

Experiences in Installation and Operation of Energy Efficient Rice Parboiling Systems

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Abstract

This study was conducted under Sustainable Energy for Development (SED) programme of German Technical Cooperation (GTZ). The main objective of this study was to improve the efficiency of rice husk biomass energy utilization in parboiling of paddy. Bangladesh produced about 41 million tons of paddy and the total husk production would be about 8 million tons in 2006. About 87% of the rice husk is used for parboiling of paddy and the rest is available for other alternative usage like densified biomass fuel. The existing parboiling systems are traditional in nature, designed and fabricated by local *mistries* (artisans) and very inefficient (only 20-30% in terms of energy utilization). Based on the results of field survey on traditional parboiling systems. Two different design aspects were fabricated and installed. Thickness of the steel sheet and other structures were chosen for safety and long life of the system. After installation, the systems were operated and adjusted for optimum performances. The improved systems have increased energy efficiencies of 42.75 % and 50.3% from an average efficiency of 20% of the traditional systems. Several trial runs and field tests were conducted for the new systems. The test results indicated that the rice husk consumption has been reduced to more than 50% with the new system compared to traditional one. Carbon monoxide level in flue gas has been reduced to 100- 500 ppm from present level of more than 10,000 ppm. However, the newly developed two types of rice parboiling systems are found very energy efficient, safe, environment friendly, less hazardous, socially acceptable and economically viable having a BC ratio ranges from 7.24 to 11.48.

Introduction

Biomass is by far the dominant energy source in Bangladesh, accounting to about 67% of the country's total energy consumption (RWEDP 2000). Among the Asian countries, India has the highest total use of biomass-mainly as wood. Whereas, Bangladesh has proportionally high use of non-wood biomass such as rice husk and crop residues. Rice husk is obtained as the by-product from the milling process of paddy. It is reported that in 2006 Bangladesh produced about 41 million tons of paddy which in turn produced about 8 million tons of rice husk (BRRI, 2006). It is also reported that about 90% of husk is produced in the rice mills situated in a scattered way all over the country. About 87% of the produced husk is consumed in the mills themselves in parboiling of paddy (Tariq, 1999).

It is reported that there are about 100,000 (including large, medium and small) rice mills in the country (Baqui et al, 1997). Among them about 40,000 rice mills have parboiling units (Ali 2004) with a capacity of 7.5 to 16 tons of paddy per batch (3 days). The average rice husk production from this type of rice mills is 2400 kg/batch (800kg/day). Presently, on an

average, 87% of rice husk is used for parboiling. A study indicated that the variation of husk consumption in the traditional parboiling systems is very wide. It varies from 60 kg to 200 kg per ton of paddy parboiled (Dasgupta et al. 2003).

Household sector consumes about 80% of total biomass energy and the rural households use it almost exclusively for cooking purpose (Bari et al 1998). It is reported that biomass combustion contributes to as much as 20–50% of global greenhouse gas emissions, of which about one-third may come from households. This has an adverse effect on human health and environment (Smith 1999). With the growing concern about environmental pollution and health risks, it is very important to find out a sustainable and efficient rice-processing method.

In the national energy context, it is essential to mention that traditional biomass fuels are the major energy resources in all regions of Bangladesh. This biomass is derived from rice husk (23.3%), cow-dung (20.4%), rice straw (11.6%) and the rest from lesser amounts of jute stick, bagasse, fire wood, twigs, leaves and other waste materials (BBS 2004). The contribution of rice husk in the total energy consumption is about 17% (Ahiduzzaman, 2006). Reports indicate that there is a potential of about 50% savings in rice husk (used as fuel) by replacing the primitive parboiling system (steam vessel and furnace) with improved one.

Project Objectives

The project objectives are to:

1. Identify efficient rice parboiling technology available in Bangladesh.
2. Design and manufacture 2 efficient rice parboiling systems.
3. Commission the efficient rice parboiling systems.
4. Assess the socio-economic aspects of improved rice parboiling systems.

Study the Efficiency of Indigenous Rice Parboiling Systems

There are several models of traditional rice parboiling systems. But, by and large, they can be classified into two major types. These are:

- i) Semi-cylindrical vessel and
- ii) Cylindrical vessel

Furnaces with Semi-cylindrical Vessel

Fig. 1 gives a conceptual view of the semi-cylindrical vessel used in the rice mill industries. The bottom of the steam vessel is flat and made of 10-12 mm thick Mild Steel (MS) plate. The top, front and back sheets are made with a thinner gauge MS sheet of 2-3 mm. The furnace of the parboiling systems constructed with brick and local clay mixed with lime. The ash removal port of the furnace is very large. The heat loss through this opening happens in two forms: a) Heat loss through high temperature flue gas leakage; and b) heat loss when hot ash is removed frequently.

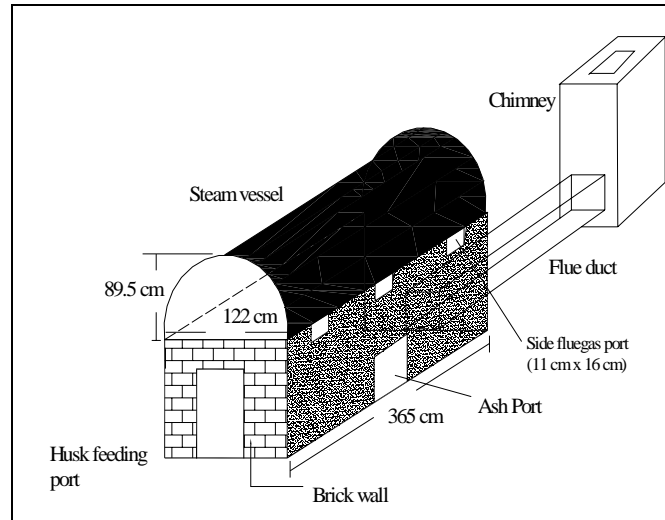


Fig. 1 Schematic diagram of a traditional semi-cylindrical steam vessel installed on a furnace

Furnaces with cylindrical vessel

Cylindrical vessels are mostly found in rice mills situated in Northern part of Bangladesh. Similar to the furnaces of semi-cylindrical vessels, these furnaces are constructed with brick and local clay mixed with lime. However, here, furnace does not have any flue gas exits on the sides like semi-cylindrical models. However, they have also has large husk feeding port and a large ash port and similar ash removal practices (Fig. 2).

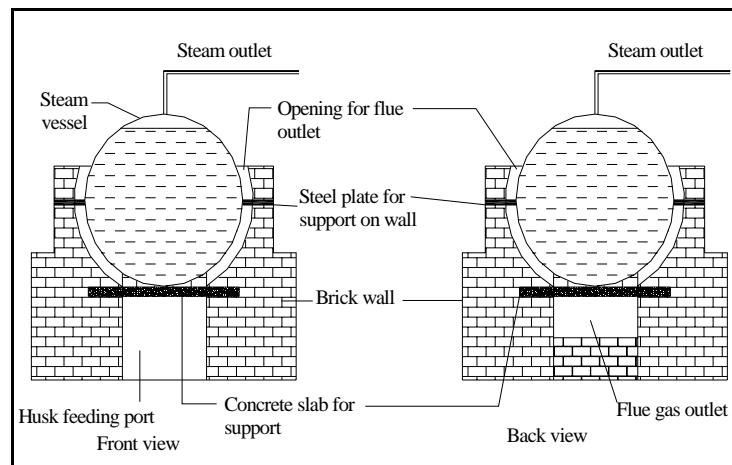


Fig. 2 Schematic diagram of traditional furnace with cylindrical steam vessel

The cylindrical vessel is fabricated generally with 2.5 to 4 mm thick MS sheet (Fig. 3 shows a traditional cylindrical steam vessel). Furthermore, both of these furnaces also have a large masonry structure connecting it to the chimney.



Fig. 3 Showing a traditional circular steam vessel

Operating practices of furnaces

Normally, two persons are continuously engaged in feeding rice husk manually in the traditional furnace. Since the husk is fed continuously at a very high rate, the pressure builds up inside the furnace. The furnace design does not allow thorough mixing and sufficient flow of air required for firing the full amount of husk being fed. This leads to a partial combustion of husk and produces a high concentration of carbon monoxide (CO), which causes health hazards to the operator. Generally, the normal operating gauge pressure of these vessels is found to be 0.5 kg/cm^2 .

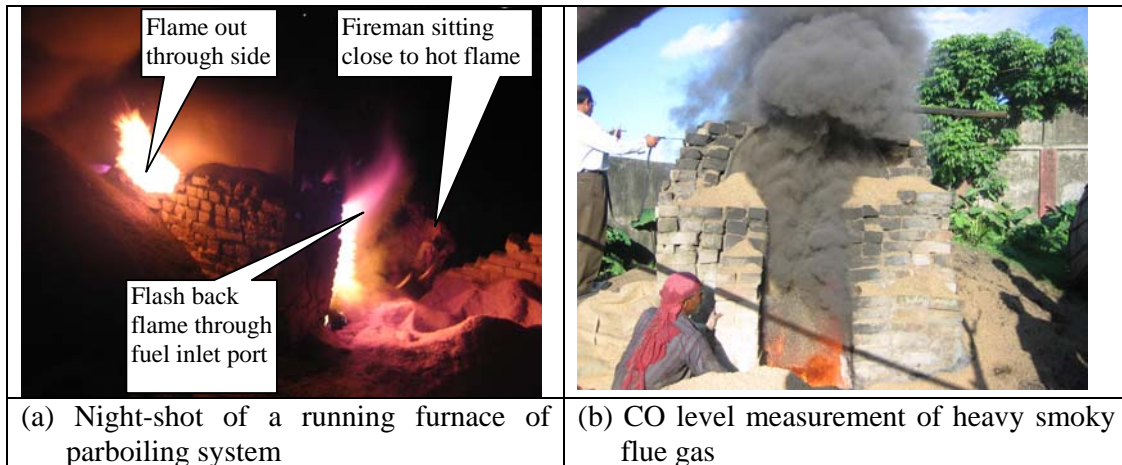


Fig. 4 Showing hazardous working practices of the traditional rice parboiling system creating heavy smoke

Heat loss factors of the traditional furnace

The heat loss components are : i)Heat loss from vessel surface and heat loss through flue gas ii)Radiation heat loss from inlet port and ash port, iii)Heat loss though furnace sidewall and sensible heat in ash, iv) Partially burnt carbon (C) and unburnt carbon in ash.

Table 1 Results of the flue gas analysis of traditional furnace

Sl No	Parameter	Measures
1	Ambient temperature	28°C
2	Flue gas temperature	750°C
3	CO	> 10,000 ppm
4	O ₂	Nil

Heat transfer area and thermal efficiency of the traditional system

Generally a typical semi-circular vessel used for steam generation has a total area of about 15 m² out of which only about 5m² is used to receive the heat. That means only 33% of the total vessel surface area is receiving heat and the rest 67% of the vessel surface area is exposed to atmosphere. In case of a typical cylindrical vessel system generally the total vessel surface area is about 11m² out of which about 40% of the area is used as heating area. To achieve higher efficiency, vessel heating surface area should be increased to absorb more heat. The field level data are given in Table 2. Different components of heat flow have been shown a Sankay diagram (Fig. 5).

Table 2 Details of paddy processing in the rice mills of Bangladesh

Name of Rice Mill	Husk production (ton/day)	Husk consumed (kg)	Total energy supplied (MJ)	Steam produced (kg)	Total energy consumed for steaming (MJ)	Overall Thermal system efficiency (%)
Nahid Rice Mill	3.38	1251	17518	1634	3971	22.67
Bablu Rice Mill*	1.5	283	3962	339	830	20.94
M/S Kishan Rice Mill	1.13	370	5620	667	1669	29.69
Sonali Auto Rice Mill	2.25	1144	16019	919	2287	14.28
Satter Rice Mill	2.66	1162	16274	1419	3561	21.89
M/S Rasel Auto Rice Mill	3.38	1805	25270	1858	4589	18.16
Boxshi Auto Rice Mill	2.25	1330	18617	1403	3563	19.14
Average						20.97

*Only steam production and husk consumption was observed, Source: Field Survey (2007)

From Fig. 5 it can be seen that the maximum heat loss occurs through high temperature flue gas, which is almost 50%.

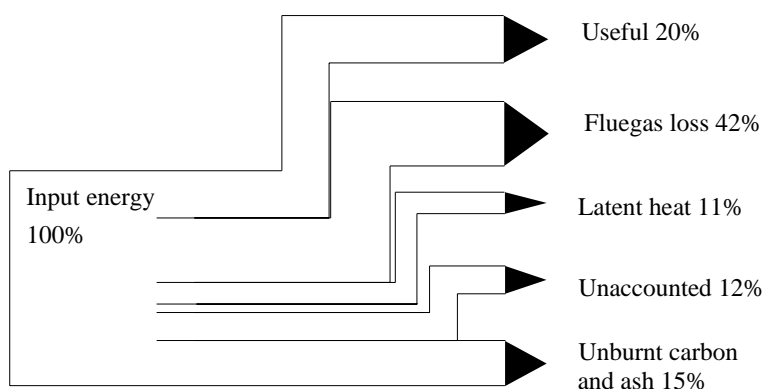


Fig. 5 Energy flow through the conventional parboiling furnace

Steam consumption in paddy processing

The steam consumption in paddy parboiling falls in the range of 80 to 120 kg of steam per tonne of paddy processed. The detail information on paddy processing in the rice mills of Bangladesh are given in Table 3.

Table 3 Details of steam consumption in the rice mills of Bangladesh

Name of Rice Mill	Paddy processed (ton/day)	Steam produced (kg/day)	Husk feeding rate (kg/hr)	Steam production rate (kg/hr)	Husk consumed (kg/ton paddy)	Steam consumed (kg/ton paddy)
Nahid Rice Mill	16.875	1634	178	286	74.13	99
Bablu Rice Mill*	-	339	188	314	-	-
M/S Kishan Rice Mill	5.625	667	96	206	65.77	119
Sonali Auto Rice Mill	11.25	919	193	204	101.67	82
Satter Rice Mill	13.275	1419	147	227	87.53	107
M/S Rasel Auto Rice Mill	16.875	1858	228	293	106.96	110
Boxshi Auto Rice Mill	12.75	1403	207	263	104.31	110

*Only steam production and husk consumption was observed, Source: Field Survey (2007)

Design Considerations of Improved Rice Parboiling System

Based on the results of study the following points were considered for designing of the improved systems:

- ◆ A minimum of 40% efficiency is targeted to be achieve;

- ◆ attention was given to keep the capital cost affordable and economic;
- ◆ steam pressure of 1.0 kg/cm² instead of 0.5 kg/cm² his will quicken the processing operation.
- ◆ furnace will be constructed using the same materials and methods of conventional furnaces.
- ◆ Flame flashback from the large husk feeding inlet port, flame exit from the side walls, below the vessel etc;
- ◆ The flue gas exit with a high level of CO;
- ◆ Use of high quality MS sheet used for fabricating the vessel;
- ◆ Use of high quality welding materials by trained mistries ;
- ◆ Use of safety measures such as temperature gauge, pressure gauge, water level gauge etc.

Different aspects incorporated in the improved parboiling system

Type 1 design

Improved pure husk fired steam vessel (semi-cylindrical): The system is designed to handle up to 18000 kg paddy/day (5 hrs) capacity of paddy processing mills. The size of the vessel is 4878 mm in length and 1016 mm in width. The heating surface area is about 12 m². The vessel is designed to have a steam delivery capacity of 400 to 600 kg/hr. The schematic diagram of the improved system (TYPE 1) at Kaliakoir is shown in Figure 3.1.

Type 2 design:

Improved mixed bran-husk fired steam vessel (Cylindrical): The design parameter is similar to that of the semicircular one. The size of the vessel is 4878 mm in length and 1000 mm in diameter. The total heating surface area is about 16 m². The processing capacity of the circular design is 15.75 ton paddy/day (4hrs). The schematic diagram of the improved system (TYPE 2) at Sherpur, Bogra is shown in Fig. 6.

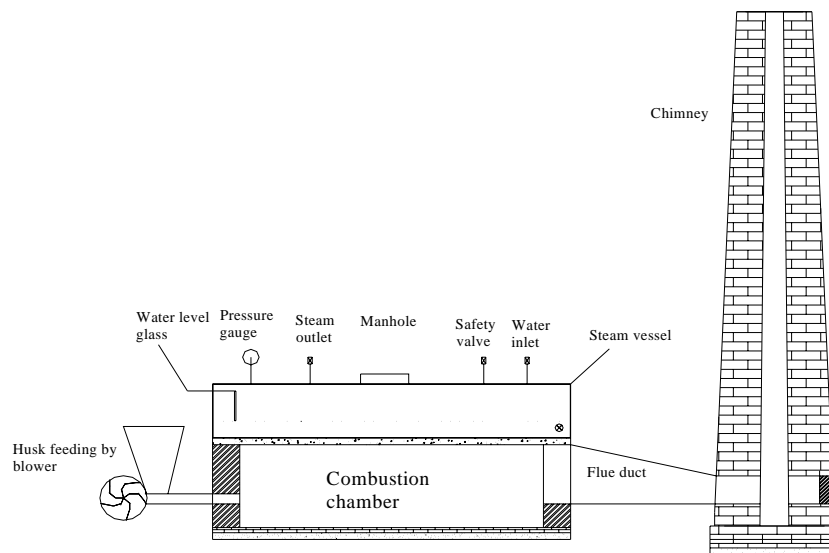


Fig. 6 Schematic diagram of improved rice parboiling system (TYPE 1) installed at Kaliakoir, Gazipur

Installation and Operation of the Improved Rice Parboiling System

Fabrication of improved rice parboiling system

(a)



(b)

Fig. 7 Showing the different stages of fabrication of steam vessel of rice parboiling system (semi-circular)



(a)



(b)

Fig. 8 Showing the different stages of fabrication of steam vessel of rice parboiling system (Circular vessel)

Construction of improved furnace and chimney

(a) Chimney base construction at Kaliakoir



(b) Chimney under construction at Kaliakoir

Fig. 9 Showing the stages of chimney construction



(a)



(b)

Fig. 10 Showing the placing processes of the steam vessel on the furnace (TYPE 1) at Kaliakoir, Gazipur site



Fig. 11 A view of the steam generation process in running condition showing very good color of flame in the furnace at Kaliakoir, Gazipur



Fig. 12 A view of the steam generation process in running condition at Sherpur, Bogra



Fig. 13 A view of the measurement of CO, O₂ and temperature in flue gas (a MRU AirFair Emission Monitoring Device)

Performances of Improved Rice Parboiling Systems

Steam production rate of new vessels

Several test runs were conducted in the presence of both the team members and the users of the rice mills. The test results are given in Tables 3 and 4. Rice husk feeding rate during all the test runs were maintained in the range of 156 to 222 kg/hr and the steam consumption rate was 486 to 596 kg/h at 0.50 to 1.0 kg/cm² pressure of steam. Whereas, at Sherpur, Bogra, the rice husk feeding rate during all the test runs were in the range of 145 - 159 kg/hr and the steam consumption rate was 467 – 508.8 kg/hr at 0.50 to 1.0 kg/cm² pressure of steam. The flue gas was analysed to find out the air supply quantity for complete combustion and reduction in the CO-level.

Table 3 Comparative test results for conventional and improved system (TYPE 1) at Kaliakoir

	Parameter	Conventional system	Improved system	
		Regular Operations	Under Controlled Condition *	Regular Operation **
1	Husk feeding rate (kg/h)	228	156	222
2	Steam production rate (kg/h)	293	486	596
3	Specific fuel consumption (SFC) (kg husk/kg steam)	0.78	0.32	0.37
4	Efficiency (%)	20	49	42.75

* Test runs carried out in presence of project team – average of 4 test runs

** Test runs carried out by the mill operators – average of 2 test runs.

Source: Field test data (2007)

Table 4 Comparative test results for conventional and improved systems at (TYPE 2) at Sherpur, Bogra

	Parameter	Conventional system	Improved system
		Regular Operations	Regular Operation **
1	Husk feeding rate (kg/h)	229	151.88
2	Steam production rate (kg/h)	450	488.08
3	Specific fuel consumption (SFC) (kg husk/kg steam)	0.62	0.31
4	Efficiency (%)	30	50.03

** Test runs carried out by the mill operators – average of 2 test runs.

Source: Field test data (June 2008)

It is being seen from the above tables that the increase in combustion efficiency is about 29% during controlled operation (TYPE 1). The specific fuel consumption for steam generation was calculated. It shows that more than 50% of husk can be saved.

Comparison of performance

The system performance was compared with different ambient conditions. A substantial reduction in the flue gas temperature from 750°C to 450°C was achieved in the improved system. The CO level was brought down to a level well below the acceptable norms of air quality standards (100- 500 ppm). In general, the conventional systems process the paddy at a steam pressure of 0.5 kg/cm². The improved system can process paddy with a steam pressure of 1 kg/cm². Process duration has been brought down to 3 to 4 minutes/bin, whereas the conventional system takes about 7 minutes to process each bin of paddy. The comparison of performance is given in Table 5.3.

Table 5 A comparison of the test results obtained by the user from both conventional and improved system at regular operating condition

Sl No	Parameter	Unit	Conventional System	Improved System (TYPE 1)	Improved System (TYPE 2)
1	Ambient temperature	°C	27	26	29
2	Flue gas temperature	°C	750-800	450-600	450-610
3	O ₂ content	%	Nil	7.1 - 8.0	4.2-8.6
4	CO content	ppm	>10000	100-500	558-2209
5	Steam pressure	kg/Cm ²	0.5	0.7-1.0	0.7-1.0
6	Efficiency	%	20.97	42.75	50.03
7	Processing duration	Min	7.0	3-4	3-4
8	Time required to process the whole batch	hr	7.9	4.0	3.5
9	Cost of making the complete parboiling unit	Tk	210,000.00	300,000.00	300,000.00

Source: Field test data (2008)

Husk savings

According to the specific fuel consumption the rate of rice husk savings is in the range of 50% to 59%. However, by user level operation 42.75% efficiency has been achieved at Kaliakoir cluster. In addition to the direct saving, there is an extra advantage of reduction in the processing time. The steam production rate of the conventional system is 277 kg/hr while that for the improved one is 486 kg/hr.

Environmental benefits

In addition to the efficiency improvement and rice husk saving, the improved system provides several benefits through environmental improvement:

- Exposure excessive heat is almost nil due to feeding of husk by a power blower.
- Temperature around the furnace provides more comfortable working environment because (i) the vessel is insulated and not exposed to the atmosphere; and (ii) There is no flame exit port through the sidewalls as in the case of the conventional system.
- In the improved furnace, O₂ content in the flue is found at optimum required range of 7 to 8% instead of 0% O₂ in case of conventional furnace
- In the conventional furnace flue gas contains more than 10,000 ppm of CO. It is a clear indication of the hazardous environmental condition for the workers. The

improved furnace brings down the CO content in the flue gas to the range of 100-500 ppm, which is within acceptable level for such industrial applications.

Safety factor

Main aspects of safety improvements are:

- (i) safer air quality;
- (ii) eliminating flash back fires; and
- (iii) safety in terms of avoiding accidents due to vessel explosion at high pressure.

Ease of operation

- Manual husk feeding is eliminated by introducing a power operated blower;
- Comfortable working environment around the furnace, due to less radiation of heat and less CO emission;
- Instrumentation provides a clear indication of how the furnace is operating. In the conventional furnace, the operator has no information on temperature, pressure, water level etc.

Potential for economic gains

In the national context, out of these 8 million tonnes, about 40-50% is consumed within the rice mills in the husk fired furnaces. By improving the fuel saving potential is the range of 50% to 59%, the total potential of husk saving would be about 2.5 million tonnes per year. At the present efficiency of improved furnace an individual owner at Kaliakoir could make an additional profit of Tk 640,000.00 per annum/per unit (husk price @3.0 TK/kg). However, at the Bogra cluster the individual owner saved the cost of husk-bran mixture of Tk 187,500.00 per annum/per unit (bran-husk mix price @ 5.0 Tk/kg).

Socio-Economic Aspects of Improved Rice Parboiling Systems

Employment generation

Employment generation ranged from 13 to 26 persons per mill, and on average it was 17.75 person of which 28% is women. Considering this parameter, total employment generation in 100,000 rice mills (Baqui et al. 1997) of Bangladesh is about 17,75,000 of which 4,97,000 is women.

Structure of selected rice mills

On an average the husking capacity of the selected rice mill is 14.41 ton. This capacity is found to vary by selected regions. On an average it was 3.25 days/week during summer and winter and 4.5 days/week during monsoon.

Table 6 Advantages of using improved parboiling system

Special features of the	Rice parboiling system
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technology	Type 1 (At Kaliakoir)			Type 2 (At Bogra)		
	Traditional	Improved	Change	Traditional	Improved	Change
Average efficiency (%)	19-20	43-55	23*	30	49.8-50.3	19.9**
Average pure husk required for parboiling 18 ton paddy for type 1 system (kg)	1800	837.5	962.5 (Saved)	-	-	-
Mixture of rice bran and husk required for parboiling 15.7 ton paddy for type 2 system (kg)	-	-	-	1050	800	250 (Saved)
Time required to parboil 18 ton paddy for type 1 and 15.7 ton for type 2	7.5	4	3.5	5	3.5	1.5
CO Emission (ppm)	> 10,000	100-500	9500-9900 (reduced)	> 10,000	100-500	9500-9900 (reduced)
Estimated cost, Tk.	210000	300000	90000	190000	300000	110000
Useful life, yr	5	15	10	5	15	10

Cost-benefit assessment

Considering 15 years of useful economic life, it was found that total incremental benefit of using Type 1 parboiling system was Tk 2411065 and resulted from energy saving and it was Tk 1447875 for Type 2 against the incremental cost of Tk 210000 and Tk 200000. The benefit-cost ratio is found to be very high, 11.48 and 7.24 for Type 1 and Type 2 systems respectively (Table 6.2). The pay back period for Type 1 and Type 2 systems found to be 16 month and 25 months, respectively. Thus the technology is found to be economically viable, environment friendly and socially acceptable.

Table 7 Partial budget of improved rice parboiling replacing traditional ones (for 15 years useful life)

Particular		Parboiling System	
		Type 1	Type 2
Incremental benefits			
Reduced cost, (Tk).			
	Saving Husk/mixture of bran and husk	2411062.50	1447875.00
Added return			
	Increased revenue	0	0
Total incremental benefits, (Tk.)		2411062.50	1447875.00
Incremental costs			
Added cost, (Tk.)			
	Furnace, chimney	210000.00	200000.00

	and blower		
Reduced return		0	0
Total incremental cost, (Tk.)		210000.00	200000.00
Net Incremental benefits, (Tk.)		2201062.50	1247875.00
Inc B:C ratio		11.48	7.24
Monthly extra income from savings of bioenergy (Tk)		13090.00	8043.75
Payback period (month)		16	25

Adoption of the improved rice parboiling technology and social benefits

At present it is estimated that there are about 100,000 rice mills in Bangladesh (Baqui et al. 1997). It is assumed that adoption rate of improved rice parboiling system will be 50%, so a total of 50,000 mills will adapt it. With this adoption rate it is estimated that total annual husk saving would be Tk6431.6 million of which Tk.4018.4 million will be from Type 1 system and Tk.2413.2 million from Type 2 parboiling system.

Impact on the environment

It was found that CO emission in traditional system is very high (> 10, 000 ppm). On the other hand, CO emission in new technology is found to be very low 100-500 ppm. If new parboiling system is adapted to 50,000 mills of Bangladesh then emission of greenhouse gas will be largely reduced by an estimated amount of 24.25 million ppm. Thus the improved parboiling technology is found to be environment friendly.

Conclusion and Recommendation

Conclusion

Following detailed analyses of the designs of existing steam vessels and furnaces and the heat flow through various components, this project has developed an improved design that has average increased system efficiency to 42.75 % from earlier 20%. This model went through several trial runs and field tests. Based on the analysis of these field tests and user feedback modifications the following conclusions are made:

- At least 50% of the rice husk currently used for parboiling, i.e. about 3.12 million tons per year, will be saved amounting to Tk .6431 million/year.
- Saved rice husk will be available for other purposes like briquette production, power generation, animal feed. This will contribute positively to overall energy supply and animal feed situation of the country,
- The small and medium rice mills will become more profitable.
- The rice mills will be safer. The probability of danger of explosion will be reduced to a minimum. Along side, the victim families will be saved from losing their income. The mills will also be benefited in two ways. Firstly, the mills will be able to operate longer period and thus yield more income for the owner. Secondly, the owner will not have to pay compensation for accidents.
- More employment will be created in rice husk briquette making. Scope for husk based production of power in rural industries will increase. This will foster industrialization in rural areas.

- Pressure on forest for cooking fuel will considerably be reduced and less green house gas will be emitted.
- Flash fires from fuel inlet port and side ports have totally been eliminated. Heat loss has also been reduced by insulating most of the vessel surface. This means considerable improvements in the workers' working conditions.
- A more complete combustion of the rice husk means lower emissions. The thick black smoke with high TSP has been replaced with more transparent smoke with little dust content. CO emission, present level of more than 10,000ppm, has been reduced to the minimum acceptable standard of 100- 500 ppm. Thus the pollution in and around rice mill premises will be reduced significantly. The health benefit of the rice mill workers will be enormous.
- Again, as rice mills are not included in the Small Industries category, because of its rural location, the mill owners are not entitled to any loans available to small enterprises in urban areas. These issues will be addressed in the dissemination plan.
- The project will contribute to a sustainable development in conserving natural resources of the country.

Recommendation

- Install 10 new parboiling systems at 10 different clusters of Bangladesh immediately.
- Arrange training programme of furnace making for the vessel technicians so that they are capable enough for setting up new parboiling system, through a pilot project.
- Operators of rice mills should also be trained on safe operation and maintenance of the systems.
- Carryout promotion and awareness building activities through information materials, seminar / workshops and demonstration to the target groups.
- Transfer the know how on improved parboiling technology to local levels for its availability all over the country.
- Introduce innovative financing mechanism in order to make the improved rice parboiling systems affordable to the rice mill owners.
- Provision of after sales services should be guaranteed to the rice mill owners.
- Continuous efforts for further improvement of the parboiling system should be provided and the knowledge should be transferred to the beneficiaries.
- Gasification technology should be introduced in the rice mills for the self sufficiency of power

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