FIXED BED PYROLYSIS OF DATE SEED WASTE FOR LIQUID OIL PRODUCTION

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ABSTRACT

The conversion of biomass waste in the form of date seed into pyrolysis oil by fixed bed pyrolysis reactor has been taken into consideration in this study. A fixed bed pyrolysis has been designed and fabricated for obtaining liquid fuel from these date seeds. The major component of the system are fixed bed pyrolysis reactor, liquid condenser and liquid collector. The date seed in particle form is pyrolysed in an externally heated 7.6 cm diameter and 46 cm high fixed bed reactor with nitrogen as the carrier gas. The reactor is heated by means of a biomass source cylindrical heater from 400^0C to 600^0C. The products are oil, char and gas. The reactor bed temperature, running time and feed particle size are considered as process parameters. The parameters are found to influence the product yield significantly. A maximum liquid yield of 50 wt. % is obtained at a reactor bed temperature of 500^0 C for a feed size volume of 0.11- 0.20 cm^3 with a running time of 120 minutes. The pyrolysis oil obtained at this optimum process conditions are analyzed for some fuel properties and compared with some other biomass derived pyrolysis oils and also with conventional fuels. The oil is found to possess favorable flash point and reasonable density and viscosity. The higher calorific value is found to be 28.636 MJ/kg which is significantly higher than other biomass derived pyrolysis oils.

Keywords: Renewable Energy, Pyrolysis Oil, Fixed Bed, Date Seeds.

1. INTRODUCTION

Biomass has been recognized as a major renewable energy source to supplement declining fossil fuel sources of energy [1]. It is the most popular form of renewable energy and currently biofuel production is becoming very much promising [2]. Transformation of energy into useful and sustainable forms that can fulfill and suit the needs and requirements of human beings in the best possible way is the common concern of the scientists, engineers and technologists. From the view point of energy transformation, pyrolysis is more attractive among various thermo chemical conversion processes because of its simplicity and higher conversion capability of biomass and its solid wastes into liquid product. Pyrolysis is generally described as the thermal decomposition of the organic components in biomass wastes in absence of oxygen at mediate temperature (about 500° C) to yield tar (bio oil, bio fuel, bio crude), char (charcoal) and gaseous fractions (fuel gases). Pyrolysis may be either fixed bed pyrolysis or fluidized bed pyrolysis. In fixed bed pyrolysis, a fixed bed pyrolyser is used. The feed material in the reactor is fixed and heated at high temperature. As the feed is fixed in the reaction bed (reactor), it is called fixed bed pyrolysis. In this process, the feed material is fed into the reactor and heat is applied externally. Usually nitrogen is used as inert gas for making inert condition and for helping the gaseous mixture to dispose of the reactor. The losses in fixed bed pyrolysis are relatively less than fluidized bed pyrolysis. A possible reaction pathway of pyrolysis process is shown in Figure 1. This technology is spreading with research and experimental work in many countries of the present world [3]. Energy is the major requirement of modern society, its development and management carries a lot of significance in the economic development of any country. There is a close relationship between the level of energy consumption in a country and its economic development. The energy consumption in the world has been growing at an alarming rate. By the year 2100, the world population is expected to be more than 12 billion and it is estimated that the demand for energy would increase by five times the current demand [4]. Under such circumstances, man has to find out some sources of energy for his survival that be able to meet considerable part of the energy demand in future. In this contest, fixed bed pyrolysis system from the date seed is one of the promising sources of energy. Dates are grown extensively in the whole world especially in Middle East and Asia. According to UN Food & Agriculture Organization in 2005, the top ten date producer countries produced 1.67 billion tons of dates. The seeds of these dates are almost unutilized. This waste may be used for energy recovery as fuel.

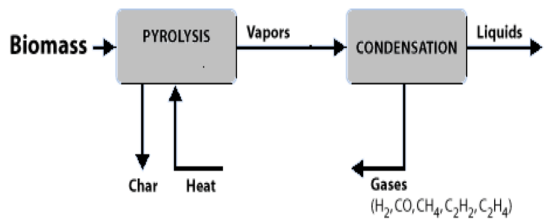

Fig 1. A possible reaction pathway of pyrolysis of organic solid waste

The pyrolysis oil is of moderate heating value, is easily transported, can be burnt directly in the thermal power plant, can possibly be injected into the flow of a conventional petroleum refinery, burnt in a gas turbine or upgraded to obtain light hydrocarbons for transport fuel [5]. Besides these, there are scopes to upgrade the oil to obtain high grade fuel and valuable chemicals. The solid char can be used for making activated carbon. The char has its potential as a solid fuel [5].

2. MATERIALS AND METHODS

2.1 Material

Date seed is collected locally in Rajshahi (Bangladesh). The feedstock is ground and cut into three different volume sizes and is finally oven dried for 24 hours at 110 ^oC prior to pyrolysis. The higher heating value of date seed is found to be 18.936 MJ/kg. The proximate analysis of date seed is presented in Table 1.

Table 1: Higher heating value and proximate analysis of date seed [6]

Moisture	Oil	Crude fiber	Carbohydrates	Ash
5-10%	7-10%	10-20%	55-65%	1-2%

2.2 Experimental Setup

Date seed is pyrolyzed in an externally heated stainless steel fixed bed reactor system. The main components of the system are fixed bed reactor, liquid condenser and ice cooled liquid collectors. The effective length of the reactor is 46 cm and the diameter is 7.60 cm. The schematic diagram of the fixed bed pyrolysis system is shown in Figure 2. The reactor is heated externally by a biomass heater at different temperatures (400, 450, 500, 550 and 600^{0}C) and this temperature is measured by means of a mercury thermometer. Nitrogen gas is supplied in order to maintain the inert atmosphere in the reactor, and to dispose of the pyrolyzed vapor products to the condenser. Pyrolysis vapor is condensed into liquid in the condenser and then is collected in the liquid collectors. The non-condensed gas is flared to the atmosphere.

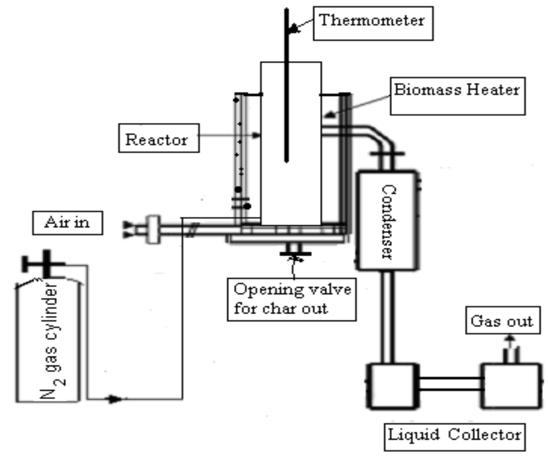

Fig 2. Schematic diagram of fixed bed pyrolysis system

3. RESULT AND DISCUSSION

3.1 Product Yield

The products obtained from the pyrolysis of date seed are liquid oil, solid char and gas. At an operating temperature of 500 ^{0}C for a feed size volume of 0.11-0.2cm^3 (quarter of date seed) at a gas flow rate of 5 liter/min with a running time of 120 minute, liquid production is found to be the maximum (50 wt%) of the dry feedstock.

3.2 Effect of Operating Temperature

The relationship between the variation of percentage of mass of liquid, char, and gaseous products at different reactor bed temperature is presented in Figure 3. The results show that as the operating temperature is increased, the liquid yield is increased up to 500 ^{0}C at a liquid yield of 50 wt%. After this temperature, the liquid yield decreased. At a lower temperature of 400 ^{0}C, the liquid product is found to be 30 wt% of the dry feedstock. The higher temperature above 500^0 C may cause secondary cracking reaction of the vapors, yielding more gas at the cost of liquid product. On the other hand the reason for the lower liquid yield at lower temperature may be due to fact that the temperature is not enough for complete pyrolysis to take place.

3.3 Effect of Feed Particle Size

Figure 4 represents the percentage mass of liquid and solid char products for different feed particle size of feed at a bed temperature of 500 ^{0}C and an operating time of 120 minutes. It is observed that at 500 ^{0}C the percentage of liquid collection is maximum at 50% of total biomass feed for particle size volume of 0.11-0.20 cm^3. Liquid yield is found to be maximum for the smaller particles because the larger size particles might not be adequately heated up so rapidly causing incomplete pyrolysis.

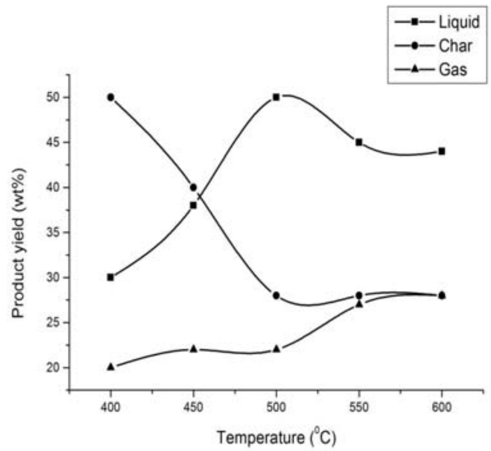

Fig 3. Effect of operation temperature on product yield.

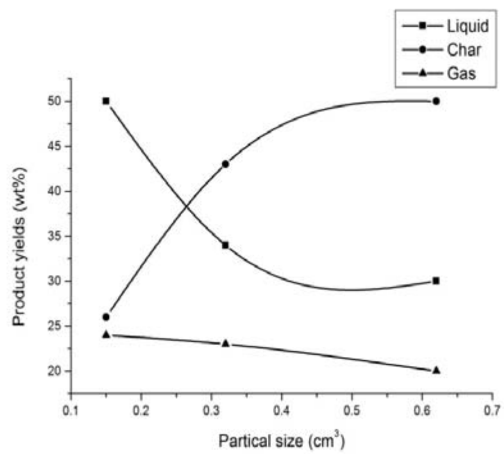

Fig 4. Effect of feed particle size on product yields.

plotted result shows that the liquid yield increases with the increase of running time. The maximum liquid product is found to be 50 wt% of biomass feed while the solid char product is 32 wt% of dry feed at 120 minutes. After this, the liquid product yield is not optimum that may be due to complete devolatilization of the feedstock and higher rate of gas discharge.

4. ANALYSIS OF PYROLYSIS OIL

4.1 Physical Property Analysis of Pyrolysis Oil

The energy content of the oil is 28.636 MJ/kg. The oil is found to be slightly heavier than water with a density of 1042.4 kg/m^3 at 26 ^{0}C. The flash point of the oil is 126 ^{0}C and hence precautions are not required in handling and storage at normal atmosphere. The low viscosity of the oil of 6.63 cSt at 26 ^{0}C is a favorable feature in the handling and transportation.

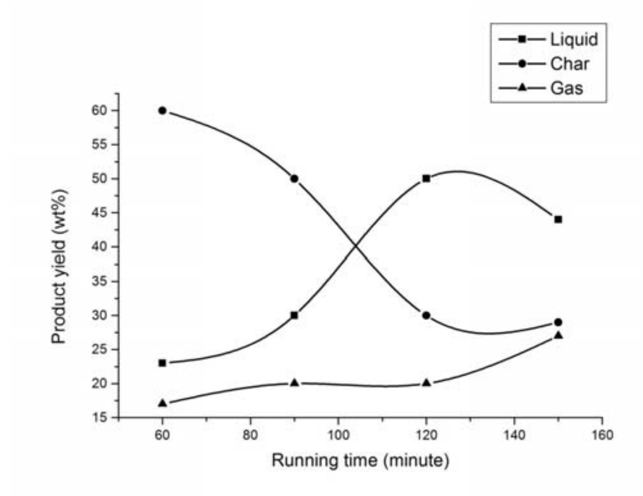

Fig 5. Effect of running time on product yield

4.2 Comparison with other Biomass Derived Oil and Diesel Fuel

Table 2 shows the characteristics of the pyrolysis oil derived from date seed in comparison with other biomass derived oils and diesel fuel. It is evident that the density and viscosity of date seed oil is favorable than other pyrolysis oils and very much closer to diesel. The higher heating value of date seed oil is found to be higher than other biomass derived oil.

Table 2: Comparison of date seed pyrolysis oil with biomass derived pyrolysis oil

Analysis	**Date seed oil**	**Waste paper oil [7]**	**Sugarcane bagasse oil [8]**	**Jute stick oil [8]**
Kinematic viscosity at 26^{0}C (cSt)	6.63	2.00	89.34	12.8
Density (kg/m^3)	1042.4	1205	1198	1224
Flash Point (^{0}C)	126	200	105	>70
HHV(MJ/kg)	28.636	13.10	20.072	21.091

Table 3: Comparison of date seed pyrolysis oil with diesel fuel

Analysis	**Date seed oil**	**Diesel [9]**	**Heavy fuel oil [10]**
Kinematic viscosity at 26^{0}C (cSt)	6.63	2.61*	200#
Density (kg/m^3)	1042.4	827.1*	980*
Flash Point (^{0}C)	126	53	90-180
HHV(MJ/kg)	28.636	45.18	42-43

5. CONCLUSION

The biomass solid waste in the form of date seed is successfully converted into liquid, char and gas by fixed bed pyrolysis system. The heating value of the pyrolysis oil is found to be 28.64 MJ/kg, which is higher than other biomass derived pyrolysis oils and also significantly higher than that of solid date seed waste. The maximum liquid yield is found to be 50 wt% of dry biomass feedstock at the temperature range of 500 ^{0} C. The density and viscosity of the liquid are greater than that of diesel. However, the oil from the date seed may be considered as an important candidate of potential source of alternative fuel,

6. REFERENCES

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7. NOMENCLATURE

Symbol	Meaning
cm	Centimeter
^{0} C	Degree Celsius
wt%	Weight Percentage
MJ	Mega Joule
Kg	Kilogram
cSt	Centistokes

8. MAILING ADDRESS

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