Journal of Engineering Science and Technology
Vol. 9, No. 3 (2014) 398 - 409

DRYING PERFORMANCE AND OVERALL ENERGY REQUISITE OF INDUSTRIAL INCLINED BED PADDY DRYING IN MALAYSIA

M. NORDIN IBRAHIM[1,*], M. S. H. SARKER[1,2], AB. AZIZ N.[1], MOHD SALLEH, P.[3]

[1]Department of Process and Food Engineering, Universiti Putra Malaysia (UPM), 43400 Serdang, Selangor, Darul Ehsan, Malaysia
[2]Department of Food Engineering and Technology, Hajee Mohammad Danesh Science and Technology University (HSTU), Dinajpur-5200, Bangladesh
[3]Deputy Director (Packaging and Handling Programme), Food Technology Research Centre, MARDI, 43400 Serdang, Selangor, Darul Ehsan, Malaysia
*Corresponding Author: nordinib@upm.edu.my

Abstract

An attempt was undertaken to evaluate the performance of industrial inclined bed dryers (IBDs) in terms of drying capacity, drying rate, overall energy requisite and final quality of dried product in drying of freshly harvested paddy. In drying of paddy with initial moisture content of 22-23% wet basis (wb) to around 12.5% (wb) final moisture content, drying capacity and drying rate of the dryers were found to vary between 0.66 to 1.03 ton dry paddy/hour and 90 to 121 kg moisture/hour, respectively, for the holding capacity of each dryer at about 15 ton. The electrical energy consumption of the IBDs was found to vary between 18.15 to 27.55 kWh/t while the thermal energy consumption ranged between 960 to 1328.15 MJ/t. The IBDs operated at air temperature of 38-39°C yielded 1 to 4% higher head rice yield than the IBDs were operated at 41-42°C for drying of similar moist paddy, but milling recovery and whiteness were comparable.

Keywords: Industrial paddy drying, Inclined bed dryer, Drying capacity, Drying rate, Energy requisite, Rice quality.

1. Introduction

In all paddy producing countries, paddy drying and management are the great concern of the millers and processors. Ineffective drying decreases grain quality. The moisture content of freshly harvested paddy is usually varied between 20 and 25% wet basis in tropical countries [1, 2].

Nomenclatures

C_h	Heat value of rice husk, MJ/kg
$Cos\emptyset$	Power factor
E_b	Electrical energy consumed by blower, MJ
E_m	Electrical energy, kJ
E_T	The total electrical energy, kWh
E_{th}	Thermal energy, MJ
H_w	Rice husk consumption rate, kg/h
I	Line current, ampere
P_m	Motor rated power, kW
$SPEEC$	Specific electrical energy consumption, kWh/t
$SPTEC$	Specific thermal energy consumption, MJ/t
t	Time, hr
V	Line voltage, V
W_p	Amount of paddy, tonne

The fixed deep bed dryers either in the form of rectangular bins such as flat bed/inclined bed or circular bins are common in Asia [3]. Spouted bed drying, steam drying and combined microwave or infrared–hot air drying have been stated as efficient drying methods for quality rice [4-8] but their uses for industrial purpose are still limited. In commercial rice mills of Malaysia, inclined bed dryer (IBD) is very popular as single stage dryer for complete drying of high moisture (20-26% wb) paddy with drying bed usually fixed at 1.0 m as shown in Fig. 1. Besides, for two stage drying, IBD is found to be used as second stage dryer after first stage drying by fluidized bed dryer (FBD) in certain drying complexes of Padiberas Nasional Berhad (BERNAS) of Malaysia. Drying bed of IBD is inclined to get advantages for easy and faster discharge of paddy after drying. The moisture gradient of final product between top and bottom layers after drying in fixed bed dryer is usually higher (3-4%) [8].

The results on paddy drying using industrial scale dryers are seldom reported in scientific journal except several reviews on modelling and simulation on deep bed drying are found [2, 9-15] where results discussed are based on laboratory experiments. The drying characteristics and further analysis of the drying rate periods of Malaysian paddy were studied by Daud et al. [16] and Law et al. [17, 18]. However, information on the overall energy analysis and quality aspects of rice dried in industrial IBD is scarce.

Jittanit et al. [8] reported that paddy drying is a highly energy-intensive process and sensitive to the quality of rice. If an in-store dryer is used after the first-stage drying by LSU dryer, the energy cost of the industry can be reduced [19]. The operational data of paddy drying with the industrial scale dryers must be obtained to compare drying performance and energy consumption between industrial drying options [20]. Inconsistent operating parameters, such as drying air temperature, drying time and air flow rate among the drying process lines were found during industrial drying [21]. In reducing paddy moisture content (mc) from 22- 23% wet basis (wb) down to around 12.5% wb, the final mc, the specific electrical (in terms of primary energy) and specific thermal energy consumption were found to be varied between 1.44 to 1.95 MJ/kg water evaporated and 2.77 to 3.47 MJ/kg water evaporated, respectively [22]. The effect of different drying temperatures on rice quality and energy requisite for a particular bed thickness used in the industry warrants a thorough study for further efficient operation of the dryer; necessarily, the performances of industrial inclined bed dryers should be assessed to check its operational status.

Therefore, this study was undertaken to assess the actual drying practices using IBD in two commercial paddy drying complexes of BERNAS. Moisture reduction, drying capacity, drying rate, overall energy requirement and final quality of product had been assessed to determine further efficient drying option using IBD in the industry.

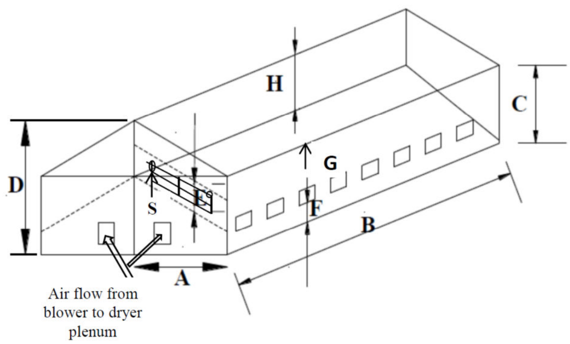

Fig. 1. Schematic Diagram of Industrial Inclined Bed Drying Chamber.

(A is the width; B is the length; C is the height of edge; D is the middle height; E is the actual paddy bed depth; F is the out let height; G is the paddy storage depth; H is the height of discharge carrier from bottom of paddy bed; S indicates the sample collection points at paddy bed) [22].

2. Materials and Methods

2.1. Field observation and data collection

The existing inclined bed dryers of two paddy processing plants of BERNAS at Bukit Besar, Kedah and at Simpang Empat, Perlis, Malaysia were used for this study. The dryers consisted of inclined drying bed (10.72 m × 2.92 m and 9.783 m × 3.048 m) at 38^{o}-45^{o} inclination with 9.5 mm stainless steel sieve, blower equipped with 1.524×1.31×0.533 m impeller and 18.65 kW motor. Freshly harvested paddy ‘MR-219’ variety was collected from the farmer’s fields in the vicinity of respective processing plant sites for all experiments. Table 1 shows the drying operations with detailed operating conditions used for this study.

Before filling up each selected IBD under observation, the freshly harvested paddy was first cleaned with the pre-cleaner. Paddy was dried in batch mode with each dryer holding capacity was considered as 15 ton. It is noted that dryer holding capacity varies with amount of impurities in paddy and its moisture content. Paddy bed depth was considered as 1.0 m. After completing the loading of each IBD, the associated blower fan was switched on around 15 min before switching on the cyclonic furnace (hot air) line. The drying air was heated from the heat produced by the combustion of rice husk in a cyclonic furnace. Drying air at desired temperature was then supplied through the plenum of the dryer.

Paddy moisture content, impurities in paddy (such as immature paddy, straw, leaves, stones etc.), drying air temperature, drying time, air flow and motor power were recorded as necessary. The average moisture content of paddy in drying bed was determined at 2 to 5 hours interval until end of drying operation and the paddy samples for this purpose were collected from 27 points within the paddy bed [22]. The Satake digital grain moisture tester model "SS-6" with an accuracy of ±0.5% was used to measure the moisture content of paddy samples. Meanwhile, K-type thermocouple connected with data logger (HANNA, Italy) with ±0.5°C accuracy and Thermo Hygrometer (H19564, HANNA, Taiwan) were used to record the drying air temperature and relative humidity, respectively. Thermal Anemometer (TESTO 4235, Italy) with ± 0.03 m/s accuracy was used to record the inlet air velocity of the dryer. It is noted that the cross-section area at the point of velocity measurement was measured earlier and the volume of air was calculated by continuity equation [21]. The same equation was employed to calculate the bed air velocity of each dryer.

Table 1. Operating Parameters of Industrial Inclined Bed Dryer (IBD) for Drying of Fresh Paddy.

Identity of drying line	Drying operating conditions in two location of drying Complex	
	KBB, Bukit Besar, Kedah	**KBB, Simpang Empat, Perlis,**
Control drying	T_{db}=27-32°C; RH=55-75%; V_{air}=0.06 to 0.5 m/s	T_{db}=26-32°C; RH=55-75%; V=0.06 to 0.15 m/s
IBD-1	V_{air} = 0.24 m^3/s/m^2 ; T=38-39°C; h=1.0 m	V_{air} = 0.21 m^3/s/m^2 ; T=41-42°C; h=1.0 m
IBD-2	V_{air} = 0.27 m^3/s/m^2 ; T=38-39°C; h=1.0 m	V_{air} = 0.29 m^3/s/m^2 ; T=41-42°C, h=1.0 m

[KBB: Kelang Beras BERNAS, V_{air}: Average bed air velocity, T: Drying air temperature, h: Bed depth, T_{db}: Dry bulb temperature of ambient air, RH: Relative humidity of ambient air].

2.2. Drying of control sample

Ambient air drying (AAD) method was used to dry the control paddy samples while the paddy was spread at 1-2 cm bed thickness on plastic mat under shed. Control drying was carried out to compare the milling quality of rice with the samples dried by the industrial dryers.

2.3. Analysis of overall energy requisite

Overall energy requirement was defined here as the energy required to process each tonne (t) of paddy which is of great concern to rice drying industry. Therefore, the present approach was adopted to determine specific electrical energy consumption in kWh/t and specific thermal energy consumption in MJ/t. The sum of the energy consumed by all motors associated with cleaning, handling, discharging of paddy, managing husk for combustion in cyclonic furnace and the centrifugal blower used to deliver hot air for drying was taken as the total electrical energy consumption.

The electrical energy *(E_m)* required for driving all motors except blower fan motor was calculated as

$$E_m = P_m \times t \quad (1)$$

where, E_m is electrical energy, P_m is motor rated power (kW) and t is total operating time in hr.

The following formula was used for calculating the electrical energy actually consumed by the blower motors. Voltage and current were recorded approximately at 30 min interval.

$$E_b = \sqrt{3}VICos\emptyset \tag{2}$$

where, E_b is the electrical energy consumed by blower, V is the line voltage in Volt, I is the line current, ampere, $Cos\emptyset$ is the power factor and t is the blower operating time, hour (h).

For each drying method, the specific electrical energy consumption (*SPEEC*) in kWh/t was finally calculated as follows

$$SPEEC = \frac{E_T}{W_p} \tag{3}$$

where, W_p is the amount of moist paddy to be dried (in tonne) in a batch

$$E_T = E_m + E_b \tag{4}$$

where, E_T is the total electrical energy, kWh.

Total thermal energy was calculated using the following equation

$$E_{th} = H_w \times C_h \times t \tag{5}$$

E_{th} is the thermal energy, MJ; H_w is rice husk consumption rate for each IBD, kg/h; C_h is heat value of rice husk, MJ/kg (C_h was considered as 13.4 MJ/kg alike other authors [23-25]).

The specific thermal energy consumption (*SPTEC*) in MJ/t was also calculated as follows:

$$SPTEC = \frac{E_{th}}{W_p} \tag{6}$$

2.4. Determination of rice quality

Dried paddy (five to seven kilograms) was collected from different layers of IBD. For further quality tests, the paddy samples were then stored in the refrigerator at 5-8^{o}C for 3-4 weeks after packing and sealing in poly packages.

2.4.1. Head rice yield

125 gm of dried and cleaned paddy samples with two replications were de-husked using a Testing Husker (THU-35A, Satake Engineering Co., Ltd. Japan) for determination of head rice yield (HRY). Rice bran was removed with a Satake Testing Mill (TM 05C) running for 45 sec for each amount of dehusked brown sample. Head rice was separated by the Satake Test Grain Grader (TRG 05B) using a 5.2-mm S-type identical cylinder.

2.4.2. Whiteness

Satake whiteness metre was used to measure the whiteness degree with four replications as samples obtained were double from each sample for HRY determination.

2.4.3. Milling recovery

Milling recovery was calculated as follows:

$$\%\ \text{Milling Recovery} = \frac{\text{Amount of milled rice(head rice and broken rice)}}{\text{weight of dried paddy sample}} \times 100 \qquad (6)$$

2.5. Statistical analysis

Single factor experiment in completely randomized design (CRD) was employed for the statistical analysis. The only factor was drying treatment in each drying complex as shown in Table 1. Each drying treatment was replicated twice. To calculate the mean values, standard error mean (SEM) and analysis of variance of obtained values on head rice yield, whiteness and milling recovery, the statistical software package SAS 9.2 version was used. Duncan's Multiple Range Test (DMRT) analysis was employed for determination the differences in rice quality parameters among the drying treatments to determine.

3. Results and Discussion

3.1. Moisture reduction, drying capacity and drying rate of inclined bed dryers used in two drying complexes

Table 2 shows the moisture reduction, drying capacity and drying rate during paddy drying using industrial inclined bed dryer in the two drying complexes. For the case of Bukit Besar, the results indicated that the percentage moisture drops in IBD-1 and IBD-2 were found to be 10.77% and 10.44%, respectively, from an average initial moisture content of around 23% after 20 hr of drying time. On the other hand, lower drying time of 18 hr and 13 hr were achieved for almost same moisture drops of 10.02% and 9.45% from an average initial moisture content of around 22.5% by IBD-1 and IBD-2, respectively, in Simpang Empat complex.

Table 2. Moisture Reduction, Drying Capacity and Drying Rate during Paddy Drying using Industrial Inclined Bed Dryer (IBD).

Location	Dryer	M_i (%wb)	M_f (%wb)	%MC drop	Drying time (h)	Drying capacity (ton /h)	Drying rate (kg /h)
Bukit Besar Kedah	IBD-1	*23.2 ±0.87	12.23±0.68	10.77	20	0.66	94
	IBD-2	22.80±0.73	12.56±0.53	10.44	20	0.66	90
Simpang Empat, Perlis	IBD-1	22.5±1.12	12.48±0.61	10.02	18	0.74	95
	IBD-2	22.0±0.89	12.85±0.46	9.15	13	1.03	121

*Mean values ±standard deviation; M_i, Initial moisture content; M_f, Final moisture content; MC, moisture content.

As shown in Table 1, clear differences in air flow or bed velocity and air temperature in the drying chambers were observed and thus variations of moisture drop were exhibited. A simple calculation revealed that paddy drying using higher drying air temperature of 41-42°C resulted in higher drying capacity by the IBDs with almost same holding capacity of 15 ton as observed in Simpang Empat. Meanwhile, the drying capacity ranged between 0.66 to 1.03 ton dry paddy per hour. Consequently, drying rate was found to be varied between 90 to 121 kg moisture per hour. The higher temperature shortened the total drying time thus resulted in increase of drying capacity and drying rate. In addition, higher air flow of 0. 29 m^3/m^2-s used in IBD-2 of Simpang Empat complex as shown in Table 1, might lead to rapid removal of paddy moisture thus drying capacity and drying rate were increased.

3.2. Energy requisite of industrial inclined bed dryers

The energy consumption calculated from the obtained data is shown in Fig. 2 and Fig. 3. The results indicated that the specific electrical and thermal energy consumption during paddy drying in IBDs ranged from 18.15 to 27.55 kWh/t and 960 to 1328.15 MJ/t respectively. The blower fan and cyclonic furnace for the IBDs of Bukit Besar complex were needed to be operated for longer time thus required higher electrical energy of 27.55 kWh/t and thermal energy of 1328.15 MJ/t. On the other hand, IBDs of Simpang Empat complex consumed lesser electrical energy of 18.15 kWh/t and lesser thermal energy of 960 MJ/t which seemed to be contrasted with energy consumption results in drying as reported by previous researchers [15, 21] that the specific thermal energy consumption is usually higher in using higher drying air temperature and higher air flow. It must be noted that the present overall energy requirement calculation was accomplished based on the total operating time of the cyclonic furnace used for heating up the drying air rather than considering the amount of air flow and temperature in drying bed. Thus energy requirement was affected by the drying time. Thermal energy requirement in inclined bed paddy drying might be minimized if the energy generated from rice husk, the potential bio-fuel with high calorific value [25], could be ensured for maximum utilization in drying.

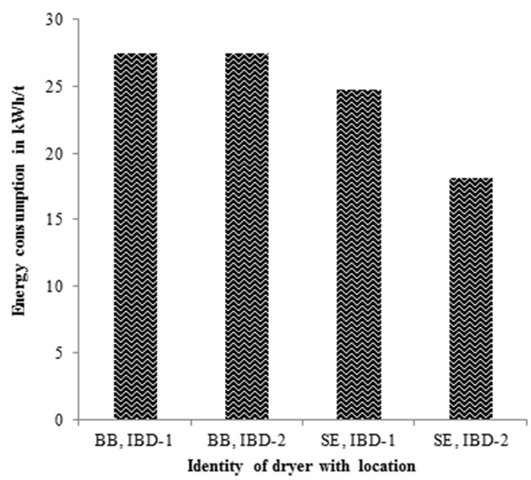

Fig. 2. Electrical Energy Requisite for Paddy Drying using Industrial Inclined Bed Dryer.
[BB: Bukit Besar, SE: Simpang Empat, IBD: inclined bed dryer]

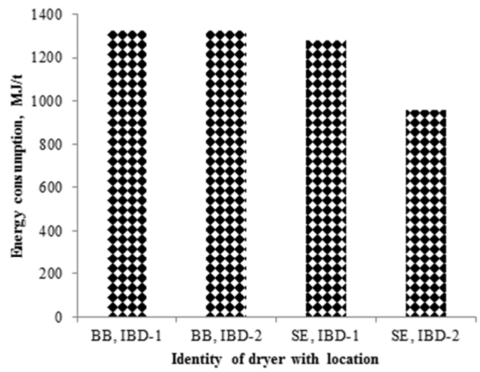

Fig. 3. Thermal Energy Requisite for Paddy Drying using Industrial Inclined Bed Dryer.
[BB: Bukit Besar, SE: Simpang Empat, IBD: inclined bed dryer]

3.3. Product quality assessment

3.3.1. Head rice yield

Figure 4 shows the percentages of head rice yield (HRY) obtained from the IBDs of the complexes under drying operating conditions stated in Table 1. Significant difference ($p \leq 0.05$) in the HRY between the two IBDs of Simpang Empat was achieved while HRY did not vary significantly between two IBDs of Bukit Besar. It is noted that there was no significant difference in HRY between industrial drying methods and control samples. Drying of control samples under shed took longer drying time up to three days that might lead to breakage of kernels thus head rice yield was affected. 1-4% higher HRY was obtained from the IBDs of Bukit Besar complex than those of Simpang Empat complex. Almost same initial moisture content paddy dried by IBD using higher temperatures degraded HRY which were similar with the previous findings [21]. Moreover, non-uniform drying due to higher temperature and lower air flow for thick paddy bed (1.0 m) caused over drying of the bottom layer paddy which led to breakage of the grains and thus ultimately decreased the HRY [22]. In depth study can be carried out to find out the best combination of drying temperature, air flow and bed thickness for drying of various initial moisture content paddy using IBD for obtaining better quality rice.

3.3.2. Whiteness of rice

Figure 4 illustrates that there is no significant difference in whiteness of milled rice obtained from the different paddy drying methods except that the whiteness of rice was degraded slightly when the paddy was dried at higher temperature in Simpang Empat dryers (the values fell in the range of 35-37%). Nevertheless, this whiteness range is still within the acceptable limit as per rice trade quality. The control samples dried by shed drying yielded in lower whiteness due to longer drying time of up to three days taken which led to non-enzymatic browning that could be the cause of lesser degree of whiteness.

3.3.3. Milling recovery

The milling recovery which includes head rice and broken rice was found to vary between 66.36 to 68.04%. The difference in milling recoveries between the IBDs of two complexes was not so much. It is interesting that the highest milling recovery of 68% was achieved from the IBD-2 of Simpang Empat complex. As it can be seen from the head rice results (Fig. 4) that IBD-2 yielded lower head rice yield. Consequently, higher breakage in IBD-2 contributed to higher milling recovery. The milling recovery more specifically graded rice (mixing of head rice yield and 15% broken rice) is usually used by the milling industry (BERNAS) to estimate the milling results which might not be the proper parameter. Therefore, head rice yield is suggested to be considered for evaluating the milling performance of the dryer.

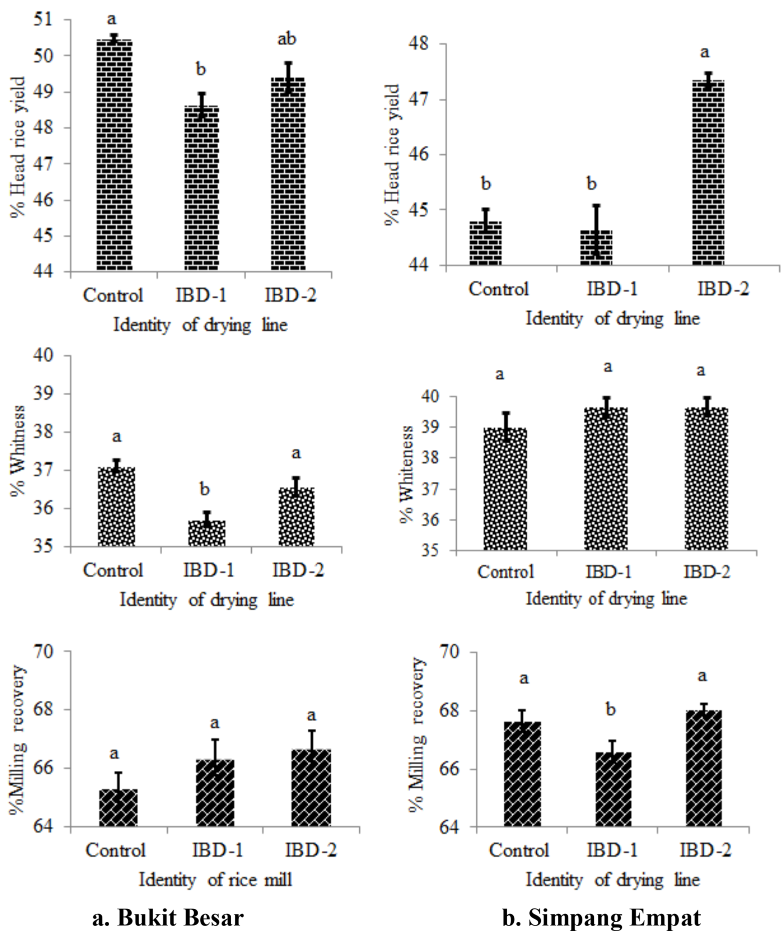

Fig.4. Comparison of Head Rice Yield, Whiteness and Milling Recovery of Rice Obtained from Selected IBDs of the Two BERNAS Complexes.
[IBD is inclined bed dryer , [a-d] The test values: Same letters for the different drying lines in each figure mean that the values are not significantly different ($p \leq 0.05$)].

4. Conclusions

The drying performances in terms of drying capacity, drying rate, overall energy requisite and final product quality of industrial inclined bed dryers as per usual drying operation in two selected complexes of BERNAS are presented in this paper. Some concluding observations from the investigation are given below

- In both complexes, the lack of consistency in operating parameters, such as drying temperature, drying time and air flow rate among the IBDs were exhibited for drying of same kind of raw paddy.
- Drying capacity and drying rate of IBDs were found to be higher by 11 to 36% and 5 to 25%, respectively in the Simpang Empat complex than those of Bukit Besar complex because of higher drying temperature of 41-42°C used for drying of almost identical paddy.
- Both overall electrical and thermal energy requirements were found to be reduced in IBDs of Simpang Empat complex than Bukit Besar mainly because of shorter drying time.
- However, IBDs yielded 1-4% higher head rice during drying of paddy with an average initial moisture content of 23% when using 38-39°C drying air temperature.

Acknowledgement

The authors would like to express their sincere thanks to BERNAS, Malaysia, for the financial support, as well as the use of drying and milling site for data collection. Our heartiest gratitude also goes to the Food Analysis Laboratory of UPM-BERNAS for facilitating the milling test.

References

1. Inprasit, C.; and Noomhorm, A. (2001). Effect of drying air temperature and grain temperature of different types of dryer and operation on rice quality. *Drying Technology,* 19(2), 389-404.
2. Igathinathane, C.; Chattopadhyay, P.K.; and Pordesimo, L.O. (2008). Moisture diffusion modelling of parboiled paddy accelerated tempering process with extended application to multi-pass drying simulation. *Journal of Food Engineering*, 88(2), 239-253.
3. www.knowledgebank.irri.org at @EbookBrowse. *Training Manual Paddy Drying pdf* free ebook download from http://ebookbrowsee.net/training-manual-paddy-drying-pdf-d88323894, pp.18- 20.
4. Sangdao, C.; Songsermpong, S.; and Krairiksh, M. (2011). A continuous fluidized bed microwave paddy drying system using applicators with perpendicular slots on a concentric cylindrical cavity. *Drying Technology*, 29(1), 35-46.
5. Das, I.; Das, S.K.; and Bal, S. (2009). Drying kinetics of high moisture paddy undergoing vibration-assisted infrared (IR) drying. *Journal of Food Engineering*, 95(1), 166-171.

6. Soponronnarit, S.; Prachayawarakorn, S.; Rordprapat, W.; Nathakaranakule, A.; and Tia, W. (2006). A superheated-steam fluidized-bed dryer for parboiled rice: Testing of a pilot-scale and mathematical model development. *Drying Technology*, 24(11), 1457-1467.
7. Evin, D.; Gul, H.; and Tanyildizi, V. (2008). Grain drying in a paraboloid-based spouted bed with and without draft tube. *Drying Technology*, 26(12), 1577-1583.
8. Jittanit, W.; Srzednicki, G.; and Driscoll, R. (2010). Seed drying in fluidized and spouted bed dryers. *Drying Technology*, 28(10), 1213-1219.
9. Zare D.; Jayas D.S.; and Singh, C.B. (2012). A generalized dimensionless model for deep bed drying of paddy. *Drying Technology*, 30(1), 44-51.
10. Naghavi, Z.; Moheb, A.; and Ziaei-rad, S. (2010). Numerical simulation of rough rice drying in a deep-bed dryer using non-equilibrium model. *Energy Conversion and Management*, 51(2), 258-264.
11. Sitompul, J.P.; Istadi, I.; and Widiasa, I.N. (2001). Modelling and simulation of deep-bed grain drying. *Drying Technology,* 19(2), 269-280.
12. Srivastava, V.K.; and John J. (2002). Deep bed grain drying modelling. *Energy Conversion and Management*, 43(13), 1689-1708.
13. Kribs, J.D.; and Spolek G.A. (1997). Drying energy conservation for deep bed barley-malt kilns. *Journal of Agricultural Engineering Research*, 68(4), 367-373.
14. Zare, D.; Minaei, S.; Mohamad Zadeh, M.; and Khoshtaghaza, M.H. (2006). Computer simulation of rough rice drying in a batch dryer. *Energy Conversion and Management*, 47(18-19), 3241-3254.
15. Zare, D.; and Chen, G. (2009). Evaluation of a simulation model in predicting the drying parameters for deep-bed paddy drying. *Computers and Electronics in Agriculture*, 68(1), 78-87.
16. Daud, W.R.W.; Sarker, M.N.H.; and Talib M.Z.M. (2000). Drying characteristics of Malaysian Padi., *Pertanika Journal of Science & Technology,* 8(1), 105-115.
17. Law, C.L.; Tasirin, S.M.; and Daud, W.R.W. (2001). Batch drying of paddy in a rapid bin dryer. *The 2nd Asian-Oceania Drying Conference*, 607-616.
18. Law, C.L.; Tasirin, S.M.; and Daud, W.R.W. (2003). A new variable diffusion drying model for the second falling rate period of paddy dried in a rapid bin dryer. *Drying Technology*, 21(9), 1699-1718.
19. Jittanit, W.; Saeteaw, N.; and Charoenchaisri, A. (2010). Industrial paddy drying and energy saving options. *Journal of Stored Products Research*, 46(4), 209-213.
20. Wan, D.; Gong Y.; Jin H. ; Jian M.; and Chenghua Li. (2010). Study on the moisture uniformity of paddy drying in a deep fixed-bed. *World Automation Congress (WAC)*, 19-23 Sept.
21. Sarker M.S.H.; Ibrahim M.N.; Aziz, N. Ab.; and Salleh, P.M. (2013). Drying kinetics, energy consumption and quality of paddy (MAR-219) during drying by the industrial inclined-bed dryer with or without the fluidized bed dryer. *Drying Technology*, 31(3), 286-294.

22. Sarker, M.S.H.; Ibrahim, M.N.; Aziz, N. Ab.; and Salleh, P.M. (2014). Energy and rice quality aspects during drying of freshly harvested paddy with industrial inclined bed dryer. *Energy Conversion and Management*, 77, 389-395.
23. EGCO Green Co. Ltd. (2002). *Information and operation report. April. Roi Et*, 2002, Thailand.
24. Beagle, E.C. (1981). *Rice husk conversion to energy*. FAO, Rome.
25. Kapur, T.; Kandpal, T.C.; and Garg, H.P. (1996). Electricity generation from rice husk in Indian rice mills: potential and financial viability. *Biomass and Bioenergy*, 10 (5-6), 393-403.