Wood material of Cassia Fistula for Power Generation: An eco-friendly approach

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ABSTRACT Bioenergy potential of Cassia fistula wood material for power generation is described in the first time. The combustion profiles of the wood like proximate analysis (moisture, volatile matter, fixed carbon, and ash contents), ultimate analysis (C, H, N, S and O composition) and thermal analysis were fully studied using appropriate analytical techniques. From the proximate analysis calorific value is 3743 Kcal/kg. Functional group present in the wood material were also determined using FT-IR spectrum. The particle size of the material is 23 nm from the data obtained from PXRD analysis and surface of the particle also analyzed by employing SEM. The gasifier efficiency and thermal output measurement were determined as 61.0% and 5.5 kW/hr respectively.

Keywords: Cassia fistula, Calorific Value, Power Generation, Proximate Analysis, Woody Biomass

Introduction

Fossil fuels (coal, petroleum and gas) are limited abundance in nature. These fossil fuels are not renewable within a short time-scale human can use. Fossil coals are mostly used in the thermal power plants. Thermal power plants also produce a large amount of pollutants, such as carbon dioxide, sulphur oxides, fly ash, etc which are highly hazardous to mankind, animals and environment. Hence, researchers are in search of alternative sources of energy which should be environment-friendly [1]. In the search of alternative, Biomass resources are the world’s largest and most sustainable energy source for power generation [2]. Application of plant materials for power generation has various benefits over other sources; those are, Sustainable plantation and use of biomass in power plants will be reduce in the concentration of CO₂ in the atmosphere [3]. The ash content in biomass is very less (2-6% approx as against 20-50% in coal) [4]. Energy content in biomass is more than those of E and F grade coals (mostly used in Indian power plants). Biomass will operate lesser temperature compared with coal due to its higher reactivity towards oxygen and carbon dioxide. Electricity generation on decentralized basis is possible; it will reduce the cost of transmission [5]. Unlike other renewable, biomass materials, pre-dried up to about 15% moisture, can be stored for a considerable time without any difficulty. In the present investigation, we have described the woody part of Cassia fistula is an easily available, unutilized, biomass feedstock as a raw material for power generation. To the best of our knowledge, Cassia fistula plant materials in the aspect of biomass for power generation are still unknown. Fistula L. is known as Golden Shower worldwide and “Amaltas” locally for Indian laburnum. It is abundantly distributed in worldwide and more specifically in Asian countries. It is a popular medium sized deciduous ornamental tree (8–24 m height), it belongs to family- Fabaceae, genus-Cassia, species-Fistula [6] Pruthi and coworkers described Biodiesel production from non-edible lignocellulosic biomass of Cassia fistula L. fruit [7]. Tripathi disclosed Biomass functions and physiology of carbon dynamics of Cassia fistula [8]. Phytochemical analysis and their biological analysis are reported in the literature [9].

Materials and Methods

Biomass collection and sample preparation

The study material Cassia fistula wood was collected from Agricultural College and Research Institute, Killikulam, Vellanadu, Thoothukudi District, Tamil Nadu, located at 8°46 N latitude and 77°42 E longitude and lies in south India. The collected material dried over sunlight until completely dried (around 20-25 days). Dried materials were chopped in a household blender used without any pretreatment for research paper IJRAR- International Journal of Research and Analytical Reviews i978
proximate analysis. Powdered form of dried materials was used for ultimate, PXRD, FT-IR, SEM, EDAX and thermal analysis.

**Characterization**

Powder X-Ray Diffraction (PXRD) of Cassia fistula wood powder was done by using X-ray Diffractometer (PANANALYTICAL, NETHERLAND& X’PERT POWDER) with CuKα radiations. Scanning Electron Microscope (SEM) measurements were carried out using SEM (Vega 3 Tescan) equipped with Energy Dispersive X-Ray Analysis (EDAX, Bruker). Elemental analysis was carried out in a Thermo Finnigan Flash EA 1112 analyzer. IR spectrum was recorded on a JASCO FT/IR-5300 instrument. Thermal behavior of the wood material was studied using thermal analyzer (NETZSCH STA 449F3). The proximate analysis to analyze moisture, volatile, fixed carbon and ash content were done by ordinary oven and muffle furnace (GUNA model TC141P) respectively. The calorific value of the woody material was determined by Bomb calimeter. The thermal output and gasifier efficiency were determined by the Biomass gasifier.

**Result and discussion**

The PXRD analysis shown is in figure 1. The particle size of the material is found to be 23 nm. Irregularly shaped particles is determined in SEM image shown in figure 2, which can be considered as the aggregates of cylindrical shaped particles are also present in the materials. The EDAX spectrum of the Cassia fistula is shown in fig.3 and presented in table 1. The EDAX spectrum reveals the main elements are C (49.6) and Oxygen (37.08); K, Ca and P are in small quantity of 8.71, 3.53, 0.51 wt% respectively. The presence of the strong signal from carbon (49.6 Wt.%; 60.81 at.%) atoms also clear indication that carbon is the major constituent in the material. The higher in carbon percentage, compared with other elements oxygen and hydrogen, increases in energy value of feed stock because of higher energy of C-C bonds. The element analysis showed 67.9% of carbon 10.91% of hydrogen and very small amount of nitrogen 0.04% suggested that this material is full of hydrocarbons, hence it would be the opt material for the application of power generation. It should be noted that negligible percentage of nitrogen and sulphur is suggest that this woody material might generate power without producing the environmentally hazardous gases NOx and SOx. CHN Spectrum of C.fistula woody biomass is shown in fig.4 and the % of elements presented in table 2. The functional groups present in the wood material are analyzed with the help of FT-IR spectrum is shown in figure 5. The band at 3331 cm⁻¹ is a -OH stretching vibration, the band is broad in nature that clearly indicates the presence of hydrogen bonding, might be attributed to adsorbed water. The presence of hydrogen-bonding in that woody material it has high volatility and flammability. Sp² hybridized carbon's stretching vibration is found to be at 2919 cm⁻¹. The characteristic band of carbonyl group found in the IR spectrum at 1735 cm⁻¹. Other bands 1626, 1508, 1420, 1318, 1232 and 1027 are assigned -C=C- (Olefin carbon), -C-O- (alcohol), -C-C-  and -C-H anti-symmetric stretch respectively.

Proximate analysis of C.fistula wood materials is shown in table 3. From the values presented in the table 4, the volatile content of 72.1%, fixed carbon (18.8%), calorific value (3743 kcal/kg) favours the gasification can be utilized for plasma gasification process [10]. The upper acceptable limit of moisture content in biomass is 40 per cent on dry basis for gasification process [11]. In the woody material of Cassia fistula has less moisture content (5.7%), leads to the good candidate with high calorific value. Volatile content is also highly favors the gasification efficiency. The woody material undergoes a thermal decomposition with subsequent release of the volatiles. Ash content is an important proximate composition in agro residues. Ash content less than 6% is very significant in thermo chemical conversion process [12]. It is noteworthy to mention that C.fistula woody material has ash content of 3.4% ; this data also supports the material will be expected to be highly potential.

Thermal analysis of Cassia fistula wood is depicted in the figure 6, 7 and 8. Thermo gravimetric analysis of wood material (fig.6) shows the amount and rate of change in the weight of the material as a function of temperature in a controlled atmosphere. The initial weight loss around the temperature of 50-90 °C, due to moisture evaporation from the wood. The lesser amount of this peak area means lesser moisture content in the material. The other deviation in TGA around 200- 360 °C is a major weight loss, this is attributed to biomass volatilization and char oxidation processes which accounted about 68 per cent of total mass. (Fig 6 and 7). At temperature 550 °C, almost all the volatile compounds are combusted from wood material and the weight loss is stabilized. From DSC analysis (Fig-8), a small peak around 550 °C corresponds to cellulose present in the wood material. There is no sample left after 83 minutes, the temperature has then reached 1200 °C. The thermo gravimetric analyses of wood Cassia fistula clearly indicate that biomass is highly reactive due to the fast pyrolysis. The gasifier efficiency and thermal output measurement were tabulated in table 4. Gasifier efficiency and thermal output are 61.0% and 5.5 kw/hr respectively.
Fig. 1: PXRD Analysis of C.fistula woody biomass

Fig. 2: SEM Images of C.fistula woody biomass
Fig.3: EDAX Spectrum of C.fistula woody biomass

Fig.4: CHN Spectrum of C.fistula woody biomass

Fig.5: FTIR Spectrum of C.fistula woody biomass

Fig.6: TGA Spectrum of C.fistula woody biomass
Fig. 7: TGA-DTG Spectrum of C. fistula woody biomass

Fig. 7: DSC Spectrum of C. fistula woody biomass

Table 1: EDAX micro analysis of C. fistula woody biomass

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Elements</th>
<th>Weight %</th>
<th>Atom %</th>
</tr>
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<tr>
<td>1</td>
<td>C</td>
<td>49.60</td>
<td>60.81</td>
</tr>
<tr>
<td>2</td>
<td>O</td>
<td>37.08</td>
<td>34.13</td>
</tr>
<tr>
<td>3</td>
<td>K</td>
<td>8.71</td>
<td>3.28</td>
</tr>
<tr>
<td>4</td>
<td>Ca</td>
<td>3.53</td>
<td>1.30</td>
</tr>
<tr>
<td>5</td>
<td>P</td>
<td>0.51</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Table 2: CHN Data of C. fistula woody biomass

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Elements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>C</td>
<td>67.90</td>
</tr>
<tr>
<td>2</td>
<td>H</td>
<td>10.91</td>
</tr>
<tr>
<td>3</td>
<td>N</td>
<td>0.04</td>
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Table 3: Proximate analysis of C. fistula wood

<table>
<thead>
<tr>
<th>Moisture (%)</th>
<th>Ash (%)</th>
<th>Volatile matter (%)</th>
<th>Fixed Carbon (%)</th>
<th>Calorific value kcal/kg</th>
</tr>
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<tbody>
<tr>
<td>5.7</td>
<td>3.4</td>
<td>72.1</td>
<td>18.8</td>
<td>3743</td>
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Table 4: Measured parameter used to calculate the Gasifier efficiency and thermal output

<table>
<thead>
<tr>
<th>Calorific value kJ/kg</th>
<th>Gasifier running time (Hrs)</th>
<th>Wood consumption rate (Kg/hr)</th>
<th>Ash produced (Kg)</th>
<th>Gasifier efficiency (%)</th>
<th>Thermal output (kw/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>15661</td>
<td>2.35</td>
<td>4.5</td>
<td>0.275</td>
<td>61.0</td>
<td>5.5</td>
</tr>
</tbody>
</table>
Conclusion

In summary, wood material of Cassia fistula is found to be a suitable material for the application of power generation. The proximate analysis showed the fewer amounts of ash content; moisture content and the ultimate analysis showed very less content of nitrogen and sulphur have more benefits for utilizing the study material with high potential and pollutant free. The calorific value is found to be 15661 KJ/kg and the gasifier efficiency is 61.0%. The particle size of wood material is found to be 23 nm and in irregular shape. Thermal analysis of wood Cassia fistula showed that the biomass is highly reactive. All the data strongly suggest that the investigated material would be highly potential in the aspect of power generation. Considering, biomass materials for power generation has more environmental benefits compared to both fossil fuels and other renewable. This protocol is easy to scale up, and therefore a large scale production in the point of industrial is also possible. This methodology is general and further related studies using other wood material are currently pursued in our laboratory and will be reported as events materialize.

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References