Rice Husk Briquette with Shredded Paper Additives: a Potential Energy Source at par with the Progress of Bangladesh

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Abstract

As a consequence of recent uplift of the status of Bangladesh, the country has to face a number of challenges in the energy sector. To overcome these challenges all possible energy sources should be explored for efficient use. Rice being the staple food of Bangladesh, rice husk is available in large quantity and so briquette made from rice husk has already gained popularity. As about 67% people living in the rural areas of the country depended on indigenous bio-fuels for cooking; biomass briquette has replaced those indigenous fuels for its convenience. Although a lot of works have been done on different aspects of briquette making process using agricultural residues all over the world, little data is available on rice husk regarding its characteristic properties when other available additives are added. This paper consists of the summary of findings obtained from a research conducted on effect of various additives on rice husk briquette to determine its properties, field surveys on its acceptability, challenges and future potential. It is aimed at proposing the improvements towards building efficient and safer new machines compared to old ones to overcome the problems and suggesting realistic management policy for its sustainable use.

Keywords:
Bangladesh status, Rice husk briquette, Paper additive, Future potential, Sustainable use

1. Introduction

Bangladesh recently fulfilled the current criteria of the United Nation (UN) to graduate from a least developed country (LDC) to a 'developing country' status. According to the UN, a country is eligible to graduate from the LDC category if it has a Gross National Income (GNI) per capita of $1,230 or above for three years, a Human Assets Index (HAI) of 66 or above and an Economic Vulnerability Index (EVI) of 32 or below. Bangladesh has fulfilled the three conditions on a very large margin. Bangladesh's current per capita income is $1,610. The HAI is 72.9 and the EVI is 25. Economists say Bangladesh will have to face a number of challenges after coming off its LDC status. Failures to meet the challenges will give rise to fears that Bangladesh will lag behind. There has to be more industrialization in Bangladesh. Both production and jobs have to be increased (UNDP 2010). For this, more industries have to be set up and internal resources have to be increased and therefore, all new, renewable and alternate sources of energy should be explored for efficient and sustainable utilization.

1.1 Biomass Energy Source and Briquetting in Bangladesh

Biomass briquette production technology is used in many districts of Bangladesh where raw materials are available. Figure 1 shows the different districts of Bangladesh with star marks locating the main cluster of rice mills where most rice husk is available as found in M.Sc. research conducted by Miah (2017). In Bangladesh biomass briquettes

have gained a huge popularity and occupied a large portion of cooking fuel needs of rural people. Rice being the main food of the country, rice husk is easily available at a cheap rate which contributed significantly towards its enormous popularity (Alam and Islam 2011).

Figure 1: Different districts of Bangladesh with star marks locating the main cluster of rice mills

Bangladesh is the 4th largest rice producing country of the world. An overview of the rice producing countries is shown in Figure 2 (Islam and Hasan 2011). It produces around 50 million tons of rice per year, providing approximately 10.5 million ton of rice husk per year. Approximately 67% of the total energy supply is derived from biomass. Traditional biomass is often hard to collect, difficult to transport and not easy to store due to their irregular and troublesome characteristics. An efficient solution to these problems is to convert them into briquette. Briquetting is a process of densification of biomass by compressing them into products of regular shape of high density. Briquetting significantly contributes to the environment by reducing CO_2 emission and deforestation. Moreover, it contributes to economy by generating employment and income.

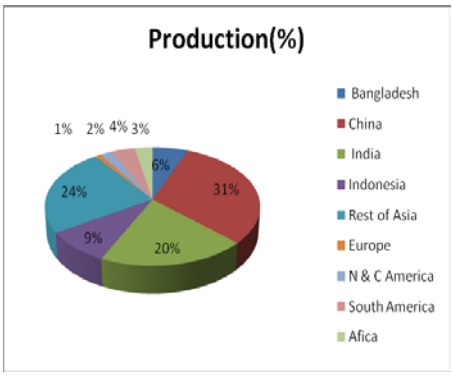

Figure 2: An overview of the rice producing countries of the world

2. Briquetting Resources and Processes

In Bangladesh, biomass is obtained from various plants and animal sources, such as rice husk (24%), cow dung (18%), rice straw (16%) and smaller amounts of jute straw, sugarcane bagasse, coconut husk, twigs, leaves and other smaller amount of agricultural products. Figure 3 shows some pictures of most common biomass used for briquette.

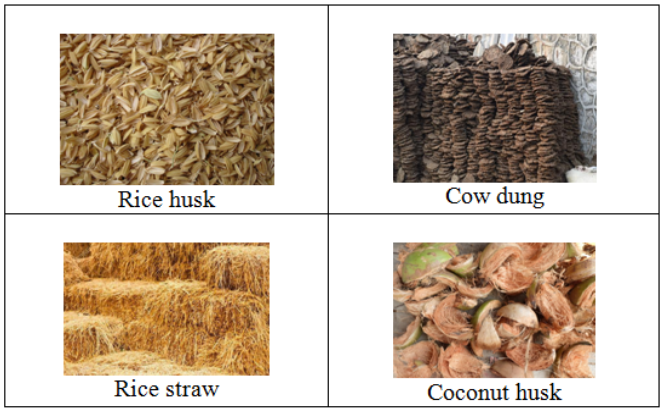

Figure 3: Some pictures of most common biomass used for briquette used in Bangladesh

Two common types of briquetting processes are employed in developing countries: (1) heated die screw press and (2) piston press. The heated die screw press technology was invented in Japan in 1940 and it has spread now to China, Korea, Thailand and Bangladesh. The piston press technology is dominant in India, Brazil and other parts of Africa [3]. History of biomass densification process is very old. Rural people have been using cow dung briquettes for cooking since time immemorial. Before the introduction of briquetting the huge amount of rice husk was thrown into river which eventually caused problems for fishermen and boatmen. In Bangladesh briquette system was first introduced in the North-eastern part of the country, Sylhet in 1990. It was first introduced there by a rice mill owner who imported a briquette production unit from Taiwan to reuse the huge amount of rice husk. The briquetting machines used are of heated-die screw press type similar to Thailand, Malaysia and South Korea. Heated die screw press type briquetting machine with detail parts drawing is shown in Figure 4 (Ahiduzzaman 2006). Due to lack of power supply and some safety issues related to fire hazards piston press type briquetting is a suitable alternative. A 5 compartment piston press type briquetting machine was developed at the department of Mechanical Engineering, Bangladesh University of Engineering and Technology (BUET) to study the effect of various additives on rice husk briquette, shown in Figure 5 (Miah 2017).

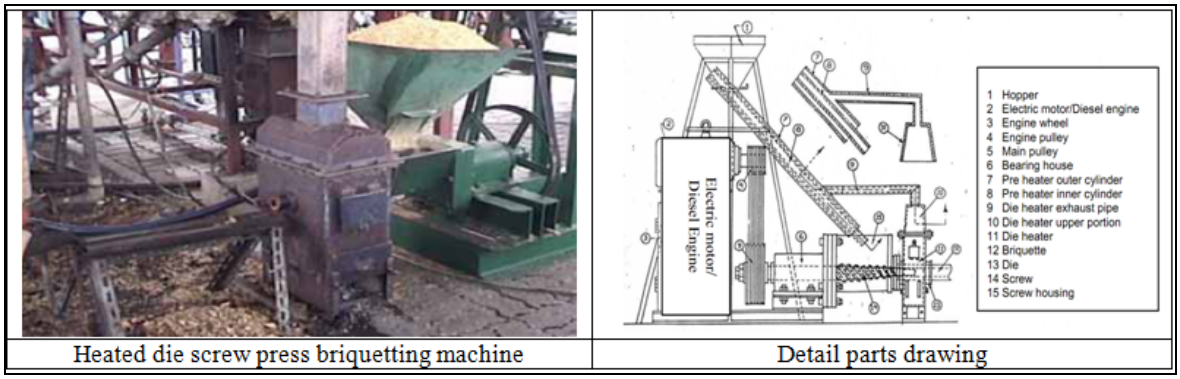

Figure 4: Heated die screw press type briquetting machine with detail parts drawing

Figure 5: A 5 compartment piston press type briquetting machine developed at BUET

2.1 Rice Husk Furnaces

After the completion of rice parboiling and drying process, the remaining rice husk is used to make briquette fuel. It produces less smoke and burns slowly compared to biomass fuel wood. It is used as an alternative to fuel wood for cooking purposes. Figure 6 shows pictures of a (1) rice husk furnace and a (2) rice husk briquette furnace. The performance of briquette fuel is better than biomass wood fuel. One kilogram of rice husk briquette can provide the same service of 1.63 kilogram of biomass wood fuel during cooking purposes (Ahiduzzaman and Islam 2009). The briquette fuel production can be increased by ensuring the surplus rice husk when a new technology for rice husk burning is introduced (Smith 2000). Moreover, with addition of different other waste material available in Bangladesh, production could be further increased with better waste management scenario (Hossain and Saha 2015).

Figure 6: Pictures of a (1) raw rice husk furnace and a (2) rice husk briquette furnace

2.2 Effect of Various Additives on Rice Husk Briquette

Experimental were carried out to find out different properties of rice husk briquette when mixed with available waste materials: like waste paper, mustard oil cake, Sesame oil cake, Nigela seed oil cake, saw dust etc. in different proportions. Pictures of 14 samples with their % compositions are presented in tabular form in Figure 7. Figure 8 shows the experimental set-up of oxygen Bomb Calorimeter arrangement to obtain calorific value of 14 samples (Miah 2017). The ASTM D5865 standard was followed to obtain the results. With the addition of various additives,

calorific values of all the samples stay in the range between 14.2 and 14.7 MJ/kg. Therefore, it could not make any significant difference when a portion of rice husk is replaced with other additives according to availability in the vicinity of particular location of the country. But this would definitely provide a better waste management scenario. Details of other experimental process and results are presented in detail in the thesis of Miah (2017).

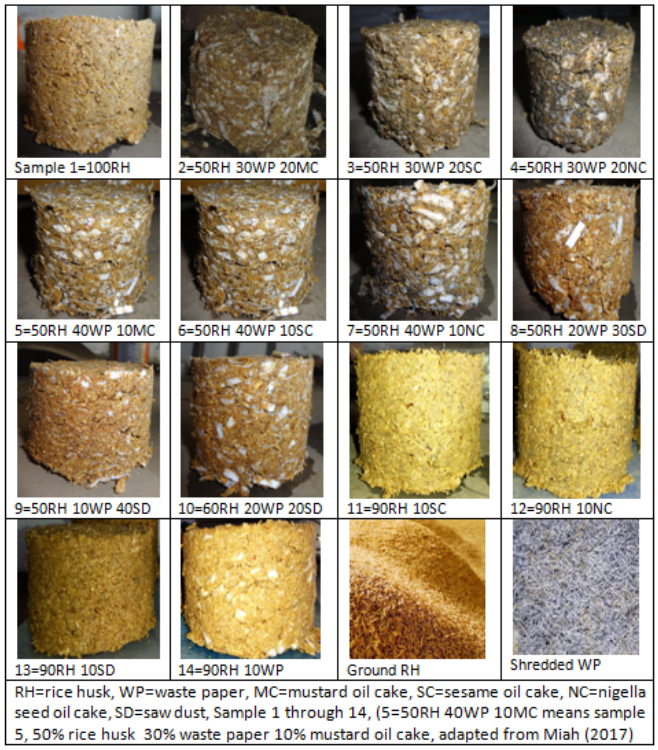

Figure 7: Pictures of 14 samples of rice husk briquette made by machine shown in Figure 5.

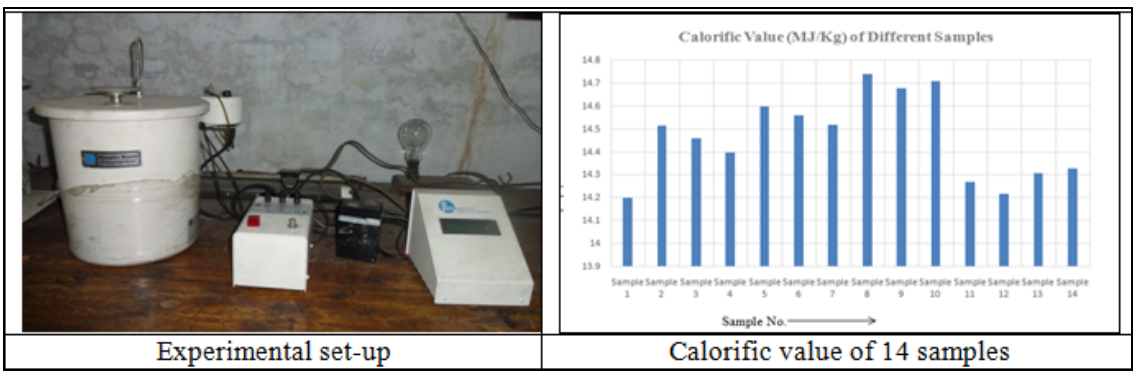

Figure 8: Experimental set-up of oxygen Bomb Calorimeter and calorific value of 14 samples of Figure 7.

3. Use of Rice Husk and Briquette

Raw rice husk is mainly used as fuel for parboiling and drying processes of paddy in rice mill and some portion of husk is used for making briquette fuel (Miah 1999). With the present system of rice processing, i.e., for rice parboiling and drying, the annual estimated consumption of rice husk will increase up to 6.6 million ton in 2030 (BBS 2011). Rice husk briquette fuel has got popularity as a feasible replacement of biomass wood fuel (BBS

2014). A case study showed environmental impact of rice husk briquette used for a district town of Bangladesh reveals that it has a potential to save biomass wood fuel (Foysal 2012). The comprehensive and integrated study shows: (1) rice husk conversion process, (2) rice husk burning in rice processing mills, (3) rice husk briquette production, (4) benefit of changing from biomass wood fuel to rice husk briquette and (5) impact of associated Green House Gas (GHG) reduction on deforestation process. The study was based on review of existing papers (Moral and Rahman 1999) made by earlier researches in the department of Agro-Processing, Faculty of Agriculture, Bangabandhu Sheikh Mujibur Rahman Agricultural University and the experiments carried out in the Department of Mechanical Engineering of BUET.

3.1 Additional uses

In some urban areas of Bangladesh tea stalls, small retailers and poor households uses rice husk briquette (Hassan and Pelkonen 2012). The main reason for this is that biomass firewood has been reducing alarmingly and briquette is smokeless and provides higher temperature more quickly than that of coal and wood (Ellery and Siddiqi 2000). The households who could not avail the gas or grid connection were using rice husk briquette fuel particularly during rainy season (BCSAP 2008). Rice husk is also burnt for bitumen melting in road construction work. Moreover, some non-energy uses of rice husk were found in the poultry bed and as reinforcement material in low cost mud-house construction.

4. Benefit Analysis

There are several benefits of using rice husk briquette. It is compact, easy to transport and storage. Moreover, with improved furnace, pollution is also reduced Economic analyses made by Ahiduzzaman (2016) shows that the cost of CO_2 reduction due to the use of rice husk briquette satisfies its capability to sustain its future requirements.

4.1 Benefit due to reduction of deforestation

At present rice husk energy is consumed predominantly for parboiling and drying of raw rice in the rice milling industries in Bangladesh. Rice husk is used as fuel to produce steam and hot air. The combustion product, carbon dioxide, obtained from furnace exhaust is renewed by rice plant during the next vegetative period. A rice plantation has a rotation period of 100-150 days. Therefore, the rice husk energy is produced and renewed twice in a year easily (Mia 2009). As a developing country there is a huge demand of biomass wood fuel in Bangladesh. The fuel wood is exploited from an unsustainable forest of Bangladesh (Salam 1998). Therefore, an extra million ton of carbon dioxide is emitted to atmosphere due to burning of wood fuel obtained from the deforestation process.

4.2 Development of Analytical Model

An analytical model approach was developed by Ahiduzzaman (2016) to incorporate biomass wood fuel market and rice husk briquette. As the rice husk briquette will replace the biomass wood fuel, therefore, it will help to protect a portion of forest from the deforestation process. In this approach the undisturbed portion of forest will continue to accumulate the carbon dioxide from the environment. As a result, a carbon sink will be developed and the deforestation process turns into the sustainable forest. There are three close loops of carbon cycle observed in this approach as shown in Figure 9.

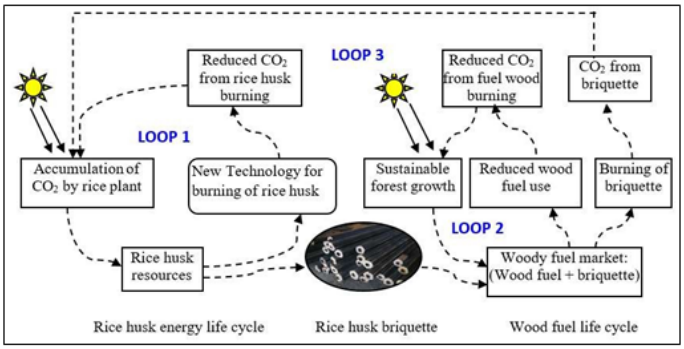

Figure 9: Analytical model development using 3 closed loop carbon cycle

The first loop is for the existing cycle of rice husk energy with a new burning technology of rice husk. The new burning technology of rice husk can be an improved version that can save additional amount rice husk and enters into the biomass wood fuel market. The second loop is for the existing wood fuel cycle with reduced consumption of biomass wood fuel. Finally, the third loop is for rice husk briquette fuel (a subsidiary loop of rice husk energy). In this loop rice husk briquette reduces the pressure on wood fuel and thus reduces the emission from wood fuel and this gap is filled up by the use of husk briquette. The emission from rice husk briquette is captured by re-growing rice plant during the next vegetation period.

4.3 Mathematical Expression

In this analytical model, the existing scenario of the carbon cycle of rice husk is analyzed by using emission factors of the biomass energy. Consumption of rice husk (RH) is calculated as:

$$RH_{present\_consumption} = RH_{production} \times C_f \quad (1)$$

where, C_f = consumption factor, the portion of total husk production consumed in rice parboiling system.
Husk consumption at new situation at reduced rate is calculated as:

$$RH_{reduced\_consumption} = RH_{present\_consumption} \times E_{f\_present}/E_{f\_improved} \quad (2)$$

where, $E_{f\_present}$ = efficiency of present system; $E_{f\_improved}$ = efficiency of improved system

Quantity of surplus amount of rice husk after intervention of new technology is calculated as:

$$RH_{surplus} = RH_{present\_consumption} - RH_{reduced\_consumption} \quad (3)$$

The surplus amount of rice husk is converted into compressed briquette fuel. The briquette fuel will replace a portion wood fuel. The quantity of rice husk is calculated as:

$$Q_{RHB} = RH_{surplus} \text{ x } R_f \quad (4)$$

Where, Q_{RHB} = quantity of rice husk briquette and R_f = mass recovery factor.
By combining the Eq. (1) to Eq. (4) a new relationship is found:

$$Q_{RHB} = RH_{production} x C_f x \left(1 - \frac{E_{f-present}}{E_{f-improved}}\right) x R_f \quad (5)$$

Rice husk briquette fuel has an advantage over wood fuel use. One kilogram of rice husk briquette fuel can provide equivalent service of 1.63 kilogram of wood fuel. The equivalent quantity of wood fuel replaced by the rice husk briquette is calculated as:

$$WF_{replaced} = Q_{RHB} \times P_f \quad (6)$$

By substituting the quantity of briquette in Eq. (5) into the Eq. (6) the new relationship is found:

$$WF_{replaced\ by\ RHB} = RH_{production} x C_f x \left(1 - \frac{E_{f-present}}{E_{f-improved}}\right) x R_f x P_f \quad (7)$$

where P_f = performance factor of briquette over wood fuel according to Baqrai (2008).

Forest area (FA) saved due to the saving amount fuel wood (WF) obtained from equation (7) can be calculated as:

$$FA = WF_{replaced\ by\ RHB} / Y_f \quad (8)$$

where, FA = forest area, and Y_f = yield factor of forest biomass. From equation (7) and (8) a new relationship is found:

$$FA = RH_{production} x C_f x \left(1 - \frac{E_{f-present}}{E_{f-improved}}\right) x R_f x P_{f/Y_f} \quad (9)$$

Finally, the reduction of carbon dioxide emission due to substitution of wood fuel from non-sustainable source by rice husk briquette is calculated as:

$$CO_{2\_reduction} = WF_{replaced} \times GWC_{woodfuel} \quad (10)$$

where, $GWC_{woodfuel}$ global warming potential of wood fuel burning

From equation (7) and equation (10) a new relationship is found to calculate the carbon dioxide reduction as:

$$CO_{2reduction} = RH_{production} x C_f x \left(1 - \frac{E_{f-present}}{E_{f-improved}}\right) x R_f x P_f x GWC_{woodfuel} \quad (11)$$

5. Results and Discussions

The existing scenario of the carbon cycle of rice husk is analyzed by using emission factors of the biomass energy. The reduced amount of emission due to intervention of rice husk briquette fuel in biomass wood fuel market has been quantified applying the analytical model. The quantity of regeneration of forest is also investigated. The Green House Gas (GHG) such as CO_2, CO, CH_4, total non-methane organic compound (TNMOC) and N_2O are accounted in the estimation. The emission factors on energy basis for those components in g/MJ are presented in Table 1. Rice husk energy is considered as renewable source and wood fuel is considered as non-renewable source.

Table 1: Basics of estimating GHG commitment

GW Potential	1	4.5	22.6	12	290	
	Emission factors on energy basis (g/MJ)					
Fuel Type	CO2	CO	CH4	TNMOC	N2O	GWC
Fuel wood	90.7	4.34	0.26	0.53	0.0059	124.17
Crop Residues (rice husk)	84.5	3.74	0.41	0.72	0.0169	34.76

GWC: Global Warming Commitment = Σ GHGi x GWPi; GWP = global warming potential
GWC of fuel wood = 90.7 x 1 + 4.34 x 4.5 + 0.26 x 22.6 + 0.53 x 12 + 0.0059 x 290 = 124.177

6. Conclusion

As biomass contributes the major share of rural energy in Bangladesh, briquetting and other improved methods of using the rice husk would contribute positively in its economy. At present the biomass is consumed in traditional conversion way and causes wastage and produces air pollution. Biomass demand increases due to the growth of population each year and creates an extra pressure on forest. Improved use of rice husk energy could meet a significant amount of biomass wood fuel demand that could reduce extra pressure on forest and also reduces pollution (Figure 6). There is a potential of 4.8 million ton of biomass wood fuel substitution by rice husk briquette which saves an equivalent of 24.14 thousand hectares of forest land annually. This forest creates carbon sink by renewing an equivalent of 7.45 million ton of CO_2 annually. The economic analysis at three different technological changes (improved rice husk combustion boiler, rice husk briquette production, and wood fuel replaced with briquette) shows financial viability. A negative cost of CO_2 reduction clearly indicates the technology could be adopted without addition cost involvement. Moreover, as a consequence of uplifting of the country's status, use of paper and paper products has tremendously in recent years. Removal of this waste paper creates a huge problem. Since the results of research made by Miah (2017) shown that with paper additives properties of briquette does not vary significantly, using shredded paper as an additive to rice husk provides two-fold benefits.(1) It reduces the amount of biomass fuel wood that would otherwise used thereby reduces deforestation and (2) makes an easy way to manage waste paper products. Hence the use of rice husk briquette with paper additives would reduce deforestation

process and develop a carbon stock towards a sustainable growth of forest resources in Bangladesh. For this to happen, all concerned authorities must act collaboratively so that the components like: government support, industrial development and university research facility etc. are to be improved toward achieving the required goal to make these research findings sustainable and thereby to carry forward the nation as an emerging developing country.

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