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EVALUATING THE BIO-ENERGY POTENTIAL OF SUGARCANE BIO-MASS BRIQUETTES

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ABSTRACT

The study was conducted to assess the conversion potentiality of sugarcane bio-mass into bio-energy through briquetting. Samples of sugarcane bagasse, sugarcane trash and a 50:50 mixture of sugarcane bagasse and trash were used to produce briquettes. An automated briquetting press with a capacity of 150-200 kg/hr was employed to produce cylindrical briquettes of 100 mm length. The quality parameters of briquettes such as moisture content, bulk density, compressive strength, shatter resistance, resistance to water penetration,volatile matter, fixed carbon, and calorific value were determined. Among the various briquettes investigated, briquettes made of bagasse have low ash content (5.32%), high shatter resistance (99.4%), and a high calorific value (15.15 MJ/kg), all of which are desirable characteristics for fuel combustion. However, the briquettes produced from bagasse-trash mixture were statistically on par with the briquettes of bagasse alone. Thus, briquettes produced from bagasse alone and bagasse-trash combination can be recommended for use in boilers in the food processing sector as an eco-friendly biofuel, which in turn helps in curbing environmental pollution. Further, there is a scope for entrepreneurship development by converting sugarcane biomass to briquettes, which would create employment for the rural youth.

KEY WORDS : Sugarcane bagasse, Sugarcane trash, Briquettes, Calorific value.

INTRODUCTION

The biomass centric energy meets major chunk of energy demand in most of the developing countries inclusive of India. Depletion of fossil fuels such as petroleum, coal and natural gas demands for replacement of eco-friendly alternative biofuels. About 350 million tons of agricultural wastes such as rice husk, coffee husk, coir pith, sugarcane bagasse, sugarcane trash, jute sticks, ground nut shells, mustard and cotton stalks are produced in India every year. Agricultural waste management poses problem not only in transportation, storage and handling but also biomass burning in conventional grates leads to low thermal efficiency and wide spread air pollution.

Sugarcane is a multidimensional crop utilized for rich food source (white sugar, jaggery, sugarcane juice and syrups), fodder (green leaves and tops of cane), fuel and chemicals (bagasse and alcohol) and fertilizer (press mud and spent wash) Solomon (2011). In recent years, sugarcane crop has attracted global interest among researchers due to its economic effect on sustainable energy generation. The sugar producing countries in the world have diverted their attention towards production of diversified by-products from sugarcane apart from producing sugar alone. Compared to other crops, sugarcane yields major agricultural residues recording annual production of about 280 million tons in India Chandel *et al.* (2012). Sugarcane residues comprise bagasse, trash, and tops which contain cellulose, hemicellulose, lignin, and proteins as major nutrient, and vary depending on the age of the plant and the soil conditions Canilha *et al.* (2011); Diedericks *et al.* (2012); Zhang *et al.* (2013). The United State Department of Energy (2016) has identified sugarcane as one of the most abundantly

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used feasible feed stocks for second-generation fuel production.

India occupies second place in sugarcane production in the world producing about 376 milliontonnes of cane during 2017-18 and out of it, about 80.2 percent of the cane is diverted for white sugar, 11.5 percent for seed and chewing etc. and the remaining 8.3 per cent for jaggery and khandhasari production (Anonymous, 2019). During jaggery making, approximately 20% of dry bagasse is obtained (Jakkamputi *et al*., 2016) and 0.65% of it is required to produce 1 kg of jaggery Shiralkar, *et al.* (2014). Based on 2017-18 sugarcane production, approximately 62 lakh tonnes of bagasse is produced during jaggery making, out of which 20 lakh tonnes is utilised for jaggery making and the remaining 42 lakh tonnes is either burnt or left as waste material. However, the bagasse produced during sugar production was utilized for cogeneration in the sugar mills.

Similarly, it was estimated that for every 100 tons of cane harvested, about 10 tonnes of sugarcane trash was produced. Generally, the trash obtained is burnt in the field creating environmental pollution and depleting the soil fertility. The low moisture content in sugarcane trash helps in energy production either by cogeneration or biochemical conversion. Sugarcane trash consists of cellulose (40%), Polyoses (30%) and lignin (23%) and possesses high calorific value (Devi *et al.*, 2020). It was reported that dry bagasse consists of 45% cellulose, 28% pentosans, 20% lignin, 5% sugar, 1% minerals and 2% ash content thus utilizing in many ways Solomon *et al*., 2011). Considering the above facts, the biomass feedstock from the sugarcane can be diverted for energy generation through improved conversion technologies. Briquetting technology is a process of densification of bulk feed stock which can be used for wide range of agricultural residues. Hence, the main objective of the present study was to evaluate the possibility for conversion of sugarcane biomass into briquettes with different compositions and to analyse fuel parameters based on physical and mechanical qualities to recommend for both domestic and industrial usage.

Cane trash comprises mixture of fractions such as cellulose (40%), polyoses (30%), and lignin (23%), and also possesses high calorific value. Due to the low moisture content, it possesses high demand for energy production by means of either cogeneration or biochemical conversion processes.

MATERIALS AND METHODS

The bagasse obtained from crushing of sugarcane contains 50% moisture content (d.b.) and has to be dried in open yard to moisture content of 8-10% (d.b.) for further usage in briquetting machine. In order to make it ideal for briquetting, the dry bagasse was then chopped into smaller pieces of less than 10 mm. Similarly, sugarcane trash was also dried and chopped into small size particles. The flow chart for preparation of briquettes from sugarcane biomass was depicted in Fig. 1.

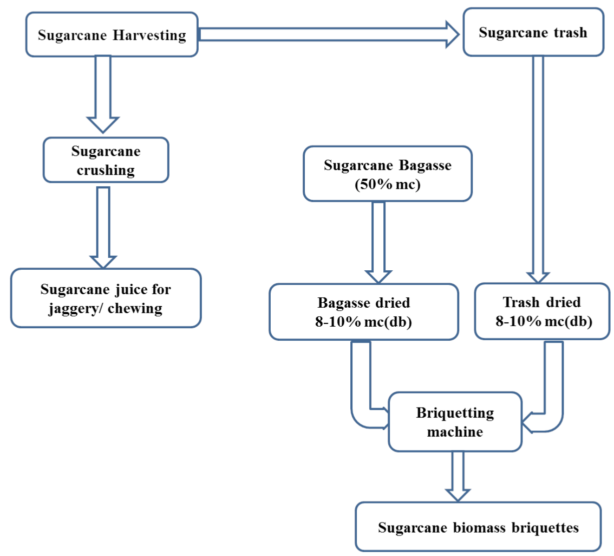

Fig. 1. Flow chart of sugarcane biomass briquettes production *mc-moisture content; db- dry basis

Briquetting machine

The high pressure briquetting machine (Model: BP 40125; Make: Hi Tech Agro Energy PVT LTD, Haryana) with capacity of 150-200kg/hr was used for producing sugarcane biomass briquettes. The briquetting machine consists of feeding screw of 150 mm diameter, hammer mill grinder, pneumatic system and briquetting press (Fig. 2). The sugarcane biomass was fed to hammer mill through feeding screw. Here the sugarcane biomass was pulverized in hammer mill and fed to pneumatic system. The cyclone separator in the pneumatic system separates the lighter materials that were not fit for briquetting and the fine powder is passed to the briquetting press unit through screw conveyor. Here the powdery raw material was pressed under high pressure and the briquettes were formed in the shape of the die fixed in it.

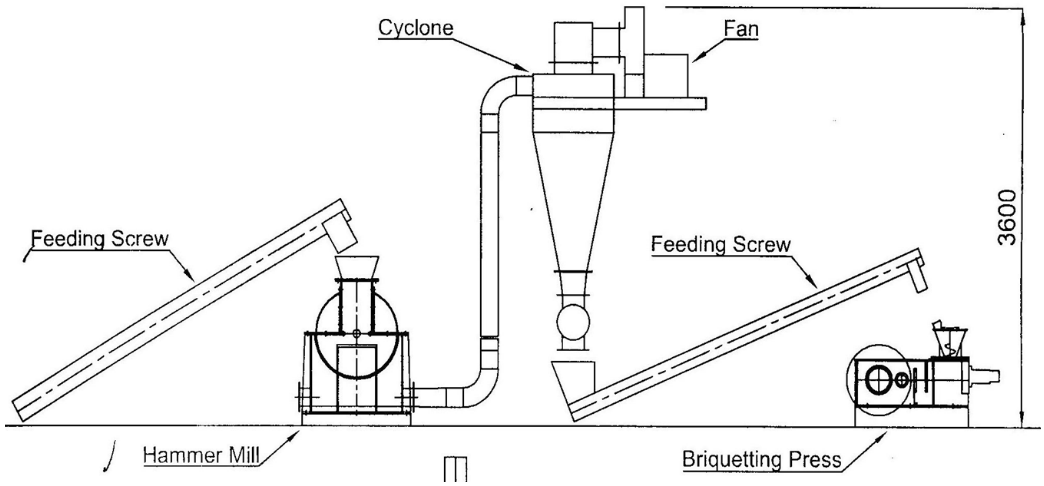

Fig. 2. Line diagram of Briquetting machine

Physical Properties

The briquettes were produced using bagasse, sugarcane trash and mixture of bagasse and trash (50:50) and analysed for physical properties.

Moisture content

The moisture content of the samples was determined by gravimetric method according to AOAC (1990) and represented as a percentage dry basis. A known weight of the sample placed in uncovered crucible and oven dried at 105±2 °C until constant weight is obtained and the loss in moisture represents the moisture content.

Bulk Density

The bulk density of the bagasse samples was determined using procedure reported by Jittabut *et al.* (2015). A cylindrical shaped container of known volume was taken and weighed. The cylinder is then filled with the sample and its weight was recoded. The difference in weight represents the mass of the sample and the bulk density of the sample was calculated using the formula

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Mass of the sample(kg)}}{\text{Volims of the cylinder (m}^3\text{)}} \quad (1)$$

Compressive strength

The compressive strength of the briquettes was determined using Textural analyser (Model: TAXT PLUS Textural Analyser; Make: Stable Micro Systems). The compressive strength was measured using P/75 cylindrical probe with 5 kg cell load and expressed as N/mm.

Proximate Analysis

Volatile matter

About 5 g of the briquette sample was taken in a crucible and placed in a furnace until it attains constant weight. The sample was then kept in a muffle furnace at 550 °C for 10 min. The weight of the sample was taken after cooling. The percentage volatile matter was determined using the formula

$$\text{Volatile matter \%} = \frac{\text{Weight of the oven dried sample – weight of the sample taken from furnace}}{\text{Weight of oven dried sample}} \quad .. (2)$$

Ash content

The ash content of bagasse sample was determined by placing 5 g of the sample in crucible and heating in a muffle furnace at a temperature of 550 °C for 4 hr. The sample taken from the furnace is then cooled in a desiccator and weighed. The percentage ash content was calculated using the formula

$$\text{Ash content \%} = \frac{\text{Weight of the sample taken from furnace (g)}}{\text{Weight of oven dried sample (g)}} \times 100 \quad .. (3)$$

Fixed carbon

Moisture content (%), volatile matter (%), and ash (%) are subtracted from 100 to yield the percentage fixed carbon as given below:

Fixed carbon, % =100 - (Ash content, % + volatile matter, % + moisture content, %) (4)

Shear resistance

The sample briquettes of known weight were allowed to drop from 1m height on a concrete surface recurrently for 10 times Madhava *et al*. (2012). There will be loss in sample weight due to shattering. The shatter resistance was calculated based on the percent weight retained by the sample.

Resistance to water penetration

The known weight of sample was allowed to immerse completely in water for about 30 seconds at room temperature Madhava *et al.* (2012). There will be increase in weight of the sample due to water absorption. The percent gain in weight was calculated as resistance to water penetration.

Calorific Value

The digital bomb calorimeter (Make: Optics Technology) is used for estimate the calorific value of the biomass briquettes. In the presence of oxygen, a known weight of the sample was burnt in a crucible. Rise in temperature of surrounding fluid was measured and caloric value was calculated with the following equation.

$$\text{Calorific value (kcal/kg)} = \frac{(W+w)\times(T1-T2)}{\text{Weight of the fuel sample}} \quad .. (5)$$

Where W = weight of water in calorimeter, kg
w = water equivalent of apparatus
T1 = initial temperature of water, °C
T2 = final temperature of water, °C

Statistical Analysis

The experiments were performed in triplicates and the results are represented as mean ± standard deviations. The parameters were statistically analyzed at 95% confidence level using SPSS-20 software (IBM SPSS Statistics, USA).

RESULTS AND DISCUSSION

Sugarcane biomass briquettes of 0.1 m length and 0.04 m diameter were produced with briquetting machine using sugarcane bagasse (SBB), sugarcane trash (STB), 50:50 ratio mixture of mixture of sugarcane trash and bagasse (STBB) (Fig. 3). Experiments were conducted for making briquettes with sugarcane biomass without using any binder. The process of non-binder briquetting mechanism can be well adopted for sugarcane biomass as it contains significant amount of lignite. It was reported by Zhang *et al*. (2018) that lignite and its

a) Sugarcane bagasse briquettes
b) Briquettes of bagasse and trash mixture (50:50)
c) Sugarcane trash briquettes

Fig. 3. Briquettes prepared from sugarcane bio mass

Table 1. Physical properties of Biomass before briquetting

S. No.	Parameter	Sugarcane biomass			Sugarcane biomass briquettes		
		Sugarcane bagasse	Bagasse & Trash (50:50)	Sugarcane trash	Sugarcane bagasse	Bagasse & Trash (50:50)	Sugarcane trash
1.	Moisture content, db%,	8.22±0.5 a	8.20±0.4 a	8.02±0.4 a	7.41±0.6 a	7.73±0.5 a	7.59±0.5 a
2.	Bulk density, kg/m^3	68± 7.5 a	43±3.5 a	20±1.7 a	529±45 c	540±49 c	427±41 b
3.	Shatter resistance, %	NA	NA	NA	99±8.5 a	88±7.2 a	ND
4.	Resistance to water penetration,%	NA	NA	NA	63±5.2 a	85±7.4 b	93±8.4 b
5.	Compressive strength, N/mm	NA	NA	NA	188 ±15 b	176±13 b	142±12 a

Values are reported as mean± standard deviation (N=3). Alphabets in small letters (a,b and c) in the superscripts denote that the mean values are statistically different within the row at $p< 0.05$.
*NA- not applicable; ND- not determined

derivatives will act as binder. The lignin at 70-90 °C binds the raw material together under high pressure, resulting in briquettes formation. Presence of 25% of lignin in sugarcane bagasse Su *et al*. (2015) and 18-20% lignin in sugarcane trash Singh *et al.* (2008) results in formation of briquettes without any binder. The physical properties such as moisture content, bulk density, shatter resistance; resistance to water penetration and compressibility of the biomass before and after briquetting was carried out according to the procedures described in materials and methods. The moisture content of the sugarcane biomass was less than 15% (Table 1) which is proved to be suitable for feed stock densification Brunerova *et al*. (2020). It was observed from Table 1 that, the moisture content of biomass varied the range of 8.02-8.22%, whereas moisture content of biomass briquittes varied in the range of 7.41-7.723% d.b. In comparison with the sugarcane biomass, the sugarcane biomass briquettes showed an in significant reduction in moisture content owing to moisture evaporation at increased temperatures during compression. SBB exhibited lowest moisture content (7.41%) among all briquettes.

The bulk density of sugarcane biomass plays a major role during handling and transportation which has increased 7 to 20 folds after briquetting (Table 2). There was a significant increase in bulk density after briquetting to a tune of 677%, 1155% and 2000% in a SBB, STBB, and STB respectively. The increase in bulk density indicates high quality solid biofuel as it takes longer burning time and releases greater amount of heat energy Teixeira *et al.* (2010). The shatter resistance and resistance to water penetration are the indicators for determining the mechanical quality of briquettes. Of all the samples, SBB recorded high resistance to shattering (99%) followed by STBB (88%). However, the STB could not withstand the shattering action and found to be disintegrated into pieces. Hence, it was clear that out of the selected sugarcane biomass, the briquettes made from bagasse and mixture of bagasse and trash were well suitable for handling, storage and transportation. The resistance to water penetration was recorded to be high (93%) in STB followed by STBB (85%) and SBB (63%). The reason being that sugarcane trash has capability of absorbing more water compared to sugarcane bagasse. The compressive strength of the briquettes indicates its physical strength and was considered to be an important parameter during storage of briquettes when placed one above the other and weight is added to lower layers. Results on the compressive strength of sugarcane biomass indicates high compressive strength for SBB (188 N/mm) while lowest value of 142 N/mm recorded for STB. Brunerova *et al*. (2020) reported compressive strength of sugarcane bagasse briquettes produced in Vietnam as 150 N/mm which are similar to the results attained in the present studies. It was reported that the briquettes formed using lignin as binder will have good compressive strength with low cost of production Zhang *et al.* (2018).

The proximate analysis viz. ash content, volatile matter, fixed carbon and calorific value were carried out for the biomass and briquettes as presented in the Table 2. The ash content of the sugarcane biomass briquettes showed low value (5.32) for STB followed by STBB (7.7%) and STB (8.13%). Ash is considered as an impurity that will not burn and the fuels with high ash content leads to higher dust emission and affects combustion capacity and efficiency. The volatile matter of the briquettes recorded in the range of 57.5 to 67.6% with high value recorded for SBB. The high volatile percent indicates complete combustion of fuel and act as highly reactive fuel. The high volatile percent of SBB (67%) indicates easy ignition of briquettes and increase in flame length as suggested by Yin *et al*. (2011). The fixed carbon content of the fuel indicates the carbon content found in the material after the volatile matter is left. The SBB recorded for low

Table 2. Proximate analysis of sugar cane biomass and its briquettes

S. No.	Parameter	Sugarcane biomass			Sugarcane biomass briquettes		
		Sugarcane bagasse	Bagasse & Trash (50:50)	Sugarcane trash	Sugarcane bagasse	Bagasse & Trash (50:50)	Sugarcane trash
1.	Ash content (%)	6.3±0.51 ^{ab}	7.0±0.55^{bc}	9.3±0.62 ^{d}	5.32±0.4 ^{a}	7.7±0.6^{bc}	8.13±0.71 ^{cd}
2.	Volatile matter (%)	80.5±7.2 ^{a}	79.7±6.8 ^{a}	69.1±5.9 ^{a}	67.3±5.8 ^{a}	60.5±5.5 ^{a}	57.5±4.6 ^{a}
3.	Fixed carbon (%)	5.54±0.45 ^{a}	5.19±0.42 ^{a}	13.87±0.8 ^{b}	20.5±1.7 ^{c}	25.2±1.8 ^{d}	27.1±1.9 ^{d}
4.	Calorific value (MJ/kg)	13.80±1.2 ^{a}	12.9±1.1 ^{a}	12.5±1.1 ^{a}	15.15±1.3 ^{a}	14.8±1.1 ^{a}	14.5±1.2 ^{a}

Values are reported as mean± standard deviation (N=3). Alphabets in small letters (a,b,c and d) in the superscripts denote that the mean values are statistically different within the row at $p< 0.05$.

percent fixed carbon (20.5%) followed by STBB (25.2%) and STB (27.1%). The biofuel with high volatile matter possesses low fixed carbon and tends to be harder, heavier, stronger and easier to ignite than biofuels with high fixed carbon Pallavi *et al*. (2013).

The most crucial property of the fuel which determines its efficacy is calorific value. The calorific value of sugarcane biomass was found to increase insignificantly after briquetting. Of all the samples, SBB recorded highest calorific value (15.5MJ/kg) compared to other samples. It was reported that the biomass after densification into briquettes improves fuel efficiency and generates less smoke and more heat during combustion Eissa *et al.* (2013); Werther *et al.* (2000). Similar results of increase in calorific value of biomass after briquetting is observed in the present study.

The sugarcane biomass can be well diverted to produce briquettes without using any binder. Of the three samples of briquettes produced, SBB exhibited superior qualities in terms of ash content, compressibility, calorific value, shatter resistance etc. However, the briquettes produced from bagasse-trash mixture were statistically on par with the briquettes of bagasse alone. Though the briquettes produced from sugarcane trash recorded maximum increase in bulk density (20 times) and exhibited maximum resistance to water penetration; it could not with stand shattering which is highly requisite while handling storage and transportation. Hence, the briquettes made of sugarcane bagasse alone and mixture of bagasse and trash can be recommended for biofuels.

This study is aimed to evaluate the potentiality of sugarcane biomass for production of bio-fuel through briquetting technology. The physical and mechanical parameters of the sugarcane biomass briquettes studies showed positive results for suitability as good solid fuel. Good quality and highly durable briquettes with high calorific value can be produced from sugarcane biomass. From the briquettes samples under study, the briquettes made of bagasse alone and mixture of bagasse and trash (50:50) can be recommended as biofuels. In conclusion, the study proved for proper waste management of sugarcane biomass in worldwide to protect environmental pollution. Additionally, conversion of sugarcane biomass using briquetting technology can create entrepreneurship development and employment chances to the rural youth.

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Conflict of Interest

The authors have no conflict of interest.

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