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Feasibility Study on Utilization of Biomass Briquette in a Conventional Downdraft Gasifier

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Abstract – Use of loose biomass in the conventional downdraft gasifier, designed to operate with wood chips, is a challenging task due to the clogging of the biomass at the throat of the gasifier. Present work involves the use of loose biomass in the form of briquettes for the gasification in a 5 kW downdraft gasifier designed to run with wood chips. The biomass briquettes of spherical shape with average diameter 25 mm are made from saw dust mixed with the old news paper as the binder. Thermal behavior along with the gas quality and tar produced in the gasification with saw dust briquettes as feed material are evaluated. Results obtained are compared with wood chips gasification for an equivalent ratio of 0.32. It is observed that gasification process with saw dust briquettes is comparable to the wood chips in terms of yield of gas, tar content and the gas quality. This study reveals that feedstock design can help in utilizing various biomasses in a conventional downdraft gasifier without any modification of the same.

Keywords – Gas yield, gas quality, saw dust briquettes, tar, wood chips.

1. INTRODUCTION

Depletion of fossil fuel and its effect on the environment has lead researchers to study for the renewable energy sources [1]. About 78 million rural households in India alone do not have access to the power grid. Biomass is one of the potential resources to produce heat and power [2]. The sources of biomass energy are forest residue, wood residue, agricultural waste like rice husk, saw dust and animal wastes. The use of biomass as an energy source has high economic viability, large potential and various social and environmental benefits [3]. Wood and agricultural residues are found in abundance in India. The net production of the residue could be about 500 million tonnes. About 32% of the total primary energy use is derived from biomass and more than 70% of the population is dependent on it for the energy needs [4]. Biomass gasification is the process of converting biomass (solid) into combustible gases. It may be produced and consumed on a CO_2-neutral basis [5]-[7]. Biomasses are converted into a gaseous fuel through a thermo chemical process in a gasifier. The gaseous fuel produced from the biomass by partial combustion is known as producer gas [8]-[10]. It consists of a mixture of combustible and non-combustible gases. The combustible fraction consists of hydrogen (H_2), carbon monoxide (CO) and methane (CH_4). The non-combustible fraction consists of carbon dioxide (CO_2), nitrogen (N_2) and moisture (H_2O). Producer gas is used as a fuel in a furnace as an alternate heat source for industrial heating applications and in an internal combustion engine to produce electricity [11], [12]. The gasification of solid fuel is carried out in fixed or fluidized bed gasifiers. Feedstock flows towards the downward direction in a fixed bed due to the influence of gravity. Fixed bed gasifiers are classified as updraft, downdraft and cross draft type depending upon the relative motion of air and product gas. In updraft gasifier gas and air, flow towards the upward direction. If the flow of air and gas are downward, it is known as downdraft gasifier. While in case of a cross-draft gasifier, the air and gas flow are horizontally, perpendicular to the direction of flow of biomass [13]. Downdraft gasifiers are very popular for low to medium gas production [8]. Biomass gasification is the latest generation of biomass energy conversion process and is being used to improve the efficiency and to reduce the investment costs of biomass electricity generation through the use of gas turbine technology [14]. The agricultural residues can be the good attempt for low cost gasification. But biomass materials are not suitable for direct gasification because they are bulky, heterogeneous in size and shape and differ in density. These differences not only make it difficult to handle, transport and store the biomass, but also to convert it to gas. Most of the gasifiers cannot handle loose biomass [15]. The feasibility of the gasification process depends on the simplicity and accuracy of the equipment and on the possibility of using the biomass in the same place as it is generated in order to reduce transportation costs [16]. There are numerous ways to resolve these problems, of which briquette or pellets are the most commonly utilized technologies. The detailed description of the biomass briquette/pellet gasification process in the downdraft gasifiers are reported in the several published literature [12]-[14]. Shivkumar *et al.* [17] performed gasification experiments with saw dust and cattle dung cylindrical briquettes in the ratio of 75:25 in a 10 kW downdraft gasifier. They observed that the percentage of CO, CH_4. CO_2, increases with increase of the briquette size whereas H_2 and N_2 decrease with increase in size of the briquette [17]. Varshney *et al.* [18] evaluated the performance of 20 kW throat-less downdraft gasifier with cylindrical briquettes of pigeon pea, lantana and soybean stalks. The optimum length of the briquette was reported to be 8-12 mm with minimum choking during the operation [18]. Pongamia de-oiled

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cake pellets of 17 mm and 11.5 mm diameter and length in the range of 10-68 mm were gasified by Prasad *et al.* [19], [20] in a 20 kWe downdraft wood gasifier successfully. They had reported that thermal degradation occurred between 166^0C - 480^0C. It was also reported by them that complete gasification is not possible due to the larger thermal gradient within the pellets [19]. The gasification efficiencies were reported to be 73% and 95% for 17 mm and 11.5 mm diameter pellets, respectively [20]. Briquettes made with leather residues with nominal size of 70 - 50 mm and bulk density of 537.30 kg/m^3 were successfully gasified in a 10 kWe downdraft gasifier by Dogru *et al.* [21]. They measured the temperature of combustion, pyrolysis, and above oxidation zone to be 1050^0C, 530^0C, and 290^0C, respectively. The bridging of the leather briquettes was observed in the throat zone of the gasifier [21]. Sridhar *et al.* [22] reported severe ash fusion problem at high loading rate with fine biomass like rice husk or sugarcane trash, peanut shell or coir pith and same was overcome by use of briquettes. It was found from the literature that attempt has been made to use loose biomass in the form of briquette and pellet in a conventional down draft gasifier [17]-[22]. However most of the studies were confined to the effect of geometry of briquettes and pellets on gas production. Production of tar is another severe problem causing clogging or soaking the downdraft gasifier. Very few results on tar formation and remedial solutions to reduce or crack tar during gasification has been reported in the literature [23]. Moreover, effect of air: feed ratio or equivalence ratio on gas production is hardly discussed in the literature [17], [24]. Present work is an attempt to study the feasibility of spherical shape saw dust briquette in a 5 kW down draft gasifier and evaluate thermal behavior of gasifier along with the gas and tar yield. Characterization of biomass under study is conducted prior to the gasification experiments. Results obtained with gasification of saw dust briquettes are compared with the gasification of wood chips.

2. MATERIAL AND METHODOLOGY

2.1 Materials

In the present study wood chips and saw dust briquettes are considered as feed material for the gasification. Both the materials are obtained from pongamia pinnata trees.

The biomass briquettes are prepared using saw dust and waste news papers as binder. Water is used for making the briquettes.

2.2 Methodology

The wood chips (Figure 1) are cut with the woodcutting machine in the average size of 25 mm diameter and 25mm length. The saw dust briquettes are prepared manually in spherical shape of average diameter 25 mm as shown in Figure 2. These are prepared using the proportion of saw dust: waste news paper: water in the ratio of 85:15:40. This ratio was optimized with series of trial experiments with different ratio of saw dust, waste news paper and water [25]. Briquettes were made by hand with squeezing out the excess water. These briquettes are prone to deformation due to high moisture content. Conventional sun drying for a period of 2 weeks is done to prevent the deformation. Moisture content of the final briquettes is maintained at 15% (approximately) [25].

Fig. 1. Wood chips.

Fig. 2. Saw dust briquettes.

2.3 Feedstock characterization

The feedstock characterization implicated in the present study deals with proximate analysis, ultimate analysis, evaluation of heating value, compressive stress, Impact resistance index and density. Apart from these, fiber analysis is carried out to calculate the hemi-cellulose, cellulose and lignin content of biomass feed stocks.

2.3.1 Proximate analysis

The proximate analysis is conducted for the saw dust briquette and wood chips as per ASTM standard D 5373-02 (2003) to evaluate the percentages of volatile matter (VM) content, ash content, moisture content [ASAES 269-4 (2003)] and fixed carbon in saw dust briquette and wood chip samples. It is found by using muffle furnace (Make: Lab Tech). Table 1 presents the proximate analysis data for the wood chips and briquette.

Table 1. Proximate analysis (% by volume) of wood chip and saw dust briquette.

	Moisture	VM	Ash	Fixed carbon
Wood chip	10.35	77.	1.2	11.21
Briquette	12.39	73.	3.3	10.68

2.3.2 Ultimate analysis

The ultimate analysis is carried out to estimate the composition of carbon (C), hydrogen (H), nitrogen (N) and oxygen (O) and ash for wood chips and saw dust briquette. It is carried out by using Euro EA Elemental Analyzer and results are reported in Table 2.

Table 2. Ultimate analysis (% by volume) of wood chips and saw dust briquette.

Material	C	H	N	O	Ash
Wood chip	44.55	8.87	4.46	41.12	1.00
Briquette	43.73	7.61	5.92	40.85	1.89

2.3.3 Calorific value

The heating value of a fuel is determined by using bomb calorimeter. The calorific value of the wood chips and saw dust briquette is found to be 19.37 MJ/kg and 17.20 MJ/kg respectively. It is observed that the calorific value of wood chip is 12.62% higher than saw dust briquette.

2.3.4 Handling characteristic

Compressive Stress – Compressive strength of the densified products is determined by diametrical compression test. It is experimentally determined using Instron machine. A briquette/wood chip is placed between two flat, parallel platens which have facial areas greater than the projected area of the sawdust briquette/wood chips. An increasing load is applied at a constant rate until the test specimen fails by cracking or breaking. The load at fracture point, *i.e.* the maximum load, is converted into stress using the Equation 1.

$$\text{Stress}=\frac{\text{Load at fracture}}{\text{Cross sectional area of plane of fracture}} \qquad (1)$$

The load at fracture is read off a recorded stress-strain curve, which is the compressive strength and reported as force or stress in Table 3 [25].

Impact resistance -A practical performance target for impact resistance of a test specimen of wood chip and saw dust briquette have to sustain a number of falls from a stationary start from a height of 2 meters onto a concrete floor. This test is carried out by averaging the results of four single drop tests of each specimen. Each briquette is repeatedly dropped until it fractures. The impact resistance index (IRI) is calculated from the Eq.2 for saw dust briquettes / wood chips and reported in Table 3.

$$\text{IRI}=\frac{\text{Average number of drops}}{\text{Average number of pieces}}\times 100 \qquad (2)$$

Density - The density of the saw dust briquette is measured with the ASAE Standard, ASAE S269.4 DEC96. And for wood it is calculated as mass per unit volume. Density of wood chip and saw dust briquette is given in Table 3.

Table 3. Handling characteristic of the wood chip and saw dust briquette.

Material	Stress (MPa)	IRI	Density (kg/m^3)
Wood Chip	87	> 2000	492
Briquette	0.06	650	570

It is observed that handling characteristics values of the wood chip are relatively higher than the saw dust briquette. But saw dust briquette is found to be a promising alternative feed stock.

2.3.5 Fibre characteristics

Fibre is a starch free and fibrous part of plant materials. Cellulose, hemicellulose and lignin are its three major constituents. Pyrolysis of biomass is significantly dependent on these main components [26]. Hemicellulose and lignin started to decompose at lower temperatures compared with cellulose during TGA analysis; however, lignin is found to be decomposed over the whole investigated temperature (from ambient to 900^0C) and produced the highest residue after the thermo gravimetric analysis (TGA) experiment [26], [27]. The various researchers have carried out pyrolysis of cellulose, hemicellulose and lignin using TGA [27], [28]. Lignin decomposes slower, over a broader temperature range (200-500°C) than cellulose and the hemicellulose components of biomass [29]. Hemicellulose had higher CO_2 yield, cellulose generated higher CO yield, and lignin owned higher H_2 and CH_4 yield [26]. Lignin is the cementing material that provides elasticity and mechanical strength to the wood [30]. It is a phenolic macromolecule with a high degree of cross linking between the phenyl-propane units. This cross linking makes lignin more thermally stable than hemicellulose [31]. The chemical composition and nature of the biomass polymers differ significantly with biomass types. On a dry basis, softwoods contain 40–50% wt. cellulose, 25–35% wt. hemicellulose and 16–33% wt. lignin [32].

In the present work, fiber analysis comprises of characterization of lignocellulosic biomasses. The characterization of wood chips and saw dust briquette is done with the Vansoet method of analysis for the extraction of neutral detergent fiber (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). The experiment is performed with the Pelican make Fibreplus FES 02 R analyzer. The percentage of hemicelluloses, cellulose and lignin are calculated and reported in Table 4.

Table 4. Fibre analysis (% by weight) of wood chip and saw dust briquette.

Material	Hemicellulose	Cellulose	Lignin
Briquettes	14.04	53.96	12.26
Wood chips	18.36	56.51	14.08

3. EXPERIMENTAL SET UP AND PROCEDURE

3.1 Experimental setup

The schematic layout of downdraft gasifier used for present experiment is shown in Figure 3. The gasifier is coupled to an engine-generator set having 4 kW electrical output.

The gasifier is divided into seven zones starting from the top as (a) drying zone, (b) pre-pyrolysis zone (c) pyrolysis zone, (d) pre-combustion zone, (e) combustion zone, (f) reduction zone and (g) ash chamber.

The gas outlet at bottom (from the reduction zone) is connected with the various downstream systems *e.g.* venturi scrubber, cyclone separator, coarse filter, fine filter and a flare with valve. Gas produced in the reaction chamber is scrubbed and cooled in scrubber. The water is recirculated from water tank to the scrubber with the help of scrubber pump. Gas is separated from water in a cyclone separator connected to the scrubber and same goes to the filtration units (coarse and fine filters connected in series). Cool and clean producer gas is then available at the flare for utilization.

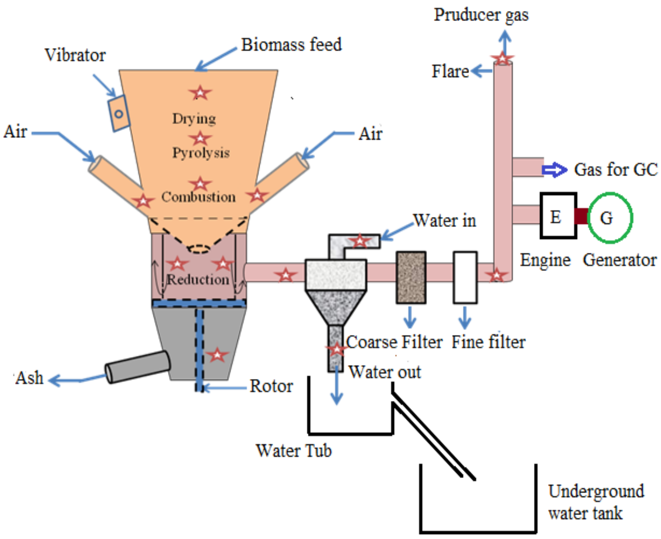

Fig. 3. Simplified layout of downdraft biomass gasifier.

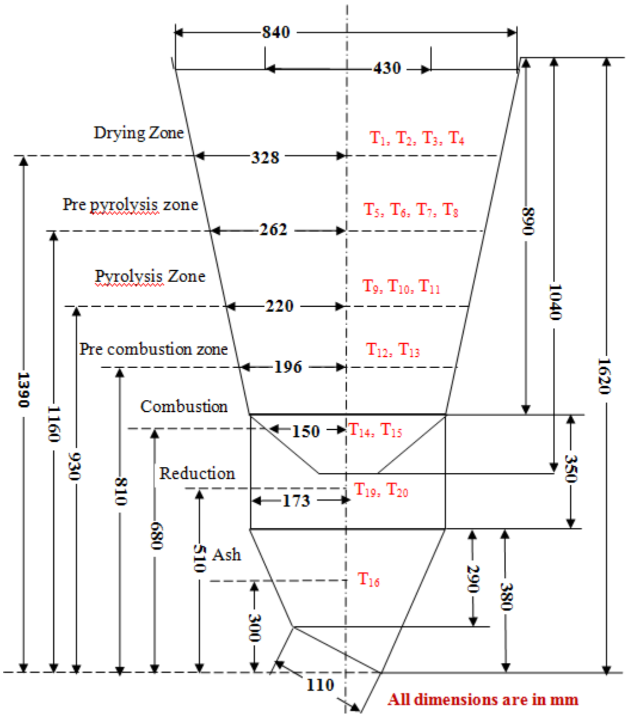

Fig. 4. Various zones of the downdraft gasifier.

Table 5. Thermocouple at various locations of the downdraft gasifier.

Location	Number of thermocouples	Distance from base of ash chamber (mm)	Diameter of the zone (mm)
Drying zone	4	1390	656
Pre-pyrolysis zone	4	1160	524
Pyrolysis zone	3	930	440
Pre-combustion zone	2	810	392
Combustion zone	2	680	300
Reduction zone	2	510	346
Ash Chamber	1	300	150

To know the thermal behavior of the gasifier, 18 thermocouples are placed inside the gasifier at various locations along the radial as well as vertical directions. K type thermocouples (Chromel -Alumel) are used to observe thermal behavior of gasification. Schematic layout of the downdraft gasifier is as shown in Figure 4.

Table 5 shows the location of the thermocouple at various positions. It elucidates the various zones diameter, distance of the each zone from the base of the ash chamber and number of thermocouple used in each zone.

The height of the gasifier is 1620 mm. The diameter at the pyrolysis zone is 440 mm and the diameter at the reduction zone is 346 mm. The height of the reduction zone is 330 mm and that of oxidation zone is approximately 300 mm. The ash produced during gasification inside the reaction chamber is removed by comb rotor. The arrangement is provided to unclog the biomass.

3.2 Experimental Procedure

The gasifier is instrumented with the thermocouples, airflow meter, gas flow meter and manometers. Manometer and airflow readings are taken by manual measurements while temperature records are collected through a data acquisition system (Agilent make) connected to a computer and thermocouples.

The experimental setup of the biomass downdraft gasifier is given in the Figure 5. In which all the aligned instruments are observed.

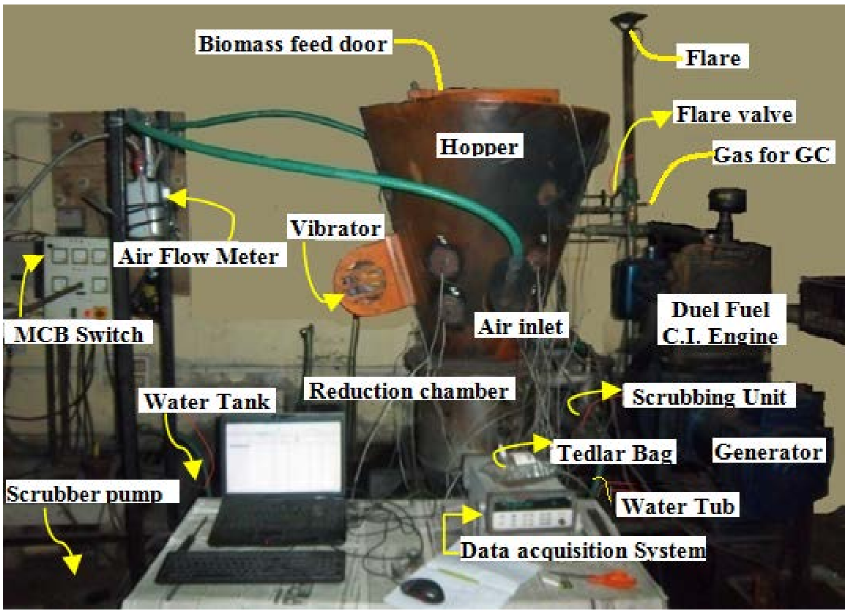

Fig. 5. Present experimental setup of biomass gasifier.

Before starting the experiments, the reaction chamber is filled with 5kg of charcoal. Subsequently the hopper is mounted over the reaction chamber. The asbestos rope of 19mm diameter is put between the reaction chamber and the hopper. This avoids the leakage of the gases.

The first test is carried out by feeding hopper with 90 kg of woodchips and second test is carried out by feeding 85 kg of sawdust briquette through the feed door at the top. The care is taken that the hopper is filled with the biomass completely. The feed door is closed after loading the solid biomass. Saw dust is added to the coarse filter. The filtering bag in the fine filter cleaned and again mounted inside the filter. The main MCB (Isolator) switch as well as control panel are switched on. Simultaneously, the pump switch is turned on from the control panel and the flare valve is slightly opened. Controlled amount of air is allowed to enter into the reaction chamber through air nozzles. The charcoal in the gasifier is ignited by bringing diesel/oil dipped lighted torch onto the two air nozzles one after another, so that flame is sucked into the combustion chamber. Gas production is detected at the flare by burning with a kindler. It is observed that medium heating value gas is generated within 5-10 minutes from the start of the gasification process. The gas is checked by lightening at flare with kindler. When it catches the fire, it is supplied to the CI Engine for power generation with coupled generator. The experiment is carried out by setting the equivalence ratio of 0.32. The equivalence ratio is obtained by controlling the air flow rate passing through the air nozzle. Equivalence ratio (ER) is defined as ratio of (measured air flow rate to biomass flow rate) to the (stoichiometric air flow rate to biomass flow rate). The equivalence ratio is calculated by the Equation 3 [24].

$$ER = \frac{\left(\frac{A}{F}\right) Measured}{\left(\frac{A}{F}\right) Stoichiometric} \tag{3}$$

The gasification process in a downdraft gasifier can be separated mainly into three different sub-processes. In the first stage, the biomass is dried and converted into volatile substances and char. The second exothermic sub-process consists of the partial oxidation of the volatile substances, supplying the heat necessary for the first stage and for the third one (the char gasification), with a simultaneous reduction of the combustion gases [14]. The reactions which take place in the oxidation zone are exothermic as given in Equations 4 and 5.

$$C + 0_2 \rightarrow CO_2 + 393.8\left[\frac{MJ}{Kmol}\right] \tag{4}$$

$$C + 2H_2 \rightarrow CH_4 + 75\left[\frac{MJ}{Kmol}\right] \quad (9)$$

$$H_2 + \frac{1}{2}O_2 \rightarrow H_2O + 242\left[\frac{MJ}{Kmol}\right] \quad (5)$$

The reactions which take place in the reduction zones are Boudouard reaction, water gas reaction, water shift reaction and methane formation reaction given in Equations 6 and 7. Boudouard reaction:

$$CO2 + C \rightarrow 2CO - 176\left[\frac{MJ}{Kmol}\right] \quad (6)$$

$$C + H_2O \rightarrow 2CO + H_2 - 131.4\left[\frac{MJ}{Kmol}\right] \quad (7)$$

Water-gas reaction:

$$CO_2 + H_2 \rightarrow CO + H_2O + 41.2\left[\frac{MJ}{Kmol}\right] \quad (8)$$

Water shift reaction:

Methane production reaction:

Exact order of reactions is very intricate and their relative significance depends on the type of fuel used and design of the gasifier. The solid fuel distribution inside the bed is always different, leading to variations in the process parameters [33], [34].

Heat is generated in the combustion zone. That heat propagates to the pyrolysis and drying zone and biomasses starts to release volatiles and convert to char which drops down to the reduction chamber. Heat generated into combustion zone also propagates into reduction zone. Special ash handling mechanism is provided at the bottom of the reduction zone so that no clinkers can form. Ash from the reduction chamber is transferred to the ash chamber which can be removed easily.

4. RESULTS AND DISCUSSION

Each of the experiments is carried out for 8 hrs duration. Various gasification stages of the experimentation on the present downdraft gasifier are estimated for both the feed stocks.

5.3 Thermal Behavior

The thermal behavior of the gasifier is evaluated for the wood chip and sawdust briquette for equivalence ratio 0.32. Figure 6 presents variation of temperature along the height of the gasifier from the bottom of the ash chamber. The variation of temperature for drying, pre-pyrolysis, pyrolysis, pre-combustion, combustion, reduction zone and ash deposition zone are presented for both the wood chips and saw dust briquettes as feed material.

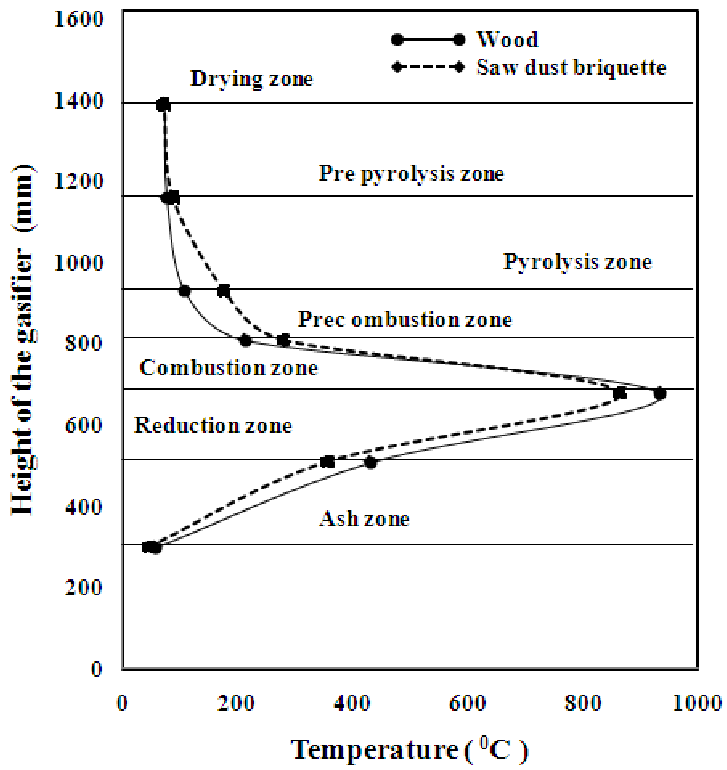

Fig. 6. Thermal behavior of gasifier at various stages.

Table 6. Temperature and gas flow rate at ER=0.32 for woodchip and sawdust briquette.

Material	Wood chip	Sawdust Briquette
Producer gas flow rate	2.35 ($Nm^{3/}hr$)	2.17 ($Nm^{3/}hr$)
Location	(Temperature ^0C)	
Drying zone	72	71
Pre-pyrolysis zone	76	87
Pyrolysis zone	107	176
Pre- combustion zone	212	279
Combustion zone	933	863
Reduction Zone	429	356
Ash zone	56	45

It is observed that the temperature rise above the combustion zone is higher while gasifying the sawdust briquettes than the wood chips. This is due the high voidage present in the saw dust briquettes allowing heat to transfer upwards. The temperature in the combustion zone and reduction zone are observed higher for the wood chips. This is due to the high calorific value of the wood chips. The average temperature variation in various zones in the gasifier is presented in Table 6 for both the feed materials. Gas flow rate (Normal cubic meter per hour) after 8 hours of operation is also presented in Table 6.

Figures 7 to 8 present the thermal behavior of the gasifier for wood chips and saw dust briquettes, respectively. Results are plotted taking average of 2-3 experimental observations. In these figures the variation of temperature with time for different zones are presented. Transient behavior for all the zones is observed during the first 2 hours of operation for saw dust briquettes subsequently the temperature become stable after 2 hours of operation. However, long duration of temporal variation of temperature is observed with wood chips. It is observed that the temperature varies between 800^0C - 1100^0C for wood chips and 750^0C - 950^0C for the sawdust briquette in the combustion zone. Large fluctuations in temperature with wood chips are due to the erratic flow of wood chips from drying zone to the combustion zone. Major problem being observed is due to the stickiness of wood chips with tar. Errors in all the plots are well within $\pm 5-8$ %.

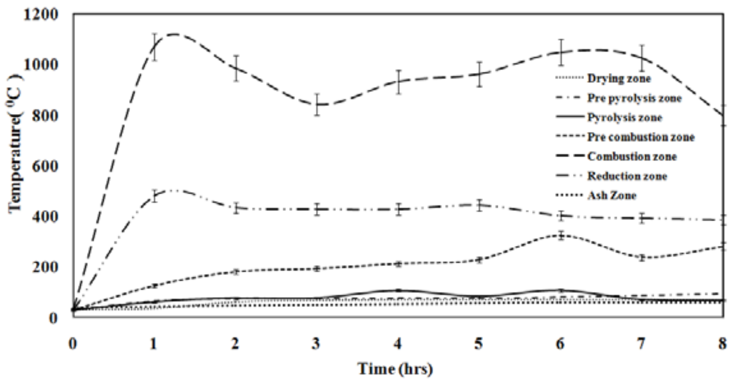

Fig. 7. Thermal behavior of gasifier for wood chip at ER 0.32 [35].

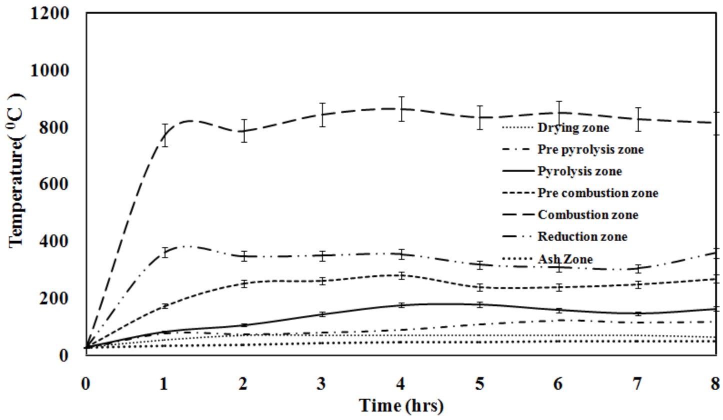

Fig. 8. Thermal behavior of gasifier for sawdust briquette at ER 0.32.

5.3 Gas Chromatography of the Producer Gas

The dry and clean producer gas is collected in Tedlar bags at the gas collection port below the flare valve. It is collected after the gas filtered through the scrubber, coarse filter and fine filter, respectively. The collected gas is analyzed in a gas chromatograph (Make- Chemito, model – CERES-800 plus). The gas chromatography showed the different peaks for different constituents of product gas mixture. The results are tabulated in Table 7.

Its comparative analysis is plotted and shown in Figure 9. It is observed that the gas composition of the saw dust briquette is comparable with the wood chips.

The percentage of CO, H_2, CH_4 and N_2 for woodchip is respectively 4.05 %, 4.98 %, 15.3 % and 1.67 % higher than the saw dust briquette and percentage of CO_2 is less by 8.25 %.

Table 7. Gas chromatography analysis of producer gas for saw dust briquette and wood chips [Vol. %].

Constituent	Wood chip	Saw dust Briquette	Briquette [23]
H_2	18.27	17.53	20
CO	15.26	14.5	24
CO_2	14.42	15.61	12
N_2	49.17	48.35	56
CH_4	2.81	2.38	3

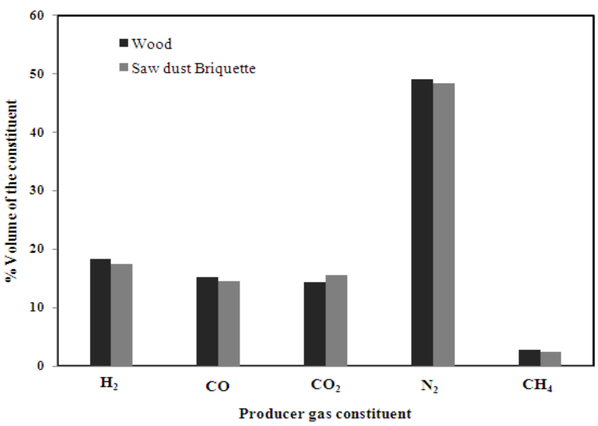

Fig. 9. Comparative analysis of gas chromatography.

5.2 Tar Content at Various Locations in the Gasification Experiment

Tar is a thick, black, highly viscous liquid which condenses at low-temperature zones of a gasifier, clogging the gas passage and leading to system disruptions. The wet tar sample obtained with wood chips gasification is shown in Figure 10.

The tar in the producer gas is condensed in the direct contact type heat exchanger (scrubber) and is collected in water tub and underground water tank as shown in Figure 3. Moreover, some amount of tar is also carried out with the producer gas after scrubbing; it is deposited in coarse and fine filters. Tar content in gasification experiments is measured at various locations and it is calculated for one kg of feedstock in an hour and is given in Table 8.

Fig. 10. Tar obtained in the gasification.

Table 8. Tar content at various locations (gm/kg of feedstock/hr) for wood chips and saw dust briquette.

Feedstock Material	Water tub	Water tank	Coarse filter	Fine filter	Total
Wood chip	2.102	5.767	1.480	0.0021	9.351
Briquette	1.932	5.310	1.578	0.0018	8.822

The comparative analysis of tar obtained from the gasification of the wood chips and saw dust briquette is given in Figure 11.

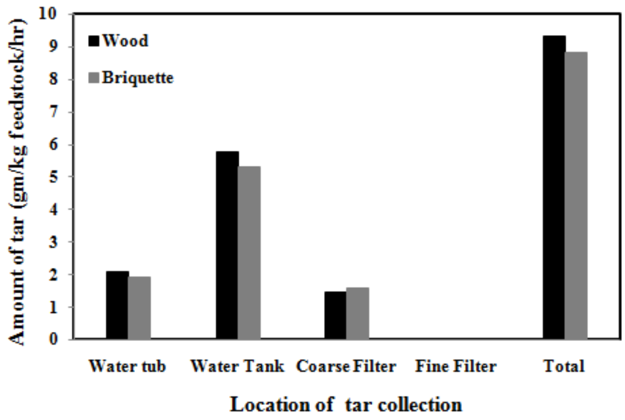

Fig. 11. Comparative analysis of tar.

It is observed that tar collected at water tub, water tank, and fine filter locations of the gasifier unit are 8.09%, 7.92% and 14.28% respectively higher for the wood chips than the briquettes. While in coarse filter it is 6.62% less than briquette. The total tar measured is observed 5.66% higher for woodchips than the sawdust briquette. Thus final gas quality is improved significantly with saw dust briquette as feed material.

5. CONCLUSIONS

In the present study feasibility of using saw dust in the form of briquettes as feed material in a conventional wood chips fed downdraft gasifier is studied. For sake of comparison, equivalent ratio ER=0.32 was maintained during gasification. Results in terms of characteristic of the feed material as well as gas and tar yield are compared. From this study it is found that saw dust briquette posed no problem while used in a conventional downdraft gasifier. Thermal behavior for both the feed material are found to be similar. Tar formed is deposited in the filters and water tanks improving the final gas quality with saw dust briquettes. This study establishes feasibility of using saw dust briquette in a conventional downdraft gasifier.

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