



Full Length Article

Saw dust pyrolysis: Effect of temperature and catalysts



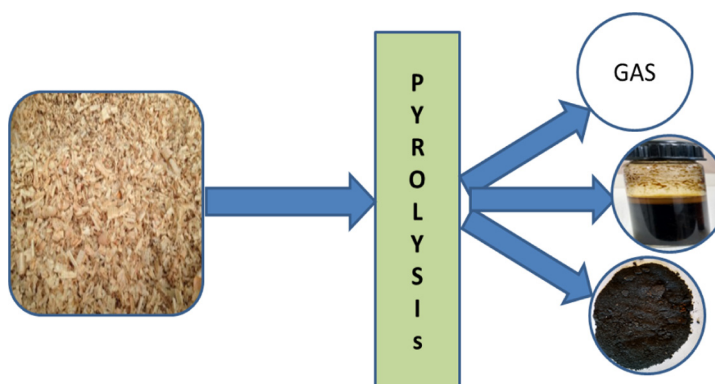
Pankaj Kumar, Pramod Kumar*, Peddy V.C. Rao, Nettem V. Choudary, Gandham Sriganesh

Hindustan Petroleum Corporation Limited, HP Green R&D Centre, KIADB Industrial Area, Tarabahalli, Devenagonthi, Hoskote, Bangalore 560067, India

HIGHLIGHTS

- Saw dust pyrolysis had been carried out at different temperatures.
- In-situ cracking of bio-oil vapors carried out with the Y-zeolite catalyst.
- Bio-oil and bio-char were characterized using various techniques.
- Bio-oil can be used as blending stock with conventional fuel.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:

Received 1 July 2016

Received in revised form 25 February 2017

Accepted 27 February 2017

Available online 10 March 2017

Keywords:

Biomass

Sawdust

Pyrolysis

Bio-oil

Bio-char

Characterization

Catalyst

ABSTRACT

A systematic study of non-catalytic pyrolysis of saw dust has been carried out in a batch reactor (fixed bed mode) in the temperature range of 375–475 °C at the heating rate of 10 °C/min to optimize the reaction temperature for maximum liquid yield. Also, catalytic cracking of pyrolysis vapors was carried out using Y-Zeolite at 450 °C. Produced bio-oil has been characterized using elemental analysis, Fourier Transform Infrared Spectroscopy (FT-IR), Gas Chromatography/Mass Spectrometry (GC-MS), ¹H NMR and bio-char using thermogravimetric analysis (TGA), FT-IR and Scanning Electron Microscopy (SEM). It has been observed that highest bio-oil yield of 26 wt.% was obtained at 450 °C without catalyst while the addition of catalyst reduces liquid yield. The obtained results showed that the bio-oil could be used as liquid fuel after upgradation and bio-char could be utilized for the generation of activated carbon.

© 2017 Published by Elsevier Ltd.

1. Introduction

The development of carbon-neutral renewable energy caught a considerable attention in recent time due to the reduction in petroleum reserves, rapid increase in energy demand and continuous degradation of environmental cleanliness [1]. Biomass as a renewable source has a potential to produce transportation fuel and chemicals. Biomass being a source to fulfill the energy demand

has an additional advantage of low sulfur and nitrogen content [2–4].

Pyrolysis is an attractive technology especially for converting lignocellulosic biomass such as agriculture and forestry residues etc. to value added products. This has attracted wide attention due to its developed technology for large scale production of bio-oil. Pyrolysis is a process in which biomass/organic materials is thermally decomposed by heating in the nitrogen atmosphere to produce liquid, solid and vapors as products [5,6].

Liquid product obtained from pyrolysis of biomass is known as bio-oil. It is a dark brown mixture of oxygenated organic

* Corresponding author.

E-mail address: pramodkumar@hpcl.in (P. Kumar).

compounds including carboxylic acids, alcohols, aldehydes, ketones, esters, phenols, furans, guaiacols, etc. [7]. Bio-oil has higher heating value than their corresponding biomass, and it easily blends with diesel [8]. Bio-oil can also be used in furnaces and boilers for heat and power generation as well as it has a high potential as a feedstock for production of value-added hydrocarbons/chemicals [9]. As such, bio-oil is producing at large scale by Ensyn group for using as fuel oil to generate electricity [10]. However, bio-oil production via pyrolysis process can be performed on a reduced scale in rural areas due to ease in the collection of lignocellulosic biomass and produced bio-oil transfer can be convenient to the nearby refinery for the production of value-added hydrocarbons [11,12]. Gaseous products of biomass pyrolysis mainly contain H_2 , CH_4 , CO , CO_2 and lighter hydrocarbon. It can be used as a substitute for the natural gas generation as well as for production of some chemical compounds. Solid product of pyrolysis of biomass is known as bio-char which contain ash and metals. It has potential to be used as fuel and as a raw material for the production of activated carbon due to its pore structure and surface area [13]. It can act as solid fuel.

The chemical composition of bio-oil is very complex due to the presence of various oxygenated compound obtained from thermal decomposition of cellulose, hemicellulose, and lignin by rapid heating [14,15]. The composition of the oxygenated compound in bio-oil depends on the quantity of cellulose, hemicellulose, and lignin in biomass [16]. The major oxygenated compounds present in the bio-oil are phenols, cresols, guaiacols, benzenodols and ketones [17–19].

Various authors have studied pyrolysis of lignocellulosic biomass to bio-oil and bio-char with the variety of feedstock [20–22], different reactors [23–25] and at a wide range of experimental conditions [19,26].

In this article, pyrolysis of saw dust was carried out in a batch reactor with fixed bed mode of operation for optimizing the reaction temperature for maximum bio-oil yield. Catalytic cracking of pyrolysis vapors in the presence of Y-Zeolite catalyst was also carried out. Detailed characterization of bio-oil and bio-char were done using various techniques.

2. Materials and methods

2.1. Materials

Saw dust used as a source of biomass in the present study was collected as the residue from the saw mills in the city of Bangalore, India. The saw dust was screened by 600 μm mesh and dried overnight at 120 °C before pyrolysis experiments. Commercially available Y-zeolite catalysts were used for cracking of vapors obtained from pyrolysis of sawdust. Important properties of saw dust & Y-zeolite catalysts are indicated in Table 1.

2.2. Experimental procedure

The pyrolysis of saw dust was performed in an in-house designed 1000 ml autoclave reactor equipped with a connection

of nitrogen gas cylinder for nitrogen gas input. The produced vapor is connected to a condenser and condensed vapors are collected in the knockout drum. The condenser was circulated by tap water to condense the pyrolysis vapors and non-condensable gases are sent to the vent. The schematic diagram of reactor setup has been shown in Fig. 1. The electrically heated furnace was used to heat the reactor and temperature of the reactor was controlled by temperature controller mounted with the reactor.

The pyrolysis of saw dust was performed in two sets. In the first set of experiments, pyrolysis was performed at temperatures of 375, 400, 425, 450, and 475 °C for optimizing the reaction temperature for getting the maximum liquid product. In each experiment, 100 g of dried (overnight at 120 °C) saw dust was charged in the reactor, closed tightly the reactor and then purged with nitrogen to remove the air present in the reactor. The reactor was then heated at a rate of ~ 10 °C/min up to desired reaction temperature and held for 15 min to condense the produced pyrolysis vapor to bio-oil. After 15 min, the reactor was set to cool to room temperature. Then, the amount of remaining solid (bio-char) was removed and weighed. The conversion of saw dust to liquid and gaseous products was calculated by subtraction of bio-char from the initial amount of saw dust. The amount of gas produced during pyrolysis was calculated by subtraction of solid and liquid from 100 g of saw dust.

In the second set of experiments, the effect of Y-zeolite catalyst on products yield was studied in the same reactor setup. In a typical run, 50 g of saw dust was charged in the reactor below the 50 g of Y-zeolite catalyst bed. So, the produced pyrolysis vapor cracked in the catalyst bed. The catalytic pyrolysis experiments were performed at the optimized temperature of non-catalytic pyrolysis to investigate the effect of the catalyst on products yield. After completion of the reaction, the products yield was calculated as indicated earlier.

2.3. Characterization

2.3.1. Thermal analysis

Thermogravimetric analysis (TGA) of saw dust is used to know thermal behavior and theoretical volatility of saw dust in the nitrogen atmosphere. Thermal analysis was studied using NETZSCH STA 449 F3 thermogravimetric analyzer. About 10 mg of sawdust was heated in nitrogen atmosphere at a heating rate of 10 °C/min up to 950 °C.

TGA of bio-char and spent Y-zeolite catalyst were also done analyzed to know the remaining volatile material and deposited carbon material in bio-char and Y-zeolite catalyst respectively. Analysis procedure was same as for TGA analysis of saw dust.

2.3.2. Bio-oil characterization

Some basic properties of bio-oil like density, viscosity, P^H , Flash point and pour point were analyzed by ASTM D 4052, ASTM D 445, P^H meter, ASTM D 93B and ASTM D 97 respectively. Ultimate analysis of produced bio-oil was analyzed by LECO CHNSO 932 elemental analyzer to measure the quantity of carbon, hydrogen, nitrogen, sulfur and oxygen in the bio-oil.

Table 1
Properties of saw dust and Y-zeolite.

| Ultimate analysis of saw dust (w/w%) | | | | | | |
|--------------------------------------|------------------------|------------------------|---------------------------|----------------|-------------------------|---|
| Carbon 47.34 | Hydrogen 6.39 | Oxygen 43.66 | Nitrogen 0.19 | Sulfur 0.11 | H/C molar ratio 1.60 | Empirical $CH_{1.60}O_{0.45}N_{0.003}$ |
| Physical properties of Y-Zeolite | | | | | | |
| SA (m^2/g) 207 | PV (cc/gm) 0.34 | MSA (m^2/g) 137 | Al_2O_3 (wt.%) 49.35 | | | |

SA-surface area, PV-Pore volume, MSA-micro surface area.

Download English Version:

<https://daneshyari.com/en/article/6474772>

Download Persian Version:

<https://daneshyari.com/article/6474772>

[Daneshyari.com](https://daneshyari.com)