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Bio Oil from Bio Waste (Mahua Oil Cake) Using Fast Pyrolysis Process

V.Sukumar, R.Senthilkumar, V.Manieniyan

Abstract**:** ***Biomass is a renewable resource utilized to produce bio fuel from bio waste. In this experiment, fixed bed fast pyrolysis is carried out on a model of mahua oil cake (MOC dimension) to conclude predominantly the consequences of pyrolysis temperature, MOC dimension and nitrogen gas flow rate from the pyrolysis yields. The temperature, MOC dimension and nitrogen gas flow rate were varied between 500 to 600 ºC, 2 mm to 6 mm and 0.2 to 0.4 liter per min (lpm). The utmost oil yield of 25.90 wt % was attained for a nitrogen gas flow rate of 0.3 lpm, particle size of 4 mm and pyrolysis temperature of 550ºC. The pyrolysis oil had a calorific value of 28180 KJ/kg. The pyrolysis gas may well be utilized as a gaseous fuel. In addition, the bio-oil was illustrated by elemental, gas chromatography/mass spectrometry (GC-MS) analyzer.***

Keywords **:** ***Biomass, Char, Fast pyrolysis, Fixed bed, Mahua oil cake***

I. INTRODUCTION

Biomass in the form of agricultural remains, particularly due to its extensive potential and plentiful usage is fetching popularity amongst innovative renewable energy resources. Among a variety of thermal conversion techniques in biomass, Pyrolysis is the predominantly preferred one. The utilization of biomass for energy generation is a problem of immense impact, as it represents an optional way out for the depleting fossil energy (Sukumar et al. 2020). Bio-energy symbolizes a renewable, economical and plentiful reserve of energy and chemicals. To utilize the abundant variety of available biomass resources for renewable energy generation, a large number of technical options have been presented. The energy conversion techniques can be categorized as biochemical conversion and thermo chemical conversion. Thermo chemical methods can be executed by means of gasification or pyrolysis (slow, fast and flash). Compared to all other methods, pyrolysis is the most appropriate technique to extract bio-oil from bio-waste (Sensoz et al 2008)

Pyrolysis for bio-oil extraction is the thermal disintegration of organic substances in deficiency of oxygen, resulting in the conversion of organic materials into utilizable bio fuels and chemical feedstock (Sukumar et al 2015 and Uresin et al 2019). This technique when functional with lignocelluloses materials results in charcoal, bio-oil and non-condensable gasses. Mahua trees gives way 18–42 kg of seed per annum and the annual yield of mahua seeds is 0.18 million tonnes. Mahua seeds on average have 35% to 40% of oil. 1 kg of mahua seed yields approximately between 240 to 300 g of oil by mechanical pressing and the residue can be further utilized as a resource of biomass fuel. Recently, numerous studies have been made on the pyrolysis of oil cakes.

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II. EXPERIMENTAL DETAILS

The fast pyrolysis of fixed bed 316 stainless steel reactor consists of temperature controller, condenser and heater. The pyrolysis stainless steel reactor capacity is 2 kg. The reactor is electrically heated by 440 V AC using a PCD controller. K-type thermocouples are utilized for the measurement of reactor temperature and heating coil temperature. The condenser consists of a tube of copper. The reactor length is 450 mm and diameter is 220 mm. During the quick pyrolysis method, the condenser condenses the vapor. The nitrogen gas flow rate was calculated for steady flow rate using a rotameter. The reactor's inert gas nitrogen removes the biomass and reactor oxygen and controls the combustion. The experiments were carried out in 27 groups by altering the course parameters like temperature, flow rate and size. The parameters were temperature of 500 ºC, 550 ºC and 600 ºC, gas flow rates of 0.2 lpm, 0.3 lpm and 0.4 lpm and particle sizes of 2, 4 and 6 mm. A separator is utilized for separating bio oil and water from the condensed liquid yield. Using material balance equation, the gas products can be computed.

Fig.1 MAHUA OIL CAKE

Fig. 2 Photo Graphic View Of Fast Pyrolysis Plant

Table- II: Pyrolysis oil Properties

Properties	Value
Cetane number	25
Kinematic viscosity @ 40° C in cSt	2.71
Net Calorific value kJ/kg	28180
Flash point in ° C	52
Fire point in ° C	64

III. RESULT AND DISCUSSION

Product yields in mahua oil cake

In this experimental investigation to optimize the oil yield of mahua oil cake the following results were obtained based on temperature, particle size and N_2 flow rate.

3.1 Product yields with Effect of Temperature

Fig 3 to 11 shows the pyrolysis yield of mahua oil cake in different pyrolysis temperature, feed stock size and N_2 gas flow rate at heating rate 10 ºC/min. The maximum bio oil yield of 25.9 % was found at 550 ºC. The pyrolysis temperature was raised from 500 ºC to 600 ºC, the bio oil yield also augmented from 12.3 % to 25.9 %. In all the figures, bio oil yield increases or decreases depending upon the temperature. On the whole, the bio-oil yield increases to a best possible value with an increase in temperature and then it gets reduced (Zhang et al. 2018). At a temperature of 500 ºC, disintegration was comparatively sluggish and char products were 41.2%. At higher temperature of 600 ºC, bio oil and char yield were reduced, this was due to the increased carbon conversion into gas. While the pyrolysis temperature was raised, char yields decreased. The reduction yield of char at the high temperatures is steady with the rise in the volatile matter (Pimenta et al 2018). The yield of char was reduced from 44.2 % to 26.1 % at temperature various from 500 ºC to 600 ºC. At higher pyrolysis temperature, the water content raises because of water reaction during disintegration of the mahua oil cake (David et al 2018).

3.2 Product yields with Effect of size

Fig 3 to 11 demonstrates the consequences of Particle dimension on product yields. For the particle dimension of 2 mm to 6 mm, the bio-oil yield was 25.9 wt %. With the increase in particle dimensions, the char yield gets higher. For a bigger particle, the heat transfer rate from superficial layer to interior surface is less. This outcome implies that size and heat transfer limitations had a deep impact for a smaller particle with dimension of 2 mm, ensuing maximum amount of oil yield. The gas yield was amid 21.8 % to 31.5 % for all dimensions of particles. Particle sizes influence the yield of pyrolysis outcome (Chen et al 2018). The investigational outcomes illustrate that particle dimension had considerable impact on product yields.

3.3 Product yields with Effect of Nitrogen gas

Fig 3 to 11 illustrates the consequences of N_2 gas flow rate on pyrolysis oil extraction with mahua particle dimension of 2 mm to 6 mm at a temperature of 500°C to 600°C. It was noticed the raise in N_2 gas flow rate from 0.2 lpm to 0.4 lpm raises the bio-oil extraction from 13.7% to 25.9 %. Also the gaseous products shrink from 31.1% to 21.8 %. The reaction time is shorter in volatiles matter in reactor, leads to decomposition of larger molecule (Sukumar et al 2019). A notable decrease in the yield of char has been observed for increased rate of nitrogen gas. For a variation of 0.2 lpm to 0.4 lpm N_2 gas flow rate, the char yield decreases by 9.3%. The investigational outcome of the present work confirms the effect of N_2 gas flow rate on yield of oil and non-condensable gases. It is notable that broad the answer condition with nitrogen could improve the oil yield. As clearing the earth shortens the habitation times of the volatiles and lessens their likelihood of being gotten up to speed with scorch and radical framing optional responses (Yan et al. 2010).In this experimental investigation to optimize the oil yield of mahua oil cake the following results in table II.

Table - II: Summation Of Details For Optimal Oil Yield

Criteria	Temperature	Particle size	N_2 flow rate	liquid yield
Mahua Oil Cake	550 °C	4 mm	0.3 lit/min	25.90 wt%

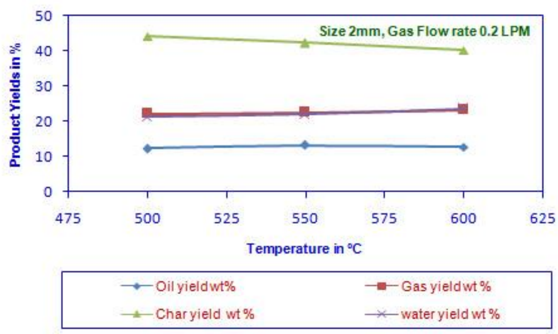

Fig 3 Product Yields (2 Mm And 0.2 Lpm) Vs Temperature

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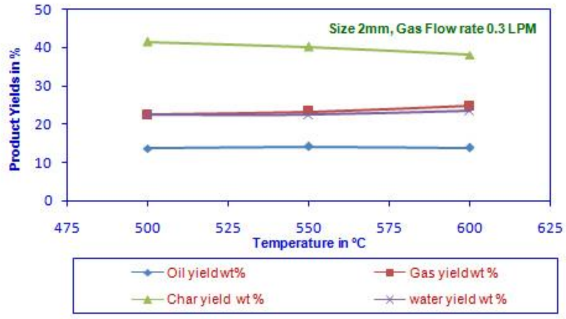

Fig 4 Product yields (2 mm and 0.3 lpm) Vs Temperature

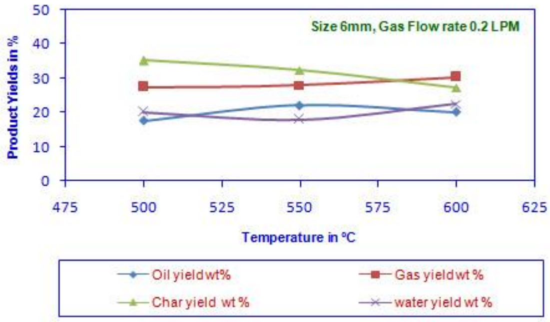

Fig 9 Product yields (6 mm and 0.2 lpm)Vs Temperature

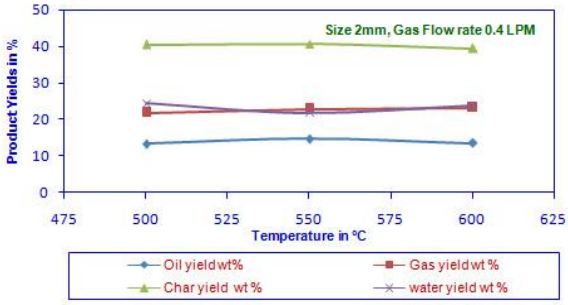

Fig 5 Product yields (2 mm and 0.4 lpm) Vs Temperature

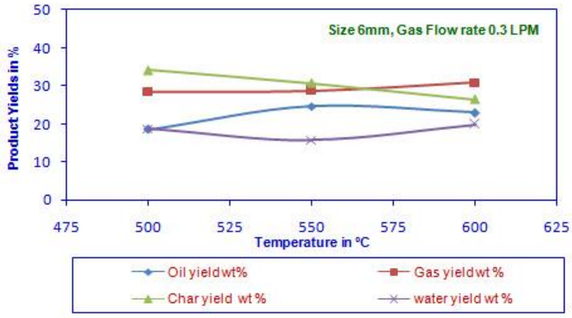

Fig 10 Product yields (6 mm and 0.3 lpm) Vs Temperature

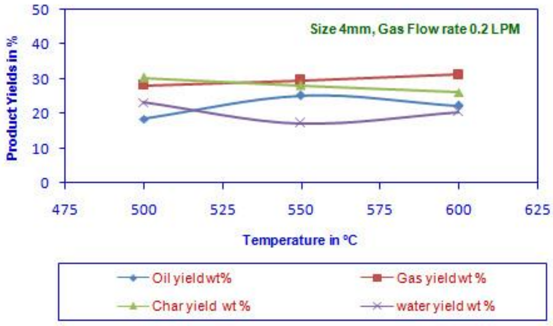

Fig 6 Product yields (4 mm and 0.2 lpm) Vs Temperature

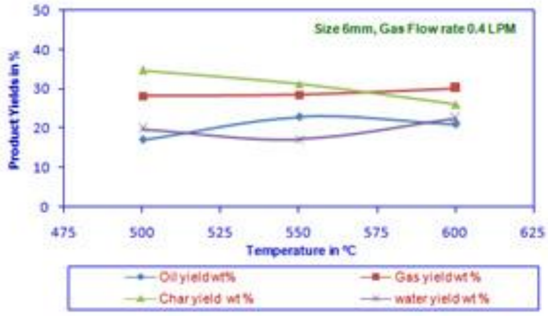

Fig 11 Product yields (6 mm and 0.4 lpm) Vs Temperature

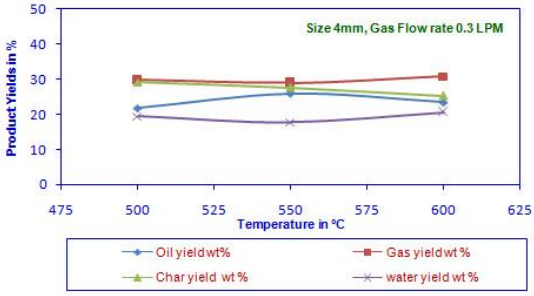

Fig 7 Product yields (4 mm and 0.3 lpm) Vs Temperature

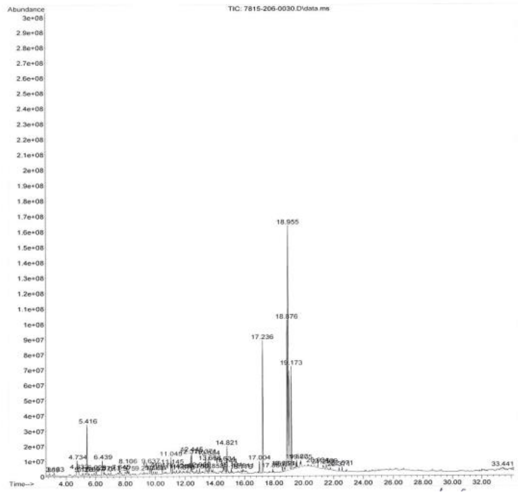

Figure 12 GC-MS test results for bio oil – MOC

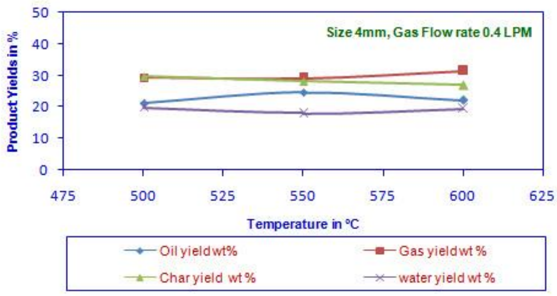

Fig 8 Product yields (4 mm and 0.4 lpm) Vs Temperature

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Table - III: GC-MS RESULT IN BIO OIL -MOC

S.No	Name	Formula	RT	Area in %	Synonyms	MW
1	Phenol	C_6H_6O	4.731	2.08	Carbolic	94.11
2	Naphthalene, 1,6,7-trimethyl-	$C_{13}H_{14}$	13.371	2.12	2,3, 5-Trimethylnaphthalene	170.25
3	9-octadecenoic acid(Z), methyl ester	$C_{19}H_{36}O_2$	18.913	27.45	Oleic acid methyl ester	296.48
4	9,12-octadecadienoic acid (Z,Z)- methyl ester	$C_{19}H_{34}O_2$	718.876	12.18	Methyl octadeca-9,12-dienoate	294.47
5	Methyl stearate	$C_{19}H_{38}O_2$	119.173	6.00	Octadecanoic acid methyl ester	298.50

3.4 Bio oil characteristics for mahua oil cake

The investigation of the oil sample extracted from mahua oil cake by means of GC-MS was prepared to identify the exact composition of the oil (Figure 12). Seventy two different compounds were noticed which are listed in Table 3. The peak components 9-octadecenoic acid (Z), methyl ester being present in highest amount (27.45%), many derivatives of 9-octadecenoic acid (Z), methyl ester were also detected. The other some components are Phenol, Naphthalene, 1,6,7-trimethyl- , 9-octadecenoic acid(Z), methyl ester, 9,12-octadecadienoic acid, (Z,Z)- methyl ester Methyl stearate.

IV. CONCLUSION

In this investigation, fast pyrolysis test of mahua oil cake was carried out in a fixed bed reactor. The utmost bio-oil yield of 25.90 wt % is attained at a temperature of 550ºC, particle dimension of 4 mm and N_2 gas flow rate of 0.3 lpm. The bio oil is acknowledged as a candidate for bio-fuel. The calorific value of bio oil was revealed to be 28180 KJ/kg. Calorific value of bio oil points out that the energy level of the oil is almost closer to that of diesel. The bio-oil can be utilized as a resource of low-grade fuel directly or it may be up graded to superior quality liquid fuel. The benefit of bio oil is no sulfur content, so sulfur oxides are not emitted into the atmosphere when used as an alternative fuel. Bio oil can be used for IC engine, oil fired furnace and boiler as an alternative fuel. GC–MS investigation was proceeded to acquire a suggestion of the environment and category of organic compounds in the bio-oil.

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