

# A Study on Drier Performance and Milling of Parboiled Rice in a Selected Auto Rice Mill

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## Abstract

This study addresses the performance of the drier and milling in connection with the processing of parboiled rice of variety BRRI-14 (Gazi) at a local auto rice mill located at Gopalpur, Mymensingh. The rice mill practices the cycle of pre-steaming, soaking and steaming for parboiling operation. The moisture content (17.5% w.b.) of the paddy increased to 29.7% (w.b.) after soaking and steaming. The materials were then dried to 14.6% (w.b.) moisture content in a continuous flow re-circulating type mechanical drier of capacity 11000 kg for about 7 hours. The average drying air temperature was 40.3°C. The efficiency of the drier was found to be 84.77%. The drying rate constant was 0.35 per hour. The average percentage of cracked or fissured rice kernels after drying was found to be 5.2. The rice mill used a rubber roll huller and three disc type polishers for milling operations. The milling recovery and head rice yield for mechanically dried paddy were 71.5% and 70% respectively while for sun dried paddy these were 68% and 65%, respectively.

**Key words :** Drier performance, Milling performance

## 1. Introduction

As rice is the staple food of the population of Bangladesh majority of the rural population are involved in its production, processing and marketing. But the rice processing technology practiced by the mill owners are either completely traditional or a combination of modern and traditional method (Farouk and Islam, 1994). The millers are processing rice at their own convenience using partial mechanization in combination with some obsolete techniques (Sarkar, 2001).

Poor or defective drying facilities or incorrect drying procedures may result in very fast drying rates, incomplete drying, moisture re-absorption and uneven moisture distribution within the grain mass (Alam, 2004). Improper drying results in high cost, low efficiencies, high milling losses and poor quality of milled rice. Unless the grain is dried immediately and properly stored after harvest losses are likely to be incurred at the pre-milling and milling stages. A grain drier can be evaluated properly only after reliable tests have been performed (RNAM, 1995).

Parboiled paddy should be dried to 12-14% moisture for safe storage or milling (Bala, 1997). Parboiled paddy is more difficult to dry and requires more energy than non-parboiled paddy because its moisture content is much higher. However, higher air temperatures help to reduce the drying time. If drying is done too fast, internal stresses develop in

the grain and cause breakage during milling. Drying temperatures between 35°C and 45°C showed less fissuring effect depending on varieties (Islam, 2003).

Since 1960's, the production of rice has been increased many fold but the matter of product quality is still neglected. At this stage, production and processing of quality rice for internal consumption and export can be the means of augmenting farmers' as well as national income. Appearance of milled rice is an important consideration to the consumer. Appearance depends upon the size and shape of the rice kernel, translucency and chalkiness of the grain (Vhutto, 2004).

During the whitening process of brown rice, kernels are subjected to intensive mechanical and thermal stresses which might damage or break some of the kernels. Some parameters such as the type of whitening machine, the paddy characteristics, and the environmental factors affect the rice kernel damage and breakage during the milling process (Afzalnia *et al.*, 2004). In the old milling plants, a friction type whitener is often used in such a way that brown rice is whitened by passing it through this whitener without using a polisher. In some cases, these whiteners are used in series. In the modern milling plants, a set of three or four vertical abrasive whiteners in series is used as whitener with a friction whitener as a polisher.

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Unlike any other grain rice is consumed as a whole kernel. Therefore, head rice yield during milling is of great importance as it is one of the vital quality indicators of milled rice. The quality of milled rice is greatly influenced by the whole processing system. But in Bangladesh the processing system of rice has not been developed technically yet. With the growing concern of the consumers regarding the quality milled rice, auto rice milling industries incorporating a mechanical drier have been flourishing in the country since the recent years. At present 141 automatic rice mills, 109 major rice mills and 13,329 husking mills are in operation in the country (Anonymous, 2008). In order to develop the quality milling of rice it is primarily necessary to examine the existing processing system, specially drying and milling and to address the quality of the end product. Therefore, the specific objectives of this study were: i) to study the existing processing system of the parboiled paddy in a selected auto rice mill, ii) to evaluate the drier performance and milling performance of that auto rice mill.

## 2. Methodology

### 2.1 Site and mill selection

This study was conducted in a selected rice mill (Progoti Auto Rice Mill) located at Gopalpur Union under Mymensingh sadar upazila. The rice mill was fully automatic with the provisions of large drying yard for sun drying as well. The mill processes both parboiled and unparboiled rice and all the available local varieties. But this study covered only the processing of parboiled rice.

### 2.2 Rough rice

The rough rice processed was of variety BRRI-14 (*Gazi*). Average length and breadth of the rough rice kernels were 5.2 mm and 3.2 mm, respectively measured using a slide calipers. Initial moisture content of the sample was 17.5 % (w.b).

### 2.3 Soaking and steaming parameter

After cleaning the paddy was pre-steamed by passing steam inside the soaking or steaming chamber and then soaked in water. The condition of soaking water and the duration of soaking were measured. The steam temperature, duration of pre-steaming and steaming were also measured by using a stop watch and a digital thermometer equipped with a thermocouple.

### 2.4 Ambient air condition and air flow rate

The ambient air temperature and relative humidity were measured by using thermocouple at the

blower inlet. The air velocity through the blower was measured by using a digital anemometer (TA35, TSI Instruments Ltd., England) at the suction point of the blower. The inlet area of the blower was measured and then air flow rate was calculated. An average air flow rate of 11.58 m<sup>3</sup>/s that is 13.4 kg/s (at ambient condition specific volume of air is 0.865 m<sup>3</sup>/kg) was used during drying.

### 2.5 Psychrometric properties of drying air

From the temperature and the relative humidity of drying air measured at three locations as shown in Fig. 1, other psychrometric properties (enthalpy, specific volume of air) were found out from the psychrometric chart.

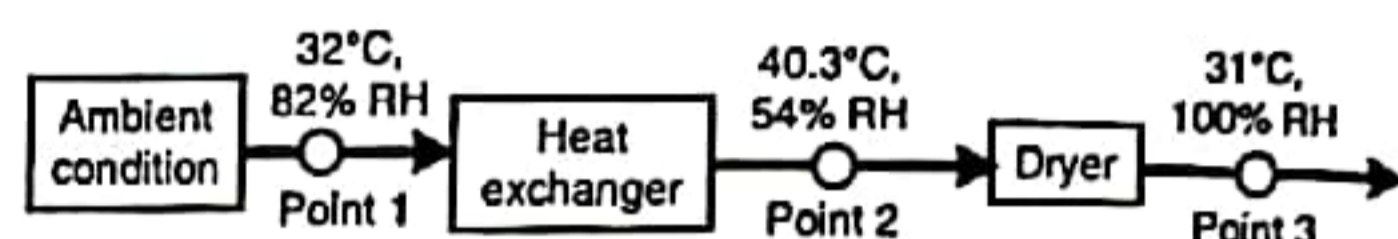


Fig. 1. Measuring points of psychrometric properties of drying air

### 2.6 Energy consumed by the drier

The energy consumed by the drier was supplied from three sources: the heat exchanger, blower motor and conveyor motor. The energy supplied by the heat exchanger was obtained from the psychrometric chart from the difference of enthalpy of drying air before and after passing the heat exchanger multiplied by the total mass of drying air utilized throughout the drying period (Saha and Alam, 2007). Energy supplied to the motors, to drive the blower as well as the conveyors, were taken directly from their rated power.

### 2.7 The energy actually utilized by the drier

This is the energy actually required to remove the moisture from the paddy to dry it to desired level and it was calculated as follows (Saha and Alam, 2007):

$$\text{The energy actually required} = M \cdot E \dots\dots\dots (1)$$

where,  $M$  = Mass of moisture removed, kg  
 $E$  = Energy required to remove per kg of moisture from rough rice, kJ/kg  
 {1800 kJ/kg (Bala, 1997)}

### 2.8 Drier efficiency

The energy consumed by the drier (i.e. energy input) and the energy actually utilized by the drier (i.e. the energy output) were measured. Efficiency of the drier was then calculated as follows:

$$\text{Efficiency} = \frac{\text{Energy output}}{\text{Energy input}} \times 100 \dots\dots\dots (2)$$

### 2.9 Changes in moisture content of paddy during drying

During drying moisture content of the paddy sample drawn at 15 to 20 min interval from the conveyor outlet, was measured by using a moisture meter (Kett Electric Co., Japan) following standard procedure. Drying rate was calculated from the difference of two consecutive readings of moisture contents of the drying material divided by the average time interval. Mathematically the drying rate is expressed by the following equation:

$$dm/dt = -(m_2 - m_1)/\Delta t \quad \dots\dots\dots (3)$$

where,  $dm/dt$  = drying rate,  $hr^{-1}$

$m_2 - m_1$  = difference of moisture contents of grain at time interval  $\Delta t$

$\Delta t$  = time in hour

### 2.10 Drying rate constant

Drying rate constant was calculated by graphical method using the single exponential equation (Bala, 1997), as follows:  $\frac{M - M_e}{M_o - M_e} = ae^{-kt}$  and the

equation can be rewritten as

$$\ln\left(\frac{M - M_e}{M_o - M_e}\right) = \ln(a) - kt \quad \dots\dots\dots (4)$$

Where,

$M$  = moisture content at time  $t$ , % wb

$M_e$  = equilibrium moisture content, % wb

$M_o$  = initial moisture content, % wb

$k$  = drying rate constant,  $h^{-1}$

$t$  = drying time, min

$a$  = constant

When equation (4) was plotted on a semi-log paper, it gave a straight line with a negative slope of

$$\frac{y_2 - y_1}{x_2 - x_1} = 0.4343 \times k \times f \quad \dots\dots\dots (5)$$

Where,  $f$  = scale factor

$k$  was then determined graphically from the slope of the straight line (Saha and Alam, 2007).

### 2.11 Fissured kernel after drying

The percentage of fissured kernel was determined by randomly taking samples of 50 rough rice kernels. Manually dehusked brown rice kernels were examined by a fabricated grain scope (a square box having a light source and a glass cover over which the grains are kept for inspection) and the fissured kernels were counted to calculate percentage of fissured kernels.

### 2.12 Milling recovery and different fractions

Milling performance was determined from the milling recovery, head rice yield, quantity of broken rice, husk and bran obtained from a batch of 40 kg of paddy and was expressed as percentage.

## 3. Results and Discussion

### 3.1 Processing of parboiled rice

The impurities and foreign materials in the paddy were removed by using a two stage sieve along with air blasting before entering the soaking chamber.

Soaking was done using fresh ground water in the cylindrical soaking vessels. The duration of soaking was 6 hours. Before soaking, pre-steaming was done for 5 mins in order to shorten the soaking period. Thus the bad odor of rice kernels resulting from the fermentation, which occurs during long time soaking, can be avoided. After soaking the steam was passed through the grains for 12 mins for complete gelatinization of paddy kernels. The steam temperature was 105°C. The steam temperature and duration of steaming were in compliance with the standard suggested by the researchers. The parboiled paddy was then unloaded from the steaming vessel with a moisture content of 29.7 % (wb) and loaded into the drier conveyor.

A continuous flow re-circulating type mechanical drier was used to dry the parboiled paddy. The paddy re-circulated in the drier and hot air was passed through the drier as cross-flow. The average drying air temperature was 40.3°C. It was a low temperature for drying.

Husking was done by a rubber-roll huller. The husks, brown rice and unhusked rice were separated by a tray-type paddy separator. The brown rice was polished in an abrasion type polisher. There were three polishers coupled with sieves arranged in series. After polishing the head rice, bran and broken rice were delivered through different outlets.

### 3.3 Drying

Drying was done in a continuous flow re-circulating type drier. The capacity of the drier was 11000 kg per batch. During drying the change in moisture content of paddy in drier was observed for two different runs and are presented in Fig. 2 and Fig. 4. The drying rates versus moisture content are also presented in Fig. 3 and Fig. 5 for these two runs respectively. From Fig. 2 and Fig. 4 it is

evident that the moisture content initially reduced rapidly but later it changed slowly, because of higher resistance to move moisture from inside to outer surface of the kernel. It required 430 min (7.17 hrs) to reduce the moisture content from 29.5 % to 15.8 % for the 1<sup>st</sup> run and 350 min (5.83 hrs) to reduce the moisture content from 29.4 % to 15.8 % for the 2<sup>nd</sup> run. The drying rate versus moisture content graphs show that the drying rate reduced with the reduction of moisture and the trend could be explained by a straight line for the range of moisture contents shown in the graphs.

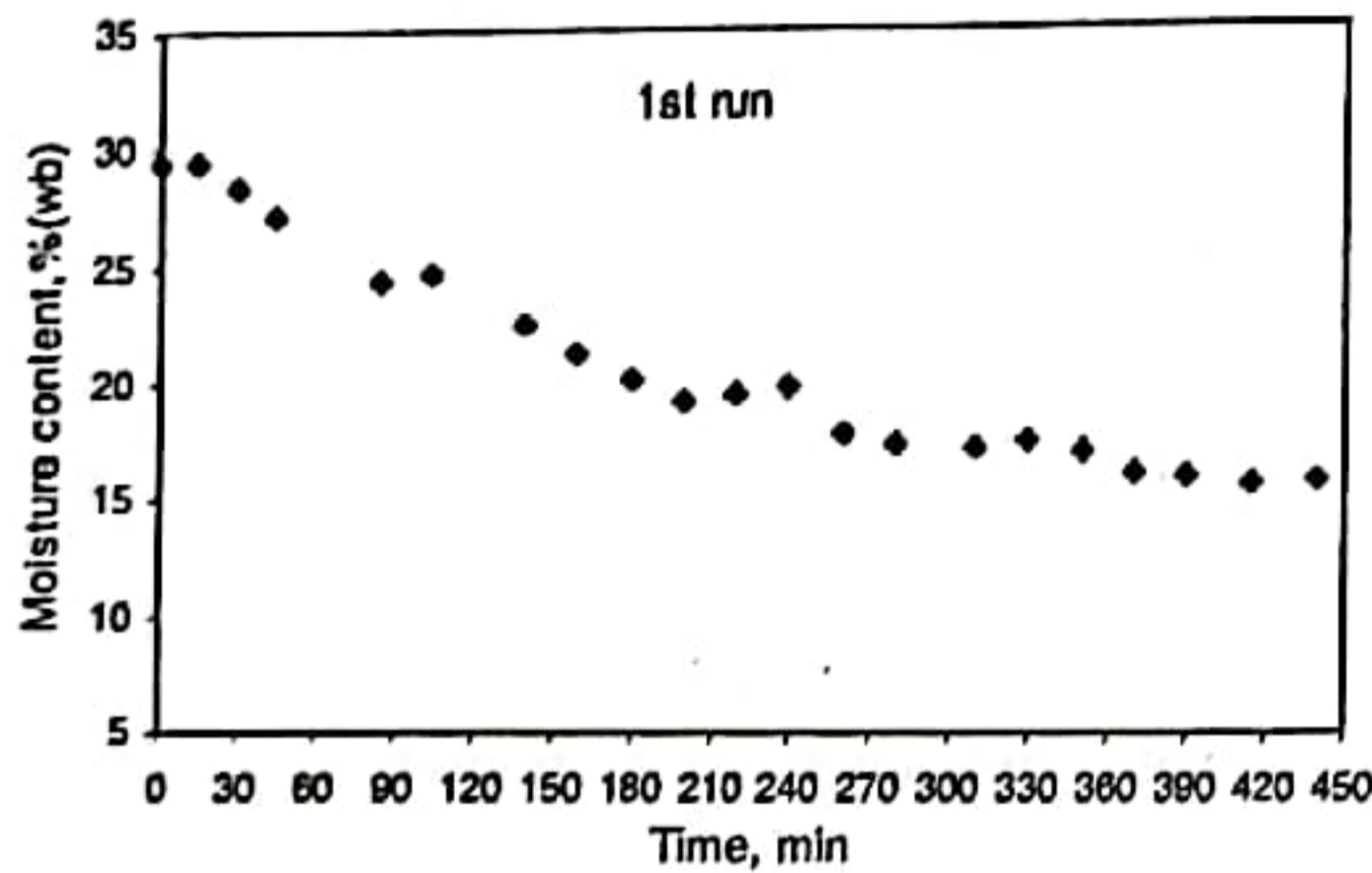


Fig. 2. Change of moisture content of paddy in drier with time for 1<sup>st</sup> run.

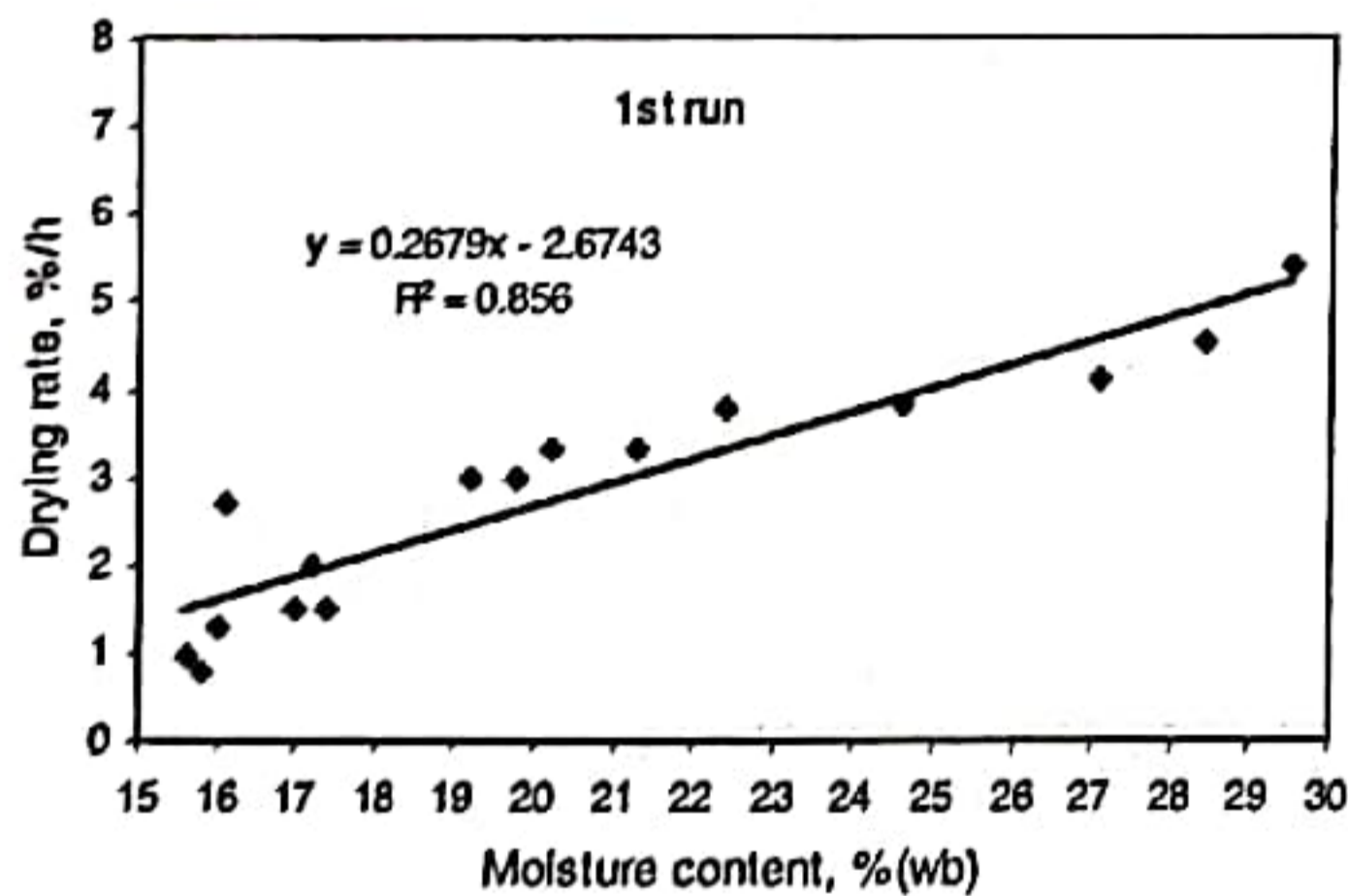


Fig. 3. Variation of drying rate with moisture content during drying of paddy for 1<sup>st</sup> run.

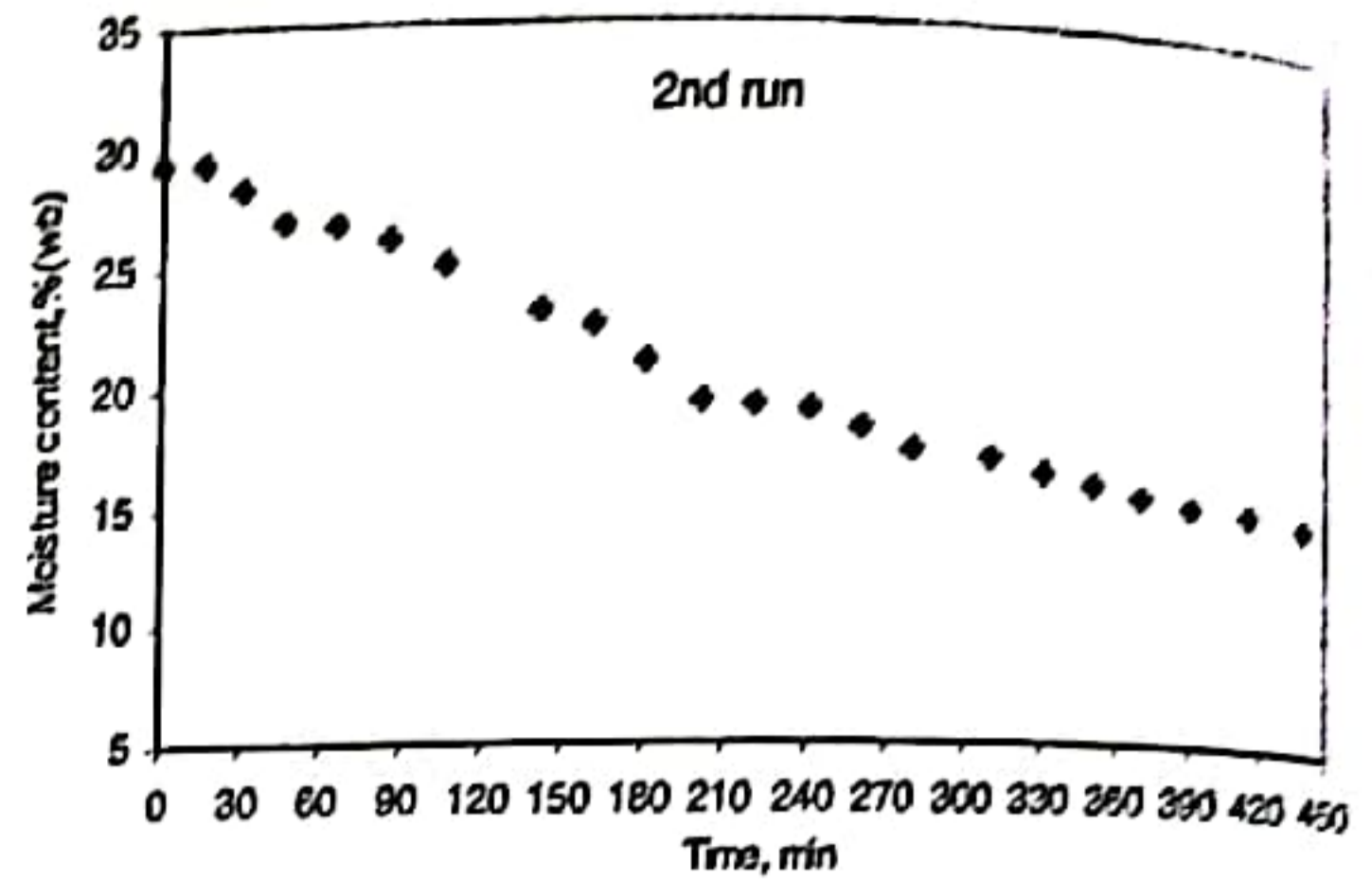


Fig. 4. Change of moisture content of paddy in drier with time for 2<sup>nd</sup> run.

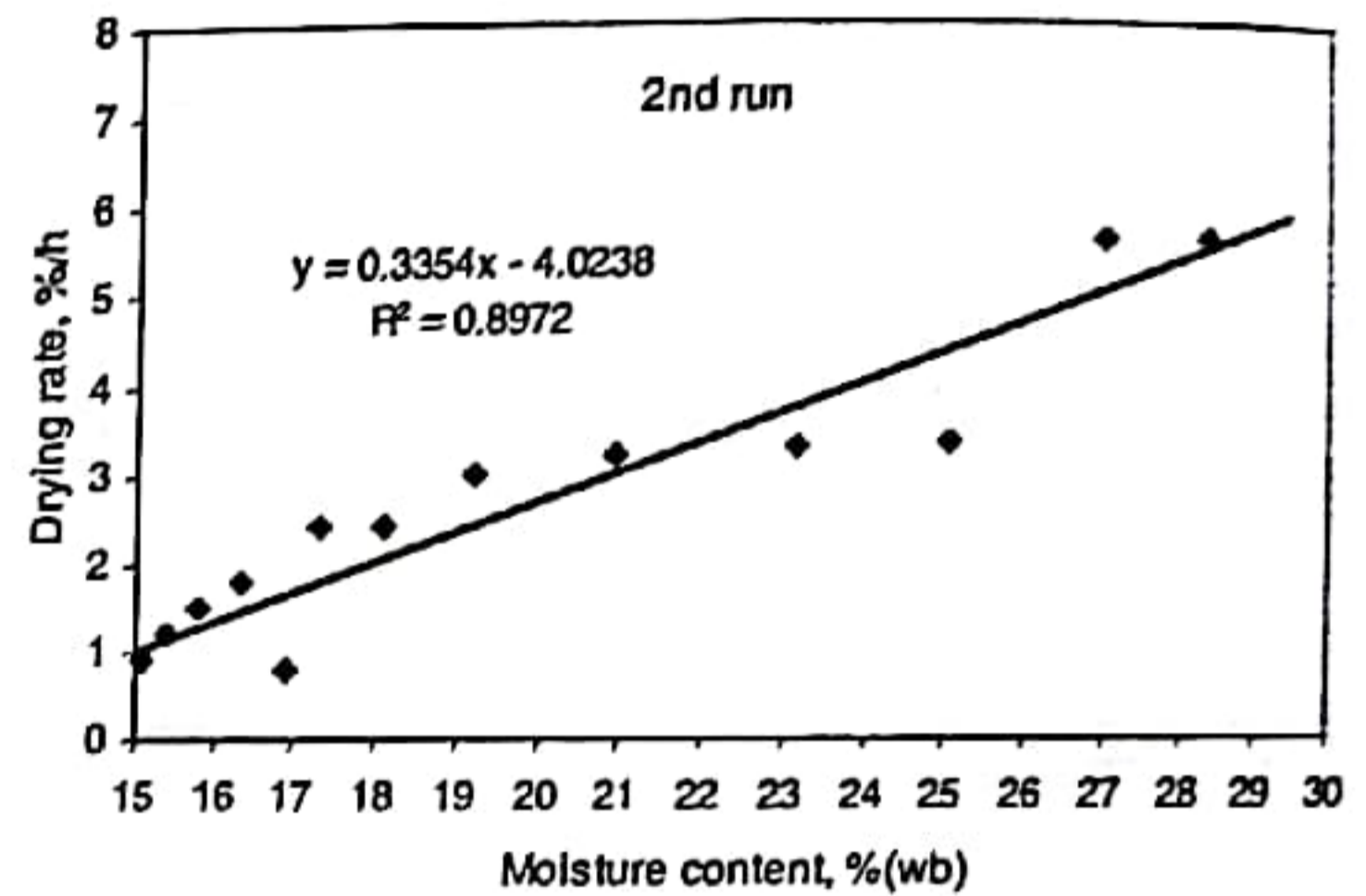


Fig. 5. Variation of drying rate with moisture content during drying of paddy for 2<sup>nd</sup> run.

### 3.3 Performance of the drier

Table 1 shows the amount of energy supplied to the drier from its different components. The total energy input to the drier was 4439.54 MJ and the energy utilized was 3763.58 MJ. The efficiency of the drier was found to be 84.77 %. The boiler efficiency and fuel burning efficiency were not considered in this case due to some limitations. The efficiency of the drier indicated its quite satisfactory performance although the figure would be lesser if the efficiencies mentioned were considered.

Table 1. Performance of the drier

| Component      | Energy Input (MJ) | Total Energy Input (MJ) | Molsture removed (kg) | Energy actually utilized (MJ) | Drier efficiency (%) |
|----------------|-------------------|-------------------------|-----------------------|-------------------------------|----------------------|
| Heat exchanger | 3477.20           |                         |                       |                               |                      |
| Blower motor   | 577.404           | 4439.54                 | 2090.88               | 3763.58                       | 84.77                |
| Conveyor motor | 384.936           |                         |                       |                               |                      |

### 3.4 Drying rate constant

The experimental data plotted in a semi-log paper in the form of equation (4) yielded  $y_2 - y_1$ ,  $x_2 - x_1$  and  $f$  as 1.15, 3.0 and 150 respectively. Therefore, the drying rate constant,  $k$  was found to be  $0.35 \text{ h}^{-1}$  from equation 5. The rate of moisture removal was very low resulting in a low drying rate constant.

### 3.5 Percentage of fissured grain

After drying the percentage of fissured kernel was found to be 5.2 % in the sample dried by the mechanical drier. The observed percentage of fissured kernel was within the reasonable limit. It was because, the drying air temperature was  $40.3^\circ\text{C}$  which was within the suitable range (Islam, 2003) for lowering the fissure occurrence. Generally fissure results from high drying air temperature and high drying rate. Moreover, the hydrothermal stress experienced by the kernel during drying, responsible for propagation of cracks in the kernel, might be less due to uniform drying of parboiled rice by the mechanical drier.

### 3.6 Milling recovery and head rice yield

The average percentage of head rice yield (HRY), broken rice, husk and bran recovery were 70.0, 1.5, 16.0 and 5.5, respectively for the milled rice dried by the mechanical drier. On the other hand for sun dried paddy these recovery percentages were 65.0, 3.0, 16.0 and 6.0, respectively while the final moisture content of mechanically dried and sun dried paddy was 14.6 % (wb) and 14.0 % (wb), respectively. From these comparative data it is clear that mechanical drier resulted better milling yield over sun drying.

## 4. Conclusions

Pre-steaming was done to paddy followed by soaking for 6 hours with fresh water. The moisture content of the paddy after soaking was found 29.7 % (wb). The steaming temperature was  $105^\circ\text{C}$  and duration was 12 min for parboiling. The mill used rubber-roll huller and mechanical drier while it had a yard for sun drying also. The whole rice processing system was highly technical, which required skilled labor and technicians. It was observed that, the mill did not have sufficient skilled labor and technicians. Most of the mill operators were untrained and they operated mill with indigenous knowledge. The boiler used in the mill had no standard for steam pressure and temperature. Operating the boiler seemed to be very risky.

The drying air temperature used by the mill was  $40.3^\circ\text{C}$ , resulting in a drying rate which was not high. The drier efficiency found in this study was 84.77 %. The drying rate constant was found to be 0.35 per hour, which was very low and indicated that the drying rate was not high. Percentage of fissured kernel was observed to be 5.2 % after drying, which was reasonable. The milling recovery and head rice yield were found as 71.5 % and 70 %, respectively for mechanically dried paddy and those for sun dried paddy were 68 % and 65 %, respectively. These indicated the better performance of the mechanical drier than sun drying for drying rough rice to be milled.

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