Contents list available at IJRED website
Int. Journal of Renewable Energy Development (IJRED)
Journal homepage: http://ejournal.undip.ac.id/index.php/ijred

Development of Briquette from Coir Dust and Rice Husk Blend: An Alternative Energy Source

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ABSTRACT: Biomass is one of the predominant renewable energy sources and the use of biomass for the energy generation has got much attention due to its environmental friendliness. Densification of coir dust into fuel briquette can solve waste disposal problem as well as can serve as an alternative energy source. The objective of this study was to investigate the possibility of producing briquette from coir dust and rice husk blend without binder. During this study, a briquetting experiment was conducted with different coir dust and rice husk blends (i.e. coir dust and rice husk ratio of 80:20, 60:40, 50:50, 40:60, 20:80 and 0:100). Briquetting operation was performed using a die-screw press type briquetting machine. The briquettes were tested to evaluate their density, compressive strength, calorific value, burning rate and water vaporizing capacity and it was found that mixing ratio had a significant effect on the physical, mechanical and combustion properties of the coir dust-rice husk briquettes. Density, compressive strength and calorific value and water vaporizing capacity were increased with increasing mixing ratio while burning rate was decreased. Coir dust-rice husk briquettes with mixing ratio of 20:80 had higher density (1.413 g/cm^3), compressive strength (218.4 N/cm^2), calorific value (4879 kcal/kg), water vaporizing capacity (0.853 l/kg) and low burning rate (0.783 kg/hour) followed by the mixing ratio 40:60, 50:50, 60:40 and 0:100. The results indicate that coir dust and rice husk blend briquettes were found to have better overall handling characteristics over rice husk briquette. However, production of briquettes from coir dust and rice husk at mixing ratio of 50:50 was found to be more suitable for commercial application in terms of cost effectiveness.

Keywords: coconut coir pith, biomass briquette, briquetting process, calorific value, combustion

Article History: Received March 16, 2014; Received in revised form April 25, 2014; Accepted May 29, 2014; Available online

How to Cite This Article: Islam, M.H., Hossain, M.M. & Momin, M.A. (2014) Development of Briquette from Coir Dust and Rice Husk Blend: An Alternative Energy Source. *Int. Journal of Renewable Energy Development*, 3(2), 119-123.
http://dx.doi.org/10.14710/ijred.3.2.119-123

1. Introduction

Around 43,000 hectares are under coconut cultivation in Bangladesh, producing about 82,000 tons of coconut annually (FAO Stat 2012). Based on this resource many coconut oil mills and coir industries have been established. As a result, the coir industries, alone produce around 30,000 tons of coir dust per year as an unwanted by-product. Moreover, due to high moisture content, coir dusts used as a bio-compost feed is limited. Consequently, mostly it is dumped as a waste. In addition, the coir dust has a high lingo-cellulose content, which means it takes decades to decompose in natural environment. These slowly degrading coir dust piles mounting up and create an environmental hazard.

A number of researchers have shown the potential for making briquettes from agricultural wastes, such as rice husk (Grover & Mishra 1996), water hyacinths and cotton stalk (Köser *et al.* 1983), sawdust and wheat straw (Wamukonya & Jekins 1995), cotton stalk (Onaji & Siemons 1993), corn cob (Medhiyanon *et al.* 2006), waste paper and wheat straw (Demirbas & Sahin 1998), but research on briquetting coconut coir dust has yet to be reported. Though previous published research has reported that coir dust is rich in lignin (31.2%) and cellulose (40.6%) content, and has a high calorific value i.e. 4300 kcal/kg (Raveendran *et al.* 1995). Thus, the possibility exists to use this unwanted resource to make an alternative energy source (for cooking and heating),

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solve the coir industry's waste disposal problem and create an industry in both rural and urban areas.

The objective of this study was to investigate the feasibility of producing briquettes from coconut coir dust and rice husk blends without binder. Furthermore, the effect of mixing ratio on briquette properties i.e. density, compressive strength, calorific value and combustion characteristics were compared.

2. Materials and Methods

2.1 Raw materials collection

The coir dust used in this study was collected from a coir fibre mill situated in Jessore district of Bangladesh, while rice husk was collected from an auto rice mill situated in Mymensingh district of Bangladesh.

2.2 Sample preparation

The initial moisture content of the raw coir dust was about 71 % (dry basis). The coir dust was then sun dried for 7 days to reduce its moisture content to around 11% (dry basis). While moisture content of the rice husk was 10.3 % (dry basis). Moisture content was determined by oven drying method. Thereafter, coir dust and rice husk were thoroughly mixed at ratios of 0:100, 20:80, 40:60, 50:50, 60:40 and 80:20 and labelled throughout the manuscript as Control, A, B, C, D and E, respectively.

2.3 Briquetting operation

Briquetting operation was carried out using a die-screw press type briquetting machine previously used for rice husk briquetting. A schematic diagram of the die-screw press type briquetting machine is shown in Fig. 1. The screw used for briquetting the coir dust and rice husk blends is tapered in shape and rotates at a speed of about 450-480 rpm. Since the compression strength of the briquettes depends on the densification temperature, the temperature of the heated die was maintained in the range of 250 to 280 ^{0}C. This temperature is sufficient to fluidize the lignin present in the biomass and thus act as a binder. Briquettes obtained from this process were 60 mm in diameter with a central hole and carbonized outer surface (Fig. 2).

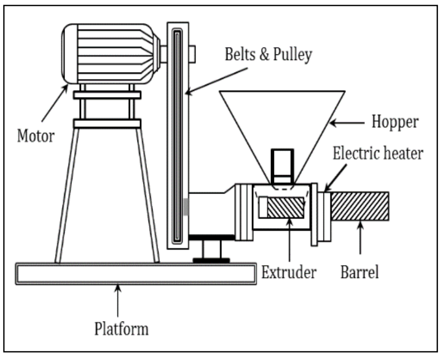

Fig. 1 Schematic diagram of a single extrusion die-screw press type briquetting machine

2.4 Determination of bulk density of briquettes

Density is an important parameter of biomass briquettes, since high density is desirable in terms of transportation, storage and handling (Demirbas & Sahin 1998). Five samples were prepared for each blend ratio to determine their average density values. Dimensions and weight of the samples were measured using a vernier callipers and a digital balance, respectively. The density of the briquettes was calculated using equation (1).

$$\rho = \frac{W}{(A_1 - A_2)L} \quad \textbf{(1)}$$

where:
ρ is density, g/cm^3
W is weight, g
A_1 is outer surface area, cm^2
A_2 is hole area, cm^2
L is length, cm

2.5 Determination of compressive strength

Compressive strength is the maximum crushing load a briquette can withstand before cracking or breaking. This parameter is used as an evaluation criterion for briquette durability (Richards 1990). Compressive strength of the produced briquettes was determined by diametrical compression (Kaliyan & Morey 2009). The compression test was performed using a universal testing machine. Five samples with different lengths from each blend were prepared for this measurement and the average value reported. The compressive strength of the briquettes was calculated using equation (2).

$$C = \frac{P}{A_1 - A_2} \quad \textbf{(2)}$$

where:
C is compressive strength, N/cm^2
P is applied load, N
A_1 is outer surface area, cm^2
A_2 is hole area, cm^2

Fig. 2 Coir dust and rice husk blend briquettes at mixing ratio of 50:50

2.6 Determination of calorific value

Calorific value is one of the most important characteristics of a fuel. This is the measurement of the heat or energy released by a fuel during the complete combustion and expressed as kcal/kg or MJ/kg. During this experiment, calorific value of produced briquettes was determined from Institute of Fuel Research and Development, Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka-1205, Bangladesh.

2.7 Determination of burning rate

This determines the rate at which a certain mass of fuel is combusted in air (Davis & Abolude 2013). For this test, 2 kg of briquettes from each blend were prepared. Samples were stacked in the hearth of different household stoves and stoves were ignited at the same time. This was continued for two hours. After that, amount of fuel unburnt was recorded. Time was recorded with stop watch. Burning rate was calculated from the equation (3).

$$B_R = \frac{Q_1 - Q_2}{T} \tag{3}$$

where:
B_R is burning rate, kg/min
T is total burning time, hour
Q_1 is initial weight of fuel prior to cooking, kg
Q_2 is final weight of fuel after cooking, kg

2.8 Determination of water vaporizing capacity

This a measure of how much water vaporized with a specific amount of fuel during combustion. During this test, 3 kg of briquettes from each blend were prepared and were stacked in the hearth of different household stoves. Aluminium pots containing 3 litres (l) of water were mounted on each stove. Then stoves were ignited at the same time and continued until briquettes burnt completely. After that volume of water evaporated from each pot was measured. Water vaporizing capacity (WVC) was calculated using equation (4).

$$WVC = \frac{V_1 - V_2}{W} \tag{4}$$

where:
WVC is water vaporizing capacity, l/kg
W is weight of fuel, kg
V_1 is initial volume of water prior to cooking, l
V_2 is final volume of water after cooking, l

3. Result and Discussion

3.1 Briquettes

During briquetting operation it was found that no briquette was produced from the coir dust and rice husk mixing ratio of 80:20. Though briquette was achieved from the mixing ratio of 60:40, it was broken into small pieces after extruding through the barrel. However, very good shaped briquettes were obtained from the mixing ratio of 50:50, 40:60 and 20:80. Briquette produced from coir dust and rice husk mixing ratio of 50:50 is shown in Fig. 2.

3.2 Density of the briquettes

Average density of all briquettes obtained from different coir dust and rice husk mixing ratio is illustrated in Fig. 3. It was apparent that density was varied from 1.235 to 1.413 g/cm^3. The result indicates that briquette A had higher value of density followed by briquette B, C, control and D. From the Fig. 3, it is observed that the density of the briquette A (1.413±0.033 g/cm^3), B (1.384±0.031 g/cm^3) and C (1.336±0.028 g/cm^3) were higher than control samples (1.273±0.032 g/cm^3), while density of the briquette D (1.24±0.035 g/cm^3) was lower than the control sample.

Because of bulk density of coir dust is lower than rice husk, after briquetting coir dust-rice husk blend becomes more compact than rice husk briquettes. The possible reason is higher lignin content in coir dust. Another consideration to be that lignin contain in rice husk (14.3 %) and coir dust (31.2 %) melted during briquetting and act as a binder. So briquettes produced from coir dust and rice husk blend became more compact and resulted in high density products.

3.3 Compressive strength

Average compressive strength of briquettes obtained from different coir dust and rice husk mixing ratio is presented in Fig. 4. Compressive strength was varied from 129.3 to 218.4 N/cm^2. The result indicates that briquette A had higher value of compressive strength followed by briquette B, C, control and D. From the Fig. 4, it is apparent that the compressive strength of the briquette A (218.4 ±10.5 N/cm^2), B (193.6±11.3 N/cm^2) and C (178.3±8.8 N/cm^2) were higher than control sample (143.6±10.7 N/cm^2), while, the compressive strength of briquette D (130±9.5 N/cm^2) was lower than control sample. Material with higher density was more likely to possess higher compressive strength than that with lower density. It was also found from the figure that compressive strength increased with increasing rice husk contents but lower in rice husk briquette.

3.4 Calorific value

The initial calorific value of coir dust and rice husk was determined to calculate the change in the heating efficiency after briquetting. Initial calorific value of coir dust and rice husk was found 4120 kcal/kg and 3040 kcal/kg respectively. The calorific value of briquettes produced from different coir dust and rice husk blends are shown in Fig. 5. Calorific value was varied from 3757 to 4879 kcal/kg. The result indicates that briquette A had higher calorific value followed by briquette B, C, D and control sample. From the Fig. 5, it is apparent that the

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calorific value of the briquette D (4252 kcal/kg), C (4433 kcal/kg), B (4621 kcal/kg) and A (4879 kcal/kg) was higher than control (3757 kcal/kg) briquette. This indicates that the calorific value of the briquette depends on the calorific value of raw material and the density of the briquette. According to Demirbas (1999), the high density briquettes, should have higher energy-volume ratio.

3.5 Burning rates

The burning rate of the sampled briquettes was determined in open air. The effect of mixing ratio on burning rate was studied. Burning rate of briquettes obtained from different coir dust and rice husk mixing ratio is presented in Fig. 6. Burning rate was varied from 0.789 to 0.945 kg/hour. The result indicates that briquette A had lower combustion rate followed by briquette B, C, D and control. From the Fig. 6, it is apparent that combustion rate of the briquette D (0.917±0.033 kg/hour), C (0.853±0.027 kg/hour), B (0.812±0.029 kg/hour) and A (0.789±0.031 kg/hour) were higher than control (0.945±0.03 kg/hour) briquette. For the same amount of briquettes, briquette D, C, B and A took 2.45 %, 9.26%, 13.62% and 16.06% higher time to burn completely over control briquette respectively. A slow burning rate is desirable because less fuel is required for cooking (Davies & Abolude 2013).

3.6 Water vaporizing capacity

Water vaporizing capacity of briquettes obtained from different coir dust and rice husk mixing ratio is illustrated in Fig. 7. Water vaporizing capacity was varied from 0.663 to 0.853 l/kg. The result indicates that briquette A had higher water vaporizing capacity for a specific weight of briquettes followed by briquette B, C, D and control. From the Fig. 6, it was apparent that water vaporizing capacity of the briquette D (0.725±0.032 l/kg), C (0.785±0.025 l/kg), B (0.816±0.023 l/kg) and A (0.853±0.026 l/kg) were higher than control (0.663±0.022 l/kg) briquette. For the same amount of briquettes, briquette D, C, B and A can vaporized 10.11%, 18.35%, 22.92% and 28.65% higher volume of water over control briquette respectively. The possible reason is the variation in burning rate.

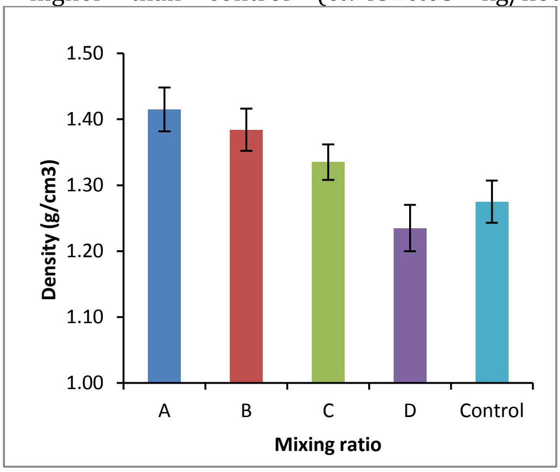

Fig. 3 Density of different coir dust and rice husk blend briquettes at various mixing ratio

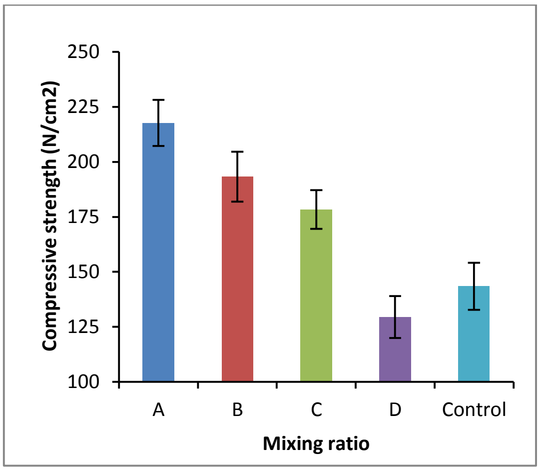

Fig. 4 Compressive strength of different coir dust and rice husk blend briquettes at various mixing ratio

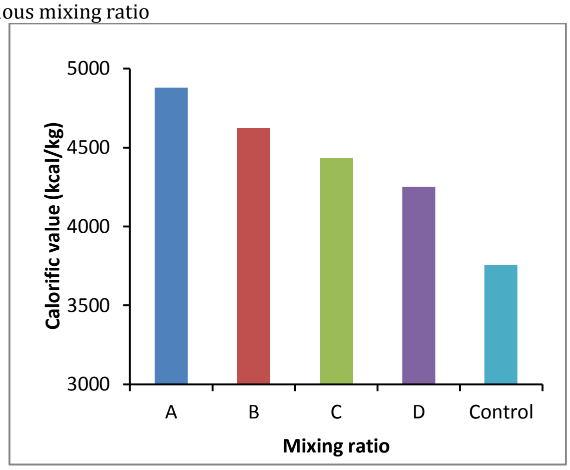

Fig. 5 Calorific value of different coir dust and rice husk blend briquettes at various mixing ratio

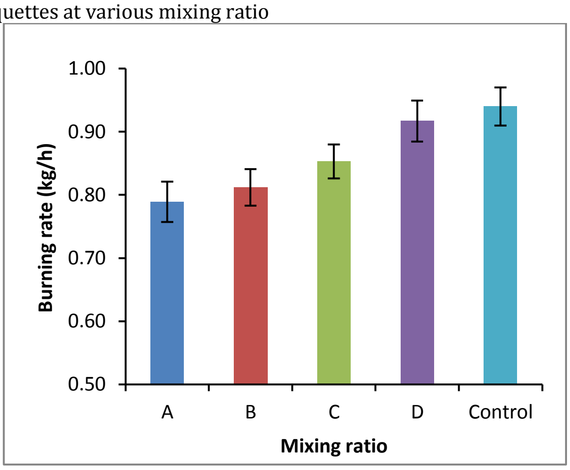

Fig. 6 Burning rate of different coir dust and rice husk blend briquettes at various mixing ratio

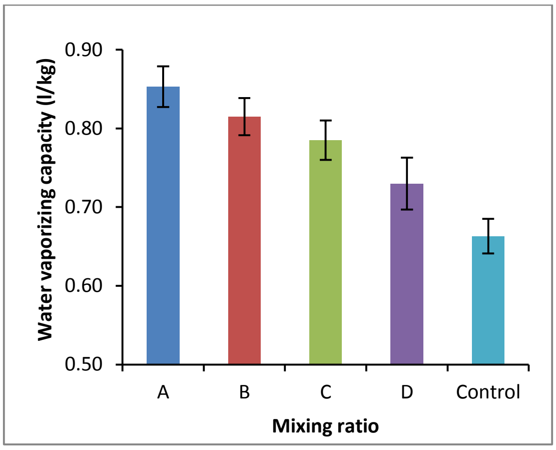

Fig. 7 Water vaporizing capacity of different coir dust and rice husk blend briquettes at various mixing ratio

4. Conclusions

In this study, the potential of producing briquette from coir dust and rice husk blend has been demonstrated. Coir dust and rice husk mixing ratio of 80:20, 60:40, 50:50, 40:60, 20:80 and 0:100 were used to produce briquette. Effect of mixing ratio on density, compressive strength, calorific value, burning rate and water vaporizing capacity was reported. The results indicate that briquettes from coir dust and mixing ratio of 50:50, 40:60 and 20:80 are superior to the rice husk briquettes in terms of density, compressive strength, calorific value, burning rate and water vaporizing capacity. Briquette produced from the mixing ratio of 20:80 has greater calorific value, compressive strength and slower burning rate hence it is more suitable for briquetting. In addition, briquette produced from the mixing ratio of 50:50 and 40:60 also have higher calorific value, compressive strength and slower burning rate over rice husk. Since the price of rice husk is higher in Bangladesh, production of briquette using coir dust and rice husk mixing ratio of 50:50 is most suitable for commercial scale.

Acknowledgements

The authors express their sincere gratitude to Professor Garry Piller, Graduate School of Agriculture, Kyoto University for proof reading of this manuscript.

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