – Jessore pilot

Dryer Test Parameters/data to be collected:

1) moisture content (MC)
2) temperature of drying air, exit air, and ambient air
3) static pressure
4) drying time

Using a specialized sampling rod (Figure 3), paddy samplings for the MC test were collected at five points in the drying bin at 1-hour intervals with some adjustments given to actual testing environment. Paddy samples were taken vertically from the bin using the paddy sampling rod. Paddy samples were then separated between the top, middle, and bottom bin samples. MC was measured using a Kett moisture meter (Figure 4) which was calibrated against (the more precise) oven drying method. MC was measured using three replications from each sample. In cases of moisture readings were deemed abnormal/faulty, two more replications were done for confirmation. Static pressure was measured using a U-shape pressure meter (Figure 6). Static pressure was checked both below the grain layer and in the plenum. The difference in water level between two sides of the instrument is the value of statice pressure in mmH_2O.

Figure 3: Paddy sampler

Figure 4: Kett Mositure Meter

Figure 5: Rotameter

Figure 6: U-shape pressure meter

Drying air volume was determined indirectly by measuring existing air velocity using a rotameter (Figure 5). Drying air volume depends on the speed of the blower. The higher the speed of the blower, the higher is the drying air volume. The blow speed (in rpm) was measured at the shaft of the blower using a tachometer. (Note: Drying air volume is a factor affecting the drying rate. The higher the drying air volume the higher is the drying rate. However, drying air volume also affects drying efficiency and dried crop quality.)

Milling Quality Test:

Paddy samples were taken from two batches of mechanically dried paddy as well as the sun-dried control (see below) to determine head rice recovery rate. A milling laboratory at BRRI was used. However, as a quick "unscientific" reference and for learning purposes, we also tested samples in a neighboring village mill.

Instrumentation:

A number of instruments were brought from Vietnam, IRRI, and BAU. *It is recommended for the future that a set of instrumentation at the pilot site be available for training purposes.*

Table 1. List of instruments used

No.	Name	Use for
1	Kett moisture meter	Measuring MC of paddy
2	Rotameter	Measuring velocity on grain surface in the drying bin
3	Tachometer	Measuring speed of drying blower
4	Static pressure meter	Checking static pressure in the plenum
5	Paddy sampling rod	Taking paddy sample during test

Two batches of parboiled paddy(plus one sun-dried control)

Two batches of freshly parboiled paddy were procured from two different local millers. The batches weighed 3.8 tons and 3.3 tons, respectively, after parboiling. For the sun-dried control, the weight of paddy for each treatment was one ton (after parboiling). Paddy was spread on a drying pavement area of 351 m^2 with the thickness of paddy layer of 2–4 cm (Figure 7). During the monitoring process, paddy was mixed manually at an interval of one hour as recommended farmers' practice.

Figure 7: Sun drying batch as control

Economic analysis:

Economic analysis was done based on test data results, actor interviews, and stated assumptions. Three important parameters were analyzed: 1) drying cost, 2) payback period, and 3) internal rate of return. Total drying cost includes fixed cost plus variable cost which were computed from investment cost, operating time, price of fuel, etc. The three said parameters for using this conventional flatbed dryer are also compared to that of another kind of flatbed dryer, a air reversible flatbed dryer, as one possible future option (see recommendations below).

Test Results and Participatory Evaluation

Introduction and discussion

The trip began in Jessore, where Dr Nyguyen Thanh Nghi met the Innovation Lab team, CSISA-BD staff, rice mill owners, NGOs, and other stakeholders and help lead a half-day training seminar. This included: 1) a review of the pilot's history and activities to date; 2) explanation of technical aspects for evaluating drying technology and parameters for data collection, and 3) introduction to various instrumentation and protocols for making performance data measurements. The 4-hour activity included some excellent discussion where attendees raised pertinent questions related to the said subject matter and subsequent testing activities they were to join in coming days as a participatory learning activity.

Although FBD technology is not overly complex, a sound theoretical understanding of heat, moisture removal, and air flow are critical. Lack of such understanding locally often results in projects unsuccessfully promoting inappropriate and sub-optimal technology that is not adequately supported or correctly matched to actor needs and local conditions. Thus this practical training provided wider stakeholders – including Bangldeshi research institutions, universities, an NGO, a private sector fabricator, and the Innovation Lab Team and CSISA hub staff as well as the dryer's owner and staff – with an opportunity to learn more about both theory and operation of mechanical dryers, as well as a "hands-on" testing and evaluation opportunity using this first training pilot as an example for study. Participants were eager to learn and actively participated throughout several days activities (in real-world inclement weather). However, more follow up training and capacity building amongst all actors is needed to pursue mechanical drying options in Bangladesh. On-site locally available instrumentation for actors to evaluate and test additional pilots should also be arranged to support future training and capacity building in the US-AID FtF region. (See recommendations below)

Inspection and preparation

Our multi-stakeholder group inspected the dryer and prepared for testing. The purpose of the inspection was to check and ensure that all parts of the dryer could work well during the test. The dryer owner has been using the 4-ton FBD for drying seed from around 20% MC to 14% MC. He has been satisfied overall with the dryer (which saved his and other farmers crops last year in excess of his investment. However, the project deemed it unwise to scale further pilots without fuller understanding of technical issues at hand and needed capacity-building amongst all actors. We noted previously that the temperature of air in the plenum chamber did not exceed 38 Degrees C, resulting in unexpectedly longer drying time and less than efficient burning of the rice husk in the furnace. (Through Dr Nghi, we found not enough secondary air entering the furnace as well as poor operator skill as the main reasons.) Local millers, on the other hand, who had seen the dryer operate during previous exposure visits, believed (perceived?) smoke from the furnace would enter the bin and affect the colour (and potentially taste) of rice after milling. (Thus millers and other actors will need a seeing-doing-, tasting-is-believing exercise to convince them to adopt the technology.)

Inspection findings: After thorough inspection of the dryer, it was found that the furnace was installed without a funnel inside the plenum to supply secondary air back to the furnace to aid more fully the combustion process. (This funnel was added in Viet Nam as an adaptation subsequent to the original design.) So this part was fabricated quickly locally by an artisan and installed for testing. We confirmed through our testing that the lack of this part causes inadequate secondary air flow and thus inefficient combustion and low air temperature in the plenum – a key learning. It also appears to eliminate smoke that occurred on the surface of paddy layer in the drying bin. Drying air temperature in the plenum of the dryer can now be increased up to 45^{0}C as designed. This is excellent for more efficient seed drying but not enough for efficiently drying fresh high moisture parboiled paddy. (See other key learnings and recommendations below)

Test data and findings

Over the course of two days, the FBD was tested using two batches of freshly parboiled paddy form nearby millers. Parboiling is a process common in South Asia where paddy is soaked in water for 24 hours, then steamed for 8-12 minutes, before the paddy is typically sun-dried 1-2 days or longer depenidng on weather, and then milled at the village level. The process of parboiling causes the starch to "gelantize" and seals fissures in the grain thereby producing better head rice recovery particularly when basic village milling technology (Engleberg-type) common to much of Bangladesh are used. Parboiling paddy also results in a unique texture to cooked rice enjoyed by South Asians as the grain is not "sticky" but separates, unlike cultural preferences and tastes in East and Southeast Asia for "stickier" cooked rice.

A summary of test results for drying two batches of parboiled paddy is shown in Table 2.

Table 2. Summary of test result

Date: May 30 and June 1, 2014	Batch No.1	Batch No.2
Testing site: Jessore, Bangladesh		
Initial weight, kg	3796	3282
Initial MC, %	29.5	24.8
Final MC, %	14.5	14.9
Drying air temperature, ^{0}C	43.0	37.3
Drying time, hour	10.5	5.5
Rice husk consumption, kg/hr	23.8	20.3

During the mechanical drying process, drying air temperature, ambient temperature, and existing air temperature were monitored as shown in Figure 8. As a test of the dryer's capacity, we tried to increase drying air temperature up to 50^{0}C during the two first hours. As fresh wet parboiled paddy is over 30% MC, this can more efficiently help reduce drying time without harming the grain. However, this temperature was not attained and deemed beyond the design capacity of this particular dryer. (Though the dryer remains most adequate for seed drying, seed being "alive" and operators won't risk damaging the seed which should be dried at temperatures of 43C or below). *One key recommendation for future applications for drying parboiled paddy is that the capacity of the furnace should be increased to achieve and maximum drying temperature of 50^{0}C.* This higher temperature of drying air is strictly recommended only for two first hours during drying process for high moisture paddy (to be milled as grain). Once the moisture content of paddy reaches 18%, the drying air temperature should be maintained lower than 40^0 C to avoid damaging the grain.

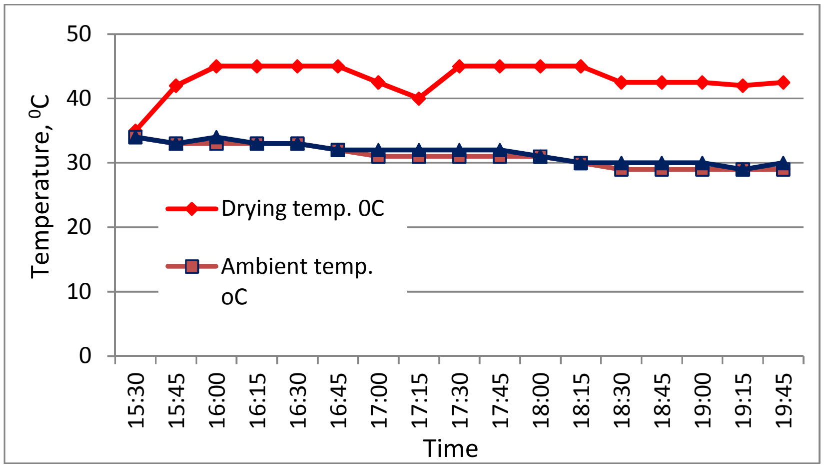

Figure 8: Fluctuation of drying temperature using FBD (first batch)

The first batch of fresh parboiled paddy (3.8 tons) was dried from 29.5% to 14.5% in 10.5 hours of drying time. The second batch (3.3 tons) of fresh parboiled paddy was dried from 24.8% to 14.9% in 5.5 hours. The relatively shorter drying time for the second batch is attributed to the initial MC and weight/volume of paddy being lower resulting in greater drying efficiency.

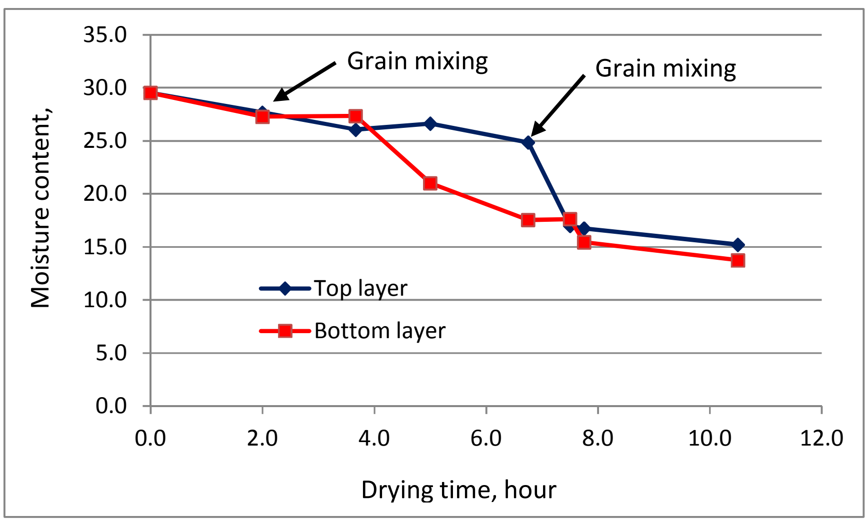

Figure 9: Moisture content reduction by FBD for first batch of parboiled paddy

For the second batch, paddy was mixed at the time when moisture content of paddy at the bottom layer reached 13.8%. (14% MC being the desired moisture content for milling grain) While the MC of paddy at top layer was 19.1%. As shown in Figure 10, the difference in MC between the top layer and bottom layer (called the "moisture gradient") before mixing was 5.3%. After mixing, this was reduced to 1.9%. However, the difference in final MC between top and bottom layers was still considered high, 4.7% for the first batch and 5.2% for the second batch. The moisture gradient differs not only between top and bottom layers but also in-between layers in drying bin. The uniformity of final moisture content is the result of static pressure which is a function of the thickness of the grain layer. Because the layer of paddy is rather less (18-20 cm) compared to drying 4-ton capacity (30 cm), the static pressure measured as only 12 mmH2O.

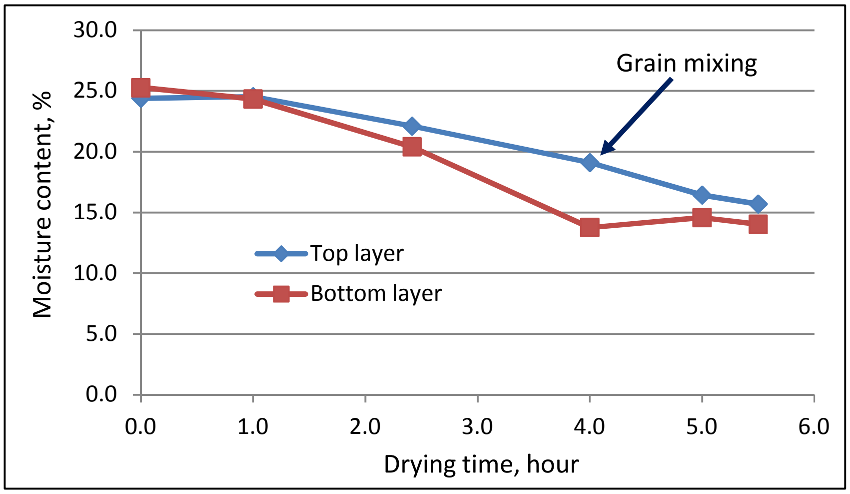

Figure 10: Moisture content reduction by FBD for 2nd batch of parboiled paddy

For the sun drying control, it took approximately 10 hours (over the course of two days) to dry parboiled paddy from 29.5% to 12.3%. Final moisture content was rather uniform with the difference of 1.0%. Drying rate for sun drying depends mainly on intensity of radiation from the sun. As shown in Figure 11, MC was reduced rapidly from the fifth hour to the ninth hour due to relative higher solar radiation from the sun at noon time. Meanwhile, MC dropped more slowly during the first and last stages because the radiation from the sun was relatively low (corresponding to the beginning and end of the day). To present the relationship between radiation and moisture content reduction, radiation can be recorded if so desired next time for learning purposes. While sun drying may offer its own advantages (e.g., less investment or cost especially if land is readily available), there are several disadvantages such as dependence on favourable weather, unavailable labor, need for large amount of land as a drying area, traffic hazards if roads are used, etc.) In this case, our test could not be continued due to heavy rain during this main seasonal harvest. If rain and lack of sunshine lasts a long time, it will negatively affect to quality of paddy, especially paddy right after harvesting and after the parboiling process. (i.e., Actors risk crop loss and damage to gain, similar to our seed processor.)

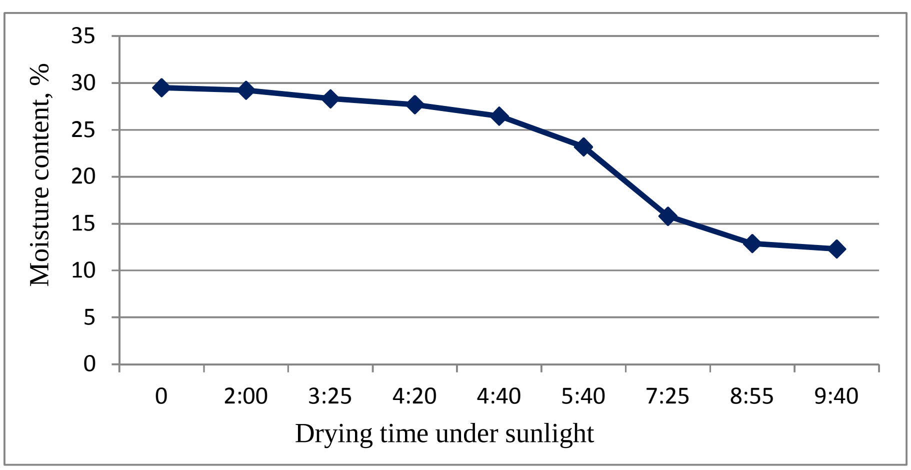

Figure 11: Graph of moisture content reduction process

Head rice recovery

Head rice recovery was analyzed using milling laboratory equipment at BRRI. Four paddy samples were taken from two batches of mechanically dried paddy, with sun drying and shade drying as (two) control samples. Results show head rice recovery from mechanical dried paddy was 62.8%, slightly lower than that from sun drying (65.1%)   (Research shows this should be the opposite relationship, as mechanical drying should produce 5-10% higher head rice recovery if done optimally – which supports our point about matching technology to actor needs and building capacity of operators). We believe the reasons for this difference were mainly due: 1) insufficient grain mixing time resulting in high moisture gradient (This was due to uneven manual mixing, done only 2-3 times causing non-uniform final moisture content; also grain samplings were overdried (12.3% MC) from the bottom of the bin and more easily broken during milling), and 2) drying air temperature was not suffciently controlled (this is operator skill and furnance capacity related for drying parboiled paddy).

As a learning activity for participants, we also did a “unscientific” milling test using the neighboring village rice mill which showed similar results (though under less controlled milling test conditions).

However, to increase the reliability of our conclusions above, our tests need to be conducted with more replications under controlled conditions.

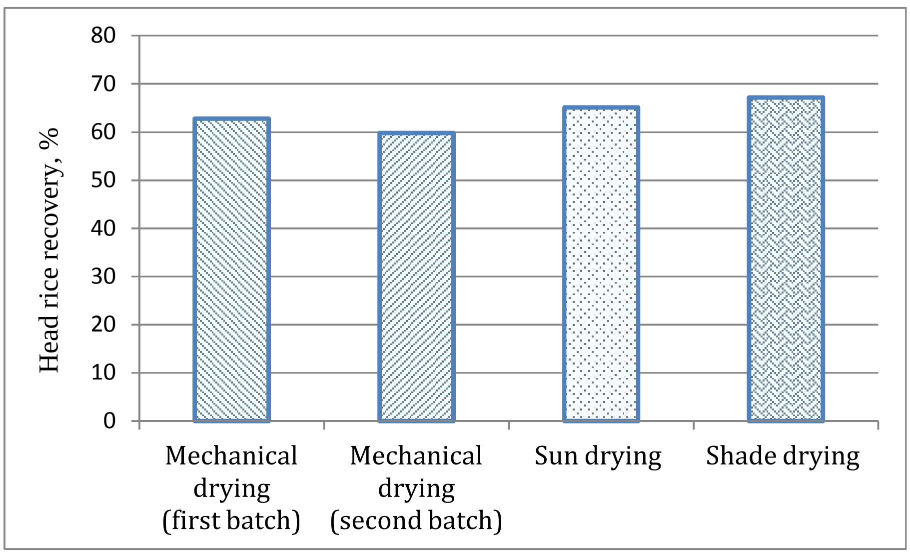

Figure 12: Head rice recovery analysis in BRRI laboratory

Economic analysis

Based on the collected data from our experiments, actor interviews, and direct communication with local farmers in Jessore, economic analyisis was carried out according to the parameters of drying cost, pay-back period, and internal rate of return (IRR).

Table 3: Data for economic analysis

Parameter	Value	Note/source of data
Design capacity, ton/batch	4	
Investment cost, USD	6 500	(5200 USD for Dryer and 1300 USD for roof/shelter)
Rice husk consumption, kg/h	25	
Price of rice husk, USD/ton	16	At Jessore, Banglaesh (2014)
Electricity consumption, kWh/h	5.5	Actual data
Price of electricity, US cents/kWh	9.5	
Drying cost, USD/ton	***9.27***	***Computed***
Pay-back period, year	*2.5*	*Computed*
Internal Rate of Return, %	*29.2*	*Computed*

As shown in Table 3, drying cost is calculated at USD 9.27/ton. This includes cost of depreciation, energy, labor, etc. which is shown as a percentage in Figure 13. Our estimated drying costs for this FBD dryer are slighly higher than that of a reversible air-flow flatbed dryer, USD 8.71/ton, assuming similar costs in Bangladesh.

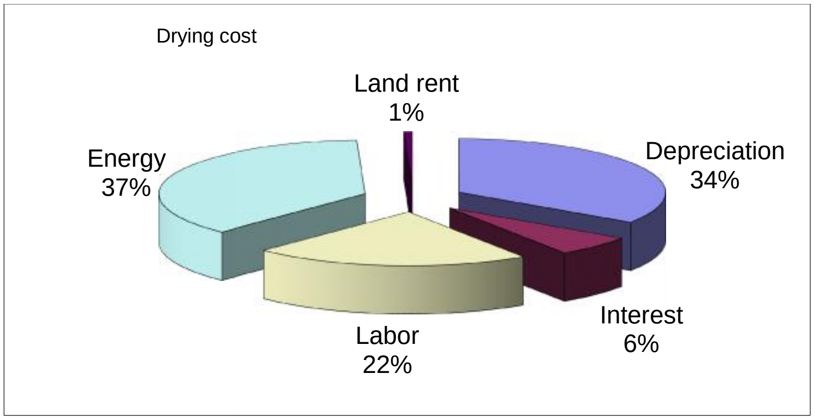

Figure 13: Estimated percentage of drying cost

As shown in Figure 13, the two highest cost components in mechanical drying are energy and depreciation. Thus, to reduce drying cost, which affects pay-back period and internal rate of return, *it is recommended that a different design of mechanical dryer for a second pilot should be selected for drying multiple crops (parboiled paddy, maize, etc, as well as regular paddy for storage or processing as rice seed). Moreover, the dryer furnace should be adapted to larger capacity and for use with various kinds of firing fuels (rice husk, corn cobs, waste wood, coal, etc. as available locally).*

Based on the experience of Dr Nghi, a reversible air-flow dryer (RAFD) would meet these requirements. Because an RAFD dryer can be used for drying many kinds of crops, operating time (and hence, economic efficiency) of the dryer per year could also be increased.

For example, in Bangladesh, an RAFD could be used for drying two seasonal crops of paddy, one crop of corn, and parboiled paddy for milling throughout the year. If we assume that operating time increases to 90 days/year (an increase of one-third), the drying cost can be futher reduced from USD 9.27/ton to USD 7.84/ton, and the payback period is reduced from 2.5 years to 1.3 years, and internal rate of return increases from 29.2% to 71.3%.

Keying Learnings and Recommendations

1. The currently installed dryer, the design for which was adapted for conditons in Vietnam, lacked sufficient secondary air-flow that was causing the dryer plenum air to not attain optimal temperature for drying paddy. This also resulted in inefficent combustion of rice hull in the furnace and a degree of "surface smoke" that millers and other actors perceived could affect colour and taste of milled paddy. These problems were solved with the installaton of a "funnel" type airway inlet to allow seconardary air from the plenum back into the furnace for more efficient combustion and air flow.

2. The current dryer pilot should continue to be used as a training and exposure site for regional actors. The dryer pilot has met the needs of the entrepreneurial owner, even more so now the the dryer is performing even more efficiently. As the heated air from the dryer does not go above 43 degrees, it can be effectively used for drying seed (which is a living thing) with minimal risk of "killing" or damaging seed viability.

3. Operator skill and actor capacities to operate mechanical dryers and evaluate their function is a key area the project needs to address. This can be done alongside conduct of any additional pilots for study and building of local knowledge and selection of other types of mechanical dryers for multiple drying uses, not just seed. For example, additional demonstrations and testing of FBD's should be done with local millers so that they can input into actor needs, adaptations, and potential for wider scale adoption.

4. Our dryer testing and evaluation of this particular FBD model reveals a relatively high moisture gradient for drying high moisture parboiled paddy for milling. Thus while offering increased efficiency and less time compared to sun-drying, additional testing of parboiled paddy using other higher capacity models of FBDs is needed to determine and quantify physical (quality) benefits to milling and to actor incomes.

5. For applications requiring multiple crops and usage (e.g., parboiled paddy, maize, etc.) a higher capacity dryer and furnace adapted to multiple fuels that are available locally is recommended. A revisible air-flow dryer (hereafter RAFD, another design of FBD) should be tested and evaluated as a second pilot to address remaining questions regarding efficiency of FBDs for drying parboiled paddy, in particular. The RAFD also has been shown in Viet Nam to result in a moisture gradient of only 2% or less for mechanical drying of regular paddy and seed (but not yet tested for parboiled paddy). Based on test data and actor info in this report, it is estimated an RAFD would have lower operational costs and greater return on investment if it could be used for multiple purposes during the cropping calendar and serve different needs of actors.

6. A system for testing (and installing) dryers with needed instrumentation should be made available at this and any other pilot sites for training and capacity building amongst actors.

7. If funds allow, the project may wish to send a promising local researcher with "hands-on" skills for further training (at NLU or IRRI, for example) to receive further knowledge on instrumentation, evaluation, and installation of various types of mechanical dryer options to aid local industry development.

(See photos below in Appendix)

APPENDIX: Photos


Photo 1: Examining furnace and cyclonic cleaner


Photo 2: Examining bin and plenum chamber


Photo 3: Parboiled paddy in bin being mechanically dried

Photo 4: Paddy being stirred (2-3 times)

Photo 5: Measuring moisture content of samplings

Photo 6: Sun-dryng control (note all the losses incurred by birds when sun-drying

----

End of document