Combustion Profiles of *Morinda tinctoria* and *Parkia biglandulosa*

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Abstract

Facing a significant challenge of the shortage problem of fossil fuels coupled with environmental damage has made the awareness of the development of alternative energy sources an urgent. For fulfilling rising daily energy demands, biomass-based energy is one of the most significant renewable energy sources. In this paper, we discuss about the combustion profiles (Ultimate, thermal and gasification) of the fast-growing biomass woody materials (*Morinda tinctoria* and *Parkia biglandulosa).* In the ultimate analysis, the carbon and hydrogen content (59.43 % and 10.54%) for *M. tinctoria* and (58.52% and 8.56%) *P. biglandulosa,* have major constituent of hydrocarbon which yield higher heating value. Thermal analysis of lignin decomposition for *M. tinctoria* is at 807^{o}C and *P. biglandulosa* is at 787^{o}C, which indicates that the two woody materials are suitable for thermochemical conversion process. The gasifier efficiency for *M. tinctoria* and *P. biglandulosa* is 72% which is in recommended range for thermal application. The producer gas composition for *M. tinctoria* is CO (20.58%), H_2 (11.62%), and CH_4 (2.24%) and for *P. biglandulosa* is CO (20.14%), H_2 (10.15%), and CH_4 (1.87%), helps to produce high syngas calorific value. Thus, the combustion profiles of *Morinda tinctoria* and *Parkia biglandulosa* reveals the selected woody materials can be recommended as feedstocks for power generation.

Keywords

Down draft gasifier, Gas composition, Thermo-gravimetric analysis, Ultimate analysis.

Introduction

Due to the depletion of fossil fuel resources and increased energy demand brought on by expanding populations and economic advancements, it is essential to research alternative energy sources in order to assure a sustainable future (GBS, 2020). Biomass is a new and renewable energy and can be an excellent substitute for conventional fuels (I. Hanif, 2018).

The biomass feedstock needs a few characteristics in order to be used in gasification applications. It must be renewable and easily accessible in large quantities, produce combustible gases, be acceptable to the environment, have enough calorific value to be processed further, and leave behind few residues. (Bhattacharya 2015). It is possible to turn biomass feedstocks into biofuels using a variety of biochemical and thermochemical methods (Zanganeh 2007). Assessing the potential of biomass as a fuel for energy generation using thermochemical characterization is a common and practical method (Titiloye 2013).

Morinda tinctoria and *Parkia biglandulosa* are one of the biomass residues which are used to generate electricity. It is a medium sized fast-growing tree. *Morinda tinctoria* is also known as Indian mulberry, is a well-known member of the Rubiaceae family. It is naturally ecofriendly material, abundance and cheap biomass (Vijayalakshmi et.al 2013). *Parkia biglandulosa* is otherwise called Ball Badminton tree, belonging to family Fabaceae. The plant is grown in gardens as ornamental tree and also on roadsides as avenue tree (Rupesh Pingale et.al.,2016). The thermal and elemental properties are important to use biomass efficiently for thermo chemical conversion process. Gasification is one of the thermochemical process of carbon – based solid fuels converted in to CO, CO_2, H_2 and hydrocarbons. The downdraft gasifier is a simple technique for energy production and produce syngas with a lower tar concentration (Monir et al., 2018). The aim of this study is to investigate the ultimate, thermochemical degradation and also focused gasification characteristics of *Morinda tinctoria and Parkia biglandulosa* in a down draft gasifier to assess their suitability for use as power generation.

MATERIALS AND METHODS

Biomass samples were collected from Agricultural College, Killikulam, Tamilnadu, India. One to two kilograms of selected woody materials were collected from the plantation. The samples were dried for several days during the sample preparation step to dry at ambient temperatures in the sun. The samples were crushed to create a powder after drying. After that, the powder samples were separated and put into sealed bags before being utilized for analysis.

Characterization

Morinda tinctoria and *Parkia biglandulosa* wood powder were subjected to the elemental composition was analyzed using a CHNS analyzer (Flash EA 1112). Thermogravimetric Analyzer (Perkin Elmer) employed TGA and DTG analysis to investigate the thermochemical degradation behavior under pyrolysis and combustion working conditions.

The down draft gasifier was used to analyze the samples and establish the gasifier efficiency, the wood consumption rate and charcoal of the samples. Gas analyzer (CEMS) was used to determine the syngas composition.

Experimental design

The gasification studies were carried out in a gasifier developed at the PG & Research Department of Physics, The MDT Hindu College, Tirunelveli, Tamilnadu, India. The gasifier is constructed of Stainless Steel 304 and has seven key components. viz., downdraft gasifier, a cyclone filter, water sprinkler, activated carbon & cloth filter, Rice husk & cloth filter, Blower and burner (Fig. 1). The fixed bed reactor is a single throat downdraft gasifier (diameter: 192 cm and height: 152 cm) with a wood consumption rate of 5-7 kg/h. A sliding grate was installed at the bottom of the gasifier to remove ash. Initially, the 20 kg of woody material was loaded into the reactor followed by run the blower using the gasifying agent (air) was sucked by the blower, then burnt the material. The gas was allowed to pass through a cyclone filter, water sprinkler, activated carbon filter and Rice husk filter to remove the tar, moisture content and the particulate matter. The syn gas formed was ignited at the burner, then the syn gas was collected in the Tedlar bag, once the stable flame was obtained. Using a gas analyzer, the syngas composition (CO, H_2, CH_4, CO_2, and N_2) and heating value were examined. The wood consumption rate, charcoal, and producer gas efficiency of the downdraft gasifier were estimated and tabulated.

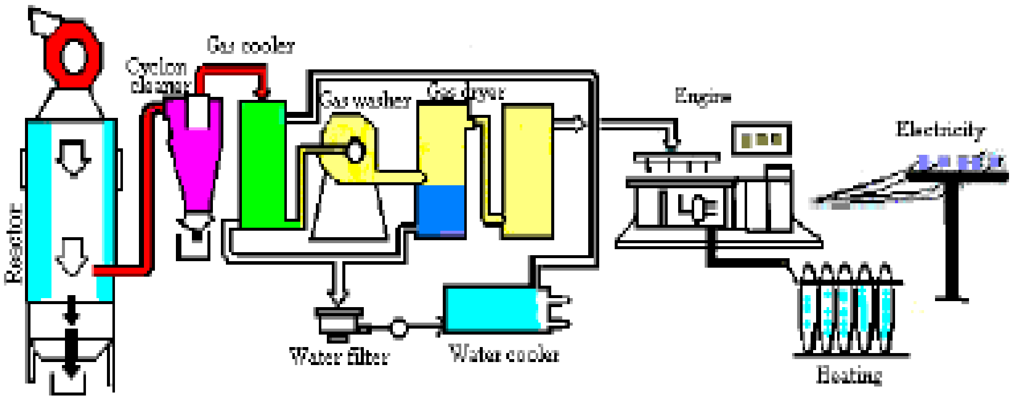

Fig 1. Block diagram of 5kW/h

RESULTS AND DISCUSSION

Ultimate Analysis:

The ultimate analysis is one of the important factors for evaluating the qualities of biomass fuel. It aids in calculating the percentage of each element contained in each sample of biomass, including carbon (C), hydrogen (H), oxygen (O), nitrogen (N), chlorine (Cl), and sulphur (S), as well as the impact of these constituents on the combustion in boilers and environmental implications. Additionally, it helps in estimating the C, O, and H heating values of the biomass sample. By using a Como catalyst, Stummann et al., catalytically hydro pyrolyzed biomass, showing improved heating value. The deactivation of the catalyst was related to biomass samples with greater C and H percentages. CHN analysis shows the presence of carbon and hydrogen content (58.52 %,59.43 %) and (10.54 %, 9.56 %) for *M.tinctoria* and *P.biglandulosa* (Table 1) respectively. The chosen woody material contains very little nitrogen, which clearly shows that it won't produce any environmentally harmful gases during combustion, such as NOx, SOx, etc. (Parmar, 2017). It is important to note that the chosen woody material contains significant amounts of hydrocarbons, making it is a suitable material for use in power generation. (Arumugasamy et.al.,2019)

Table.1. CHN Analysis of *M.tinctoria* and *P.biglandulosa* woody material

Element (K)	*M.tinctoria*	*P.biglandulosa*
C	58.52	59.43
H	10.54	9.56
N	0.06	0.04

Thermogravimetric Analysis:

In order to study the thermochemical behaviour of biomass constituents during pyrolysis and combustion at temperatures between 38°C and 870°C and 40°C and 835°C, respectively, at a heating rate of 25°C/min, and with a continuous flow of pure nitrogen gas to ensure the necessary environment, thermogravimetric analysis (TGA and DTG) was used. Thermogravimetric analysis and Differential thermogravimetric analysis curves of the *M.tinctoria* and *P.biglandulosa* under pyrolysis conditions are shown in Fig (2,3) respectively. According to several studies for the lignocellulosic biomass researched in the past, decomposition of biomass was shown to occur in four key stages that correlate to the loss of moisture, lighter volatile, heavier volatile, and lignin components (Mehmood MA et. al., 2017). The initial significant decomposition stage was noticed, in the temperature range of 38°C to 239°C for *M.tinctoria* and 40°C to 227°C for *P.biglandulosa* equivalent to the reduction of moisture content that was present in the samples. The second decomposition stage was lighter volatile recorded at 399°C for both woody materials. The third decomposition stage was heavier volatile ranges were at 599°C for *M.tinctoria* and 579°C for *P.biglandulosa* which are comparable to the results of other research that have been described in the literature. (Marquez-Montesino Fet.al.,2015). The maximum conversion temperatures noted on the DTG curves during the second stage values are 346°C for *M.tinctoria* and 356°C for *P.biglandulosa*. The findings of this investigation are well-concordant with the decomposition patterns of different biomass (Naik S et.al.,2010). In this stage volatiles are decomposed, the greatest amount of biomass is converted into biofuels.The lignin degradation process is extremely intricate, gradual, and continuous (Chen Z et.al.,2015) throughout the process since, the lignin decomposition was observed as 807°C for *M.tinctoria* and 787°C for *P.biglandulosa*. Reduced mass loss rates at this stage reveal the gradual deterioration of lignin components as well as the charring of the non-volatile components (Braga RM et.al.,2014). The decomposition shows that the selected woody materials is a feedstock for thermochemical conversion processes that can be used to create biofuels with good efficiency.

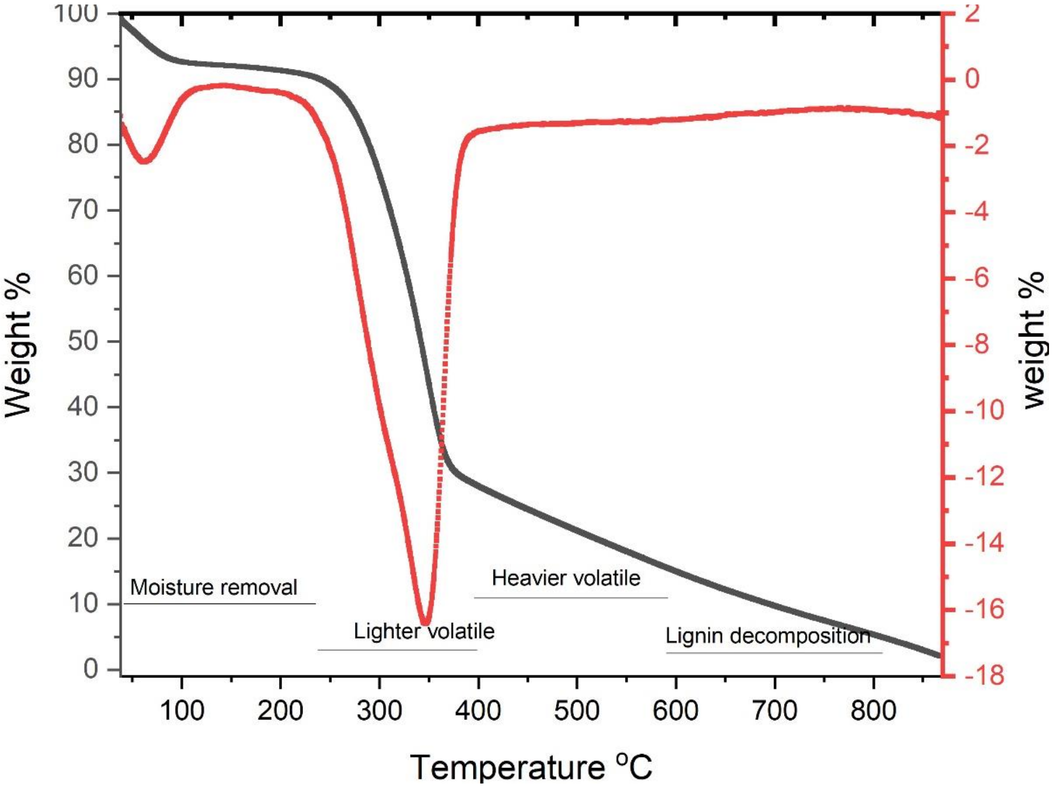

Fig 2: TGA and DTG of *M.tinctoria*

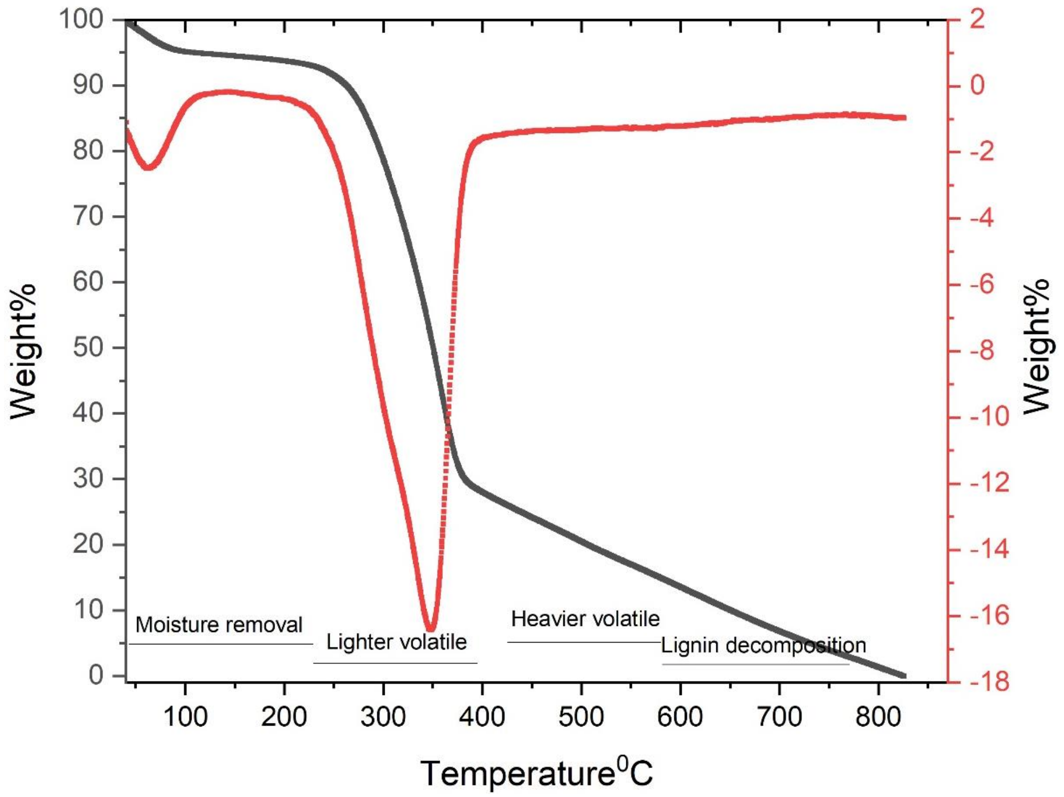

Fig 3: TGA and DTG of *P.biglandulosa*

Gasification yield:

Table 2 shows the gasification parameters and performance of the *M.tinctoria* and *P.biglandulosa*, the gasification process . In this down draft gasifier, how the fuel withstands and the ratio of the input load and the output load than the comparison of two woody materials in order to find out their generation efficiency are discussed. When a substance completely burns with oxygen under normal conditions, the amount of energy produced as heat is measured as the calorific value. The chemical reaction is typically a hydrocarbon or other organic molecule reacting with oxygen to form carbon dioxide and water and release heat. The calorific values were determined using bomb calorimeter, the values are 3752kcal/kg and 3215kcal/kg (Veerakalyanamunnadi et.al., 2020). According to published research, downdraft gasifier efficiency is between 50 and 70 percent, which is a better efficiency (Martinez et.al., 2012). The efficiency of the chosen woody materials is 72% for both samples, which is greater than the stated value. *M. tinctoria* and *P. biglandulosa* produce charcoal with yields of 1.950% and 2.070%, respectively. The wood consumption rate of *M. tinctoria* and *P. biglandulosa* is 7.170 Kg/h and 7.300 Kg/h, respectively. An analysis of the particular fuel consumption was done using fuel wood usage. According to the usual technical assessment, a 5kW/h generator uses 0.800 lr/h of conventional fuel (just diesel). Upon evaluation, it was discovered that engine generators using producer gas produce more power than engines, using diesel 223 V - the output voltage. The chosen woody materials, *M. tinctoria* and *P. biglandulosa*, run the gasifier to produce electricity using the conventional fuel at a rate of 0.290 lr/h and 0.310 lr/h, respectively. The output voltage is 218 volts.

Table 2: Gasification parameters and Thermal Efficiency of *M.tinctoria* and *P.biglandulosa*

Characteristics	*M.tinctoria*	*P.biglandulosa*
Generation power efficiency (%)	73	72
Charcoal produced (kg)	1.950	2.070
Wood consumption rate (kg/hr)	7.170	7.300
Fuel (Diesel) consumption (l/hr)	0.290	0.310
Output voltage (volt)	219	217
Calorific value kJ/kg(vkm2020)	15698	15125

From the fuel consumption result, shows that the selected woody materials are the most suitable option for the reduction of conventional fuel for the power generation. Thus, we can reduce the fuel consumption rate by using biomass gasifier in that *M.tinctoria* and *P.biglandulosa* gives good efficiency.

Gasifier performance

Table 4 shows Gas composition of Syn gas. Commonly, only CO, H_2, and CH_4 were combustible gases; all other gases were non-combustible. Dogru's 2013 reported that combustible gases are flammable gases. Noncombustible gases significantly reduce syngas yields during the gasification process. The percentage of CO, H_2 and CH_4 can be obtained from gas analysis using Gas Chromatograph (A.A.P. Susatriawan et.al., 2020). The producer gas has a high calorific value because it contains a larger amount of CO, H_2, and CH_4.

Table 4: Experimental values of the chemical composition of syngas

Samples	Gas composition (%)						HHV (MJ/m^3)
	CO	H_2	CH_4	CO_2	O_2	N_2	
M. tinctoria	20.58	11.62	2.24	15.49	1.39	49.55	4.6
P. biglandulosa	20.14	10.15	1.87	14.83	1.69	50.95	4.4

The average composition of the combustible gases was CO (20.58%), H_2 (11.62%), and CH_4 (2.24%), CO (20.14%), H_2 (10.15%), and CH_4 (1.87%), with CO having the largest yield followed by H_2 and CH_4. Due to its importance, these gas yields contributed to developing high syngas calorific value for gas engine applications and the gas-liquid fuel conversion process (Guo et al. 2014). During the gasification of *M. tinctoria* and *P. biglandulosa*, ambient air served as the gasification agent, and nitrogen gas (N_2) made up the majority of the other gases that entered the reactor with it. Here CO_2 values for both species is approximately 15%, in past investigations, similar findings were also made. (Muhammad Afif Ariffin et.al., 2016). Moreover, CO_2 production should be minimized as much as possible because it is a greenhouse gas with negative environmental effects. According to our research, it is evident that the heating high value (HHV) of the producer gases from *M. tinctoria* and *P. biglandulosa* do not differ by a significant ratio, but there is a difference in gas efficiency. The calorific value of that material is another aspect that skews the estimate. In comparison to "*M. tinctoria*, *P. biglandulosa* likewise has calorific value", however their producer gas efficiency is the lowest and the combustible gases are also low.

Conclusion

Ultimate studies revealed that *M. tinctoria* and *P.biglandulosa* have major hydrocarbon content suggests that they are suitable for meeting thermochemical process requirements. The TGA and DTG decomposition demonstrates that the *M. tinctoria* and *P.biglandulosa* can be utilised as a raw material for thermochemical conversion processes to produce biofuels with high efficiency. Syngas composition and gasifier efficiency investigations show that *M. tinctoria* and *P.biglandulosa* have high combustible gases and efficiency also high. As a result, the chosen biomass materials are suggested as a feedstock for power generation.

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