Analysis of Non woody Biomass Briquetted Fuel

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Abstract

This paper deals with analysis of non woody biomass briquetted fuel made from grass, mango leaves, cashew leaves, rice husk, rice bran, cow dung and waste flour. The ten combination with different proportion of raw biomass grass, mango leaves, cashew leaves, rice husk, rice bran, dry cow dung and waste flour T1(42:0:0:8:20:20:10), T2(0:42:0:8 :20:20:10),T3(0:0:42:8:20:20:10),T4(28:14:0:8:20: 20:10),T5(28:0:14:8:20:20:10),T6(0:28:14:8:20:20: 10),T7(14:28:0:8:20:20:10),T8(0:14:28:8:20:20:10) ,T9(14:0:28:8:20:20:10), T10(14:14:14:8:20:20:10) were used during the study. The moisture content of dried briquetted fuel was found to be in the range of 6.87 to 9.20 per cent. Volatile matter varied from 71.13 to 77.4 per cent, Ash content of mixed raw biomass varied from 7.73 to 9.95 per cent and average fixed carbon was varied from 6.93 to 11.59 per cent. It was observed that the maximum higher calorific value (HCV) of (4339.2 kcal kg^{-1}) found in T3 (0:0:42:8:20:20:10) combination. The maximum average shatter resistance and tumbling resistance was 85.19 percent and 99.35 percent respectively in T3 combination. Average density of briquettes and degree of densification was found to be 254 kg m^{-3} and 23.84 per cent respectively. Also average energy density ratio was found to be 1.37.

Keyword: Non woody biomass, HCV, shatter resistance, briquetted fuel.

Introduction

Biomass is renewable organic matter derived from trees, plants, crops or from human, animal, municipal and industrial wastes. Biomass can be classified into two types, woody and non-woody. Woody biomass is derived from forests, plantations and forestry residues. Non-woody biomass comprises agricultural and agro industrial residues and animal, municipal and industrial wastes. A major disadvantage of agricultural residue as a fuel is its low bulk density, which makes it difficult handling, transport and storageand is also expensive. (Kumar and Patel 2008)

The technology of briquetting is defined as the densification process for improving the biomass fuel characteristics. The important properties of briquettes which affect the fuel quality are their physical and chemical attributes. Briquetting process is one of the promising technologies, which has been investigated by several researchers (Birwatkar 2014).

Nowadays, briquetting technology plays an important role in the utilization of agro-wastes for higher calorific value and high-energy utilization. In this study, a briquetting process will be aimed to investigate production of an alternate eco-friendly fuel from locally available non woody biomass namely as mango leaves, cashew leaves, rice husk and grass.

Material and Methods

Materials including locally available dry grass, dry mango leaves, dry cashew leaves, rice husk, rice bran, dry dung were manually collected from university experimental plots, in Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli and waste flour was collected from local flourmills.

Preparations of briquettes

Selected biomass mango leaves, cashew leaves and

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Table 1. Different Treatments (mixture of raw materials and binder) for production of briquettes in different proportions.

Treatment	Dry grass	Dry mango leaves (powder)	Dry cashew leaves (powder)	Rice husk	Rice bran	Cow dung	Binder (waste flour)
T_1	42	0	0	8	20	20	10
T_2	0	42	0	8	20	20	10
T_3	0	0	42	8	20	20	10
T_4	28	14	0	8	20	20	10
T_5	28	0	14	8	20	20	10
T_6	0	28	14	8	20	20	10
T_7	14	28	0	8	20	20	10
T8	0	14	28	8	20	20	10
T_9	14	0	28	8	20	20	10
T_{10}	14	14	14	8	20	20	10

grass was converted into powder form by using shredder having of capacity of 5 kg and was sieved through a 2 mm size sieve to get the desired size of raw material. Briquettes were prepared by using newly developed manually operated briquetting machine for non woody biomass with addition of water, cow dung and flour as binder in each selected biomass sample. The different combination of briquettes was prepared as per Table 1.

Proximate Analysis

Moisture Content

The moisture content of biomass was measured by oven dry method. Initially the sample with the known weight was kept in oven at ± 105ºC till the constant weight. Then the oven dry sample was weighed (ASTM D-3173). The moisture content of sample was calculated by following formula.

$$\text{Moisture content (\% wb)} = \frac{w_2 - w_1}{w_2 - w_1} \times 100 \quad \ldots\ldots(1)$$

Where,

W1 = weight of crucible, (g)

W2 = weight of crucible + sample, (g)

W3 = weight of crucible + sample, after heating, (g)

Volatile Matter

The dried sample left in the crucible was covered with a lid and placed in muffle furnace, maintained at 950 ± 20 ºC for 7 minutes (ASTM D-3175). The crucible was cooled first in air, then inside desiccators and weighed again. Loss in weight was reported as volatile matter on percentage basis.

$$\text{Volatile Matter (\%)} \frac{w_3 - w_4}{w_2 - w_1} \times 100 \quad \ldots\ldots\ldots\ldots(2)$$

Where,

W1= weight of empty crucible, (g)

W2 = weight of crucible + sample taken, (g)

W3= weight of crucible + sample in muffle furnace, (g)

W4 = weight of crucible + sample after heating, (g)

Ash content

The residual sample in the crucible was heated without lid in a muffle furnace at 700ºC ± 50ºC for 90 minutes (ASTM D- 3174). The crucible was then taken out, cool initially in air, then in desiccator and weighed. Heating, cooling and weighing was repeated, till a constant weight was obtained. The residue was reported as ash on percentage basis.

$$\text{Ash content (\%)} = \frac{w_5 - w_1}{w_2 - w_1} \times 100 \quad \ldots\ldots\ldots(3)$$

Where,

W1= weight of empty crucible, (g)

W2 = weight of crucible + sample taken, (g)

W5 = weight of crucible + ash, (g)

Fixed Carbon

The fixed carbon content was calculated by applying the mass balance for the biomass sample.

Fixed Carbon (%) = 100 - % of (MC + VM +C)…..... (4)

Where,

FC= Fixed carbon, (%)

MC= Moisture content, (%)

VM= Volatile matter, (%)

AC= Ash content, (%)

Calorific Value

The higher heating value of material was determined by using of bomb calorimeter (ASTME-711), where the combustion was carried out in environment with 25 atmospheric pressure of oxygen to ensure complete combustion. Water equivalent of the apparatus was determined by burning a known weight (1.0gm.) of pure and dry benzoic acid in powdered form in the bomb under identical condition. The rise in temperature was noted for 5 minute. The standard calorific value of benzoic acid was taken as 6324 cal g^{-1}, since all other values in the formula were known. So water equivalent was calculated. The higher calorific value of solid fuel using the bomb calorimeter experiment was determined as,

$$\text{Caloric Value}(\text{K cal kg}^{-1}) = \frac{(w - w) \times (T_2 - T_1)}{x} \times 100 \; \ldots\ldots (5)$$

Where,

W = Mass of water placed in the calorimeter (g)

w = Water equivalent of the apparatus (g)

T1 = Initial temperature of water in the calorimeter (˚C)

T2 = Final temperature of water in the calorimeter (˚C)

X = Mass of fuel sample taken in the crucible (g)

True density of briquetted fuel

Water displacement method was used to measure the volume of individual briquette. The briquettes were coated with wax, in order to prevent any water absorption during merging process. Each briquette was weighed and then coated with wax. The wax coated briquettes were weighed and then submerged into water in suspension position and weight of displaced water was measured and recorded as the volume of the wax briquettes. The volume of each briquette was calculated by subtracting the volume of coating wax from the volume of wax briquettes. The volume of coating wax was obtained by dividing its weight of the wax obtained by subtracting original weight of briquette from the weight of wax briquette by its volume. (Tayade 2009)

Bulk density

The bulk density of material was determined as per the standard procedure. A cylindrically shaped container of fixed volume was used for determination. The container was weighed empty to determine its weight and then it was filled with the sample, after completely filling the container, excess material at the top was removed by moving a straight edge over the container and weighed once again. The bulk density was determined by dividing the mass of the material by the volume of the container. The bulk density was calculated by using the formula.

$$\text{Bulk density (kg m}^{-3}) = \frac{\text{Mass of biomass sample}}{\text{volume of vessel}} \ldots\ldots\ldots..(6)$$

Shatter indices

These tests were used for determining the hardness of the briquettes. The briquette of known weight and length was dropped from the height of one meter on RCC floor for ten times. The weight of disintegrated briquette and its size was noted. The percent loss of material was calculated. The shatter indices of the briquette was calculated by using equation (Madhava et al., 2012).

$$\text{Percent weight loss} = \frac{w_2 - w_1}{w_1} \times 100 \ldots\ldots\ldots (7)$$

Shatter resistance (%) = 100- % weight loss

Where,

W_1= Weight of briquette before shattering, g

W_2= Weight of briquette after shattering, g

Tumbling resistance

It is used for testing the durability of briquetted fuel during handling. The test was measured for the tumbling loss of weight of single briquettes subjected to tumbling action for 5min. Each briquette subjected to tumbling action. Each briquette was weighed and placed in 100mmID cylinder and rotation speed was fixed to 50 rpm. Then weight loss in the briquettes was noted and the tumbling resistance was calculated by using equation (Khobragade 2015).

$$\text{Weight loss (\%)} = \frac{w_2 - w_1}{w_1} \times 100 \quad \ldots\ldots\ldots (8)$$

Tumbling resistance = 100 - % weight loss

Where,

W_1= Weight of briquette before tumbling, g

W_2= Weight of briquette after tumbling, g

Resistance to Water Penetration

It is measure of percentage water absorbed by a briquette when immersed in water, each briquette was immersed in 25 mm of water at room temperature for 30 seconds. The percent water gained and resistance to water penetration was calculated by using following equation,

$$\text{Water gained by briquette} = \frac{w_2 - w_1}{w_1} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots (9)$$

Percent resistance to water penetration = 100 – water gain

Where,

W_1= Initial weight of briquette, g

W_2= Final weight of briquette, g

Degree of Densification

Degree of densification represents ability of material to get bounded. It was calculated and recorded by using equation, as below

$$\text{Degree of densification} = \frac{\text{Density of briquette} - \text{Density of raw material}}{\text{Density of raw material}} \ldots (10)$$

Energy Density Ratio

The energy density ratio of briquetted fuel was calculated by using equation, as below

$$\text{Energy Density Ratio} = \frac{\text{energy content of briquetted fuel (K cal kg}^{-1}\text{)}}{\text{Energy content of raw biomass}} \ldots (11)$$

Results and Disscuion

Proximate analysis

The proximate analysis of ten different combinations of briquetted fuel was determined and the results obtained are as shown in Figure1.

From Table 2, it was observed that the moisture content of dried briquetted fuel was found to be in the range of

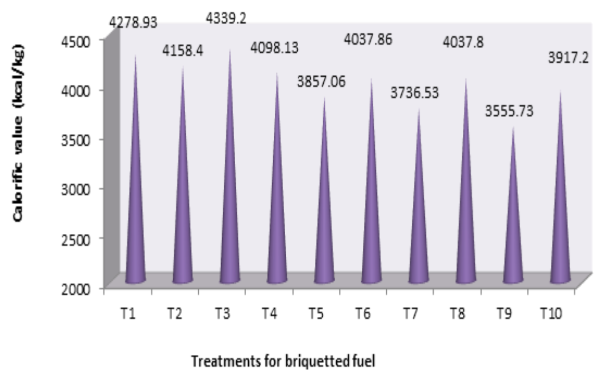

Figure 1. Proximate analysis of briquetted fuel

Table 2. Proximate analysis of briquette fuel

Sr. no.	Treatments	Average moisture content	Average volatile matter	Aver-age ash content	Average fixed carbon
1	(42:0:0:8:20:20:10)	7.59	77.4	9.17	5.86
2	(0:42:0:8:20:20:10)	7.60	70.94	8.20	13.60
3	(0:0:42:8:20:20:10)	6.87	70.87	10.00	12.26
4	(28:14:0:8:20:20:10)	7.78	74.87	9.23	8.12
5	(28:0:14:8:20:20:10)	9.20	74.53	8.00	8.27
6	(0:28:14:8:20:20:10)	7.71	73.47	9.40	9.40
7	(14:28:0:8:20:20:10)	8.78	74.40	8.73	8.09
8	(0:14:28:8:20:20:10)	8.31	77.67	7.90	6.12
9	(14:0:28:8:20:20:10)	9.00	74.53	8.00	8.47
10	(14:14:14:8:20:20:10)	8.40	75.93	8.07	7.60

6.87 to 9.20 per cent. The lower amount of moisture might be due to removal of moisture from biomass due to compression during briquetting process. The values for volatile matter, fixed carbon and ash content were almost same as that of original raw biomass. The small change observed was due to non homogeneous mix of raw biomass.

Calorific value of briquetted fuel

The maximum higher calorific value of briquetted fuel was found 4339 k cal kg^{-1} in T3 combination. The minimum calorific value was found 3555.7 k cal kg^{-1} in T9 combination. This was due to percentage of fixed carbon content, which is main contributor to HCV. The results obtained are as shown in Figure 2.

Bulk density of briquetted fuel

It was observed that bulk density was considerably increased from 185 to 321 kg m^{-3} compared to mixed raw material (139-266 kg m^{-3}), selected non woody biomass (85-315 kg m^{-3}) as shown in Figure 3.

True density of briquetted fuel

True density varied from 0.619 g cc^{-1} to1.32 g cc^{-1} because of different particle size of raw material for briquetting as shown in Figure 4.

Shatter resistance of briquetted fuel

The maximum average shatter resistance was found to be 85.19 percent in T3. Similarly, the minimum shatter index was found to be 16.83 per cent in T1 as shown in Figure 5. High shatter index showed the briquette had high shock and impact resistance.

Tumbler Test

Tumbler test was carried out for checking the durability index of the briquetted fuel.It was observed that tumbling resistance was maximum in T3 combination (99.35%) and minimum in T1 combination (93.31%) as shown in Figure 6 and it was also observed that because of higher percentage of powdered cashew leaves which has more tumbling resistance, the briquettes with higher percentage shredded grass showed lowest tumbler resistance.

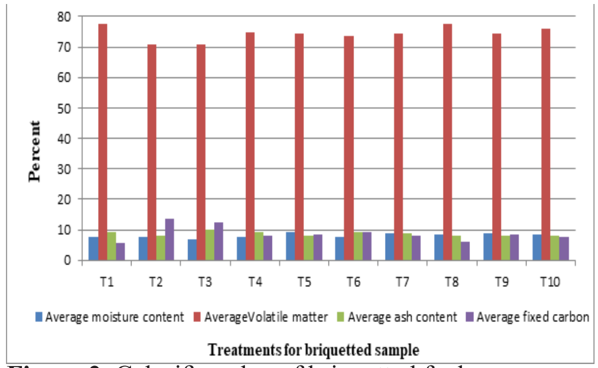

Figure 2. Calorific value of briquetted fuel

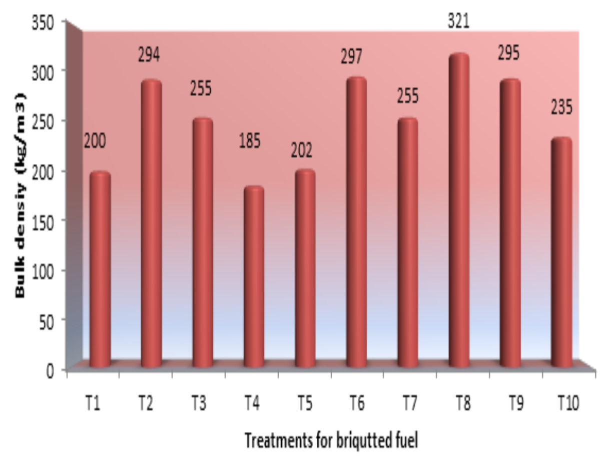

Figure 3. Average bulk density of briquetted fuel

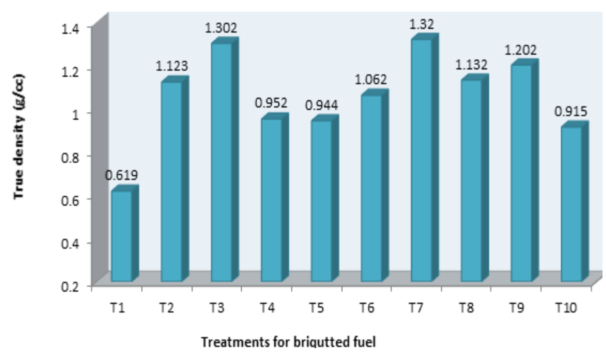

Figure 4. True density of briquetted fuel

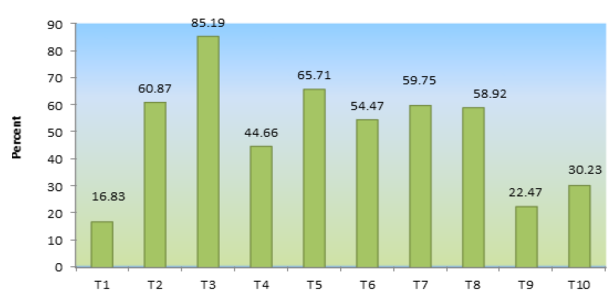

Figure 5. Shatter resistance of briquetted fuel

Resistance to water penetration

Observations are as shown in Figure 7. Maximum resistance to water penetration observed in combination T8, because of its less porosity and high density. It was due to higher percentage of powdered leaves. Least resistance to water penetration was observed for combination T1 briquettes having resistance to water penetration of 40.98. The briquette formed using higher percentage of grass was porous and non-homogeneous, which allowed water penetration. It indicates that T8 was suitable for storage.

Degree of densification

Degree of densification represents per cent increase in density of biomass due to briquetting was calculated and presented in Figure 8. The maximum degree of densification was found to be 43.88 per cent in T1 and the lowest degree of densification was found to be 11.84 in T3. It indicated that during briquetting the material with higher amount biomass in form of leaves could not be compressed as compared to biomass containing more grass.

Energy density ratio of briquettes

The energy density ratio of ten combinations is presented in Figure 9. It was observed that the energy density ratio of ten combination briquettes varied from 1.26 to 1.67.

Conclusions

The best treatment found was treatment T3 (0:0:42:8:20:20:20:10) having maximum calorific value bulk density, shatter resistance, tumbling resistance as 4339.2 k cal kg^{-1}, 255 kg m^{-3}, 85.19 percent, 99.35 percent respectively (42%), rise husk (8%), rice bran (20%), cow dung (20%), flour (10%). But major locally available biomass i.e. grass and mango leaves were not included in the treatment.

Among all treatments T10 (14:14:14:8:20:20:10) which comprises all selected non woody biomass as grass (14%), mango leaves (14%), cashew leaves (14%), rice husk (8%), rice bran (20%), flour (10%) having bulk density was 235 kg/m3, calorific value was 3917.2 kcal/kg, shatter resistance was 22.47 per cent, tumbling

Figure 6. Tumbling resistance of briquetted fuel

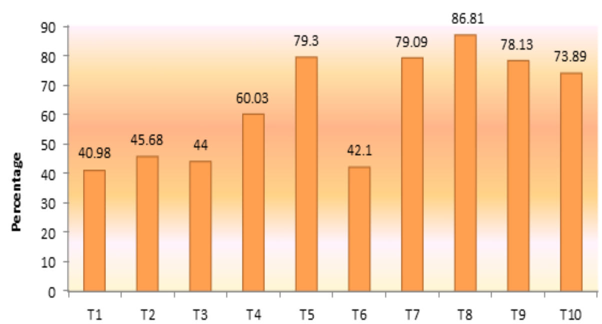

Figure 7. Resistance to water penetration of briquetted fuel

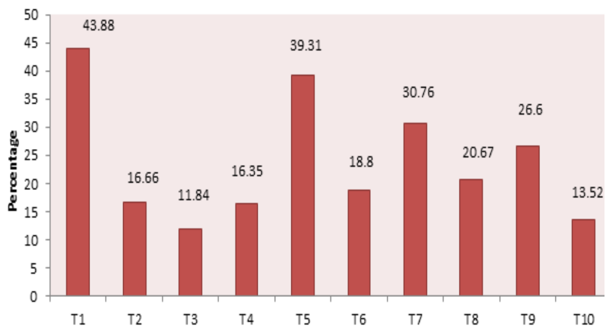

Figure 8. Degree of densification for briquetted fuel

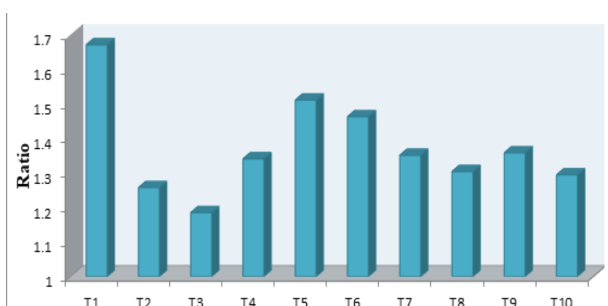

Figure 9. Energy density ratio of briquetted fuel

resistance 94.91 per cent which was less than best treatments.

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