AN EXPERIMENTAL INVESTIGATION ABOUT THE PYROLYSIS PROCESS BY USING WOOD AND PLASTIC WASTE

D. Selvaganesh
PG scholar & Department of Civil Engineering
Pandian Saraswathi Yadav Engineering College, Tamilnadu, India

G. Ragha Dharini
Assistant Professor, Department of Civil Engineering
Pandian Saraswathi Yadav Engineering College, Tamilnadu, India

Abstract

The project demonstrates the experimental investigation of the pyrolysis process by using wood and plastic waste. The wastes are taken in different ratios and it will be thermally decomposed to obtain the yields of biomass such as Bio char, Biogas, and Bio-fuel which may be used as an alternate for fossil fuels. The Pyrolysis process includes the following steps such as combustion, production of carbon products, and conversion to liquid and gaseous fuels. Despite the fuel from the pyrolysis of wood waste being environment-friendly, the fuel characteristic of it remains lower than fossil fuel, especially with regard to combustion efficiency. In this case, the high composition of oxygenated compounds in pyrolysis fuel is responsible for this problem. Co-pyrolysis using plastics have been found to be a promising option for a biomass conversion technique to produce pyrolysis fuel as plastics have abundant hydrogen source. The final temperature range for this study is taken as 350°C to 500°C and the highest liquid product yield is obtained at optimum temperature. Bio-fuel can be used as a substitute for fossil fuels to generate heat, power, and chemicals. The calorific value of bio-fuel will be determined for the different mix proportions and also optimum temperature range will be found. Comparison of the calorific values of different mix proportions will be held and discover the best mix proportion which having the greater calorific value than others mix - ratios respectively. Further, the characterization of bio-oil can be done by using the FTIR Spectrometer and by using Origin Pro Software.
***Keywords**: calorific value of bio-fuel; FTIR spectrometer analysis; pyrolysis process; co-pyrolysis process.*

Introduction

In the present scenario energy sectors and individual entrepreneurs can opt a new way of power generation using the most abundantly available renewable sources of energy in the form of biomass wastes. Considerable efforts have been made to convert wood biomass to liquid fuels and chemicals since the fuel crisis in mid1970s. This experiment focuses on the recent developments in the wood with plastic pyrolysis and reports the characteristics of the resulting bio-fuels, which is the main product of wood pyrolysis. Literature reviews show that limited research studies had been carried out on yielding the pyrolytic product from saw dust. Despite of the fuel from pyrolysis of wood waste being environmentally-friendly, the fuel characteristic of it remains lower than fossil fuel, especially with regard to combustion efficiency.

Objective

The objective of the experiment on pyrolysis of wood waste is to extract the valuable products like char, fuel, and gas and analyze their properties to apply as fuel supplement. To assess the energy potential of wood waste by using pyrolysis studies. To identify the suitable proportion of raw materials to be used and operational parameter for the pyrolysis study to get good yield. To minimize the land filling of those wastes like wood or plastic and used in a convenient manner and environment friendly in a economical way.

Process Adopted – Pyrolysis

Pyrolysis is a thermo chemical decomposition of organic material at elevated temperatures in the absence of oxygen. Pyrolysis products always produce solid (charcoal, biochar), liquid and non – condensable gases.

In general, pyrolysis of organic substances produces gas and liquid products and leaves a solid residue richer in carbon content, char. Extreme pyrolysis, which leaves mostly carbon as the residue, is called carbonization. Up to the temperature of 200°C only water is driven off. Between 200°C and 280°C carbon dioxide, acetic acid and water are given off. The real pyrolysis, which takes place between 280°C and 500°C, produces large quantities of tar and gases containing carbon dioxide. Besides light tars, some methyl alcohol is also formed. Between 500°C and 700°C the gas production is small and contains hydrogen. Thus it is easy to see that updraft gasifier will produce much more tar than downdraft one. In downdraft gasifier the tars have to go through combustion and reduction zone and are partially broken down. Since majority of fuels like wood and biomass residue do have large quantities of tar, downdraft gasifier is preferred over others. Finally in the drying zone the main process is of drying of wood. Wood entering the gasifier has moisture content of 10–30 per cent.

Materials Required for the Experiment

Ground and oven dried Neem wood waste which is retained in 425micron sieve is selected for the pyrolysis experiment. It is then added with shredded plastics. Zeolites-based catalyst and silica catalyst are also added onto the Neem wood waste and plastic mixture in preliminary experiments and real experiments respectively. Ground Neem wood waste and shredded plastics are fed into the pyrolysis reactor in four different proportions.

Experimental Procedures

Different proportions of Neem wood waste and plastics are mixed and fed into the pyrolytic reactor. The heat supplied converts them into condensable and non-condensable gases which pass through the condenser. Condensable gases get condensed and come out in the form of bio-fuel and non-condensable gases pass through other outlet and can be collected. The obtained end products are Bio-fuel and Biochar.

Pyrolysis reactor: Pyrolysis reactors are mostly modeled in laboratory equipment or in pilot plant for the time being in order to aid understanding of the principal factors controlling the processes and for finding the optimal parameters to obtain recycled products of required quality and quantity at the same time.

Condenser: A condenser is a device or unit used to condense a gaseous substance into a liquid state through cooling. In so doing, the latent heat is released by the substance and transferred to the surrounding environment.

Pyrolysis fuel and gas: Bio-fuel is the liquid by-product obtained from condensable gases and non-condensable gases passes through other outlet.

Neem wood waste sample is dried and ground. The drying process is performed using the oven method (temperature at 100 °C for 1 hour). The ground Neem wood waste is sieved through four different sizes of sieves. The wood waste retained in 425micron sieve is selected for the pyrolysis study. Zeolites-based catalyst and silica catalyst are added onto the neem wood waste and plastic mixture in preliminary experiments and real experiments respectively. Mixture of different proportions of Neem wood waste and Plastics and catalyst are fed into the pyrolysis reactor. Preliminary studies are conducted in electrical pyrolysis reactor from which only solid like substance is obtained.

Good yield of Bio-fuel and good quality biochar are obtained from real experiments conducted in gas pyrolysis reactor set-up. In gas set-up, the condensable and non-condensable gases pass through the condenser. The condenser condenses the condensable gases into a liquid substance so called the bio - fuel which is collected for the study and non-condensable gases are allowed to pass through a separate outlet. Bio-fuel obtained from real experiments is characterized in FTIR spectrometer and FTIR results are interpreted and compared using Originpro software.

Bomb Calorimeter Analysis to Determine Calorific Value

A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. The bomb, with the known mass of the sample and oxygen, form a closed system then no gases escape during the reaction. The weighed reactant put inside the steel container is then ignited. The Bomb Calorimeter (Model- CC01/ M3) was used to measure the Gross calorific value of the solid and liquid samples. It is a constant-volume type calorimeter that measures the heat of a particular reaction or measures the calorific value of the fuels. Bomb calorimeter consists of a strong steel vessel (called bomb) which can stand high pressure when the substance is burnt in it. Hence, it is called bomb calorimeter.

Figure 1 Bomb calorimeter–automated system CC01/M3

A sample of 1g of Bio-fuel obtained from two different ratios is kept inside the arrangement of bomb calorimeter. The gross calorific value for the sample is determined as per the procedure given in IS 1350:1970- part 2. The formula for the determination of gross calorific value is given below:

Calorific value of the sample, H = (WT-E1-E2)/M

Where, W = Water equivalent of the benzoic acid

M = Mass of the sample, g

E1 =Weight *calorific value of the insulation wire

E2 = Weight *calorific value of the thread

T = Maximum temperature

Its unit is KJ/KG or MJ/KG or Cal/G.

Fourier-Transform Infrared Spectroscopy (FTIR) Analysis

FTIR stands for Fourier transform infrared, the preferred method of infrared spectroscopy. When IR radiation is passed through a sample, some radiation is absorbed by the sample and some passes through (is transmitted). The resulting signal at the detector is a spectrum representing a molecular ‘fingerprint’ of the sample. The usefulness of infrared spectroscopy arises because different chemical structures (molecules) produce different spectral fingerprints. According to quantum mechanics, these frequencies correspond to the ground state (lowest frequency) and several excited states (higher frequencies). One way to cause the frequency of a molecular vibration to increase is to excite the bond by having it absorb light energy. FTIR is a rapid, nondestructive, time saving method that can detect a range of functional groups and is sensitive to changes in molecular structure. FTIR provide information on the basis of chemical composition and physical state of the whole sample.

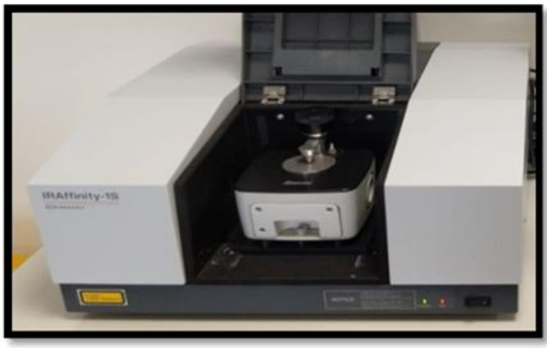

Figure 2 FTIR

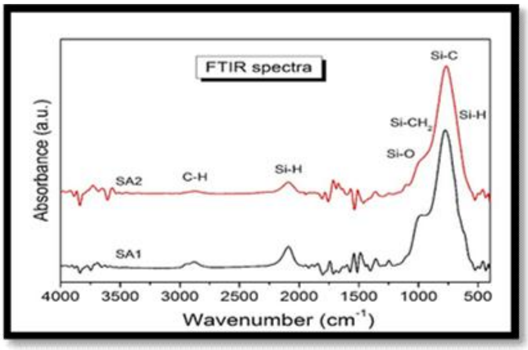

Figure 3 Analysis in ftir

Extracted bio-fuel is characterized by testing it in Fourier Transform Infrared (FTIR) Spectrometer. The FTIR results of different proportions are compared to identify the proportion which yields good quality bio-oil. Calorific value of the extracted Bio-fuel is to be calculated.

Experimental Investigations

Preliminary Experiments

100g Neem wood powder retained on 1mm sieve and 100g shredded plastic are mixed and fed into the reactor, Bio-oil is obtained at the temperature of 400°C. 100g oven dried Neem wood powder retained on 1mm sieve and 100g shredded plastic and catalyst is fed into the reactor, Bio-fuel is obtained at the temperature of 400°C. 100g oven dried and grounded Neem wood powder retained on 425micron sieve and 100g shredded plastic and 6g silica catalyst are fed into the reactor, Bio-fuel is obtained at the temperature of 420°C.

Figure 4 Semi – solid substance

Figure 5 White vapour

Figure 6 Bio–char

Steps Involved in the Real Experiments with Different Proportions Based on the Project

Neem wood waste: plastic = 1:1

250g oven dried and ground Neem wood powder retained on 425micron sieve and 250g shredded plastic and 15g silica catalyst is mixed and fed into the pyrolysis reactor. Bio-oil is obtained at the temperature of about 375°C.

Neem wood waste: Plastic = 1:3

250g oven dried and ground Neem wood powder retained on 425micron sieve and 250g shredded plastic and 15g silica catalyst are added into the reactor. The cracking temperature is 340°C.

Neem wood waste: Plastic = 3:1

250g oven dried and grounded Neem wood powder retained on 425micron sieve and 250g shredded plastic and 15g silica catalyst is mixed and bio-oil is obtained at the temperature of 360°C.

Neem wood waste: Plastic = 9:1

450g Ground Neem wood waste retained on 425micron sieve and 50g shredded plastic and 15g silica catalyst are added into the reactor. The cracking temperature is 390°C.

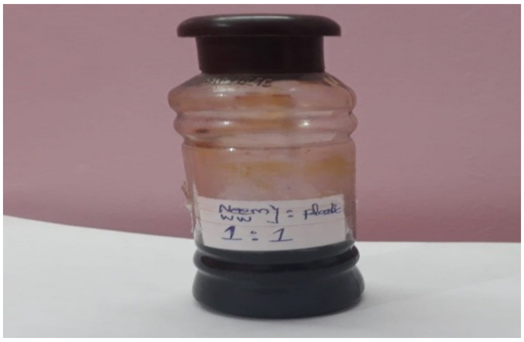

Figure 7 Bio – fuel

Figure 8 Bio - char

Determination of Calorific Value for the Obtained Bio – Fuel by using Digital Bomb Calorimeter–Toshniwal (MODEL – CC01/M3)

Sample Calculation

Water equivalent of the Benzoic acid, W = 2281.103 cal/ °C
Weight × calorific value of the insulation wire, E1 = 8.375 cal
Weight × calorific value of the thread, E2 = 105.336 cal
Mass of the sample (Pyro - fuel), M = 1g

So then by the formula,
Calorific value of the sample, H = (WT-E1-E2) / M

Table 1 Calorific value of Pyro-fuel

Proportions of Neem Wood waste and Plastics	Maximum Temperature	Calorific value of bio-fuel (MJ/Kg)
1:1	3.81	35.85
1:3	3.78	35.62
3:1	3.55	33.43
9:1	2.88	27.03

Characterization of Bio – Fuel Compounds by using the Ftir Analysis

The results obtained are as follows:

Bio-fuel is a complex mixture of saturated and unsaturated hydrocarbon with oxygenated compounds, so in order to simplify the results the products have been grouped according to their functional groups by performing FTIR analysis for the sample.

Neem: Plastic = 1:1

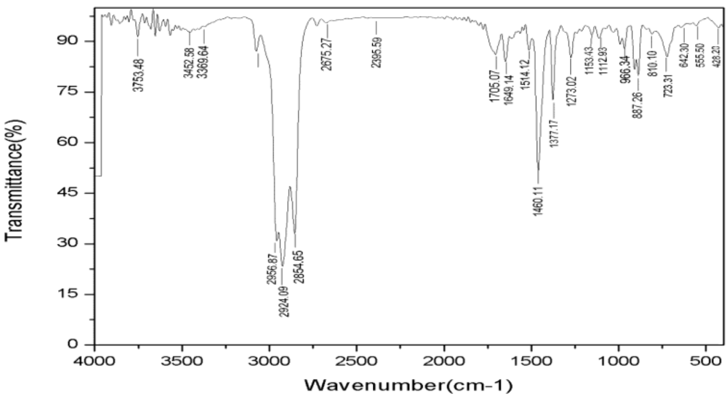

Figure 9 Neem wood waste: plastic =1:1

Neem: Plastic = 1:3

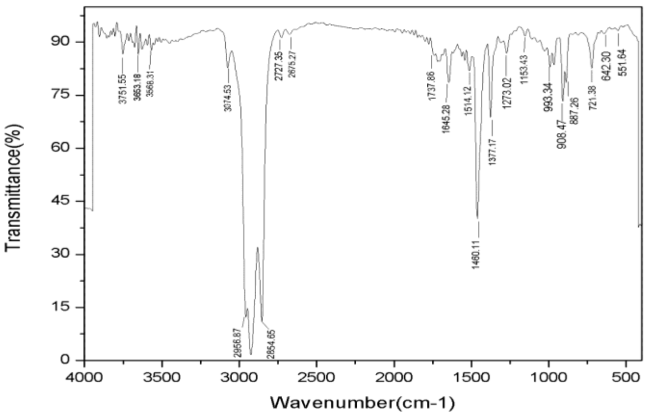

Figure 10 Neem wood waste: plastic =1:3

Neem: Plastic = 3:1

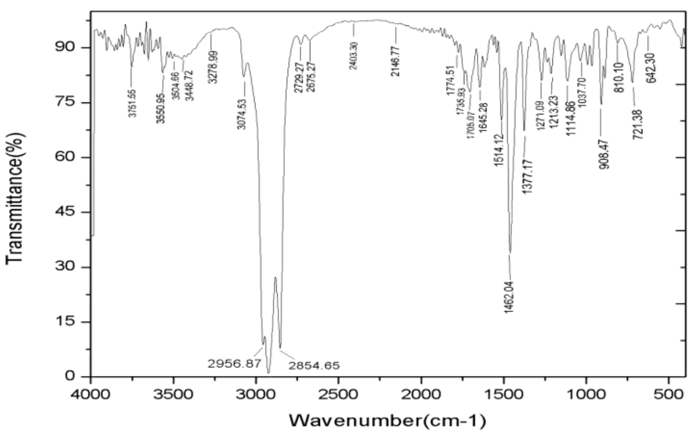

Figure 11Neem wood waste: plastic =3:1

Neem: Plastic = 9:1

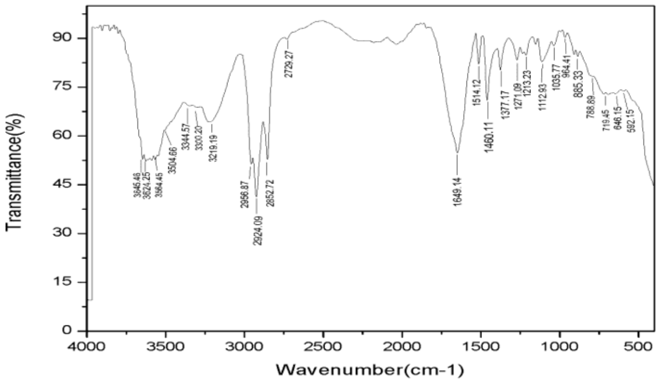

Figure 11 Neem wood waste: plastic =9:1

These are the compounds present in the obtained Bio – fuel i.e.) Saturated Aliphatic structures : Only one strong peak is found in the region between 1470 cm-1 and 1430 cm-1 indicating methyl C-H and methylene C-H bend. Hydrocarbon C-H stretch: Very small peaks are found below 3000 cm-1 Aromatic compound: Many small peaks of Aromatic C-H in-plane bend and out-of-plane bend are found in the regions between 1225 cm-1 and 950 cm-1 and between 900 cm-1 and 670 cm-1. No Aromatic C-H stretch is found. Olefin C=C structures : Small peak of Alkenyl C=C stretch is found in the region between 1680 cm-1 and 1620 cm-1. Carbonyl group : No peak of C=O is found between the region 1725 cm-1 and 1705 cm-1.

Comparison between 1:1, 1:3, 3:1 and 9:1 Proportions of Neem Wood Waste and Plastics

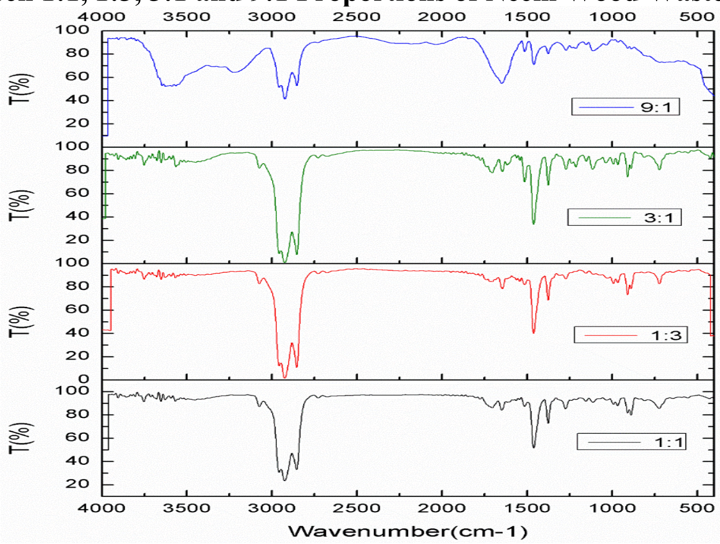

Figure 13 Comparison between 1:1, 1:3, 3:1 and 9:1 proportions of neem wood waste and plastics

Therefore, Broad peaks of Hydrocarbon C-H stretching absorptions are found in 1:1, 1:3 and 3:1 proportions of Neem wood waste and plastic. In 9:1 proportion of Neem wood waste and plastic, small peaks demonstrate the presence of less amount of hydrocarbon as oxygen level is high.

Conclusion

The use of pyrolysis of plastic waste and co-pyrolysis by using with ground neem wood waste, which could be summarized and concluded as:

a) It was Co-pyrolysis should be preferred as plastics have abundant hydrogen source and it removes the oxygen content in wood waste and increases fuel characteristics as hydrocarbon content is increased.
b) It is found that bio-fuel with good calorific value can be obtained from co-pyrolysis of the wood waste with plastics.
c) As particle size of Neem wood waste is reduced, bio-oil yield is increased when compared to the results obtained from using actual Neem wood waste (without grinding) when FTIR results are interpreted and compared using Originpro software.
d) Calorific value of bio-fuel gets increased with decrease in moisture content of the feedstock attaining maximum of 35.91MJ/Kg in 1:1 proportion of Neem wood waste and plastic.
e) FTIR analysis of the bio-fuel sample shows that it is mainly composed of functional groups such as Aromatic C-H stretch, presence of exchangeable protons, typically from carboxylic acid groups and carbonyl group such as ketone and aldehyde and presence of hydrocarbon C-H stretch.
f) FTIR also demonstrate the presence of small amount of Olefinic and Saturated Aliphatic compounds in bio-fuel.

References

1. Ville Paasikallio et al., “Bio-oil production of softwood and hardwood forest industry residues through fast and intermediate pyrolysis and its chromatographic characterization” – Journal, volume 200, January 2016
2. Ayhan Demiribas, “Effects of temperature and particle size on bio-char yield from pyrolysis of agricultural residues” J.Anal. Appl. Pyrolysis 72 (2004) 243-248
3. Faisal Abnisa, Wan Mohd Ashri Wan Daud, “A review on co-pyrolysis of biomass: an optional technique to obtain a high grade pyrolysis oil” Energy Conversion and Management 87 (2014) 71-85.
4. Galina Dobele et al., ncsu.edu/bioresearches - “Fast pyrolysis – effect of wood drying on the yield and properties of bio-oil” – journal.
5. Mehmet Balat , “Bio-oil production from pyrolysis of black locust (Robinia pseudo acacia) wood” “Energy exploration & exploitation” • Volume 28 • Number 3 • 2010 pp. 173-186 173
6. S.C.Bhatia, “Wood pyrolysis” – Biomass gasification in Advanced Renewable Energy Systems, 2014

7. Siyi Luo, Bo Xiao, Zhiquan Hu, Shiming Liu, “Effect of particle size on pyrolysis of single-component municipal solid waste in fixed bed reactor ” International Journal of Hydrogen energy 35 (2010) 93-97
8. STEFAN CZERNIK et al., “Stability of wood fast pyrolysis oil” Biomass and Bioenergy and National Renewable Energy Laboratory (NREL), 1617 Cole Boulevard, Golden, CO 80401, U.S.A Vol. 7, Nos. Id, pp. 187-192, 1994.
9. VillePaasikallio et al., “Bio-oil production of softwood and hardwood forest industry residues through fast and intermediate pyrolysis and its chromatographic characterization” – Journal, volume 200, January 2016
10. Xiaona Lin , Zhijun Zhang , Shun Tan , Fengqiang Wang , Yongming Song , Qingwen Wang , Charles U. Pittman Jr. “ In line wood plastic composite pyrolyses and hzsm-5 conversion of the pyrolysis vapours” Energy Conversion and Management (2016)
11. Yrj.Solantausta et al., “Wood-pyrolysis oil as fuel in a diesel-power plant” Bioresource Technology – Vol 46 (1993) 177-188..