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# Characterization of bioresidues for biooil production through pyrolysis

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## HIGHLIGHTS

- 1st report on biooil production from *Melia Dubia*, *Polyalthia longifolia*, Raintree fruit.
- TGA guided pyrolytic temperature.
- Model developed to correlate the composition of bioresidues with biooil production.

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ABSTRACT

Biomass is a renewable resource utilized to produce energy, fuels and chemicals. In this study, 25 bioresidues were selected and the physical, chemical, thermal and elemental analyses of the residues were studied as per standard methods. The bioresidues were pyrolyzed at 450 °C in a fixed bed reactor to produce biooil. Among the residues, paper (pinfed computer) and Parthenium produced maximum (45%) and minimum biooil (6.33%), respectively. Arecanut stalk, redgram stalk, rice husk, wheat husk, maize cob, coir pith, Cumbu Napier grass Co5, Prosopis wood and paper resulted in a better biooil yield. Models were developed to predict the effect of constituents of bioresidues on the yield of biooil. The volatile matter and cellulose had significant effect on biooil yield. Biooil thus obtained can be used as fuel that may replace considerable fossil fuels.



## 1. Introduction

Fossil fuel shortage and severe environmental problems have drawn more attention on the utilization of clean renewable energies. Biomass is one of the promising renewable energy resources and can be a partial alternate to fossil fuels. The use of biomass can reduce the dependency on the limited fossil fuels and has the advantage of reduced net $CO_2$ emissions. Biomass includes various natural and derived materials, such as woody and herbaceous species, wood wastes, energy crops, agricultural and industrial residues, waste paper, municipal solid waste, grass, waste from food processing, animal wastes, aquatic plants and algae etc. Generation of these residues is increasing every year but due to their lesser advantages, the residues have not found any remarkable application and have negative market value (Pallav et al., 2006). The current availability of biomass in India is estimated about 120–150 million tons per annum corresponding to a potential of 18602 MW of electricity generation (Ministry of New and renewable energy, 2010). Utilization of these residues for energy generation and value addition by different thermo-chemical processes may replace a significant portion of the conventional energy sources for fuel, energy and chemicals supply.

Pyrolysis is one of the thermo-chemical processes carried out in the absence of oxygen. It yields carbon-rich char, condensable vapors and non-condensable gases. The condensed vapor referred as biooil – a dark brown liquid, can be used in boilers, diesel engines for power generation to replace fossil fuels. It can also be a chemical source with more than 300 organic compounds. It has environmental benefits as a clean fuel and causes less pollution as compared to fossil fuels (Churin and Delmon, 1989). In this study, various bioresidues were selected and their suitability to produce biooil with a higher heating value was investigated.

## 2. Methods

Utilization of lignocellulosic material as feedstock faces problems due to their complex structure and the difficulty to separate their components in an economically feasible way (Meier and Faix, 1999). In this study, 25 lignocellulose materials such as agro-residues, energy crops, grasses, wood and weed were selected to carry out the biooil production. It includes arecanut stalk, cotton stalk, redgram stalk, soybean stalk, paddy straw, arecanut husk, jatropha husk, rice husk, wheat husk, cashew nut shell, coconut shell,

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**Table 1**
Proximate composition of selected bioresidues.

| Sample | Moisture (%) | Volatile matter (%) | Fixed carbon (%) | Ash (%) | Density (kg/m$^3$) |
|---|---|---|---|---|---|
| Arecanut stalk | 9.80 (0.03) | 68.70 (0.26) | 15.60 (0.06) | 5.90 (0.05) | 270.30 (7.50) |
| Cotton stalk | 10.20 (0.05) | 62.07 (0.30) | 19.53 (0.02) | 8.20 (0.09) | 321.50 (2.30) |
| Redgram stalk | 5.91 (0.10) | 72.09 (0.84) | 11.38 (0.90) | 10.62 (0.1) | 257.20 (5.20) |
| Soybean stalk | 11.84 (0.85) | 58.43 (0.30) | 16.14 (1.20) | 13.59 (0.5) | 263.50 (7.90) |
| Paddy straw | 8.66 (1.40) | 65.47 (0.20) | 10.37 (0.40) | 15.50 (0.8) | 272.0 (6.80) |
| Arecanut husk | 12.50 (0.09) | 62.97 (0.07) | 18.93 (0.30) | 5.60 (0.80) | 298.40 (4.80) |
| Jatropha husk | 11.30 (0.23) | 60.70 (0.01) | 13.70 (0.40) | 14.3 (0.20) | 283.80 (9.60) |
| Rice husk | 5.83 (1.02) | 73.80 (0.14) | 15.80 (0.60) | 4.57 (0.90) | 510.10 (7.40) |
| Wheat husk | 13.90 (0.97) | 68.10 (0.80) | 16.40 (0.60) | 1.60 (0.80) | 369.20 (9.50) |
| Cashew nut shells | 6.93 (1.49) | 70.44 (0.91) | 14.73 (0.43) | 7.90 (0.60) | 231.60 (6.64) |
| Coconut shell | 4.40 (0.02) | 71.99 (0.20) | 19.79 (0.09) | 3.82 (0.50) | 293.90 (11.9) |
| Tamarind shell | 8.44 (0.32) | 68.56 (0.06) | 13.44 (0.91) | 9.56 (0.30) | 302.30 (8.40) |
| Maize cob | 15.20 (0.80) | 64.80 (0.50) | 16.69 (0.4) | 3.31 (0.94) | 319.0 (12.10) |
| Sugarcane bagasse | 8.50 (1.20) | 70.04 (0.03) | 13.44 (0.07) | 8.02 (0.06) | 293.0 (5.93) |
| Coir pith | 9.65 (0.50) | 69.35 (0.4) | 15.44 (0.50) | 5.56 (0.01) | 415.90 (7.38) |
| Saw dust | 7.01 (0.06) | 73.0 (0.08) | 14.04 (0.09) | 5.95 (0.10) | 792.80 (4.80) |
| Cumbu Napier grass Co5 | 7.07 (0.91) | 71.43 (0.20) | 18.47 (0.40) | 3.03 (0.02) | 236.0 (6.90) |
| Blue buffel grass | 10.14 (1.30) | 69.47 (1.05) | 9.93 (0.20) | 10.46(0.14) | 294.0 (8.40) |
| *Polyalthia longifolia* | 8.86 (0.20) | 61.64 (0.50) | 16.39 (0.83) | 13.11 (0.4) | 265.10 (9.20) |
| *Melia dubia* wood | 9.80 (0.90) | 65.82 (0.44) | 16.77 (0.20) | 7.61 (0.06) | 258.50 (10.1) |
| Prosopis wood | 7.77 (0.02) | 71.25 (0.56) | 15.11 (0.91) | 5.87 (0.01) | 690.30 (11.8) |
| *Samanea saman* fruit | 3.47 (0.02) | 75.27 (0.08) | 16.96 (0.50) | 4.30 (0.40) | 287.43 (8.90) |
| Chlorella | 9.05 (0.40) | 62.20 (0.6) | 16.19 (0.30) | 12.56(0.06) | 373.60 (7.30) |
| Parthenium *hysterophorus* | 6.08 (0.80) | 69.14 (0.02) | 10.31 (0.93) | 14.47(0.01) | 269.30 (9.40) |
| Pinfed computer paper | 8.26 (0.80) | 79.14 (0.40) | 7.24 (0.66) | 5.36 (0.40) | 246.0 (6.90) |

The values in parenthesis are standard deviation at 95% confidence interval. Number of determination is 3.

**Table 2**
Elemental composition of selected bioresidues.

| Sample | C (%) | H (%) | O (%) | N (%) |
|---|---|---|---|---|
| Arecanut stalk | 47.12 (0.84) | 5.95 (0.44) | 43.54 (0.43) | 3.39 (0.60) |
| Cotton stalk | 46.77 (0.50) | 5.76 (1.09) | 41.71 (0.82) | 5.75 (0.93) |
| Redgram stalk | 44.11 (1.20) | 5.69 (1.84) | 41.97 (0.37) | 8.23 (0.70) |
| Soybean stalk | 43.61 (0.19) | 5.45 (0.02) | 44.66 (0.29) | 6.28 (0.57) |
| Paddy straw | 41.62 (0.14) | 5.39 (0.93) | 45.12 (0.07) | 7.87 (0.73) |
| Arecanut husk | 47.89 (0.94) | 5.93 (0.40) | 43.10 (0.18) | 3.08 (0.68) |
| Jatropha husk | 42.82 (0.65) | 5.43 (0.33) | 46.34 (1.27) | 5.41 (0.94) |
| Rice husk | 47.79 (0.88) | 6.04 (0.69) | 44.16 (0.40) | 2.02 (0.56) |
| Wheat husk | 48.29 (0.90) | 6.22 (0.88) | 44.87 (0.25) | 0.62 (0.79) |
| Cashew nut shells | 46.02 (0.19) | 5.83 (0.42) | 42.71 (0.32) | 5.44 (0.03) |
| Coconut shell | 48.88 (0.40) | 6.05 (0.36) | 43.82 (0.98) | 1.25 (0.38) |
| Tamarind shell | 45.00 (0.33) | 5.73 (0.76) | 44.13 (0.76) | 5.14 (0.53) |
| Maize cob | 48.54 (1.32) | 6.11 (0.65) | 44.62 (1.11) | 0.73 (0.09) |
| Sugarcane bagasse | 45.72 (0.74) | 5.84 (0.78) | 42.88 (0.34) | 5.56 (0.35) |
| Coir pith | 47.25 (0.25) | 5.97 (1.06) | 43.74 (0.14) | 3.04 (0.58) |
| Saw dust | 46.81 (0.30) | 5.96 (0.36) | 43.79 (0.59) | 3.44 (0.47) |
| Cumbu Napier grass Co5 | 49.00 (0.59) | 6.11 (0.25) | 44.44 (0.55) | 0.45 (0.15) |
| Blue buffel grass | 43.92 (1.19) | 5.71 (0.78) | 42.30 (0.89) | 8.07 (1.08) |
| *Polyalthia longifolia* | 47.12 (0.63) | 5.95 (0.63) | 43.54 (0.30) | 3.39 (0.57) |
| *Melia dubia* wood | 46.77 (0.03) | 5.76 (0.58) | 41.71 (0.76) | 5.75 (0.30) |
| Prosopis wood | 44.11 (0.76) | 5.69 (0.49) | 41.97 (0.03) | 8.23 (0.76) |
| *Samanea saman* fruit | 43.61 (0.93) | 5.45 (1.12) | 44.66 (0.49) | 6.28 (0.35) |
| Chlorella | 41.62 (0.59) | 5.39 (0.68) | 45.12 (0.82) | 7.87 (0.93) |
| Parthenium *hysterophorus* | 47.89 (0.15) | 5.93 (0.76) | 43.10 (0.90) | 3.08 (0.81) |
| Pinfed computer paper | 42.82 (0.53) | 5.43 (0.52) | 46.34 (0.48) | 5.41 (0.57) |

*Note:* Average absolute error used for carbon, hydrogen and oxygen was 3.21%, 4.79% and 3.4%, respectively of the calculated value. The values in parenthesis are standard deviation at 95% confidence interval. Number of determination is 3.

tamarind shell, maize cob, sugarcane bagasse, coir pith, saw dust, Cumbu Napier grass Co5, blue buffel grass, *Polyalthia longifolia* (False Ashoka tree leaves), *Melia dubia* wood, prosopis wood, *Samanea saman* (Rain tree) fruit, Chlorella, *Parthenium hysterophorus* and pinfed computer paper. They were selected based on the availability, low fertilizer value and higher energy content.

Paddy straw is an agro residue with a generation rate of 112 MT yr$^{-1}$. Most of the paddy straw is burnt in the field without any proper utilization and minimal percentage is fed for cattle. Wheat straw is used mainly as cattle feed with a production rate of 110 MT yr$^{-1}$. The main feed as fuel for sugar plants is from sugarcane bagasse and the production rate is 101.3 MT yr$^{-1}$ (Sukumaran et al., 2010). Redgram stalk is generated at the rate of 9 MT yr$^{-1}$. Cotton stalk has no fertilizer value and partly used as domestic fuel and the generation rate is 26.2 MT yr$^{-1}$. The production of maize cob is 4.2 MT yr$^{-1}$. Coir pith (7.5 MT yr$^{-1}$) has found no use and disposal is the major problem. In India, coconut shell is widely used as domestic fuel and partly for making mattresses and carpets etc., Jatropha husk constitutes about 35–40% of the fresh fruit and mainly used as a feed for gasification (Vyas and Singh, 2007); sometimes left as mulch around the trees. India is the largest producer and processor of cashew and the average productivity