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Study on Coarse Rice Processing in a Commercial Rice Mill

A.K.M. Saiful Islam[1], M.A. Zaman[2], M.P. Islam[3], M.Z.A. Vhutto[4]

Abstract

This study was conducted in the Minar auto rice mill located at Chapai Nawabgonj district of Bangladesh during November 2003. The variety Parija was processed as parboiled and non-parboiled rice. Parboiled paddy was dried in the sun and milled in engelburg huller whereas, non-parboiled paddy was dried in Lousiana State University (LSU) drier and milled in rubber roll huller. The initial moisture content of rough rice was 15.2%. After soaking for 36 hrs the moisture content of paddy was increased to 29.8% (wb). Steaming was done twice before and after soaking for complete gelatinization of the rice kernels. The paddy was sun dried for 3 days followed by 18 hours tempering every day to reduce moisture content of the paddy from 29.8% to 9.3% (wb). Non-parboiled paddy was dried in LSU drier for 6 hours and moisture content was reduced from 15.2% to 9.0% (wb). The range of hot air temperature was 60 to 90°C. The crushing strength of parboiled paddy was 6.2 kgf after three days of sun drying. The crushing strength of non-parboiled paddy was 4.8 kgf after 6 hours of drying in LSU dryer. The milling yield and head rice recovery of parboiled rice were 64.25% and 62.25%, respectively, whereas those of non-parboiled rice were 65.50% and 64.25%, respectively. Head rice yield was 2% higher in non-parboiled rice due to milling in rubber roll huller. The non-parboiled rice was finer than the parboiled rice due to polishing after dehusking. The production of non-parboiled rice was more profitable than the parboiled rice.

Key word: Parboiled rice, Non-parboiled rice, Crushing strength, Head rice

1. Introduction

Rice grains are categorized into coarse, fine and aromatic. The physical dimensions of rice kernels are of vital importance to those engaged in the rice industry and trading in international market. Rice varieties may be classified based on two physical parameters i.e. length and shape. Length is a measure of the rice kernels in its greatest dimension, while the shape is determined by the length/breadth ratio. The coarse rice of Bangladesh may be classified into short, bold and medium bold categories. Bangladeshi coarse rice is short and bold (BRRI, 2000). Most of the rural people and workers (labourers) prefer coarse rice; because they need more energy to work hard. Coarse rice is mainly composed of starch. This starch is composed of two-chain component such as *amylose* and *amylopectin*. Both amylose and amylopectin are converted into glucose for supplying energy (Conn and Stumpf, 1972). Beside this, rural people preferred coarse rice for its non-sticky property. Nutrients in coarse rice are 6.10-8.5% protein, 67.7-75.7% carbohydrate, 9.0-12.5% moisture content and 0.56-1.8% ash (Firmin, 1991).

Most of the commercial rice processing mills use engelburg huller for processing parboiled rice and rubber roll huller for processing non-parboiled rice. Araullo (1976) reported that the milling recovery of rice is 63% and 70% from engelburg type disc huller and rubber-roll huller, respectively. Joaysena and Ilangatilek (1986) studied commercial rice mills of Sri Lanka and found that the total output of the modern mill was 69.2% and that of semi-modern and traditional huller mills were 68.8% and 67.5%. The modern rice mill gave the highest head rice yield of 66.1% and traditional huller mill gave the lowest of 60.3% and impurities were 0.3%, 0.5% and 0.7% for modern, semi-modern and traditional mill, respectively. Kabir (1989) studied the milling quality of rice produced by local rice mills and found 85.38% head rice yield, 14.17% broken rice and 0.28% impurities. The average moisture content of the milled rice was 14.99%.

The hardness of brown rice affects ease of milling, dictating milling time, occurrence of broken grains and milling yield. In general the lower the hardness, the easier is to mill. Hardness of the grain is closely related to the characteristics of brown rice and its moisture content. Hardness decreases when white belly grains and immature grains are included and the moisture content is higher. Crushing strength of normal brown rice is 5-8 kgf, of well dried rice 10 kgf or higher and brown rice that is poorly dried has only 3-4 kgf (Chikubu, 1975).

[1] Senior Scientific Officer, Farm Machinery and Post-harvest Technology (FMPHT) Division, Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh
[2] Professor, [3] Lecturer, [4] Post graduate student, , Department of Farm Power and Machinery, Bangladesh Agricultural University (BAU), Mymensingh 2202, Bangladesh

Islam *et al.* (2003) conducted an experiment on the processing of rough rice of variety BRRI dhan 37 and 38 and observed that after two days of sun drying, the moisture content was reduced to 9%. Drying temperatures between 35°C and 45°C showed less fissuring effect depending on varieties. They also found the highest crushing strength of 8.00 kgf for BRRI dhan 37 and 6.76 kgf for BRRI dhan 38, when the samples were sun dried for 3 days. The milling yield for both varieties was 60%. Sarker and Farouk (1989) reported that among all operations performed in harvesting and post-harvest processing of rice, major losses occur during milling (6%). They observed that inadequate parboiling treatment, development of fissure in the grains, nature of milling equipment used, degree of bran removed, physical dimensions of grain and content of immature kernel were some important factors responsible for losses during milling. In some places, farmers laid the cut crop in the field for drying and alternate drying and wetting due to sun and rain induce cracks in the matured grain. Cracks are developed in the kernel because they are subjected to hydrothermal stress. In the day time, the paddy temperature increases substantially, however, at night become moistened due to dew, which produces hydro-thermal stress in the grain (Mahadevappa *et al.,* 1969; Mathews and Sapadaro, 1976). Cracks in the kernel are the most important factor contributing to rice breakage during milling. In Bangladesh, particularly in the North-West region where mostly the long grain coarse paddy is produced, the farmers laid the cut crop in the field for drying, which in turn created favorable environment to produce fissures in the grains due to hydro-thermal stress.

From the above discussion, it is evident that a thorough study is needed to assess the existing method of coarse rice processing in commercial rice mills. The specific objectives of the present study were (a) to study the processing system of coarse rice in commercial rice mills, (b) to study the milling yield, head rice recovery and by products of both parboiled and non-parboiled rice and (c) to analyze the costs and benefits of producing parboiled and non-parboiled rice.

2. Methodology

Field study was conducted in November 2003. The selected site was Namosankarbati, Chapai Nawabganj, which is a leading rice growing area and has a large number of rice mills. The Minar Auto Rice Mill of Namosankarabati was selected for the study as because the mill owner agreed to provide facility in their mill premise. The rice mill has a large drying yard for sun drying and Lousiana State University (LSU) drier for mechanical drying. Parija variety was selected for processing as parboiled and non-parboiled rice.

Parboiled paddy was dried in the sun and milled in the engelburg steel huller, whereas non-parboiled paddy was dried in the LSU drier and milled in the rubber roll huller. Paddy was sun dried for a total of 16.5 hrs in three consecutive days followed by tempering of 18 hrs a day. Paddy was dried for 6.5 hrs, 7.0 hrs and 3.0 hrs in the first, second and third day, respectively. In LSU drier, only six hours was required to complete drying.

Physical dimensions of the paddy and corresponding rice kernel was measured by a vernier calipers. Paddy samples were collected at random and measured the dimensions to obtain the average length and breadth of the kernels. Paddy and rice shape was determined by length breadth ratio. Length-breadth ratio is an index of the grain quality whether the grain is coarser, medium or fine.

A Kett moisture meter (Kett Electric Co. Ltd., Japan) was used to measure the moisture content of the grain samples. Temperatures of heated-air, drying floor, grain and atmosphere were measured by a digital thermometer. Hygrometer was used to measure the relative humidity of ambient air. The breaking strength of the rice kernels was measured by a hardness testing machine (Kiya Seisakusho Ltd., Japan) following the standard procedure. Data on temperature, relative humidity, moisture content and hardness of the grain were taken at 30-min interval during drying. Drying rate was calculated by using the following equation:

$$\frac{dm}{dt} = -\frac{m_2-m_1}{\Delta t} \quad \text{where, } \frac{dm}{dt} = \text{drying rate, hr}^{-1}$$

m_2-m_1 = difference of moisture contents of grain at time interval Δt, percent (wb)
Δt = time in hour

2.1 Parboiling of Paddy

Paddy was soaked at normal temperature in brick built tanks. Soaking was done for 36 hours to obtain moisture content of 29.8 % (wb). After soaking, paddy was loaded into two 200 kg capacity steaming vessels. Rice husks were used as fuel in husk-fired furnace to produce steam in a boiler. Steam was passed through the perforated pipe placed at the middle of the steaming vessels.

Paddy was steamed once before soaking and once after soaking. The temperature of the steam was 102°C. Before soaking, first steaming was done for 3 to 4 minutes. After full soaking, paddy was again poured into steaming vessel. Steaming process for each batch was stopped when steam was found coming out from the top and bottom of the vessel. Time required for steaming soaked paddy was 5 to 6 minutes. The parboiled paddy was then unloaded from the steaming vessel.

2.2 Sun Drying of Parboiled Paddy

The paddy was dried by spreading on cemented floor and exposed to the sun. The thickness of the layer was about 15 to 20 mm. The female and male workers moved the paddy by a rake locally called as '*naingla*' for about 10 to 15 minutes. The paddy was turned every half an hour. After 2 hours of drying, paddy was gathered in rows by '*shapta*'. This process allowed the moisture absorbed by the drying floor to be evaporated. The paddy was frequently stirred to make uniform drying. Frequent stirring and turning of the grain reduced the overheating and over drying, and improved the uniformity of drying.

2.3 Drying of Non-parboiled Paddy in LSU Drier

Non-parboiled paddy was dried in LSU drier. Heat was produced in the furnace by firing husk. Hot air was collected by a blower and forced into the drying chamber. The grains were exposed to forced ventilation of air that was heated to certain degree. As the air was heated its relative humidity was reduced and thus its moisture absorbing capacity was increased. The paddy falling vertically downward was subjected to a continuous flow of heat. The operator maintained the air temperature by controlling the supply of fuel.

2.4 Cost of Processing Parboiled and Non-parboiled Paddy

The input and output costs for parboiled and non-parboiled rice were estimated and the benefit-cost ratios were determined based on the market price of rice and the by-products. The total cost of inputs included the price of paddy, carrying cost, milling and processing charges. On the other hand, cost of outputs were the prices of rice, brokens and by-products.

3. Results and Discussion

3.1 Physical Dimensions of Paddy before Processing

The average length and breadth of paddy was 8.34 mm and 2.40 mm, respectively with average length-breadth ratio of 3.7. The average length and breadth of corresponding rice kernels was 5.07 mm and 2.33 mm, respectively with average length-breadth ratio of 2.38 (Table 1). The FAO recommended that the length more than 7 mm is extra-long, 6.0 to 7.0 mm is long, 5.5 to 5.9 mm is medium and less than 5.5 mm is short. The FAO also classified rice by the length-breadth ratio of more than 3.0 as slender, of 2.4 to 3.0 as medium, of 2.0 to 2.39 as bold (coarse) and of less than 2.0 as round. According to this grading, Parija variety can be graded as *short bold rice*.

Table 1. Physical parameters of paddy before processing

Variety	Length (L), mm	Average length (L), mm	Breadth (B), mm	Average breadth (B), mm	L/B ratio
Paddy	8.50		2.40		
	8.55		2.50		
	8.00	8.34	2.40	2.40	3.70
	8.30		2.30		
Rice	5.0		2.3		
	5.2		2.4		
	5.0	5.07	2.3	2.33	2.38
	5.1		2.3		

3.2 Sun Drying of Parboiled Paddy

The variation of temperature and relative humidity during sun drying is shown in Fig 1. The ambient and grain temperatures were increased slowly but drying yard temperature increased rapidly. In mid-day between 12.00 to 13.00 hours, the drying floor attained a maximum temperature of about 46°C and grain attained a maximum temperature of 37°C. Relative humidity (RH) was found higher at the beginning of drying and decreased at faster rate as the temperature rises rapidly. In the morning, RH value was 88.9-91% at 8:50 AM and 58-60% at 3:00 PM. The RH value just above the grain layer was found higher than that at distant places due to moisture release from the grain. RH value just above the grains was found higher in the first day and decreased with the successive days of drying.

The grain moisture content and drying rate as varied with time during drying is shown in Fig. 2. Initial moisture content of the parboiled paddy was 29.8% (wb). Moisture content of paddy decreased with time as the drying progresses. In the first day of drying, grain moisture content was decreasing faster and average drying rate was 1.71% per hr. At the end of the first day, the grain moisture content was 16.9% (wb). In second and third day of drying, grain moisture contents decreased at relatively slower rate. The average drying rate in the second and third day was 1.35% and 1.32% per hr, respectively. Drying was continued for three subsequent days to obtain moisture content of about 9.3%. Usually the miller stopped drying when moisture content was reached to 9.0% (wb). Islam *et al* (2003) observed that after two days drying the moisture contents of rice cultivers BRRI dhan 37 and 38 were reduced to 9.0%. Mill owner applied the chewing technique to check the moisture content of dried paddy and this guess technique was sufficiently accurate in determining the suitability of the grains for milling. At the end of each day, paddy was gathered in rows for further drying in the next day. The paddy was covered with the jute bags or polythene to protect from the rain. During each tempering period of 18 hrs after first and second days of drying, paddy absorbed moisture from the atmosphere. After completion of drying, the paddy was packed in the jute bags and stacked in the storeroom for several days for subsequent milling operation.

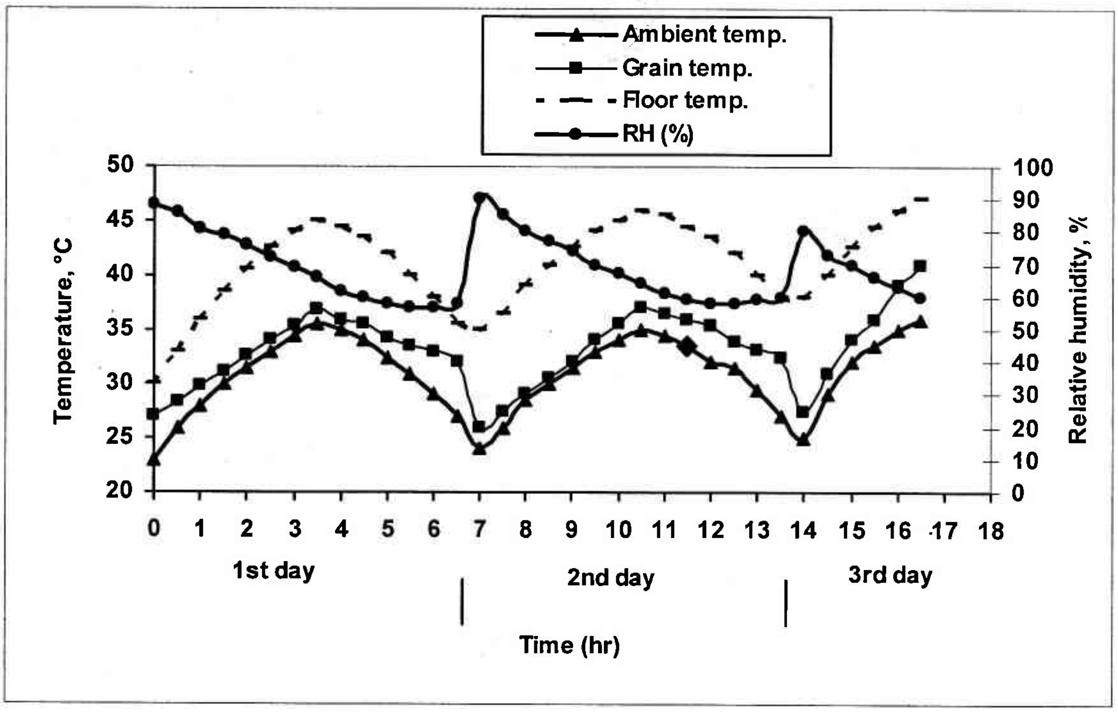

Fig. 1. Variation of temperature and relative humidity during sun drying of parboiled paddy

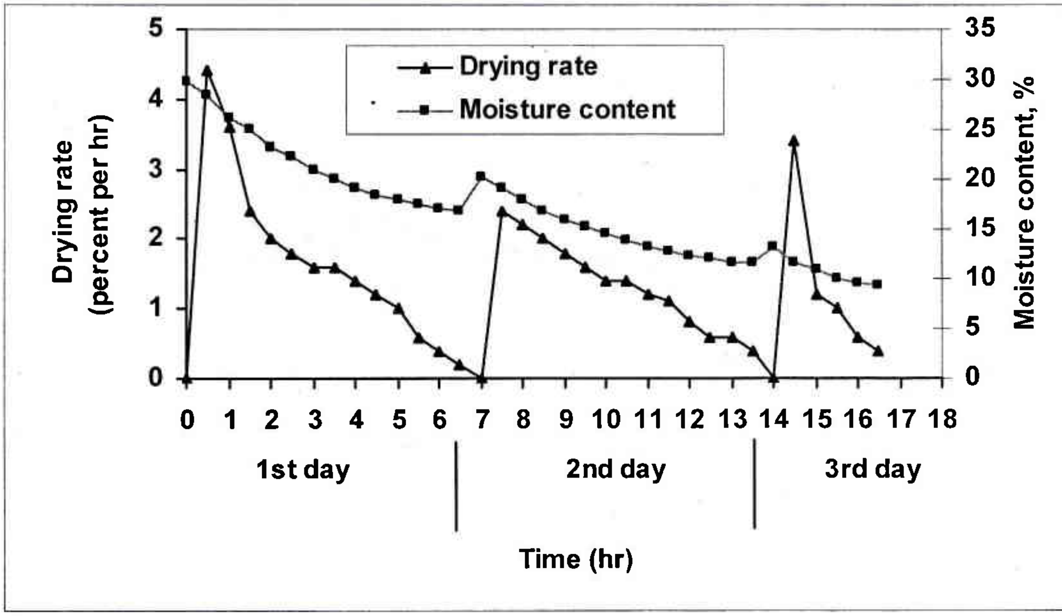

Fig. 2. Variation of moisture content and drying rate with time during drying of parboiled paddy

3.3 Crushing Strength or Hardness of Parboiled Paddy

The crushing strength and moisture content with respect to drying duration is shown in Fig. 3. Parboiled paddy with moisture contents from 29.8% to 18.5% (wb) did not show any reading in the dial of the hardness testing machine. It means that the parboiled paddy with moisture content greater than 18.5% had crushing strength less than 1.0 kgf. After 5 hrs of drying, moisture content reduced to 17.8% (wb) and the crushing strength of paddy was1.2 kgf. At the end of first day of drying the moisture content was 16.9 % (wb) and the crushing strength was measured to be 2.0 kgf. The result revealed that crushing strength increased with the reduction in moisture content. The crushing strength increased in an increasing rate starting from the first day to third day of drying. The final value of crushing strength after completion of drying in third day was 6.2 kgf at an average moisture content of 9.3% (wb). Islam *et al.* (2003) found that the crushing strength of BRRI dhan 37 and 38 increased to 8.00 and 6.76 kgf, respectively when dried for 3 days.

3.4 Drying of Non-parboiled Paddy in LSU Drier

At the inlet of the drying chamber, hot air temperature of 90°C was maintained for the first two hours, then 80°C for the next two hours, 70°C for the next one hour and 60°C for the next two hours. Fig 4 showed that the temperature of air grain mixture was increased slowly from 30°C to a constant level of 46.7°C. After 6 hrs, the air temperature was reduced to below 60°C for tempering. In LSU drier, only 6 hours was needed to complete drying of 10 metric tones of paddy. Moisture content of paddy decreased slowly and drying was completed after 6 hrs, when the moisture content was reduced from15.2% to 9.0% (wb) as shown in Fig. 5. Drying rate was increased rapidly for the first two hours of drying and then started decreasing more or less linearly with time. The average drying rate in LSU drier was 1.0% per hr (Fig. 5).

3.5 Crushing Strength of Non-parboiled Paddy

Initial crushing strength of grain was 1 kgf at moisture content of 15.2% (wb). Crushing strength increased with the decrease in moisture content. Crushing strength increased slowly for the first one hour of drying and then increased quickly and linearly with drying time (Fig. 6). The final value of crushing strength after completion of drying was 4.8 kgf at an average moisture content of 9.2% (wb). The comparative results show that the crushing strength is increased substantially due to parboiling.

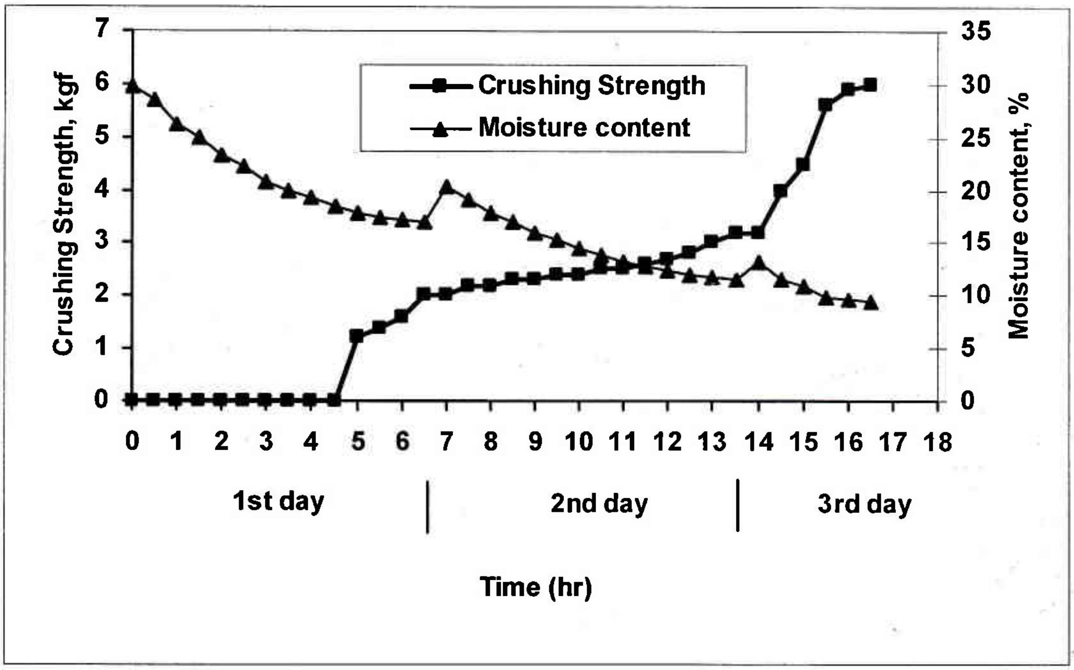

Fig. 3. Effect of drying on crushing strength of parboiled paddy

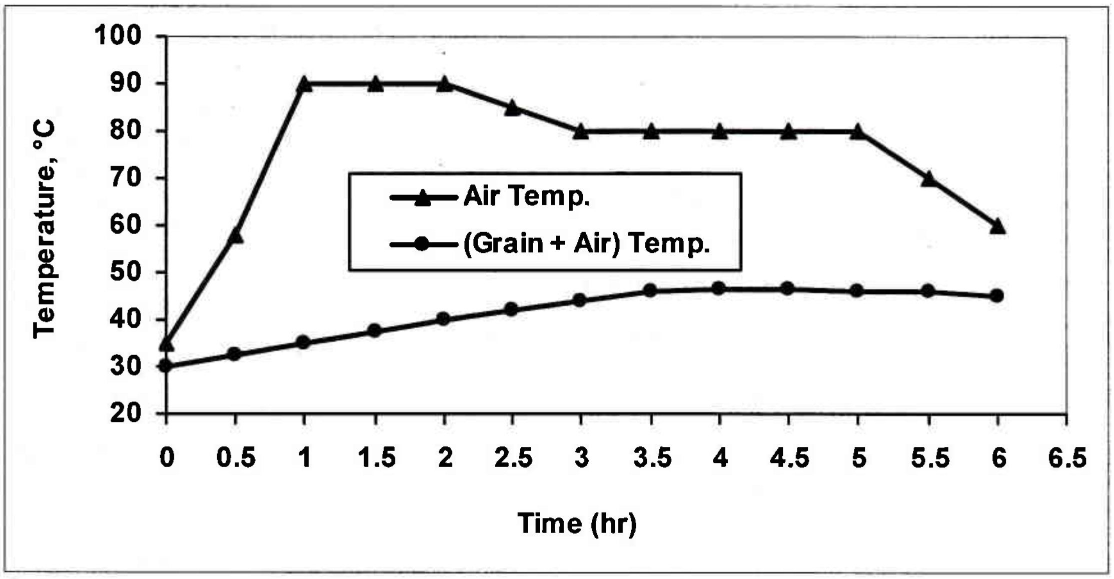

Fig. 4. Variation of temperature with time during drying of non-parboiled paddy in LSU drier

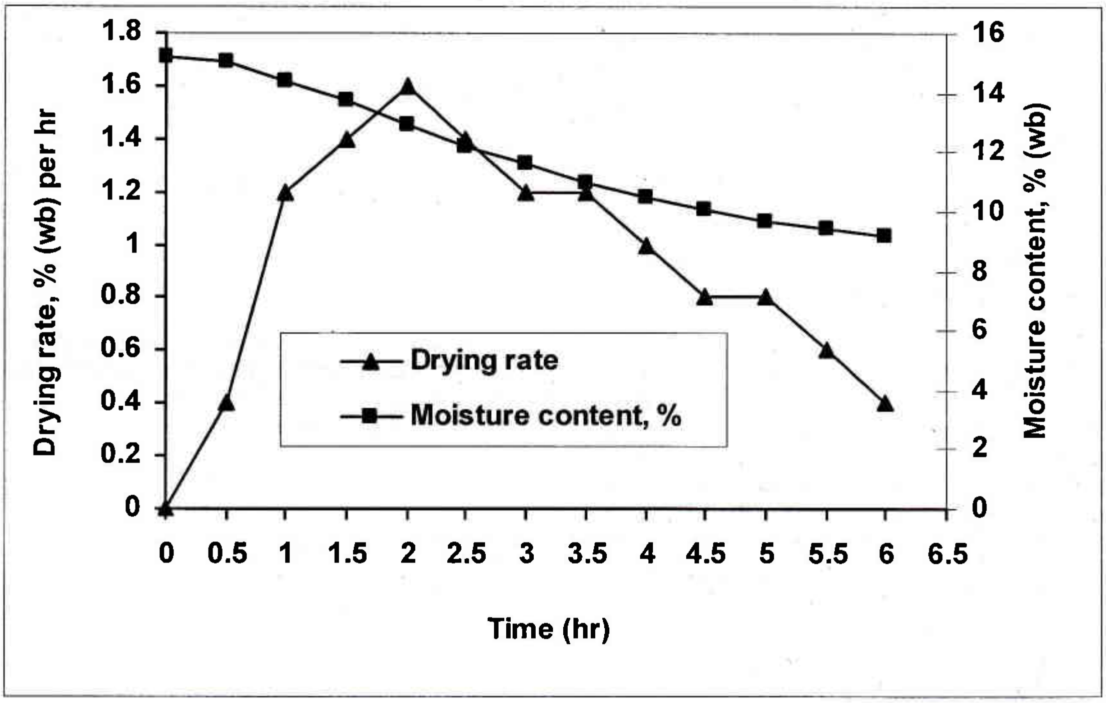

Fig. 5. Variation of moisture content and drying rate during drying of non-parboiled paddy in LSU drier

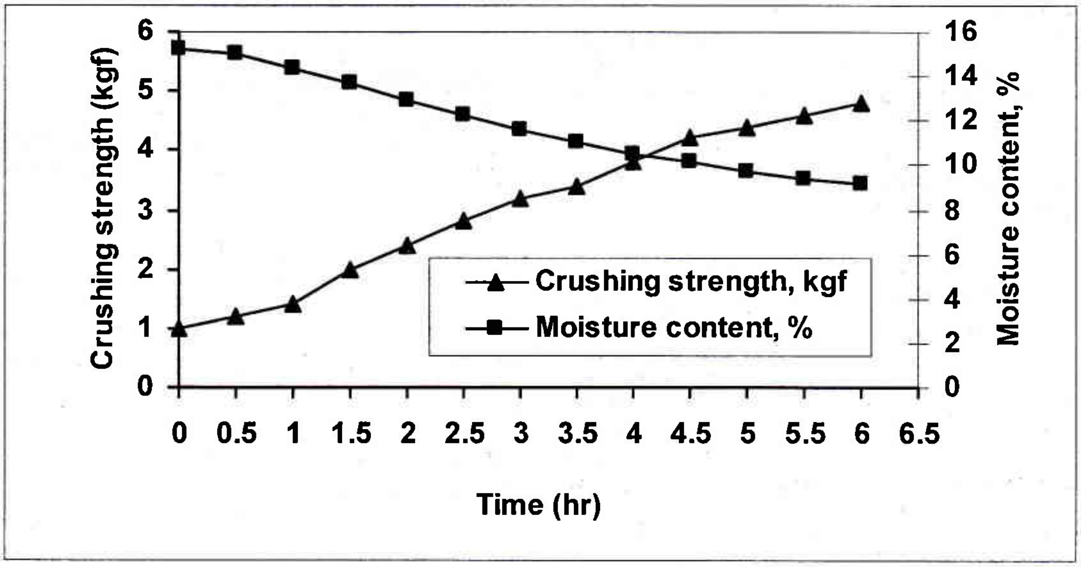

Fig. 6. Effect of drying on crushing strength of non-parboiled paddy

3.6 Milling Yield and Head Rice Yield

Parboiled paddy was milled in engelburg huller, whereas non-parboiled paddy was milled in rubber roll huller. Before milling, the moisture content of paddy increased from 9.3% to 12% due to absorption of moisture from environment. The milling yield and head rice yield of parboiled paddy were 64.25% and 62.25%, whereas those of non-parboiled rice were 65.50 % and 64.25%, respectively (Table 2). Head rice recovery was higher in non-parboiled rice due to milling in rubber roll huller.

3.7 Change of Grain Temperature in Milling

After milling, the temperature of parboiled and non-parboiled rice was 65°C and 85°C, respectively. The temperature was raised due to friction between grains and huller shaft. Temperature of non-parboiled rice was higher than parboiled rice, because non-parboiled rice was polished in a polisher. Before bagging, milled rice was spread on the floor for cooling to ambient temperature.

3.8 Physical Dimensions of Parboiled and Non-parboiled Milled Rice

The average length and breadth of parboiled milled rice was 4.85 mm and 2.24 mm, respectively, whereas the average length and breadth of non-parboiled milled rice was 4.6 mm and 2.05 mm, respectively (Table 3). The parboiled rice was bigger in dimensions than the non-parboiled rice, because parboiled rice was not polished after milling. Rice kernels of non-parboiled rice became small and slender due to polishing.

3.9 Cost of Processing Parboiled and Non-parboiled Paddy.

The input and output costs for parboiled and non-parboiled rice were estimated and the benefit-cost ratios were determined based on the market price of rice and the by-products. The results are shown in Table 4 and 5. Colour, size and shape of grain, variety, moisture content and percentage of broken rice affected the price of head rice. Gross returns and benefit-cost ratio (BCR) were then calculated. In this analysis, head rice recovery in non-parboiled rice was higher than that of parboiled rice. The head recovery of non-parboiled and parboiled rice was 642.5 and 622.5 kg rice/tonne of paddy, respectively. BCR values for non-parboiled and parboiled rice was 1.30 and 1.22, respectively. It reveals that processing of non-parboiled rice is more profitable compared to parboiled rice. Beside this, non-parboiled rice looks attractive and has higher market price due to its whitish colour compared to parboiled rice. On the other hand, the by-products of non-parboiled paddy have the higher market price due to its good quality. For example, the demand of bran of non-parboiled rice is very high because of its high quality for poultry feed and hatchery products and rice husks of non-parboiled paddy is very much suitable for briquetting.

4. Conclusions

The parboiled paddy required 3 days of sun drying to reduce its moisture content from 29.8% to 9.3% (wb). Sun drying was followed by 18 hours tempering every day. Drying of non-parboiled paddy in LSU drier required 6 hours drying time, when the moisture content was reduced from 15.2% to 9.0% (wb). In sun drying the average drying rate gradually decreased from 1.71 to 1.32 percent per hr and in LSU drier 1.0% per hr.

The crushing strength of parboiled rice was 6.2 kgf at 9.3% (wb) moisture content after 3 days of sun drying, whereas the crushing strength of non-parboiled rice was 4.8 kgf at 9.0% (wb) moisture content.

The milling yield and head rice yield of parboiled rice were 64.25 percent and 62.25 percent, respectively and the corresponding values of non-parboiled rice were 65.50 percent and 64.25 percent, respectively. Head rice yield was higher in non-parboiled rice due to milling in rubber roll huller.

Table 2. Milling yield and head rice yield of parboiled and non-parboiled paddy

Paddy	Milling yield (%)	Head rice (%)	Broken (%)	Bran (%)	Husk (%)	Loss (%)
Parboiled	64.25	62.25	2.00	4.75	26.00	5.00
Non-parboiled	65.50	64.25	1.25	6.00	25.00	3.50

Table 3. Physical parameters of parboiled and non-parboiled rice

Rice type	Length, mm	Average length, mm	Breadth, mm	Average breadth, mm
Parboiled	4.80 4.90 4.85	4.85	2.25 2.20 2.25	2.24
Non-parboiled	4.70 4.60 4.50	4.60	2.10 2.05 2.00	2.05

Table 4. Processing cost per ton of paddy.

Paddy	Purchasing cost of paddy (Tk/tonne)	Carrying cost (Tk/tonne)	Milling charge (Tk/tonne)	Total processing cost (Tk/tonne)	BCR
Parboiled	6875	200.00	975	8050	1.22
Non-parboiled	6875	200.00	1240	8315	1.30

Table 5. Benefit cost ratio (BCR) for parboiled and non-parboiled rice

Paddy	Product & by-product	Weight (kg/tonne of paddy)	Unit price (Tk/kg)	Selling price (Tk/ton)	Total selling price (Tk/tonne)
Parboiled	Head rice	622.5	14.6	9088.5	9793.5
	Broken	20	8	160	
	Bran	47.5	6	285	
	Husk	260	1	260	
Non-parboile	Head rice	642.5	15.5	9958.75	10788.75
	Broken	12.5	8	100	
	Bran	60	8	480	
	Husk	250	1	250	

The problem of sun drying in the rainy season can be resolved by using LSU drier and large amount of paddy can be dried in a very short time. The non-parboiled paddy was finer than the parboiled paddy even if they were produced from the same variety of paddy. The production of non-parboiled rice was more profitable than production of parboiled rice. The market values of non-parboiled rice and by products were more than those of parboiled rice.

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