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Efficiency of cow dung briquettes as a source of fuel for rural kitchen

M Sathiyabarathi, S Vasantha Kumar and D Thirumeignanam

Abstract
There were four combinations (T_1, T_2, T_3 and T_4) of briquettes evaluated for their properties. The breaking stability of all the four types of briquettes is considered as 100 per cent. The control group T_1 (cow dung only) was compared with other three groups. The cooking time is lesser in T_4 than other three groups for water boiling and rice cooking. But, in the milk boiling test, T_1 control briquette group boiled the milk in short time (3.58 minutes) with less quantity of briquettes (45.75g). The charcoal group (T_2) took longer time than other three groups of briquettes, in water boiling, milk boiling and rice cooking tests. The paddy husk group (T_4) with significantly less volatile matter (2.17 per cent) took short time in water boiling and rice cooking experiments, at the expense of lowest quantity of briquettes. T_2 and T_3 briquettes retained the heat energy for long time than the other two groups even after the experiment is over. This implies that the charcoal and saw dust group with more carbon, they must be useful for further cooking, that means for the subsequent cooking the efficiency might increase as there is more retention of heat energy. T_4 briquette, with second highest gross energy (3930 Kcal/Kg) it was very useful in reducing the boiling time of water and cooking time of rice with the minimum use of briquettes. T_3 group (saw dust in cow dung) was found to be less efficient than other briquettes.

Keywords: Bulk density, breaking stability, fuel efficiency, heat value

Introduction

Throughout the World, cooking is the major activity of all households. In many developing countries the main source of cooking energy is firewood, twigs of trees and shrubs collected from forests and in some regions charcoal is used in the place of firewood. The ever growing human population in the world poses great pressure for energy sources. The fossil fuel is depleting very fast and the people living below the poverty line are looking for an alternate and eco-friendly fuel source for cooking, for which the biomass is the only answer. Trees, dried leaves, dried stems of forest plants, saw dusts, paddy husk, ground nut hull and coir pith waste are some of the biomass tried in villages for cooking. The cow dung is also considered one of the best biomass and a binder to mix with other materials used as cooking fuel in kitchens and furnaces. Cow dung being a source of methane for the enteric fermentation of cows, plays a major role in making briquettes in combination with carbonaceous materials namely charcoal, saw dust, coir pith waste and paddy husks. Kiran Pandey (2018) [6] reported that between 1990 and 2010, population growth affected global gains in access to non-solid cooking fuel. The share of the global population having access to nonsolid fuel rose from 47 per cent (2.5 billion people) in 1990 to approximately 59 per cent (4.1 billion people) in 2010. He also pointed out that in southern Asia and sub-saharam Africa, the number of people using solid fuels actually increased in both urban and rural areas, because of growth in the population. In Indian rural households, about 800 million people use traditional biomass cook stoves for their cooking needs. Less than one percent of households use bio-gas for cooking. More than 70 per cent of rural households in the lowest classes use firewood and chips for cooking. The use of electrical induction stove is in just 0.01 per cent households (Patnaik *et al.*, 2017) [5]. Briquettes are made from low cost throw away materials, it is sustainable and they are desirable fuel, as it produces almost less smoke fire for cooking. Further, deforestation is there by prevented as the use of fire briquettes saves trees that are cut for fuel purpose. Thus, briquette making has got the potential to meet the energy demands of rural, urban and industrial sectors, besides briquettes have greater heat intensity than fire wood, cleanliness, convenience and relatively smaller space requirement for storage (Emerhi and Emuobonuvie 2011) [3]. The objective of this study is therefore to find out the cost and ease of making, heat intensity and the usefulness and cost effectiveness in controlled cooking experiments.

Materials and Methods

The efficiency of fire briquettes made of cow dung in four different combinations was studied during March to June 2020, at the Department of Livestock Production Management, Veterinary College and Research Institute, Tirunelveli. Fresh cow dung, powdered charcoal, saw dust and paddy husk were collected. The four combinations of fire briquettes are cow dung alone (T_1, control), cow dung + powdered charcoal in 9:1 ratio by fresh weight (T_2), cow dung + saw dust in 9:1 ratio by fresh weight (T_3) and cow dung + paddy husk in 9:1 ratio by fresh weight (T_4). The composition of the briquettes and their cost were considered to work out the cost efficiency. The size (length 13.2 cm x diameter 2.6 cm) and shape (cylindrical) of the briquettes were kept uniform with the use of a hand operated stainless steel briquette making device, designed for this purpose. The briquettes so produced were shade dried for minimum72 hours for the complete removal of moisture; and the following physical and chemical parameters were estimated. The bulk density (gcm^{-3}) was calculated by mass and weight ratio of the briquette. The breaking stability (number) was worked out by dropping the briquette from 1 meter height on a hard floor and the number of broken pieces was recorded. The percentage volatile matters (%), percentage ash content (%), percentage fixed carbon (%) and heating value (Hv) were estimated as per method suggested by Emerhi (2011) [3]. The controlled cooking experiment was carried out with all the four combinations of briquettes and a rural women was asked to carry out the cooking experiment in the presence of an observer and thus the efficiency was worked out separately for boiling 500 ml water and 500 ml of milk using a standard aluminium vessel and of rice (250 grams) cooking was done with a rice cooker. The cooking experiments were repeated three times to control errors. The time taken to complete each process was recorded against the weight of the briquette used in each trial, by subtracting the left over briquettes uniformly for all the experiments. The data thus collected were subjected to standard statistical analysis.

Results and Discussion

Bulk density

The briquettes made are estimated for their bulk density (Table.1) by measuring the length (cm) and diameter (cm) of ten numbers of individual briquettes from each category (T_1, T_2, T_3 and T_4). The bulk density of T_4 briquette is the highest (3.06 ± 0.99 gcm^{-3}) which is followed by T_3 (2.87 ± 0.97 gcm^{-3}), T_1 (2.85 ± 0.87 gcm^{-3}) and T_2 (2.52 ± 0.63 gcm^{-3}). Statistical analysis revealed significant differences between all the four compositions. When the bulk density is more the efficiency of the fuel should be more. This is evident that in Table 2, only 84 grams of briquettes were utilized to boil water in shortest time (6.52 minutes) against 124 grams in T_1, 122 grams in T_2 and 116 grams in T_3. The time taken for water boiling is also lesser in T_4 than other three groups. This trend is observed while cooking the rice also. But, in the milk boiling test, T_1 briquette group boiled the milk in short time (3.58 minutes) with less quantity of briquettes (45.75g). The charcoal group (T_2) took longer time than other three groups of briquettes, in water boiling, milk boiling and rice cooking tests.

Breaking stability

Ten numbers of randomly picked briquettes were dropped from 1 meter height on a concrete floor to check the breaking stability by counting the number of broken pieces; and it was observed that there were no broken pieces in any of the four compositions indicating good stability of the briquettes. Hence, the breaking stability of all the four types of briquettes is considered as 100 per cent. Similarly, Bandara and Kowshayini (2017) [1] tried to test the breaking stability of briquettes from 2 meter height and they used this property only to estimate the durability and storage studies. In the present study, since none of the briquette break in the 'drop test', it can be construed that cow dung is a good binding agent for making cow dung briquettes. Further the breaking stability is the outcome of the type of device used to make the briquette. Most of the earlier studies, used screw type extruders or briquette making machines whereas, in this study a hand operated small sized device made of stainless steel (Fig.1) was used.

Fig 1: Briquette device

Fig 2: Briquettes after drying

Percent volatile matter

The volatile matter content ranged from 2.17 per cent in T_4 to 3.83 per cent in T_1. The T_2 and T_3 had 2.85 per cent and 3.60 per cent, respectively. The statistical analysis revealed significant ($P<0.01$) differences between the briquette groups. The paddy husk group (T_4) with significantly less volatile matter (2.17 per cent) took short time in water boiling and rice cooking experiments, at the expense of lowest quantity of briquettes. But, contrarily, Miller (2013) [4] reported that easy ignition, better flame stability, lower nitrogen oxide emission and improved carbon burn out are the benefits of fuel with higher volatile matter. This fact was also supported by Caillat and Vakkilainen (2013) [2]. The above two statements are pertaining to experiments in gasifiers and pyrolysis process. On the other hand, in this rural kitchen cooking experiment with cow dung briquette fuel, the percent volatile matter is less when compare to the coal as an exclusive fuel in gasifier and pyrolysis process. Hence, it can be construed that less volatile matter of the briquette is facilitating easy cooking at less of fuel. To confirm this finding, poor efficiency in cooking was observed with T_3 briquettes (saw dust group) with highest volatile matter (3.60 per cent). It took a long time at the expense of more briquettes.

Per cent fixed carbon

The T_2 and T_3 group briquettes, registered more fixed carbon of 83.37 and 83.60 per cent, respectively than T_1 (75.35 percent) and T_4 (78.78 per cent) group briquettes, with the mean of 80.28±1.98 per cent for all the four combinations. Generally, lower levels of fixed carbon is desirable (Bandara and Kowshiayini 2017) [1] in biomass briquettes, as it ensures high volatile content. In this study, T_1 had significantly lower (75.35%) fixed carbon and higher (3.83%) volatile matter and T_1 consumed very less cooking time in boiling milk and cooking the rice. Sine, T_2 and T_3 group had more fixed carbon, they took long time in cooking and boiling experiments than T_1 and T_4. But, during the experiments it was noticed that T_2 and T_3 briquettes retained the heat energy for long time than the other two groups even after the experiment is over. This implies that the charcoal group and saw dust group with more carbon, they must be useful for further cooking, that means for the subsequent cooking the efficiency might increase as there is more retention of heat energy.

Total ash

The mean total ash of all the four combinations of briquettes was worked out to be 21.08±2.92 per cent. Individually, the total ash was significantly (P<0.01) more (28.80 per cent) in T_4 briquette (paddy husk group) which is followed by T_1, T_2 and T_3 group. The total ash was more in the paddy husk group briquette, since the per cent volatile matter is very less in this group when compared to other briquette combinations. The paddy husk group with highest total ash content boiled the water and cooked the rice very efficiently than the other groups. The ash content varies from briquette to briquette, as the cow dung collected varied from time to time.

Gross energy

Gross energy refers to the quality of the biomass fuel. The mean gross energy of all the four briquettes was 3790±0.13 Kcal/Kg, with a highest gross energy in T_3 group followed by T_4, T_2 and T_1 with 3930, 3630 and 3490 Kcal/Kg, respectively. The differences between the groups are highly significant. In the kitchen experiment, with regard to T_4 briquette, with second highest gross energy (3930 Kcal/Kg) it was very useful in reducing the boiling time of water and cooking time of rice with the minimum use of briquettes. This indicates that gross energy reflected the fuel efficiency. But, T_3 group (saw dust in cow dung) was found to be less efficient than other briquettes. In the rice cooking test, 340.25±38.75 grams of briquettes were spent to reach the end point while the other briquette groups, significantly (P<0.01) with less quantity (less than 300 grams) the rice cooking was completed. There were four combinations (T_1, T_2, T_3 and T_4) of briquettes evaluated for their properties. The breaking stability of all the four types of briquettes is considered as 100 per cent. The control group T_1 (cow dung only group) was compared with other three carbon sources group. When the bulk density is more the efficiency of the fuel should be more. In water boiling test, 84 grams of briquettes (T_4 group with paddy husk) were utilized to boil water in shortest time (6.52 minutes) against 124 grams in T_1, 122 grams in T_2 and 116 grams in T_3. The time taken for water boiling is also lesser in T_4 than other three groups. This trend is observed while cooking the rice also. But, in the milk boiling test, T_1 control briquette group boiled the milk in short time (3.58 minutes) with less quantity of briquettes (45.75g). The charcoal group (T_2) took longer time than other three groups of briquettes, in water boiling, milk boiling and rice cooking tests. The paddy husk group (T_4) with significantly less volatile matter (2.17 per cent) took short time in water boiling and rice cooking experiments, at the expense of lowest quantity of briquettes. Hence, it can be construed that less volatile matter of the briquette is facilitating easy cooking at less of fuel. To confirm this finding, poor efficiency in cooking was observed with T_3 briquettes (saw dust group) with highest volatile matter (3.60 per cent). It took a long time at the expense of more briquettes. T_2 and T_3 briquettes retained the heat energy for long time than the other two groups even after the experiment is over. This implies that the charcoal group and saw dust group with more carbon, they must be useful for further cooking, that means for the subsequent cooking the efficiency might increase as there is more retention of heat energy. T_4 briquette, with second highest gross energy (3930 Kcal/Kg) it was very useful in reducing the boiling time of water and cooking time of rice with the minimum use of briquettes. This indicates that gross energy reflected the fuel efficiency. T_3 group (saw dust in cow dung) was found to be less efficient than other briquettes, since T_3 briquettes (saw dust group) with highest volatile matter (3.60 per cent). It took a long time at the expense of more briquettes.

Table 1: Comparison of bulk density of cow dung briquettes (gcm^{-3})

Bulk density	Mean±SE (%)	Min.	Max.	Comparison of briquette		P-value
Cow dung	2.85±0.87^a	2.49	3.36	Cow dung	Cow dung + Charcoal	0.05
					Cow dung + Saw dust	0.99
					Cow dung + Paddy husk	0.00
Cow dung + Charcoal	2.52±0.63^b	2.07	2.72	Cow dung + Charcoal	Cow dung	0.05
					Cow dung + Saw dust	0.03
					Cow dung + Paddy husk	0.00
Cow dung + Saw dust	2.87±0.97^a	2.25	3.23	Cow dung + Saw dust	Cow dung	0.99
					Cow dung + Charcoal	0.03
					Cow dung + Paddy husk	0.00
Cow dung + Paddy husk	3.06±0.99^c	3.58	4.49	Cow dung + Paddy husk	Cow dung	0.00
					Cow dung + Charcoal	0.00
					Cow dung + Saw dust	0.00

*Means with different superscript differ significantly (p<0.05)

Table 2: Efficiency of the cow dung briquettes in cooking functions

Briquette Type		Water boiling test		Milk boiling test		Rice cooking test	
		Time taken (Minutes)	Quantity of briquette (g)	Time taken (Minutes)	Quantity of briquette (g)	Time taken (Minutes)	Quantity of briquette (g)
Cow dung alone (T_1)	1	10.3	130	4.11	51.5	22	300
	2	7.12	123	3.05	40	22.2	274
	3	7.00	119	-	-	-	-
	Mean±SE	8.14±1.08	124±3.21	3.58±0.53	45.8±5.75	22.1±0.11	287±12.8
Cow dung + Charcoal (T_2)	1	12.2	133	10.2	75	30.5	300
	2	13.8	122	5.30	80	32.1	274
	3	11.5	110	-	-	-	-
	Mean±SE	12.4±0.61	122±6.54	7.75±2.45	77.5±2.5	31.3±0.79	287±13
Cow dung + Saw dust (T_3)	1	11.2	150	3.50	55	31	379
	2	7.00	100	6.18	50	29	301
	3	7.28	100	-	-	-	-
	Mean±SE	8.48±1.34	116±16.66	4.84±1.34	52.5±2.5	30.0±1.0	340±38.8
Cow dung + Paddy husk (T_4)	1	6.20	100	5.28	62	22	250
	2	6.37	70	4.17	54	26	283
	3	7.00	82	-	-	-	-
	Mean±SE	6.52±0.24	84±8.71	4.72±0.55	58±4	24.4±2.06	266 ±16.5

Table 3: Physical and chemical properties of cow dung briquettes

Briquette type	Bulk density (gm/cm^3)	Breaking stability (%)	Gross energy (Kcal/Kg)	Total ash (%)	Per cent volatile matter (%)	Per cent fixed carbon (%)
Cowdung (T_1)	2.85	100	3490	22.4	3.83	75.4
Cowdung + Charcoal (T_2)	2.52	100	3630	16.7	2.85	83.4
Cowdung + Saw dust (T_3)	2.87	100	4100	16.5	3.60	83.6
Cowdung + Paddy husk (T_4)	3.06	100	3930	28.8	2.17	78.8

Table 4: Analysis of chemical properties of cow dung briquette

Chemical parameters	N	t-value	df	Mean±SE	P-Value
Bulk density (gm / cm^3)	4	25.2	3	2.82±0.22	0.00
Breaking stability	4	--	--	0.00	--
Gross energy (Kcal/g)	4	27.3	3	3.79±0.13	0.00
Total ash (%)	4	7.21	3	21.1±2.92	0.01
Per cent Volatile Matter	4	8.25	3	3.12±0.38	0.00
Per cent Fixed Carbon	4	40.5	3	80.3±1.98	0.00

Conclusions

- The time taken for water boiling and for rice cooking is lesser in T_4 (paddy husk group) than other three groups.
- T_1 control briquette group boiled the milk in short time with less quantity of briquettes.
- The charcoal group (T_2) took longer time than other three groups of briquettes, in water boiling, milk boiling and rice cooking tests.
- The paddy husk group (T_4) with significantly less volatile matter (2.17 per cent) took short time in water boiling and rice cooking experiments, at the expense of lowest quantity of briquettes.
- T_2 and T_3 briquettes retained the heat energy for long time than the other two groups even after the experiment is over.
- T_3 group (saw dust in cow dung) was found to be less efficient than other briquettes.

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