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Studies on characterisation of biomass fuel

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ABSTRACT : Current investigation was followed by characterization of pigeonpea briquettes, soybean briquettes and *Prosopis juliflora*. Proximate, ultimate and thermogravimetric analysis (TGA) of, pigeonpea and soybean briquettes was done by standard procedure and compared with *prosopis juliflora* (woody biomass). The calorific value of *Prosopis juliflora,* pigeonpea and soybean briquettes was 18.41, 18.52 and 18.35 MJ/kg, respectively. The volatile matter content of *Prosopis juliflora,* pigeonpea and soybean briquettes was 83.64, 76.02 and 76.89 % (d.b.), respectively. The ash content of *Prosopis juliflora,* pigeonpea and soybean briquettes was 1.14, 5.01 and 6.11 % (d.b.), respectively. The carbon content of *Prosopis juliflora,* pigeonpea and soybean briquettes was 49.86, 43.35 and 39.9 %, respectively. Thermogravimetric analysis of *Prosopis juliflora,* pigeonpea and soybean briquettes was done at 10, 20, 30 and 40 °C heating rate. It was found that at 30 °C heating rate the thermal decomposition of pigeonpea and soybean briquettes was same as *Prosopis juliflora*.

KEY WORDS : *Prosopis juliflora,* Pigeonpea briquettes, Soybean briquettes, Proximate analysis, Ultimate analysis, Thermogravimetric analysis

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India generates over 600 million tons of biomass based on agricultural residues annually which can be converted into energy. The energy content of biomass at 10 per cent moisture content is about 14 GJ/tonne. It has been used as heat energy source for thousands of years. Bio-energy can be relevant for dispersed power/energy production, particularly in small and medium capacities. Biomass is also capable of providing firm energy. Estimates have indicated that 15 per cent – 50 per cent of the world's primary energy use could come from biomass by the year 2050. Currently, about 11 per cent of the world's primary energy is estimated to be met with biomass (Anonymous, 2010).

The common sources of biomass are forest, energy crops, crop residue and agro processing residue. An area of about 107 million hectares has been estimated to be degraded with 64 million hectares categorized as wasteland, which includes degraded forests. The minimum wasteland area that might be available is about 35 million hectares. If about 5 million hectares of land by the side of highways and rail tracks is added to this, the total land available for raising plantations becomes 40 million hectares. In addition, there would be significant potential from farm forestry with farmers raising trees on bunds and in fields. Agro-forestry can also be promoted through contract farming whereby corporate bodies can organize groups of farmers to produce the required biomass under contract through development of wastelands (Ravindranath and Balachandra, 2009). The fuel wood potential of Indian forests is already fully used.

A techno-economic model study has shown that biomass electricity technologies have significant potential to penetrate Indian market under a fair competition with the fossil technologies. Under an optimum greenhouse gas mitigation regime, biomass electricity penetration is expected to reach 35,000 MW in 2035, which is approximately 9 per cent of total power capacity in India (Shukla, 2000). Biomass energy is one of humanity's earliest sources of energy particularly in rural areas where it is often the only accessible and affordable source of energy. Worldwide biomass ranks fourth as an energy resource, providing approximately 14% of the world's energy needs all human and industrial processes produce wastes, that is, normally unused and undesirable products of a specific process (Demirbas, 2004). Cordero *et al.* (2001) presented a simple equation based on proximate analysis (volatile matter and fixed carbon contents) which allows calculation of the higher heating value of lignocellulosics as well as the charcoals resulting from their carbonization. Erol *et al.* (2010) developed different 13 new formulae for estimating the calorific values of 20 different biomass samples from their proximate analyses data. Shen *et al.* (2010) presented new correlations for calculating the elemental composition based on proximate analysis of biomass. The carbon content of wood varies from about 47 to 53% due to varying lignin and extractives content (Ragland and Aerts, 1991). The properties of biomass fuel are among the key factors that influence the selection of the processing technology and its design, operation, efficiency, maintenance schedule, etc. Characterization of biomass is the first step for efficient utilization of its energy potential therefore, present investigation was done with major objective of characterization of biomass fule.

METHODOLOGY

Materials:

The material selected for study was *Prosopis juliflora*, briquettes of pigeonpea and soybean stalk. *Prosopis juliflora* was procured, from local market of Bhopal (MP). The size of wood pieces maintained not more than 30 mm x 50 mm. Moisture meter was used to measure the moisture content of wood pieces which was maintained less than 15 per cent. The briquettes of soybean and pigeonpea was made by respective stalk in briquetting plant available at Central Institute of Agricultural Engineering, Bhopal.

Characterization of *Prosopis juliflora:*

The methods for finding the moisture content, bulk density, proximate, ultimate and thermo gravimetric analysis of biomass fuel are discussed. The observations were recorded in triplicate and average values were used.

Moisture content:

Electric oven was used to determine the moisture content of *Prosopis juliflora*. A known quantity of biomass sample was dried at 110 ± 5°C until constant weight was attained and the moisture content was calculated by using formula:

$$\text{Moisture, \% (wet basis)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

$$\text{Moisture, \% (dry basis)} = \frac{(W_2 - W_3)}{(W_3 - W_1)} \times 100$$

where, W_1 is the weight of empty crucible,

W_2 is the weight of the crucible and sample, and

W_3 is the constant weight of crucible and sample after drying.

Bulk density:

Bulk density of the biomass is the ratio of its mass to bulk volume of the sample. To measure the density of biomass sample, a standard measuring cylinder was filled up with pellets and then the contents were weighed on weighing balance. Average of three replications was reported as the bulk density value of grain sample.

Calorific value:

The calorific value of the sample was measured by using CP 500 calorimeter manufactured by Digital Data System Pvt. Ltd., South Africa. The sample was filled in gelatin capsule and then it was burnt in oxygen in bomb calorimeter. The total weight of sample and the capsule was fed to controller and the results including the gross heating value were printed. Knowing the heat and weight value of the capsule, the heat value of the sample was calculated.

Proximate analysis:

Proximate analysis includes characterization of biomass for volatile matter, fixed carbon, and ash content.

Volatile matter:

A known quantity oven-dried sample was heated at 600 ± 25 ºC for six minutes and then at 900 ± 25 ºC for another six minutes in a pre-weighed open silica crucible in a muffle furnace. The amount of weight loss in the sample gives the volatile matter of the biomass sample estimated using the formula given below.

$$\text{Volatile matter \% (dry basis)} = \frac{(W_2 - W_3)}{(W_2 - W_1)} \times 100$$

where, W_1 is the weight of empty silica crucible,

W_2 is the weight of the crucible and sample, and

W_3 is the constant weight of crucible and sample after heating.

Ash content:

A known quantity oven-dried sample was combusted in a pre-weighed and closed silica crucible at 750 ± 25 ºC for a minimum four hours for *Prosopis juliflora* and pigeonpea and soybean briquettes sample was combusted in a pre-weighed and closed silica crucible at 750 ± 25 ºC for a minimum of six hours in a muffle furnace. The amount is estimated using the formula given below:

$$\text{Ash content \% (dry basis)} = \frac{(W_3 - W_1)}{(W_2 - W_1)} \times 100$$

where, W_1 is the weight of empty silica crucible,

W_2 is the weight of the crucible and sample, and

W_3 is the constant weight of crucible and sample after combustion.

Fixed carbon:

The amount of fixed carbon (FC) present gives a rough indication of the charcoal yield. Also, a higher FC material is generally better suited for gasification than a lower FC material. The fixed carbon is estimated by using the following formula:

Fixed carbon % (dry basis) = 100–% volatile matter–% ash content

Ultimate analysis:

The ultimate analysis determines the elemental analysis containing carbon, hydrogen, oxygen, nitrogen, and sulpher. The elemental analysis of the sample was done CHN analyzer. The known quantity of sample was placed in analyzer and data of carbon, hydrogen, oxygen, nitrogen and sulpher was recorded.

Thermo gravimetric analysis:

Thermo gravimetric analysis (TGA) gives weight loss of the biomass with respect to change in temperature/time. A weighed sample of the biomass was placed in the furnace chamber of TGA analyzer. Inert gas (nitrogen) flow is started at least 15 minutes prior to furnace heat-up so as to maintain an oxygen-free atmosphere to restrict the combustion of biomass. Continuous data is generated and graph is plotted for mass change of the sample with respect to temperature/ time.

RESULTS AND DISCUSSION

Table 1 presents the proximate and ultimate analysis of the biomass samples that have been studied in this work. The bulk density of *Prosopis juliflora*, pigeonpea and soybean briquettes was 407, 640 and 630 kg/m^3, respectively. The bulk density of pigeonpea and soybean briquettes was higher than the *Prosopis juliflora.* Biomass with high bulk density is advantageous for combustion systems because it represents a high energy value for smaller volumes and needs less storage space. Bhoi *et al.* (2006) reported bulk density of babul wood (*Prosopis juliflora)* 407 kg/m^3 and stated that low bulk density results in improper flow of fuel. Lata and Mande (2011) reported average bulk density of wood in the range of 300 to 550 kg/m^3.

The calorific value of *Prosopis juliflora*, pigeonpea and soybean briquettes was 18.41, 18.52 and 18.35 MJ/kg respectively. High calorific value indicates good characteristics for gasification, because higher heat generated during combustion leads to high temperature in reaction zone. Bhoi *et al.* (2006) reported the calorific value of babul wood (*Prosopis juliflora)* 16.82 MJ/kg. Erol *et al.* (2010) analyzed 20 different biomass samples and determined net calorific value in the range of 15.41-19.52 MJ/kg. Singh *et al.* (2006) determined the lower calorific value of cashewnut shell was 4252 kcal/kg.

The volatile matter content of *prosopis juliflora*, pigeonpea and soybean briquettes was 83.64, 76.02 and 74.89 % (d.b.) respectively. The ash content of *prosopis juliflora*, pigeonpea and soybean briquettes was 1.14, 5.01 and 6.11 % (d.b.) respectively. Pigeonpea and soybean briquettes was found to be lower in volatile matter content but higher in ash and fixed carbon content than *Prosopis juliflora*. Higher fixed carbon content in pigeonpea and soybean briquettes indicates good fuel characteristics for gasification. Ramana *et al.* (2005) presented the volatile matter content, ash content, and fixed carbon content 82.68, 1.47 and 15.87 (%, d.b.) respectively for subabool wood. Sheth and Babu (2009) reported the volatile matter content, ash content, and fixed carbon content 80.40, 3.90 and 15.70 (%, d.b.), respectively for furniture waste of *D. sisoo* (Sesam wood). Singh *et al.* (2006) calculated the volatile matter content, ash content, and fixed carbon content 79.54, 1.53 and 18.93 (%, d.b.)

Table 1 : Characterization of biomass sample

Properties	*Prosopis juliflora*	Pigeonpea briquettes	Soybean Briquettes
Moisture content (%, d.b.)	12-15	12-15	14-15
Bulk density, kg/m^3	407	640	630
Calorific value (MJ/kg)	18.41	18.52	18.35
Proximate analysis			
Volatile matter content, (%, d.b.)	83.64	76.02	74.89
Ash content, (%, d.b.)	1.14	5.01	6.11
Fixed carbon content, (%, d.b.)	15.22	18.97	19
Ultimate analysis			
Carbon (%)	49.86	43.35	39.9
Hydrogen (%)	5.93	6.45	6.33
Oxygen (%)	45.87	49.34	51.62
Nitrogen (%)	0.34	0.58	1.63
Sulpher (%)	0.19	0.28	0.52

respectively for cashewnut shell.

Ultimate analysis represents the elemental analysis which belongs to carbon, hydrogen, oxygen, nitrogen and sulpher. Pigeonpea and soybean briquettes was lower in carbon content but higher in hydrogen and oxygen than *Prosopis juliflora*. For thermochemical process, carbon is the most important element in the fuel as it has direct influence on the heating value according to same; higher the carbon content (50.31 %) of *Prosopis juliflora* represents higher heating value of fuel. Hussain *et al.* (2006) performed the ultimate analysis of palm shell and determined the carbon, hydrogen, oxygen, and nitrogen content 47.62, 6.2, 43.88 and 0.7 per cent, respectively. Kim *et al.* (2006) studied the ultimate analysis of palm kernel shell and reported the carbon, hydrogen, oxygen, nitrogen and sulphur content 44.56, 5.6, 49.77, 0.4 and 0.05 per cent, respectively. Obernberger and Thek (2004) carried out the ultimate analysis of wood pellets and determined the carbon, hydrogen and nitrogen content 50.3, 5.7 and 0.22 per cent on dry basis, respectively. Tsamba *et al.* (2006) performed the ultimate analysis of wood pellets and determined the carbon, hydrogen, oxygen, nitrogen and sulphur content 50.9, 6.2, 42.06 0.2 and 0.01 per cent, respectively.

Fig. 1, 2, 3 and 4 represent the thermogravimetric analysis of *Prosopis juliflora*, pigeonpea briquettes and soybean briquettes at heating rate of 10, 20, 30, 40°C, respectively. From the thermogravimetric analysis of test sample it was clear that at 30° C heating rate the thermal decomposition of pigeonpea and soybean briquettes was same as *Prosopis juliflora*. The volatiles yield of soybean briquettes was lower at all heating rate than *Prosopis juliflora* and pigeonpea briquettes. There was no greater difference in thermal decomposition of pigeonpea and soybean

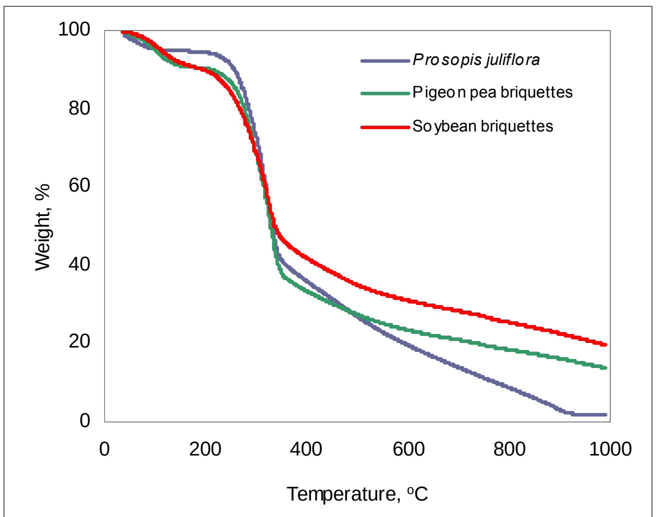

Fig. 1 : Thermo gravimetric analysis of *Prosopis juliflora*, pigeonpea briquettes and soybean briquettes at 10 °C heating rate

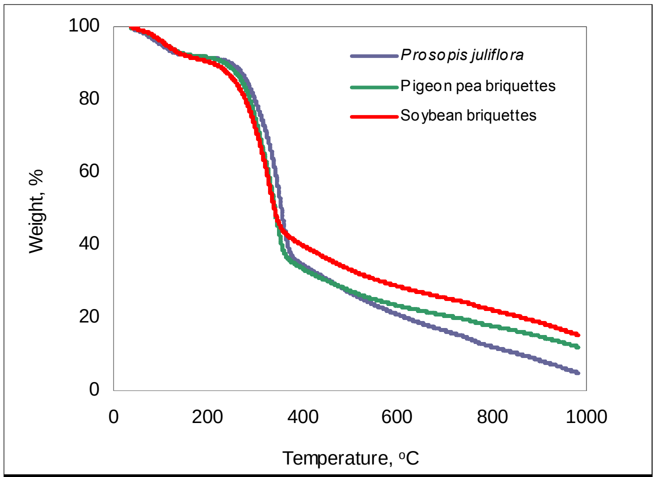

Fig. 2 : Thermo gravimetric analysis of *Prosopis juliflora*, pigeonpea briquettes and soybean briquettes at 20 °C heating rate

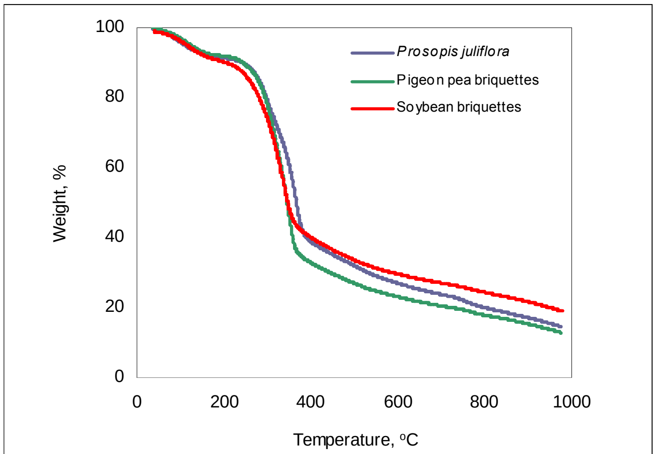

Fig. 3 : Thermo gravimetric analysis of *Prosopis juliflora*, pigeonpea briquettes and soybean briquettes at 30 °C heating rate

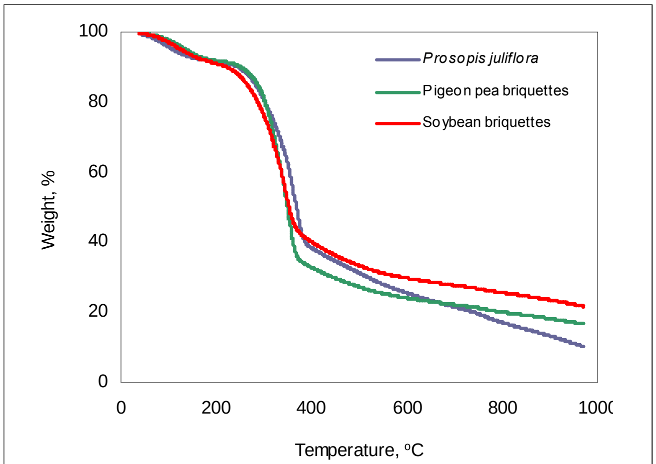

Fig. 4 : Thermo gravimetric analysis of *Prosopis juliflora*, pigeonpea briquettes and soybean briquettes at 40 °C heating rate

briquettes with the change of heating rate from 10 to 40^0 C indicating that the briquette will provide the consistent behaviour during gasification in bulk.

Conclusion:

Pigeonpea and soybean briquettes was successfully characterized. Differences and similarities between these biomass and *Prosopis juliflora* were found and discussed.

The calorific value of *Prosopis juliflora*, pigeonpea and soybean briquettes was 18.41, 18.52 and 18.35 MJ/kg, respectively.

The volatile matter content of *Prosopis juliflora*, pigeonpea and soybean briquettes was 83.64, 76.02 and 74.89 % (d.b.), respectively.

The ash content of *Prosopis juliflora,* pigeonpea and soybean briquettes was 1.14, 5.01 and 6.11 % (d.b.), respectively.

Thermogravimetric analysis of *Prosopis juliflora*, pigeonpea and soybean briquettes was done at 10, 20, 30 and 40^oC heating rate. It was found that at 30^oC heating rate the thermal decomposition of pigeonpea and soybean briquettes was same as *Prosopis juliflora*.

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