Development of a Biomass Briquetting Machine Suited to Rural Communities

Debasish Padhee[1,a], Jageshwar Komra[2], Roopnarayan Patel[3] and Divyanand Verma[4]

[1]Assistant Professor, BRSM College of Agricultural Engineering &Technology and Research Station, Indira Gandhi Agricultural University, Mungeli (C.G.), India
[2,3,4]UG Students, Faculty of Agricultural Engineering, Indira Gandhi Agricultural University, Raipur (C.G.), India

Abstract

In this study an appropriate commercial biomass briquetting machine suitable for use in rural community was fabricated. The performance of the developed machine was evaluated using sawdust and cow dung as raw material for briquetting. The properties like compressed density, shattering resistance, water resistance and water boiling test of the developed briquettes were determined at two biomass binder (sawdust : cowdung) ratios of 25:75 and 50:50 using cow dung as the biomass cum binding agent. Results of the study showed that both the physical and combustion properties of the briquettes were significantly affected by the binder level. The study indicated that briquettes having more cow dung content i.e. 25:75 mixture briquettes gave better results for compressed density, shattering indices test and resistance to water penetration as compared to 50:50 mixture briquettes. In case of calorific value and water boiling test, 50:50 mixture briquettes performed better compared to 25:75 mixture briquettes. The study concluded that briquettes produced from mixture of saw dust and cow dust at different proportion could be serve as alternative source of energy for domestic cooking.

Keywords: *Briquetting Machine, Saw Dust, Cow Dung, Shattering Resistance, Compressed Density*

Introduction

Environmental pollutions, present energy crisis, and unavoidable oil depletion are some of the major aspirations for research and development in the work for alternative fuels. During the past decade, interest in biomass came back on international stage since it is the most trusted alternative to fossil fuels and it is increasingly used as it is considered carbon neutral, since the carbon dioxide released is already part of the carbon cycle. Biomass being

[a] Author to whom correspondence should be addressed. Electronic mail: itsmedebu@gmail.com, Tel.: +91-9754431936. Assistant Professor at BRSM CAET&RS, IGKV Mungeli.

the third largest primary energy sources in the world, after coal and oil [1], it still meets a major fraction of the energy demand in rural areas of most developing countries. In India, well-recognized as one of the first rank exporters of agricultural and food products, biomass has been the traditional energy source, especially in rural areas for decades.

Biomass in its natural form is bulky, loose, and dispersed. Hence, they are difficult to handle during utilization and do not present economical and efficient transportation and storage characteristics due to low bulk density of bales (40-200 kg/m^3) and large volume requirements [2,3,4]. Despite the difficulties of handling, storage, and transportation, the direct combustion of loose biomass in conventional chulas is associated with very low thermal efficiency. The conversion efficiencies are as low as 40% with widespread of air pollution in the form of very fine particulate matters [5,6,7]. There are many conversion processes through which these residues can be converted into biomass energy, out of which, briquetting is one of the promising technologies, which has been investigated by several researchers [8,9,10,11,12].

In this study, an attempt was made to design and develop a low cost, small capacity, low pressure, manually operated briquetting machine which can uplift the rural economy.

1. Experimental

1.1 Overview of the developed machine

The briquetting machine fabricated is the isometric view of the briquetting machine. The main functional parts of the manual briquetting machines produced are the main frame, the compaction chamber and base plate.

2.1.1 The Main Frame with hydraulic jack

The main frame houses and support the other parts of the machine. The main frame was made from mild steel angular iron bars. The hydraulic jack rests on angle bars welded to the frame of the machine. By this arrangement, the force from the hydraulic jack is centrally applied to the metal plate bearing the pistons. The complete view of the developed machine was shown in Figure 1.

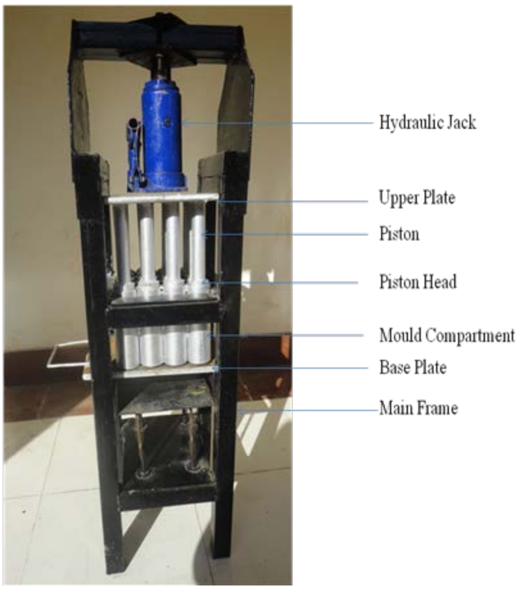

Fig. 1. Developed biomass briquetting machine

2.1.2 The Compaction Chamber

The compaction chamber was made with 16 nos. of mild steel vertical cylinders of 43 mm diameter and 150 mm height. The cylinders were welded with each other. Figure 2 shows the compaction chamber of briquetting machine half filled with biomass mixture.

Fig. 2. Compaction chamber of briquetting machine

2.1.3 *Piston and Base Plate*

The base plate (10 mm thickness) of the machine is made from mild steel and is housed within the frame of the machine just beneath the compaction chamber. 16 pressure transmitting mild steel rods are welded to the piston plate of 10 mm thickness assembly of the machine, and these rods go into holes rods made at the base of the machine to support the ejection piston. The pistons were made such that there was a clearance of about 1mm between the piston head and the mould walls of cylinder to allow the escape of water during compaction. The piston assembly of the developed briquetting machine was shown in Figure 3.

Fig. 3. Piston assembly

2.2 Briquettes Production Procedure

2.2.1 Preparation of biomass-binder mixture

In this study, two different ratios of briquetting biomass of saw dust and cow dung is used. Sawdust sample was mixed with the already prepared cow dung slurry in proportions of 50:50 and 25:75 by weight respectively in line with the works of. The slurry and the biomass sample were well mixed without forming a muddy mixture because the formation of muddy mixture due to excess addition of water reduces both the durability and density of the briquette. The biomass-binder mixture was hand fed into the mould and compacted to form the briquettes after which they were sun dried to constant weight. A dwell time of 20 minutes was observed during the production of the briquette.

2.3 Working of the machine

Firstly set the flat plate into machine frame below the cylinder for providing support to the briquetting material mixture during compaction process. For the purpose of study, sawdust was used for the performance evaluation of the machine. The sawdust sample was collected from a saw mill in Mungeli. Cow dung was procured from a local village and used as a binding agent mainly to overcome the major problem of material compaction post-compaction recovery-which represents enormous waste in energy input. The sawdust (other agro waste can be used) granules was mixed with slurry binder and feed into the cylinder dies and rammed until they are full. Then the piston assembled plate was put in the cylinder die.

The eight tonnes (8 ton) hydraulic jack which was fitted above the cylinder was used to press the piston assembly carrying the transmission rods, which then pushes the piston against the mixture inside the various dies of the compaction cylinder. The vertical motion of the pistons in and out of the moulds, and the ejection of compressed briquettes from the moulds were affected through the manual operation of the hydraulic jack. The mix is thus compacted against the flat plate of the machine, and the force required in making briquettes was measured using spring balance attached to hydraulic jack is recorded. The mix was then down to set for about two minutes after which the flat plate of the machine is removed then another flat plat is set above the spring plate for supporting & balancing the produced briquette material. The briquettes were then ejected. Fresh briquettes produced from the briquetting machine prior to drying were shown in Figure 4.

Fig. 4. Briquettes obtained from the briquetting machine

2.4 Drying

The briquettes were placed in trays and kept for drying under the sun for two days.

2.5 Physical properties of the developed briquettes

The ingredients for briquette formation viz. biomass materials vary widely in their physical characteristics which affects their briquetting properties. So the properties like compressed density, moisture content, shattering resistance and resistance to water penetration were determined.

2.5.1 Compressed Density:

Two briquettes were randomly selected from each production batch for evaluation of physical properties. The mean compressed densities of the briquettes were determined immediately after removal from the mould as a ratio of measured weight to calculated volume.

The weights of produced briquettes were determined using digital weighing balance, the diameters and heights of the briquettes were taken directly by measuring with scale. The volume of the cylindrical shaped briquette was then determined. The density was then determined for each briquettes at different binder level as a ratio of briquette weight to volume.

$$\textit{Compressed density} = \frac{\textit{weight of briquettes}}{\textit{volume of briquettes}}$$

2.5.2 Shattering index

The durability of briquettes was determined in accordance with the shattering index [13]. This involves the dropping of briquettes samples repeatedly from a specific height of 1.5 m onto the solid base. The fraction of the briquettes retained was used as an index of briquette breakability. The percentage weight loss of briquettes was expressed as a percentage of the initial mass of the material remaining on the solid base, while the shatter resistance was obtained by subtracting the percentage weight loss from 100 [14,15].

$$Percentage\ weight\ loss = \frac{initial\ weigth\ before\ shattering - weight\ of\ shattering}{initial\ weight\ of\ briquette\ before\ shattering} \times 100$$

Shatter resistance = 100 - Percentage weight loss

2.5.3 Percentage moisture content

Moisture content of bio mass fuel affects the combustion process and also affects the heating value of producer gas. High moisture content will contribute for the low heating value. The moisture content will reduce the thermal efficiency and in turn the heat produced is used for heating the wet bio mass. So moisture content must be minimum for any bio mass material. Percentage moisture content was determined by measuring initial weight of pulverized briquettes into a crucible. The content was dried in an oven at 105-110^{0}C for 24 hr to obtain over dry weight.

Moisture content was then calculated according to following formula [16].

$$\%\, m.c. = \frac{initial\ weight\ (w1) - final\ weight\ (w2)}{initial\ weight\ (w1)} \times 100$$

2.5.4 *Water Resistance*

It is measure of percentage water absorbed by a briquette when immersed in water. Each briquette was immersed in 150 mm of water column at 27°C for 30 s. The percent water gain was calculated and recorded by using following formula [17].

$$\text{Water gain by briquettes (\%)} = \{(W_2 - W_1)/W_1\} \times 100$$

Where,

W_1 = Initial weight of briquette, g

W_2 = Weight of wet briquette, g

% Resistance to water penetration = 100 - % water gain

2.6 Combustion characteristics of biomass briquette

The combustion characteristics of the developed briquettes were determined by conducting water boiling test. The other heating properties like calorific value, proximate and ultimate analysis of briquettes were measured.

a. Water boiling test

Volume of the pot was measured and filled it 2/3 by water. Pot was kept on stove and covered with propped lid for minimizing the losses. Thermometer was fixed in central part of pot. One kg of briquettes were measured and made into four parts for testing. Ambient temperature and initial temperature of water in a pot were measured. Setting time of fire was recorded after lighting the fire. Final temperature of water after boiling was observed. Kept the fire continued by burning briquettes to heat water to vaporize until the given briquettes were used up. Quickly pot lid was removed and evaporation was continued for 20 min. Pot from the cook stoves was separated; cool it for 2 hr and volume of water of were measured [18].

2. Results and Discussion

2.1 Compressed density

Compressed densities of briquettes were determined for relative compactness, easy to transportation and improve the burning quality of briquettes and also used for increase the combustion properties. The compressed density of briquettes with different binder levels are given in the Table 1.

Table 1: Compressed density of briquettes with different binder levels

Binder level (saw dust : cow dung)	Avg. Weight of briquette, gm	Avg. Volume of briquette, cm^3	Avg. Compressed density of briquette, gm/cm^3
25:75	65	82.77	0.785
50:50	56	87.47	0.64

Results from the Table 1 indicated that briquettes having binder level 25:75 recorded higher compressed density compared to briquettes having binder level 50:50. This implies that substantial space could be saved in transportation and storage of briquettes produced with higher concentration of cow dung binders.

2.2 Shattering Resistances

This test was determined for durability of briquettes and also for checking breakability during transportation. Table 2 shows the shattering resistance of briquettes with two different binder levels.

Table 2: Shattering resistance of briquettes with different binder levels

Binder level (saw dust: cow dung)	Initial wt. before shatter, gm	Final wt. after shatter, gm	Percentage wt. Loss, %	Shatter resistance, %
	A	B	C = (A-B)/A ×100	100-C

25:75	36	35	2.77	97.3
50:50	34	29	14.7	85.3

Results shows that briquettes having binder level 25:75 recorded higher shattering resistance compared to briquettes having binder level 50:50. This implies that briquettes produced with higher concentration of cow dung binders are more durable and resistant to handling stresses.

2.3 Moisture Content

Moisture content test was determined for drying of briquettes and used in the loss of chemically bound structural water. Table 3 shows the moisture content of briquetting of saw dust and cow dung with different ratio used for this experimental study.

Table 3: Moisture content of briquettes with different binder levels

Binder Level (saw dust : cow dung)	Initial wt. before oven drying, gm	Final wt. after oven drying, gm	Percentage moisture content, %
	A	B	C = (A-B)/A ×100
25:75	14.20	10.77	24.2
50:50	11.93	9.26	22.4

Since cow dung is used as binder cum bio mass material for briquette, the moisture content increases with increase in ratio of cow dung.

3.4 *Resistance to Water Penetration*

Briquettes produced from saw dust and cow dung mixture were selected for water absorption test for checking their stability values were given in Table 4.

Table 4: Resistance to water penetration of briquettes with different binder levels

Binder Level (saw dust : cow dung)	Initial wt. of briquette before deeping into the water, gm	Final wt. of briquette after deeping into the water, gm	Water absorption, %	% Resistance to water = 100-% water absorption
	W_1	W_2	$W_3 = (W_2 - W_1)/W_1 \times 100$	$100 - W_3$
25:75	33.35	56.20	68.52	31.48
50:50	37.6	70.30	86.97	13.03

Higher value of percent resistance to water in case of briquettes having binder level 25:75 indicates that, any exposure of these briquettes to moisture may have lesser disintegrating effect on them compared to briquettes having binder level 50:50.

3.5 Water boiling test

Briquettes produced from saw dust and cow dung mixture were selected for water boiling test for checking their suitability in domestic use as fuel. The results from the experiment were presented in the following Table 5.

Table 5: Water boiling test of briquettes with different binder levels

Sl. No.	Properties	Binder Level (saw dust : cow dung)	
		25:75	50:50
1	Fuel taken, gm	250	250
2	Time taken to burn briquette, min	28	22
3	Water boiling time, min	22	15
4	Water evaporated, ml	138	150
5	Ratio of water evaporated to fuel used, ml/gm	0.55	0.6
6	Ash left after complete combustion, %	16.3	8.6

Results from water boiling tests show that briquettes of combination 50:50 give cleaner flame with lesser ash content compared to the 25:75 combination briquettes.

The heating properties like calorific value, proximate analysis and ultimate analysis of developed briquettes of different binder level were presented in Table 6.

Table 6: Heating properties briquettes with different binder levels

Sl. No.	Properties	Binder Level (saw dust : cow dung)	
		25:75	50:50
1	Calorific value, KJ/kg	15700	18800
2	Proximate analysis		
	Volatile matter, %	63.2	65.6
	Fixed carbon, %	22.4	28.3
	Ash, %	14.4	6.1
3	Ultimate analysis		
	Carbon (C), %	45.3	46.8
	Hydrogen (H), %	6.1	5.2
	Nitrogen (N), %	5.1	3.2
	Sulphur (S), %	0.8	0.1
	Oxygen (O), %	42.7	44.7

From the results, it was observed that briquettes having combination 50:50 binder level have better combustion properties due to which these may be well suited for thermal application in rural communities.

3. CONCLUSION

The study indicated that briquettes having more cow dung content i.e. 25:75 mixture briquettes gave better results for compressed density, shattering indices test and resistance to water penetration as compared to 50:50 mixture briquettes.

In case of calorific value and water boiling test, 50:50 mixture briquettes performed better compared to 25:75 mixture briquettes.

Saw dust biomass is the high density biomass compared to other biomass like rice husk, dry leaf, ground nut shell etc. due to high density it indicated that substantial space could be saved in transportation and storage of briquettes prepared using the low pressure machine. Average capacity of the machine was found to be 6.24 kg/hr. Use of these briquettes in local domestic stove with grate was found to be satisfactory.

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