Development of Existing Engelberg Rice Mill for Improving Milling Yield and Quality

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Abstract

The majority of paddy is still processed through Engelberg hullers in Bangladesh, which are usually low capacity mills with a very high percentage of broken rice for simultaneous both the shelling and polishing operations. This study was conducted to improve the shelling and polishing in such a way that less rice is broken and quality rice can be produced in an economical manner. In this regard, an air blowing type Engelberg rice mill has been developed in the BRRI research workshop based on AutoCAD design during 2012-2013. A cast iron roller is used in the Engelberg rice mill. The sharp and square edge Engelberg roller of the conventional Engelberg rice mill was modified to a curved edge in one side with a less sharp edge to reduce the breakage during milling by reducing the friction and sharing force during milling operation. In the Engelberg rice mill, a round type screen (without ambush) is normally used which requires higher pressure resulting more breakage. To avoid breakage and get a higher yield, ambush type, round and hexagonal screens were designed for the modified air blowing type Engelberg rice mill. It was found that the hexagonal type screen performs better than the round type. The angle of each corner of the hexagonal screen is 60^0. In air blowing type of Engelberg rice mill, a blower is used to remove the husk and bran from rice inside the cylinder. The radius of the blower fan is 121 mm. The inlet and outlet radius of the blower is 77 mm. The blower not only cleans the rice from the husk and bran, but also reduces the temperature inside the cylinder, resulting in less breakage and higher head rice recovery as well as high milling yield. The husk and bran collection hopper used in the lower part of the Engelberg rice mill. In the outlet pipe, there is an air hole used to supply air so that the blower can get sufficient air for the suction of husk and bran. The modified rice mill were evaluated and compared with the conventional rice mill. BRRI dhan29 was used as parboiled paddy. The operational cost per hour of the two machines is almost the same, but the capacity of the modified air blowing type Engelberg rice mill is two and half times more than that of the traditional one. To process one ton of paddy by air blowing type mill, about 800 taka is needed, whereas 2,100 taka is needed for processing one ton of paddy with the traditional Engelberg rice mill. However, milling yield also increased by 2%. The modified air blowing type needs only one pass while the Engelberg rice mill needs at least two passes to get the white rice, and almost 1% paddy remains with the end product. With the modified air blowing type Engelberg, rice mill head rice recovery was increased by 1% compared to the traditional Engelberg rice mill. The modified rice mill is a promising technology for small scale farmers and rice traders in Bangladesh.

Keywords: Engelberg rice mills, air blower, milling and milling parameters

Introduction

Rice is the most important crop and staple food in Bangladesh, and accounts of 80% of the cropped area. The country produced about 50 million metric tons of paddy in 2011-2012. The per capita rice consumption is 165 kg/yr. Rice production has doubled since the nation's independence, without any increase in the rice area. The experience of technological change led by varietal improvement in Bangladesh has significantly contributed to the growth of rice production during the last two decades. The total share of rice in food grains is about 95%, of which modern

rice varieties constitute 87%. For this reason, rice milling technology plays an important role in ensuring food security, as well as in increasing the total milling yield. In Bangladesh, different milling systems such as automated, semi-automated, Engelberg mill, and mobile huller are using for processing paddy. Only 25-30% of paddy is processed by automated and semi-automated rice mills, while 60% is processed by Engelberg rice mills and 10% is processed by mobile hullers at the village level (BRRI, 2012). A proper milling system is thus essential for handling this huge amount of paddy. There is no statistical data on number of rice mills in Bangladesh. However, DG Food of GoB has listed some rice mills from where GoB procures rice. A total of 25,595 rice mills were licensed to DG Food in 2005. There are a large number of rice mills in Bangladesh that are not in the list made by DG Food.

More than 4600 rice mills were found in Dinajpur region alone in a study conducted by BRRI (2010). Since there is no statistical survey, therefore, at this stage it is very difficult to estimate the total number of rice mills in Bangladesh. But based on a sample survey of 50 mills on their rice milling capacity, it was estimated that the average milling capacity of rice mills was 9 tons/batch (ranging from 2.35 tons to 22.5 tons per batch). Average processing period of a batch is 3 days, and 100 batches could be processed by a rice mill annually. Of the total paddy produced nationally, 30% is processed by households and does not enter the market. Another 70% of the total paddy is processed in different type of medium-to-large rice mills, as reported by Dasgupta (2001).

The mechanized sector of the rice milling industry handles more than 50 million tonnes of paddy annually. About 15-20 million tonnes of paddy processed by large-scale modern mills is involved in producing good quality rice for local and city markets. The majority of paddy is still processed through Engelberg hullers, which are usually low capacity mills and result in a very high percentage of broken rice. About 20-25 million tones of paddy is processed through Engelberg rice mills. In these hullers, both shelling and polishing operations are carried out simultaneously. As a result, impure bran is mixed with husk, and a higher breakage amount results, causing a loss of revenue. On the other hand, 2 passes are required to get a finished product (white rice), even after 2-3% paddy remains in the final product. Also, with the Engelberg milling system there is no mechanism for separating rice and husk, and this is why further separation of husk and rice is needed. In addition, the capacity of the traditional Engelberg is very low, as husk and bran come out along with the inadequately polished white rice. Nevertheless, this rough process results in a certain amount of breakage. To overcome these problems, it is necessary to carry out the shelling and polishing in such a way that less rice is broken, and quality rice can be produced in an economical manner. In this regard, an air blowing type Engelberg rice mill has been developed by FMPHT Division, BRRI, Gazipur, Bangladesh under the KOICA-BRRI project.

Objectives

To develop an appropriate rice milling technology suitable for rural Bangladesh that will enhance the total milling yield as well as the income of the rural farmers to achieve the goal the following steps were followed:

- To incorporate air blow mechanism in the existing Engelberg rice mill in Bangladesh
- To evaluate the performance and compare with the conventional Engelberg rice mill

Methodology

The Engelberg rice polisher installed in the laboratory was observed and its milling performance assessed. Using AutoCAD, the design of an air blowing type of rice polisher was created. Then, the modification of the Engelberg to the modified air blowing type rice mill was done in the research workshop of the Farm Machinery and Postharvest Technology Division. After modification, milling performance of the modified air blowing type rice mill was checked and compared to that of the traditional Engelberg huller. Economic analysis of the modified air blowing type rice mill was performed. Finally, an economic analysis of a small-scale rice milling system was performed, which is more appropriate for Bangladesh. The complete milling process is given in the Figure 1.

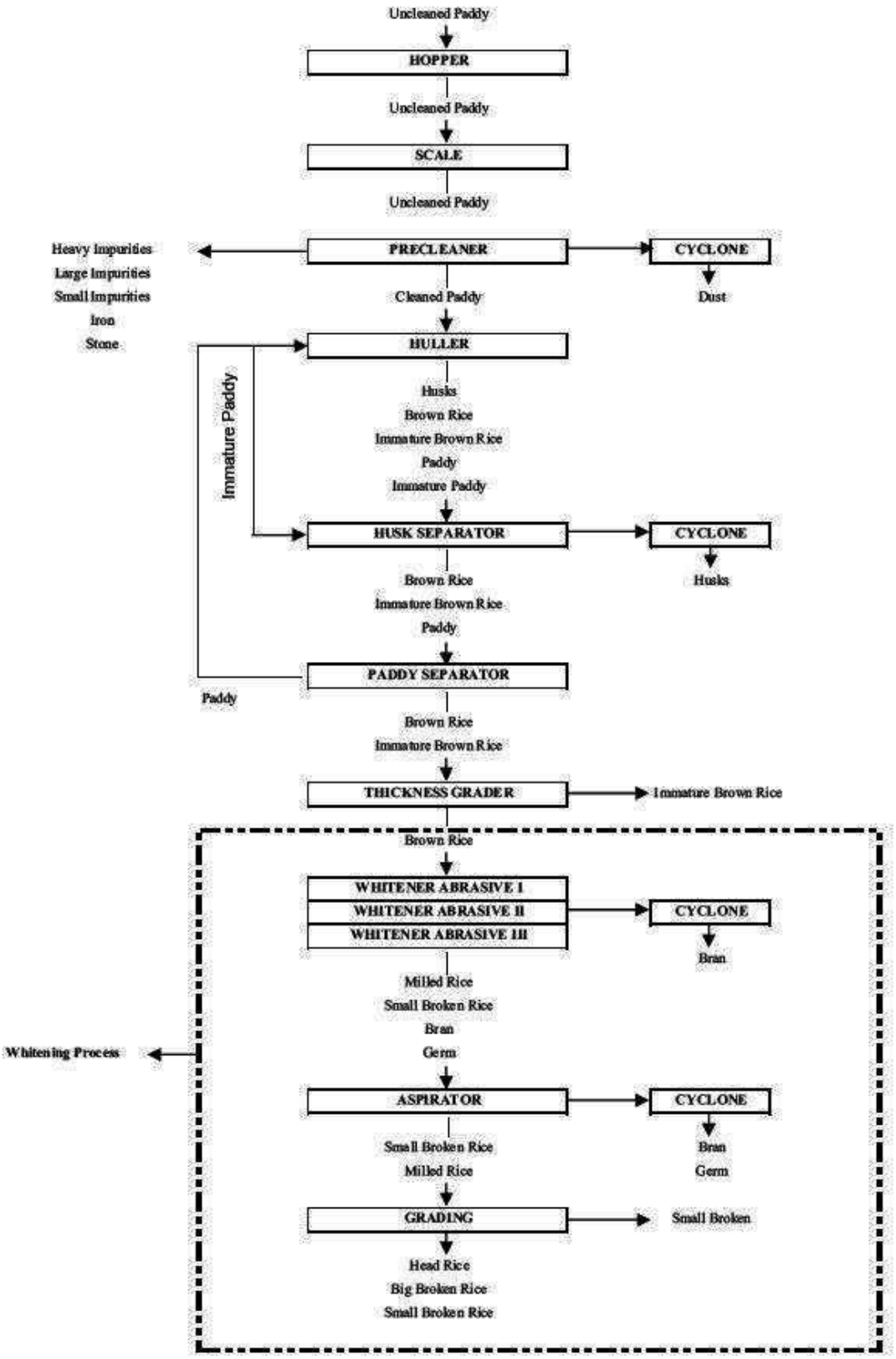


Figure 1. Flow chart of the complete rice milling process

Procedures for measuring quality of milled rice

Milling degree

Milling degree is calculated based on the amount of bran removed from the brown rice. To obtain the weight of brown rice, dehull the paddy samples using the Laboratory Huller. Estimate the milling degree using the following equation:

$$\%\,\text{Milling degree} = \frac{\text{Wt of milled rice}}{\text{Wt of brown rice}} \times 100$$

Milling recovery

Using the Abrasive Whitener, mill the dehulled samples. Calculate milling recovery by dividing the weight of milled rice recovered by the weight of the paddy sample, as follows:

$$\%\,\text{Milling recovery} = \frac{\text{Wt of milled rice}}{\text{Wt of sample used}} \times 100$$

Broken grain

Using the Grain Grader, separate the broken grain from the whole grains. Calculate the percentage of the head rice and broken grains using the following equations:

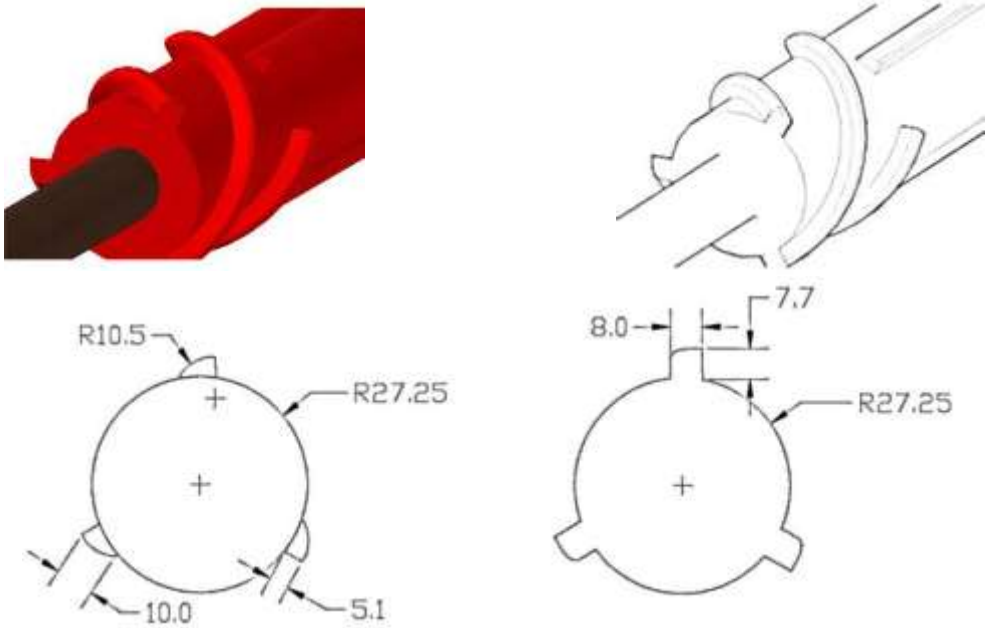
$$\%\,\text{Head rice} = \frac{\text{Wt of whole grains}}{\text{Wt of paddy samples}} \times 100$$

$$\%\,\text{Brokens} = \frac{\text{Wt of broken grains}}{\text{Wt of paddy samples}} \times 100$$

Components of the modified air blowing type Engelberg rice mill

A cast iron roller is used in the Engelberg rice mill. The total length of the roller (including shaft) is 720 mm. The radius of the shaft is 127 mm. The spiral part conveys the paddy forward for dehusking and polishing, and the length of the spiral and milling part length is 230 mm. In the conventional Engelberg roller, the edge is sharp and square in shape. As a result, there is more breakage during milling due to there being more friction and sharing force. To solve this problem, a curved edge in one side with a less sharp roller edge has been designed for an air blowing type Engelberg rice mill (Fig. 2 and 3).

In the Engelberg rice mill, a round type screen (without ambush) is normally used (Fig. 4 and 5). This screen does not meet the standard performance. A plain screen cannot polish the brown rice perfectly. As it requires higher pressure, more breakage results. To avoid breakage and get a higher yield, ambush type, round and hexagonal screens were designed for the modified air blowing type Engelberg rice mill (Fig. 6 and 7). Length and diameter of the screens are 308 mm and 43.5 mm respectively. It was found that the hexagonal type screen performs better than the round type. The angle of each corner of the hexagonal screen is 60^0.



Modified roller (Curved edge Conventional roller (Square edge))

Figure 2. Comparison of design between the two rollers

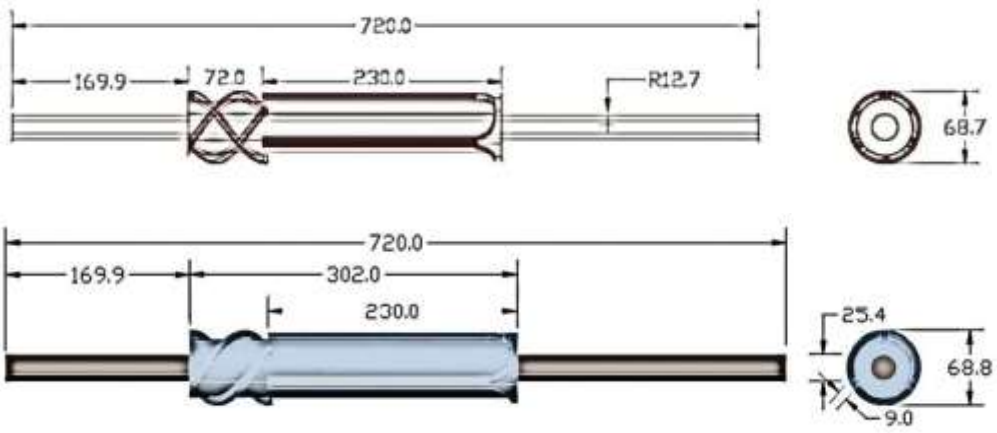


Figure. 3. Modified Cast iron roller with dimension

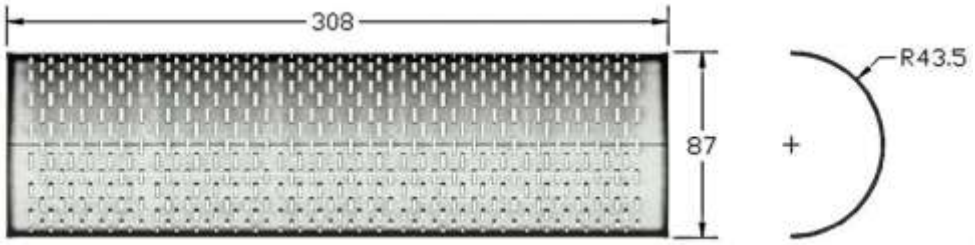


Figure. 4 . Conventional screen (Round type)

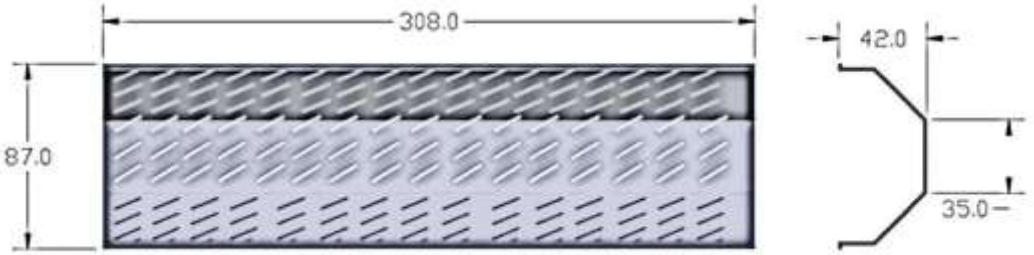


Figure. 5. Conventional screen (Hexagonal type)

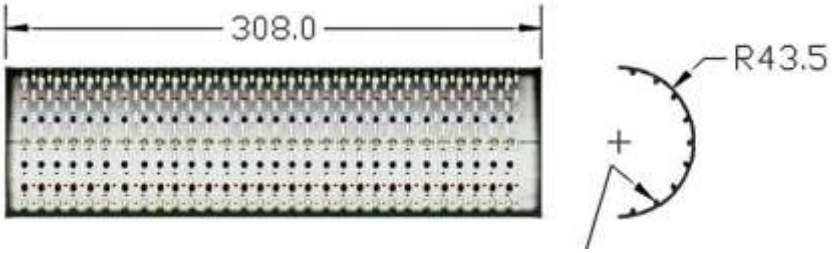


Figure. 6. Round type m**odified screen (Embossing)**

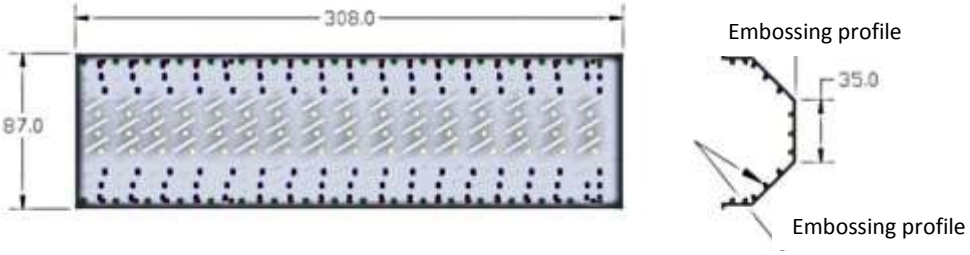


Figure. 7. Hexagonal type modified screen (Embossing)

In air blowing type of Engelberg rice mill, a blower is used to remove the husk and bran from rice inside the cylinder (Fig. 8). The radius of the blower fan is 121 mm (Fig. 9 and 10). The inlet and outlet radius of the blower is 77 mm. The blower not only cleans the rice from the husk and bran, but also reduces the temperature inside the cylinder, resulting in less breakage and higher head rice recovery. Using a blower increases the capacity of the machine, as it removes bran and husk from rice, which reduces the total volume of material inside the cylinder when feeding rate is increased.

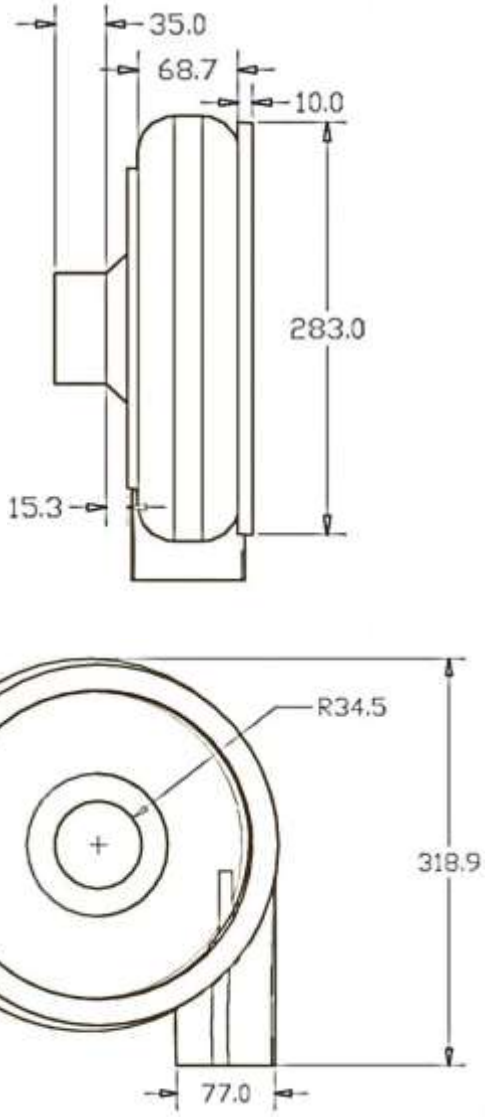


Figure 8. Blower

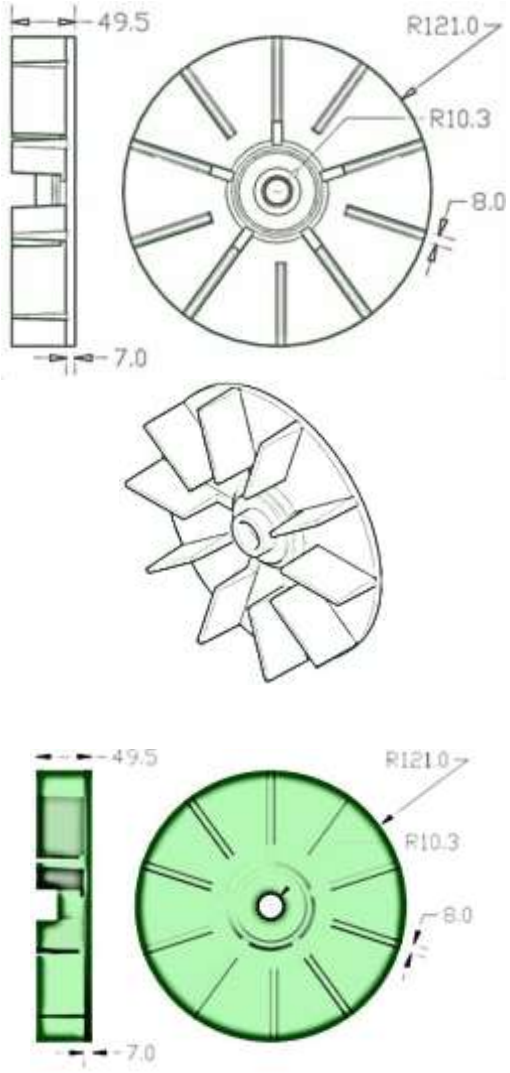


Figure 9. Blower fan

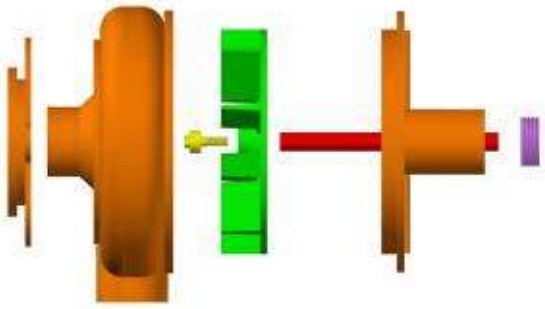


Figure 10. 3-D of blower fan

Different diameters of pulley are used in the modified air blowing type Engelberg rice mill. The diameter of the motor pulley is 130 mm (Fig. 11), and the diameter of the roller pulley connected to the motor is 166 mm (Fig. 12). On the other hand, the diameter of the roller pulley connected to the blower is 250 mm (Fig. 13) and the diameter of the blower pulley is 76 mm (Fig. 14). These different diameters of pulley in the modified air blowing type Engelberg rice mill enable better milling yield and the removal of the husk and bran from the end product.

This is the husk and bran collection hopper used in the lower part of the Engelberg rice mill. The size of the hopper is 383 × 310 mm. The outlet diameter of the hopper is 80 mm. In the outlet pipe, there is an air hole used to supply air so that the blower can get sufficient air for the suction of husk and bran.

Results

Detail specifications of the modified rice mill air blowing type Engelberg rice mill is given as follows (Table 1). Power required to operate the modified and conventional rice mill, motor speed in loading and unloading condition is almost same. Only air blower is used as additional component to the modified mill which RPM under load and no load condition was found 3788 and 3693 respectively (Table 2).

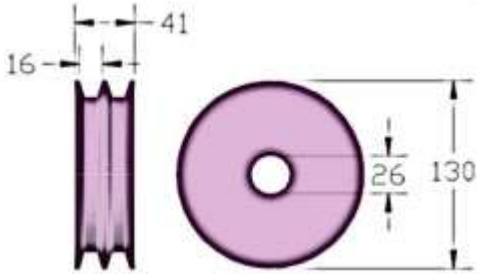


Figure 11. Pulley of motor

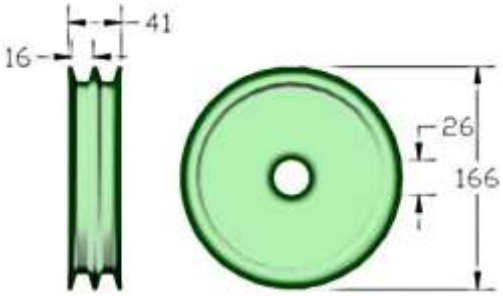


Figure 12. Pulley of roller for motor connection

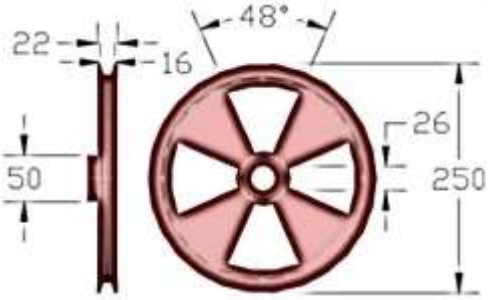


Figure 13. Pulley of roller for blower connection

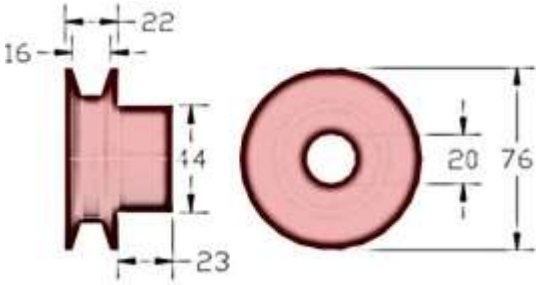


Figure 14. Pulley of blower

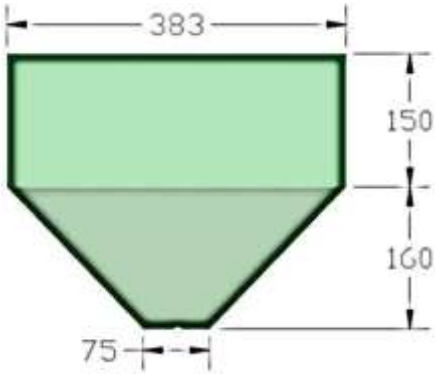


Figure 15. Husk and bran collection hopper

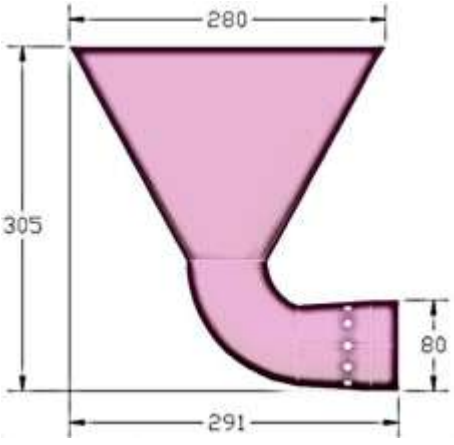


Figure 16. Lower part of the hopper

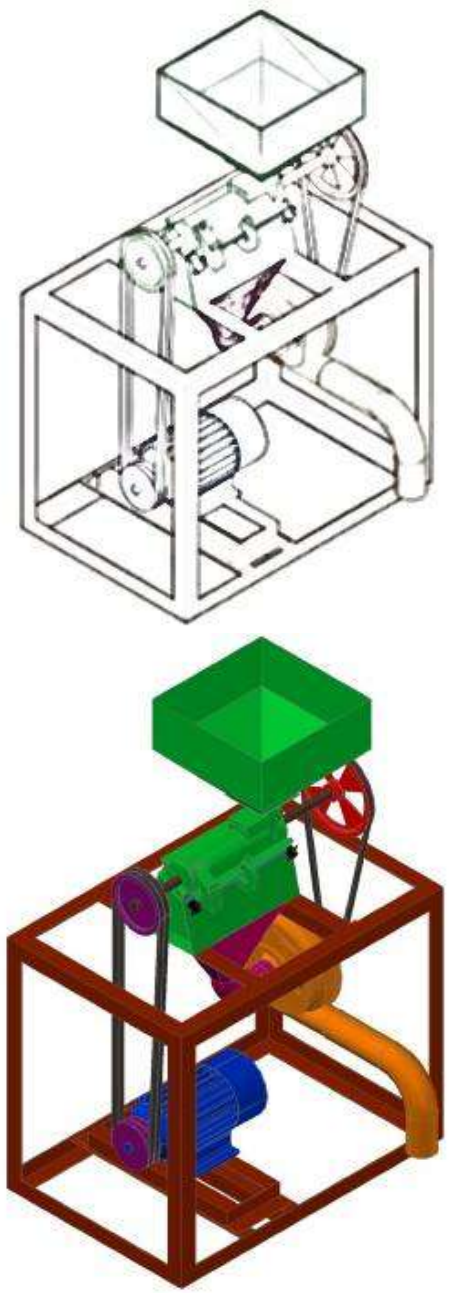


Figure 17. 3D view of air blowing type Engelberg rice mill

The capacity of the modified air blowing type is three times the capacity of the traditional Engelberg rice mill (Table 3). This is because in the Engelberg milling system, when paddy passes through the cylinder, it is dehusked by the sharing force but the husk cannot pass through the screen by gravity. Therefore, when rice with husk moves forward to the outlet, husk, small particles of bran and broken rice reduce the sharing and friction force, which reduces the capacity of the machine and the degree of milling. On the other hand, in the modified air blowing type rice mill, when the paddy is dehusked inside the cylinder all husks are removed from the cylinder at once by the suction blower. By removing husks from the cylinder, all sharing and friction force is applied to the paddy and brown rice at once, and no paddy remains in the final product, increasing the milling yield by 2% (Table 3). The modified air blowing type needs only one pass while the Engelberg rice mill needs at least two passes to get the white rice, and almost 1% paddy remains with the end product (Table 3). With the modified air blowing type Engelberg, rice mill head rice recovery was increased by 1% compared to the traditional Engelberg rice mill (Fig. 18).

It is clear that the modified air blowing type (one-pass) mills are more efficient and the quality of milled rice is better than with traditional Engelberg mills. However, as discussed, it is only if the rice price reflects the quality that both farmers and millers will benefit from the quality improvement. In order to see the effect of milled rice quality on the price, price determination functions are estimated, where the milled rice price is a function of physical as well as chemical characteristics of milled rice and rice variety.

Table 1. Specification of the modified air blowing type Engelberg rice mill

Sl. No	Items	Specification (cm)
1	Diameter of motor pulley	130
2	Diameter of iron roller pulley connected to the motor	166
3	Diameter of roller pulley connected to the blower	250
4	Diameter of blower pulley	76
5	Roller size	L= 720, D= 68.8
6	Screen size	L= 308, R= 43.5, W= 87
7	Blower size	R= 121
8	Husk removing duct size	77

Table 2. Power and RPM needed to operate the modified Engelberg rice mill

Mill type	Power, kw	Motor speed, RPM	Roller speed (unloading), RPM	Roller speed (loading), RPM	Blower speed (unloading), RPM	Blower speed (loading), RPM
Modified Air blowing type	3	1,440	1,174	1,145	3,788	3,693
Traditional Engelberg rice mill	3	1,440	1,180	1,140	-	-

Table 3. Milling yield and head rice recovery of air blowing type and Engelberg rice mill

Milling system	Variety	Capacity (kg/hr)	Milling yield (%)	Head rice (%)	Broken rice (%)	Paddy remain (%)	Power req. (kWh)	Time required, hr/t
Traditional engelberg mill	BRRI dhan29	40	64	62	2	>1	6.5 (two pass)	25
Air blowing type (one pass) mill	BRRI dhan29	100	66	63	2	0	2.5 (one pass)	10

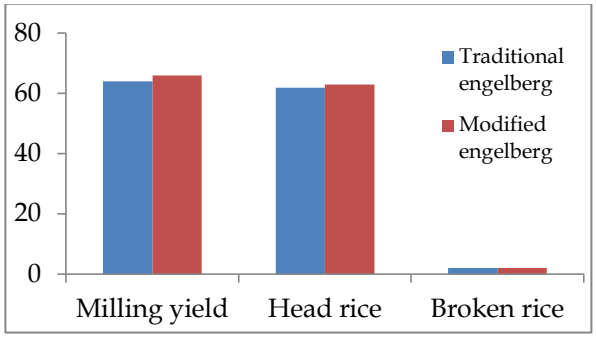


Figure 18. Milling yield and head rice recovery of air blowing type and Engelberg rice mill

Calculation of extra yield by air blowing type rice mill over traditional Engelberg rice mill

In Engelberg milling system

Annual paddy processed is about 30 million tons (60% of the total production of 50 million ton rice) which milling yield is 64% in Engelberg and 66% in air blowing type rice mill. Considering 50% paddy (15 million tons) of annual production is processed which produced 9.6 million tons of white rice in Engelberg and 9.9 million tons in air blowing type rice mill resulting 0.3 million tons of extra yield.

From figure 19, it can be observed that if 50% of the total traditional Engelberg hullers are modified to be air blowing type Engelberg rice mills, then 0.3 million tons in extra yield can be obtained, worth Tk 9000.00 million, equivalent to USD 112.5 million. And, if 100% of the traditional Engelberg hullers are modified to be air blowing type Engelberg rice mills, then 0.6 million tons in extra yield can be obtained, worth Tk 18,000 million, equivalent to USD 225 million

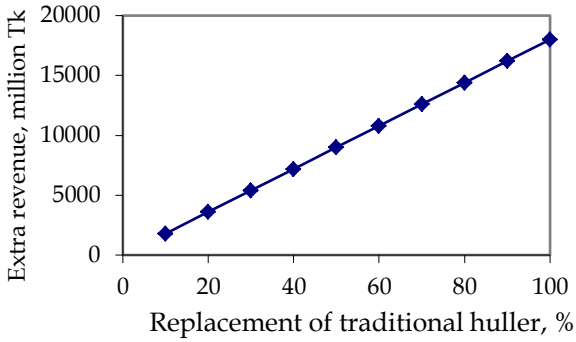


Fig. 19. Extra revenue by replacing traditional Engelberg with air blowing type rice mill

The table 6 shows that the operational cost per hour of the two machines is almost the same, but the capacity of the modified air blowing type Engelberg rice mill is two and half times more than that of the traditional one. To process one ton of paddy by air blowing type mill, about 800 taka is needed, whereas 2,100 taka is needed for processing one ton of paddy with the traditional Engelberg rice mill. Therefore, it is evident that Tk 1,300 (thirteen hundred) can be saved using the modified air blowing type Engelberg rice mill.

Table 4. Extra yield by air blowing type Engelberg rice mill over traditional Engelberg rice mill

Replacement of traditional huller, %	Milling yield (traditional), million ton	Milling yield (air blowing), million ton	Extra yield, million ton	Extra revenue, million Tk	Extra revenue, million $
10	1.92	1.98	0.06	1800	22.5
20	3.84	3.96	0.12	3600	45
30	5.76	5.94	0.18	5400	67.5
40	7.68	7.92	0.24	7200	90
50	9.6	9.9	0.3	9000	112.5
60	11.52	11.88	0.36	10800	135
70	13.44	13.86	0.42	12600	157.5
80	15.36	15.84	0.48	14400	180
90	17.28	17.82	0.54	16200	202.5
100	19.2	19.8	0.6	18000	225

Cost Analysis of air blowing type rice mill vs. traditional Engelberg rice mill: Operating cost

Table 5. Economic analysis of air blowing type Engelberg mill compared to traditional Engelberg rice mill

Name of items	Air blowing type Engelberg rice mill	Traditional Engelberg rice mill
Purchase price (p), Tk	30,000	25,000
Salvage value (S), Tk (10% of P)	3,000	2,500
Working life (L), yr	20	20
Rate of Interest (I)	0.12	0.12
Avg. annual use (Au), hr/yr	1,500	1,600
Annual depreciation, D=P-S/L	1,350	1,125
Interest on Investment, I=P+S/2*i	1,980	1,650
Tax, insurance and shelter cost, T=3% of purchase price	900	750
Total fixed cost (D+I+T), Tk/yr	4,230	3,525
Total fixed cost, Tk/hr	2.644	2.203
Labour cost per hour, L (Tk/hr)	60	60
Fuel cost per hour, F (Tk/hr)	24	24
RPM/yr =3.5 % of purchase price	1,050	875
RPM/hr =3.5 % of purchase price	0.66	0.55
Total Variable cost (Tk/hr)	84.66	84.55
Operating cost (fixed and variable cost) Tk/hr	87.30	86.75

Table 6. Benefit over traditional method, based on processing 1 ton of paddy

Name of Technology	Operating cost, Tk/hr	Capacity, kg/hr	Capacity, hr/ton	Operating Cost, Tk/ton	Save over traditional, Tk/ton
Air blowing type Engelberg rice mill	87.3	100	10	786	1,300
Traditional Engelberg rice mill	86.75	40	25	2,100	-

Detail processing cost calculation

Air blowing-type rice mill

- ❑ Cost of 1 ton paddy in air blowing type rice mill
- Purchase price of 1 ton paddy = Tk. 16,000 (Tk.650/40kg)
- Operational cost for processing of 1 ton paddy = Tk. 786
- Total cost (purchase price + operation cost) =Tk. 16,786
- ❑ Milling yield/hr
- Head Rice= 1 ton *0.675=675kg
- Broken rice=1 ton * 0.085=85kg
- Bran=1 ton *0.10=100kg
- Husk=1 ton *0.16=160kg
- ❑ Selling price
- Head rice of 670 kg rice=675*Tk.28=Tk. 18,900
- Broken rice of 85kg= 85*Tk.12=Tk. 1,020
- Bran of 100kg=100*Tk.12=Tk. 1,200
- Husk of 160kg=160 *Tk. 6=Tk.960
- Total selling price= Tk. 22,080
- ❑ Profit/1ton of paddy processing= 5,294 ~ 5,000
- ❑ Annual profit= 1,500 ton/yr *5,000= Tk.7,500,000

Traditional Engelberg rice mill

- ❑ Cost analysis of 1 ton paddy in traditional Engelberg rice mill
- Purchase price of 1 ton paddy=Tk. 16,000 (Tk.650/40kg)
- Operational cost for processing of 1 ton paddy= Tk. 2,100
- Total cost=Tk. 18,100
- ❑ Milling yield/hr
- Head Rice= 1 ton *0.65=650kg
- Broken rice=1 ton *0.086=86kg
- Bran=1 ton *0.12=120kg
- Husk=1 ton *0.16=160kg
- ❑ Selling price
- Head rice of 670 kg rice=650*Tk.28=Tk. 18,200
- Broken rice of 85kg= 86*Tk.12=Tk. 1,032
- Bran of 100kg=120*Tk.12=Tk. 1,440
- Husk of 160kg=160 *Tk. 60=Tk.960
- Total selling price= Tk. 21,632
- ❑ Profit/1000kg of paddy processing= 3,532 ~ 3,500
- ❑ Annual profit= 1,600t/yr *3500.00= Tk. 5,600,000

The modified Engelberg rice mill (one pass) capacity is increased by two and half times compared to the traditional Engelberg milling system. In addition, the modified Engelberg rice mill consumes two-thirds less electricity compared to the traditional one. Only one pass is needed to obtain a finished product with an adequate degree milling. No extra labour is required for cleaning or separating the husk from rice in the modified air blowing type Engelberg rice mill.

Rubber roll or polyurethane roll along with both abrasive and friction type polisher are most appropriate for getting higher milling yield as well as head rice recovery depending on the variety. With the automatic and semi-automatic rice mill it is possible to control the degree of polishing from 3 percent onwards. The head rice recovery of medium long grain (BRRI dhan29) under parboiled condition is 62% and under unparboiled condition is 53% (Table 3). On the other hand, the broken percentage is little higher for medium and long grain, 4% under parboiled condition and 10% under unparboiled condition. Moreover, extra yield can be obtained (1.2 mt to 1.8 mt) if the degree of milling can set as 5% to 10%. The profit margin of a small scale rice milling factory (1 t/hr) ranges from 25%-30%.

Conclusion

In conclusion, it was found that, 1 percent extra yield of head rice can be obtained by using an air blowing type Engelberg rice mill depending on the variety. One pass is enough to produce pure rice free from husk. With the modified air blowing type rice mill it is possible to control the degree of polish from 7 percent (7%) onwards. The capacity of the modified air blowing type Engelberg rice mill was increased by 250% compared to the traditional Engelberg rice mill, had a capacity as low as 100 kg of paddy/hour and can also serve as a custom milling unit. The machine efficiency is 99% and can save Tk 1300.00 per 1000 kg of paddy processing compared to traditional Engelberg milling.

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