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Evaluation of composition, burn rate and economy beehive charcoal briquettes

S. MANDAL, ARVIND KUMAR, R.K. SINGH AND S.V. NGACHAN

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See end of the Paper for authors' affiliations

Correspondence to:

S. MANDAL
Department of Farm Power and Machinery, Division of Agricultural Engineering, ICAR Research Complex for NEH Region, UMIAM (MEGHALAYA) INDIA
Email : smandal2604@gmail.com

ABSTRACT : Beehive charcoal briquette has been found to be an excellent source of alternative household fuel for the rural people of North-East India. These briquettes are produced from charcoal and mud. Mud is added as binding agent. Experiments were conducted to determine the burning characteristics of this briquette with respect to its density and composition. Five treatments were chosen with different density achieved from five different compositions of charcoal, mud and cowdung. Proximate analysis of each briquette was carried out. Combustion test was conducted on a test platform with ample supply of air and loss of weight was recorded at two minutes interval. The study revealed that Normalised Burn Rate (NBR) varied exponentially with density ($NBR=26.17e^{-0.0059*DEN}$). Higher density briquettes showed lower NBR and *vice versa*. Total burning time increased exponentially with increasing density ($TBT=34.44e^{-0.002*DEN}$). After considering all the input costs, it was calculated that an entrepreneur can earn approximately Rs. 21000 per month with an average production of 6000 briquettes.

KEY WORDS : Charcoal briquettes, Low density briquettes, Normalised burn rate, Alternate energy, Briquetting economy

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The people of North East India are still using traditional cook stoves for cooking and space heating with wood or coal as fuel. Thermal efficiency of these traditional stoves is very low and cause widespread air pollution. Also direct burning of biomass emits substantial amount of pollutants including respirable particles, carbon monoxide, nitrogen and sulphur oxides which may cause health hazards and increased green house gas emission (Bruce *et al.*, 2000). Densified biomass which is also known as briquette has been found to be a solution to these problems (Grover and Mishra, 1996).

Briquetting has been practiced for many years in several countries. Biomass briquettes can provide an alternative household solid fuel, especially in rural areas. These can be burnt clean and, therefore, are eco-friendly and also those advantages that are associated with the use of biomass are present in the briquettes (Grover and Mishra, 1996). Briquettes can be produced with a density of 1.2 Mg/m^3 from loose biomass of bulk density 0.1 to 0.2 Mg/m^3. Compared with wood, biomass briquettes are unique in that they provide opportunity to control in the manufacturing process. The dried briquettes are easy to store because they come in a uniform shape and size.

Briquettes are of mainly two types –biomass briquette and charcoal briquette. Biomass briquettes are produced by densifying loose biomass in a briquetting machine whereas charcoal briquettes are produced from charcoal and some binding agent. Beehive briquettes (Fig. A) are produced from charcoal and mud. Mud is used as binding agent. In general the ratio of charcoal and mud is 70:30 by volume. These briquettes are made cylindrical with parallel holes which make this looked like beehive. Dried beehive briquettes produce smokeless blue flame with an average burning time of 2 to 2.5 hours.

In agricultural production system, waste biomass are abundant and so as in forestry. In North-East India, 37 million tonnes of biomass are produced annually from agriculture and forestry. There are multiple uses of this biomass in plain areas such as animal feeding, production of farm yard manure, vermicompost, as fuel for bio-gasifiers etc. But in hilly areas of North-East India these practices are not common. Thus, agricultural and forest waste biomass available in the region can be used to produce briquettes to mitigate the demand of household fuel and also to provide small scale business opportunity to entrepreneurs.

The fuel density, moisture content, size and geometry

Fig. A : Beehive charcoal briquette

Fig. B : Beehive charcoal briquette mould

as well as the material properties, all these factors have been shown to have significant effect on biomass burn rates (Chaney *et al*., 2008). That is why, it is needed to find out the exact ratio of the raw materials to standardize the composition. People of North-India are mostly poor and most of them do not have access to regular cooking fuel like Liquid Petroleum Gas (LPG). An alternate eco friendly fuel can mitigate this problem and thus can address the challenge of climate change to some extent. Therefore, this study was conducted with the objectives to standardize the ratio of charcoal, cowdung and mud in beehive charcoal briquettes on the basis of burn rate and to assess the economy of production.

METHODOLOGY

Making of briquettes:

Beehive briquettes were made using finely powdered charcoal sieved through 5 mm sieve and cow dung or mud as binder. Along with binding, mud also acted as a burning controller. It reduces the rate of burning. Five ratios of charcoal, cow dung and mud on dry weight basis were taken which are presented in Table A.

After mixing charcoal, cow dung and mud, a little water was added where needed to make the paste soft enough to hold the structure. A beehive briquette mould with overall dimension of 400mm × 100mm was used to make the briquettes (Fig. B). It consists of three parts a) cylinder, b) base plate with 21 rods and c) cover plate. Cylinder dimension is 145mm diameter × 85mm height. Base plate has total 21 rods of 12mm diameter and 95 mm height welded on it. Cover plate has same number of holes of little bit higher diameter so that it can move through the rods on base plate. After putting cover plate and cylinder on base plate, the mixture was put into the cylinder and the whole unit was bitten on ground to increase compaction of the material. Then the cylinder and cover plate

Table A : Combination of charcoal, mud and cowdung taken for experiment

Treatments	Charcoal (%)	Cowdung (%)	Mud (%)
Briquette 1	50	25	25
Briquette 2	60	20	20
Briquette 3	70	15	15
Briquette 4	70	30	0
Briquette 5	70	0	30

Table B : Proximate analysis of Beehive briquettes

Treatments	Density (kg/m^3)	Moisture content % (DB)	Volatile matter % (DB)	Fixed carbon % (DB)	Ash content % (DB)
Briquette 1	645	10.8	9.3	47.4	32.5
Briquette 2	625	10.5	9.4	51.5	28.6
Briquette 3	465	8.9	10.2	59.5	21.4
Briquette 4	388	8.5	7.3	68.4	15.8
Briquette 5	677	8.6	6.4	48.9	36.1

were pulled out of the base plate along with the newly formed briquette. It was placed upside down on ground and pressed to release the briquette. Thus the dimension of each briquette was 145mm in diameter and 85mm in height which perfectly fits in an oven available in the local market. Raw briquettes were allowed to dry in open air as well as in sunlight.

Proximate analysis:

Proximate analysis was carried out to determine moisture content, volatile matter, fixed carbon and ash content. Gravimetric method was followed to determine moisture content by keeping the sample at 105^{0}C for 48 hours. Oven dried samples were kept in a muffle furnace for 30 min at 450^{0}C to determine the volatile matter content. Samples were kept in stainless steel nipple with caps in both ends. Caps were kept half round loose for escape of the gas. Another set of samples was kept in furnace at 550^{0}C for 30 min to determine the ash content. The results obtained in proximate analysis are shown in Table B.

Combustion test:

To carry out the combustion test, a test platform was made using mild steel flats and sheet. Enough holes were provided in the perforated grate to allow the free flow of air. A single briquette was placed on the grate and inside a cylindrical steel wire mesh. The whole unit was placed on an electronic digital balance with least count of 0.1g to record the mass loss in every two minute interval throughout the burning period. Each briquette was ignited by placing firelighter just below the grate without touching the balance and allowed to burn until the heat becomes too less. Loss of mass was recorded in every two minute interval and then normalised by initial briquette mass. A graph of normalised mass was plotted against time. There are three distinct phase of burning. Phase (1) is the ignition phase, phase (2) the steady state flaming combustion phase and phase (3) when the flame dies (Chaney *et al*., 2008). The gradient of phase (2) is the normalised steady-state combustion rate which is referred here as the normalised burn rate (NBR). For each briquette burnt, these graphs were plotted and NBR was calculated. Total burning time plays an important role in the acceptance of the briquettes. Longer burning time is preferred by the local people as it can provide heat for long time while space heating during winter. Considering this, total burning time was considered as one of the performance parameter of each briquette.

■ RESULTS AND DISCUSSION

The results of the present study as well as relevant discussion have been summarized under following heads:

Effect of composition on density:

Density is a parameter which significantly affects the burning properties of briquettes and it is controlled by composition (Chaney *et al*,. 2008). Bulk density of each sample was taken after drying in the oven for 24 hours at 105°C. Fig. 1 shows the effect of composition of charcoal, mud and cowdung on the density of briquettes. Percentage of mud in the composition controlled the briquette density. Highest density was observed with highest amount of mud as the density of mud is higher than other two constituents. Briquettes constituted of charcoal and cowdung had the lowest density due to their low density and high porosity. Density is also dependent upon the level of compaction but finding out this effect was out of the scope of this work.

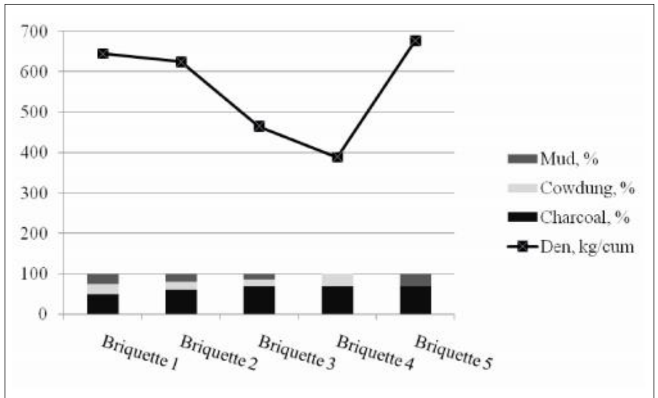

Fig. 1 : Effect of composition on briquette density

Burn rate:

Percentage loss of initial briquette mass with time has been shown in Fig. 2. This curve was made using the data of replication-1 of sample-1 which shows three distinct phases of burning. The normalised burn rate which is the slope of the phase-2 has been plotted against density (Fig. 3). Chin and Siddiqui (2008) described the effect of density on burn rate of briquettes made from various materials. They showed exponential relation between NBR and density of the following

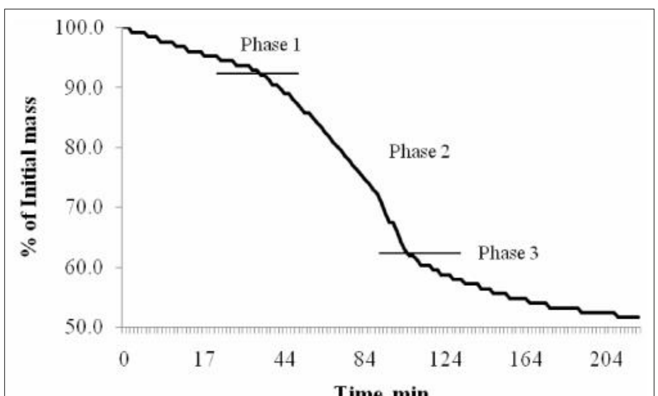

Fig. 2 : Phases of briquette burning

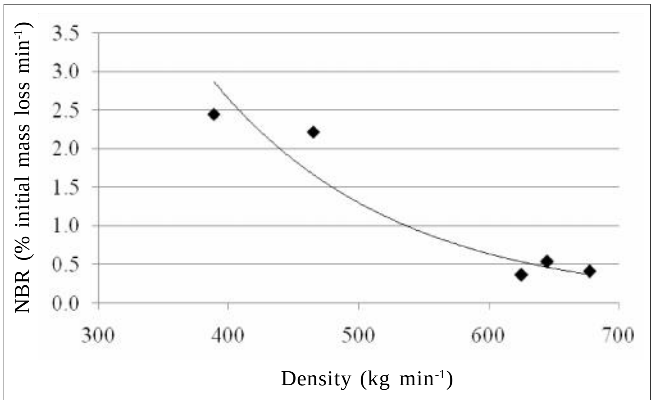

Fig. 3 : Effect of density on NBR

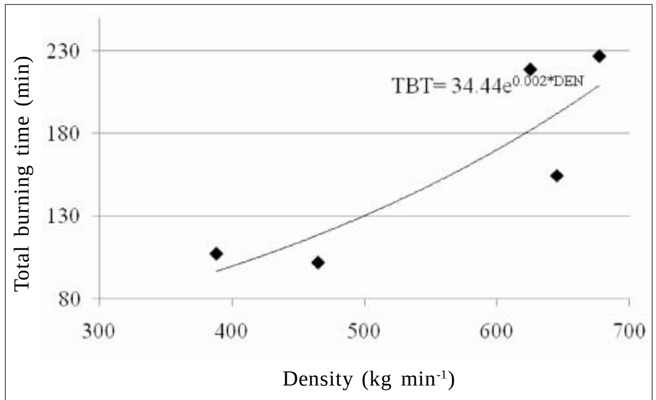

Fig. 4 : Effect of density on total burning time

form:

$$NBR = ae^{-b*DEN} \qquad (i)$$

After an exponential fit on the scattered plot of NBR verses density, values of constants 'a' and 'b' were calculated and equation took the form:

$$NBR = 26.17e^{-0.0059*DEN} \qquad (ii)$$

It shows the significance of density on normalised burn rate, higher density briquettes have slower normalised burn rate. As the percentage of mud in briquettes controlled the density, it controlled burn rate too. So, the burn rate can be slowed down by increasing the amount of mud and decreasing charcoal or cowdung. Charcoal has been found to be helpful in faster burning but briquettes with more cowdung produced more smoke than briquette with no cowdung.

Total burning time:

The time taken to burn the whole briquette starting from its 100 per cent initial weight to the maximum weight loss (approximately 50% of initial weight) was considered as Total Burning Time (TBT). TBT varied exponentially with density (Fig. 4) and followed the equation:

$$TBT = 34.44e^{-0.0002*DEN} \qquad (iii)$$

Slow propagation of fire through the briquette mass and less availability of oxygen led to slow burning of briquettes with more density. So, TBT can be increased by increasing percentage of mud. But less than 40 per cent of charcoal in briquettes led to very slow burning and less heat and caused very long ignition time. The optimum composition can be found out after examining both curves. From these curves it can be concluded that briquettes with density of 500 kg/m^3 will burn with a NBR of 1.3 min^{-1} for 130 minutes which is quite

Table 1 : Economy of beehive charcoal briquettes

1. Fixed cost monthly	Rs.	Comment
Charring drum	208	Initial cost Rs. 5000 and life two years
Mould	21	Initial cost Rs. 1000 and life four years
Total monthly depreciation	229	
2. Operation cost monthly		
Charcoal	20000	For two tons of charcoal needed to produce 6000 briquettes
Labourer @120/day for 4 labourers	14400	For making charcoal, preparing mixture, making briquettes
Transportation	2000	
Miscellaneous expenses	2000	
Total monthly cost = Rs. (229+20000+14400+2000+2000) = Rs. 38,629 say 39,000		
No. of briquettes produced:	6000 Pieces	
Cost per pieces	Rs. 10	
Cost of 6000 briquettes	Rs. 60,000	
Input cost	Rs. 39,000	
Net profit	Rs. 21000	

a long time to complete cooking and space heating at winter.

Economic evaluation:

Targeting to produce 6000 briquettes per month one beehive briquette can be produced by a cost of Rs. 6.50 (Table 1). The input cost includes both fixed and operational cost. Four labourers are needed for grinding of charcoal, mixing the charcoal with mud, making and drying of briquettes. If charcoal is not purchased and biomass is converted to charcoal, cost will be less but in that case labour requirement will increase for cutting and processing of biomass. A briquette in the local market of Shillong is sold at a price of Rs. 15. If an entrepreneur takes this as a small scale business, a monthly profit of Rs. 21000 can be earned. It also increases in cost savings when compared with wood fuel as it burns with very less efficiency than the briquettes.

Conclusion:

Beehive charcoal briquettes produced from charcoal, mud and cowdung is low density briquette. The burning characteristics of this briquette follow the same pattern as reported by earlier works for low density briquettes. The total burning time of this briquette can be increased by increasing the amount of mud but the heat released in unit time will be reduced. Burn rate of the briquette is significantly affected by compositions. The briquette is very cheap and reliable source of household fuel for the rural people of North East India.

Authors' affiliations:

ARVIND KUMAR AND R.K. SINGH, Division of Agricultural Engineering, ICAR Research Complex for NEH Region, UMIAM (MEGHALAYA) INDIA

S.V. NGACHAN, I.C.A.R. Research Complex for NEH Region, UMIAM (MEGHALAYA) INDIA

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