# AN INVESTIGATION ON THE RAW MATERIALS AND PRODUCTS OF THE BRIQUETTING MACHINE

Md. Mainul Islam[1], Kamrujjaman Khan[3], Dr. M. N. Ali[2], and Md. Shahidul Islam[1]

[1]Lecturer, [2]Professor, [3]Research Assistant
Department of Mechanical Engineering
Khulna University of Engineering & Technology
Khulna 9203, Bangladesh

## ABSTRACT

*In our country briquetting process is carried out in the screw-press type briquetting machine on which mainly briquetting of rice husk are commercially produced. Other alternatives are often run in commercial purpose because of various problem faced. But to become dependent on a single raw material will cause hamper when there is scarcity of that material in the market. Thus to take the full advantage of the locally available raw materials, different mixture of those are considered for producing briquetting. An experimental investigation has been conducted to evaluate the properties of different raw materials and their products from a briquetting machine. Significant properties of the product from different mixture of raw materials with different compositions have also been determined. A screw press type briquetting machine with heated die has been used for producing briquettes. An economic analysis of the system has also been performed in this study.*

**Keywords:** Briquetting, Raw materials, Rice husks, Rice straw, Bagasse and Sawdust.

## 1. INTRODUCTION

The realization that deforestation and wood fuel shortages are likely to become pressing problems in many countries has turned attention to other type of biomass fuel. Agricultural residues are principle, one of the most important of these. They arise in large volumes and in the rural areas, which are often subjected to some of the worst pressure of wood shortage. However, residues are often bulky and difficult to burn so various conversion techniques have been developed. One of the oldest of these is briquetting, which has been used in Europe since the 19$^{th}$ century to make fuel from low-grade peat and brown coals.

Biomass densification can be regarded as an established technology and machines of a wide range in terms of technique, raw materials and capacity are available. The compaction of loose combustible material for fuel making purpose was a technique used by most civilizations in the past, though the methods were no more the simple bundling, bailing or dying. The use of briquetting for conversion of agricultural residue is comparatively recent, however, and has only been taken up in developing countries in the last ten years. The experience of briquetting agriculture residues has been mixed. Various technical problems have been encountered but the main difficulty has been the fact that in many places, briquetting are too high in cost to complete with existing wood fuel. How in some countries, a briquetting industry has begun to develop and find its market price.

Bioenergy technologiés help to protect the environment by making use of renewable plant material such as saw dust, rice trimming's, rice straw, alfalfa and switch grass, poultry litter and other animals wastes, industrial waste and the paper component of municipal solid waste. They are used today in a variety of processes, including the production of clean transportation fuels, electricity and chemicals.

Like most of the developing countries, biomass fuel has been considered as one of the major sources in Bangladesh. Recently survey shows that, around 66% of the primary energy are now being supplied through some form of biomass energy [1]. On the other hand oil imported has been increased to 35% in the last ten years [2]. Thus the unpredictable price and dwindling supply of fuel oil impose a serious limitation on the contest of socio-economic demand. However unplanned and crude use of biomass energy affected the ecology and environment. It aggravate deforestation, environment pollution and similar other problems. Specially, crude combustion of biomass residues have a huge amount of Nitrogen oxides in this context, using improved form of biomass residue and their efficient combustion is only potential solution. There are several techniques available to use biomass fuel properly. Briquetting, torification, gasification are some of the proper means of biomass energy utilization. Briquetting is a procedure of compacting residue into higher bulk density and regular shape. This eliminates the difficulties of using raw biomass foe domestic cooking and other industrial sectors become increasingly popular. There are several ways for producing briquettes. One of the popular methods is compacting biomass residue in a heated -die-screw type briquetting machine. Now a day more than 200 similar type of small briquetting plants are in operation in Bangladesh [3]. They are mostly centered in the north and south sides of the country since these areas are not including in the national natural gas network. However the technical as well as economical bases of plants are in private stage. This is because, the technology used for biomass briquetting machine manufacturing is not well developed in Bangladesh. Most of the plants are poor copy of imported machines, which are failed to meet the proper demand of biomass densification technique. As a result, the plant has higher energy consumption, low production and severe maintenance problem, which basically lead to lower turnover and ultimately leave the whole prospect - briquetting techniques in risk. In this study an experimental investigation has been conducted to evaluate the properties of different raw materials and their products from briquetting machine. Significant properties of the product from different mixture of raw materials with different compositions have also been determined. A screw press type briquetting machine with a heated die has been used for producing briquettes. An economic analysis of the system has also been performed.

## 2. PROPERTIES OF RAW MATERIALS AND PRODUCTS

### 2.1 Properties of Raw Materials

**Moisture Contents:**

There are two ways exist to report moisture content (MC) of biomass materials such as wet basis and dry basis. MC on wet basis is the amount of moisture in the biomass expressed as a percentage of total weight of wet biomass and dry basis is the amount of moisture expressed as percentage weight of moisture of free biomass. After measuring the stabilized mass, the sample is heated to reaches a constant mass, until the difference between two successive measurements is not more than 0%. Then sample is allowed to cost and weighted to determine its anhydrous mass.



**Bulk Density:**

It is the ratio of mass volume of the material. Bulk density depends on density of each fragment of materials. This mass is measured using a balance of weighting to an accuracy of 0.1% of the mass to be measured.

**Calorific Value:**

It is the quantity of heat released by complete combustion of a unit quantity of material. The method used is Bethlot - Mahler method. A known mass of materials the moisture content of which has been determined is burnt in the presence of oxygen at high pressure in a bomb calorimeter contained in a completely insulated receptacle. Since, operation is adiabatic; the temperature rise is directly proportional to the calorific value. Most calorimeter measures the higher calorific value (HCV) which is determined after complete condensation of water vapour contained in the combustion gas. The lower calorific value (LCV) which is applicable to actual condition is calculated from the HCV.

Table 1: Properties of Single Raw Material

| Name of the raw materials | Average moisture content (%) | Bulk density $kJ/m^3$ | Calorific Value kJ/kg |
|---|---|---|---|
| Rice husk | 11.97 | 127 | 15608 |
| Rice straw | 18.76 | 72 | 11823 |
| Saw dust | 12.67 | 140 | 15296 |
| Bagasse | 10.10 | 63 | 15430 |

Table 2: Properties of Mixture of Raw Materials

| Name of the mixture of raw materials | Composition | Average moisture content (%) | Bulk density $kJ/m^3$ | Calorific Value kJ/kg |
|---|---|---|---|---|
| Rice husk and rice straw | 70% rice husk and 30% rise straw | 13.73 | 99 | 13339 |
| | 60% rice husk and 40% rise straw | 14.06 | 98 | 13212 |
| | 50% rice husk and 50% rise straw | 14.89 | 97 | 13190 |
| Rice husk and saw dust | 70% rice husk and 30% saw dust | 12.09 | 134 | 15116 |
| | 60% rice husk and 40% saw dust | 12.14 | 135 | 15110 |
| | 50% rice husk and 50% saw dust | 12.19 | 136 | 15348 |

| | | | | |
|---|---|---|---|---|
| Rice husk and baggase | 70% rice husk and 30% bagasse | 11.29 | 95 | 15257 |
| | 60% rice husk and 40% bagasse | 11.18 | 92 | 15231 |
| | 50% rice husk and 50% bagasse | 11.01 | 84 | 15110 |

**2.2 Properties of Products**

**Moisture Content:**
Products cut with small pieces were taken and then the test was carried out in the similar manner described earlier.

**Calorific Value:**
Samples of products were at first powdered in mortar and then weighted. A sample of 1 gm. was taken each time. Then the previous method of determination of calorific value was followed.

**Ignitibility:**
It is the property of the product to easily ignitable in normal cooking stores. The low porosity, low volatile content and high ash content reduces the ignitibility. Different products are burnt in the cooking strove to see the ease of ignition.

**Stability:**
It is the property of briquette or the tendency to disintegrate on exposure to water.

Table 3: Properties of Single Product:

| Name of the raw materials | Current status | Average moisture content (%) | Compaction ratio | Calorific Value kJ/kg | Ignitibility | Stability |
|---|---|---|---|---|---|---|
| Rice husk | As found | 3.75 | 9.71 | 15984 | Good | Stable |
| Rice straw | Cut into small pieces | 6.77 | 13.81 | 13279 | Poor burns with lots of smoke | Less dropdown stability |
| Saw dust | As found | 4.31 | 6.42 | 17319 | Good | Stable |
| Bagasse | Dried and cut into small pieces | 6.58 | 12.96 | 15979 | Poorest | Highly friable and sensible to moisture |



Table 4: Properties of Products Composed of Different Mixture of Raw Materials

| Name of the mixture of raw materials | Composition | Average moisture content (%) | Compaction ratio | Calorific value kJ/kg |
|---|---|---|---|---|
| Rice husk and rice straw | 70% rice husk and 30% rise straw | 5.34 | 11.51 | 14701 |
| | 60% rice husk and 40% rise straw | 4.45 | 11.41 | 14586 |
| | 50% rice husk and 50% rise straw | 3.50 | 11.40 | 14291 |
| Rice husk and saw dust | 70% rice husk and 30% saw dust | 6.91 | 8.31 | 14675 |
| | 60% rice husk and 40% saw dust | 4.65 | 7.87 | 15980 |
| | 50% rice husk and 50% saw dust | 2.71 | 7.74 | 16325 |
| Rice husk and baggase | 70% rice husk and 30% bagasse | 6.15 | 11.06 | 15340 |
| | 60% rice husk and 40% bagasse | 5.65 | 11.06 | 15334 |
| | 50% rice husk and 50% bagasse | 3.16 | 11.66 | 15384 |

**2.3 Economic Analysis**

The economic analysis of the product (rice husk briquette) and the briquetting system have been done on the basis of one hour capacity of the briquetting machine and the present market price of the raw materials. All analysis is calculated in local currency Taka.
The total cost of one complete briquetting machine = Tk. 38000.00
Economic life of the machine = 10 years
Time required to produced 81 kg of briquettes = 1 hour
Raw materials required to produce 90 kg of briquettes = 100 kg
Raw materials cost per kg = Tk. 0.90
Finished products per kg = Tk. 2.15
Economic life of a screw = 77 hours (considering 25 days operation per month and 10 hours per day)
Production cost of screw = Tk. 600.00
Economic life of a die = 750 hours (considering 25 days operation per month and 10 hours per day)

Depreciation has been calculated with straight - line method when the salvage value of the machine considered as Tk. 2000.00 for its economic life 10 years

Power consumption for electric motor 12 kW, where the price per kWh electricity is Tk. 5.0

One labor can operate the machine when his daily labor cost is considered as Tk. 100.00

Land cost of the project = Tk. 25000.00 or Tk. 300.00 rent per month

Initial cost of the total project = Tk. 10000.00

Time value of money for the total project has bees calculated considering the basic interest formula when interest rate is considered as 10%.

Table 5: Total economic analysis of the study can be summarized in the following ways:

| Type of cost | | Amount ( Taka) |
|---|---|---|
| Fixed cost | 1. Machine cost | 1.27 |
| | 2. Land cost | 1.00 |
| | 3. Installation cost | 0.10 |
| Total fixed cost | | 2.37 |
| Variable cost | 1. Raw materials cost | 90.00 |
| | 2. Machine operating cost | |
| | a) Die changing cost | 0.80 |
| | b) Screw changing cost | 17.53 |
| | c) Labor cost | 10.00 |
| | 3. Power consumption cost + Fuel (briquette) cost | 63.90 |
| Total variable cost | | 182.23 |
| Machine depreciation cost | | 1.00 |
| Maintenance cost | | 1.00 |
| Total cost | | 186.6 |

Table 6: Profile Analysis:

| | |
|---|---|
| Sales price per 90 kg of briquette | Tk. 225.00 |
| Production cost per 90 kg of briquette | Tk. 186.60 |
| Net profit per hour | Tk. 38.40 |
| per day | Tk. 384.00 |
| per year ( 300 days in operation) | Tk. 115200.00 |

### 2.4 Pay Back Analysis

Investment: For machine = Tk. 38000.00
For land = Tk. 25000.00
For installation = Tk. 10000.00
Total investment = Tk. 73000.00
Pay back period = Total investment / (Net annual savings)
= 73000.00/115200.00 = 0.63 years = 8 months
2% factor of safety has been considered during calculation.



## 3. RESULTS AND DISCUSSION

In this study a couple of properties were measured. It is found that the moisture content of rice straw has the highest value and it is about 18.76%. The lowest was bagasse with 10.10%. It is also found that the moisture contents of rice husk and saw dust was to be moderate. In bulk density test, saw dust hold the highest value of 140 kg/m$^3$ which is good for transportation and storage. For calorific value test, it is found that rice husks posses the highest calorific value and it is about 15608 kJ/kg on the contrary rice straw has the lowest calorific value of 11823 kJ/kg. For the products, it is found that briquette, made of rice straw has the highest average moisture content of 6.77% and the lowest value is for rice husk. It is also found that calorific value of saw dust is the highest and it is about 17319 kJ/kg and the lowest is for rice straw of about 13279 kJ/kg. Ignitibility is also an important property and saw dust along with rice husk is found to process better ignitibility than the other two. From table it is found that the product moisture of 50% rice husk and 50% saw dust has the highest calorific value of 16325 kJ/kg which is comparable with that of fuel wood of 19700 kJ/kg. Also rice straw can be used as independent raw materials but the product quality is not good and also creates problem during feeding through screw, as a result the production rate is quite low, also it needs preprocessing before use. Blending of rice husk and rice straw is also done which also showed good quality of products but at some cost. Sawdust alone is difficult to densify due to high power consumption though it has a higher calorific value. Rice straw, bagasse and wheat straw needed preprocessing, as these were available in various sizes. During testing it was observed that the length between 0.75 cm to 1.25 cm of the above raw materials is suitable for briquetting making. For the purpose of sizing of raw materials, they were cut into small pieces. In a die heated electricity driven screw press type briquetting machine, the best product found on the basis of comparative analysis among all the products of the experiment is the 70% rice husks and saw dust with a calorific value of 14675 kJ/kg and with a production rate 72 kg/hr. Cost of product is 2.08 Tk. /kg.

All the products developed in this study fall within the cost range of Tk. 2.00 to Tk. 2.50. Where as, the traditional fuel woods have the market price of approximately Tk. 3.00. Briquetting process that is performed efficiently served to reduce pore volume of particles and particularly eliminates void volume between solid spaces. Also high moisture content in residues reduces the heating value.
When fuel is burnt, the net calorific value is always less than the gross calorific value because of some losses associated with vaporization of moisture coming from two sources: a) Inherent fuel moisture and b) water produced by burning hydrogen. In this study in each and every single case it is found that the net calorific value of raw materials increased after densification because the inherent moisture and volatile matters reduced due to the high pressure and temperature of the compaction process.

## 4. CONCLUSION

Considering all parameters rice husk is the most suitable raw materials for briquetting although sawdust shows good properties.

- Briquettes of plane rice husk have a high production rate of 81 kg/hr with a calorific value 15984 kJ/kg within the limit of the experiments performed throughout this study.

- Product from a blend of 70% rice husk and 30% sawdust is found the calorific value, which is 14675 kJ/kg. Its production cost is Tk. 2.08 per kg. This blend is found to be the best of all within the limit of experiment.

- The cost of production of briquette is comparatively less than that of fuel wood.

- The system is economically feasible as it was found that the payback period is 1.73 years.

## 5. ACKNOWLEDGEMENT

Authors acknowledge their profound gratitude to Swedish International Development Cooperation Agency (SIDA) for the financial assistant and also to Energy Program of AIT, Thailand for their technical assistant. Thanks are extended to Grameen Shakti for their kind cooperation and other activities.

## 7. REFERENCES

[1] Moral, N. A., Biomass Briquetting in Bangladesh, Project report submitted to SIDA, 1998

[2] Bhattacharya, S. C. and Shrestha, R. M., "Biocoal Technology and Economics", Regional Energy Resources Information Center, AIT, Bangkok, Thailand, 1990

[3] Ali, M. N., A final report on Pilot Project on Briquetting of Biomass fuel, December, 1998
Bangladesh statistical Pocketbook, 1999, CD-ROM Version, Published by Bureau of statistical, Bangladesh.

[4] Ali, M. N., Final Report on Development and Dissemination of improved Biomass Briquetting System and Briquetting stoves: Renewable Energy Technologies in Asia: A Regional Research and Dissemination program, Phase 11, submitted to AIT, Thailand, December 2001.

[5] Website: www.worldenergy.org/wec

[6] Website: www.shakti.hypermart.net.