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Biofuel Production from Co-pyrolysis of Scrap tires and Saw dust

M. S. Hossain[1], R. A. Rinku[1], S. N. K. Moon[1], A. M. Parvej[1], M. R. Islam[1], M. G. Kibria[1]
[1] Department of Mechanical Engineering, Rajshahi University of Engineering & Technology, Rajshahi-6204, BANGLADESH
E-mail: sanowar122086@gmail.com

Abstract

The co-pyrolysis of scrap tires with saw dust at different blends was carried out upto 450°C which minimizes the sulphur emission occurred during scrap tire pyrolysis. This experiment was done by a fixed-bed LPG heating reactor having 8 inch diameter and 12 inch height. The feed sizes were 600 µm to 4mm for scrap tires and 600 µm to 1.18mm for saw dust. The liquid and char products were collected separately while the gas was flared into atmosphere. The maximum liquid was obtained from 80% scrap tire and 20% saw dust, while minimum from 20% tire and 80% saw dust. The percentage of liquid was decreasing with increasing amount of saw dust. The maximum heat value of the liquid obtained from 80% scrap tire and 20% saw dust was 38500 kJ/kg. It was found that some properties were much closer with diesel and gasoline and some were not closer to conventional fuels.

Keywords: Scrap tires, Saw dust, Co-pyrolysis.

1. Introduction

The propeller of the modern civilization and its development depends mainly on energy. Nowadays “Energy” has become a global concern. The energy consumption in the world has been growing at an alarming rate. Energy can be obtained from various sources among them fuel is the most common. Pyrolysis is one of the most viable and commonly used thermo-chemical conversion technologies which can be applied to both fossil-based and bio-based wastes. Bangladesh is a developing country in South Asia and it needs increasing amount of energy for its industries and men. The economic development of any country depends on its energy consumption. Renewable energy is of growing importance in satisfying environmental concerns over fossil fuel usage. Bio-based wastes are important bio resources often used to obtain bio-fuels. Co-pyrolysis is a promising technique that can produce a high grade pyrolysis oil from biomass waste [1]. The upgrading of co-pyrolysis processes can play the parallel to other conventional fuels. Bangladesh has a huge amount of biomass solid wastes from agricultural products or industrial waste that are not actually used. Pyrolysis system may be either fixed bed or fluidized bed. In fixed bed system, a fixed bed pyrolysis reactor is used. As the feedstock is kept 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 at a faster rate. The gas yield from co-pyrolysis of scrap tires and sawdust is affected by the proportion of sawdust in the mixture and pyrolysis temperature because the proportion of sawdust increases the amount of gas yield but this increment is not proportional to the addition of sawdust as a result of synthetic effect occurs among the co-pyrolysis gases [2]. The solid char can be used for making activated carbon (AC). Besides it is a fact that the whole world is generating a significant amount of scrap tires and saw dust. Mostly these are underutilized and unutilized. In many places it is creating environmental and disposal problems as well. So an attempt has been taken to convert these wastes into value added materials and energy by co-pyrolysis process. Pyrolysis is the thermal degradation of the organic components of solid wastes, at typical pyrolysis temperatures of 300° C-600° C to produce oil, gas and char products [3]. The main components of gases from co-pyrolysis of sawdust and tires are CO_2, CO, CH_4, H_2 and small amounts of C_2H_4, C_3H_8 and C_3H_6 [2]. There are various parameters which plays a great role for optimizing liquid oil production in pyrolysis such as temperature, type of reactor, residence time, pressure, type and rate of fluidizing gas etc. The solid char may be used as a solid fuel, as carbon black or upgraded to produce an activated carbon. Analysis by Py-FTIR of the mixture of sawdust and tires shows that initially the intensity of the absorption peaks of the gases increases as pyrolysis temperature rises [2]. In general most urban wastes are a mixture of variety of waste components, which adds to the complexity of their treatment separately and also add additional cost in waste to energy recovery processes. The proximate and ultimate analysis value of the used tires is dependent on the tires formulation by the tire manufactures [4]. It would be easier and cost effective if the waste mix would be converted into energy together. But it is reasonable to expect that the quality of the bio-oil will be superior, if it is upgraded by catalysis because the role of the catalysts in reducing the density of the upgraded bio-oils is not as obvious as on the viscosity [5]. Enhancing of the co-pyrolysis temperature is helpful in increasing gas yields at temperature below 550ºC [2].

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2. Materials and Methods

2.1 Feed Materials

The scrap tires were collected from Dhaka city of Bangladesh. Tire brand names are Gazi tires, MRF, CEAT. Heavy automotive tires were then brought to factory. The tires were then grinded in the grinding machine and size ranges from 600μm to 4mm were obtained. The sawdust sample was collected from a saw mill near Rajshahi city and used as feedstock. The sawdust contains some amount of moisture. The sawdust was sun-dried and finally oven-dried by an oven at a temperature of 110^{0}C for 2 hours to remove moisture. The feedstock to oil energy conversion efficiency (FOECE) is one of the performance indicators for evaluation of successful pyrolysis techniques. Feedstock-to-oil energy conversion efficiency (FOECE) is defined as the ratio of pyrolysis oil energy to the total energy of the feedstock, which is calculated using Eq. (1).

Conversion efficiency (FOECE)

$$\eta = \frac{Q_O \times W_O}{Q_p \times W_p + Q_s \times W_s} \quad (1)$$

Where Q_p, Q_s and Q_o represent the heating values of scrap tires, saw dust and product oil. W_p, W_S, and W_o are the mass fractions of the scrap tires, saw dust and product oil, respectively. The objective of the presented study is to determine the optimum process condition for co-pyrolysis of scrap tires and saw dust blends. The influence of process parameters, on the yield and FOECE from the pyrolysis of different blends of wastes are studied. The liquid products from the co-pyrolysis of organic wastes are characterized for their fuel properties. The proximate and ultimate analysis of the scrap tires and saw dust are presented in Table 2.1.

Table 2.1. Proximate and elemental analysis, heat value of scrap tires and saw dust.

Proximate analysis [wt.%]	**Scrap tires**	**Saw dust**	**Elemental analysis [wt.%]**	**Scrap tires**	**Saw dust**
Volatile matter	62.70	6.3	Carbon [C]	80.30	47.1
Moisture	0.82	74.3	Hydrogen [H]	7.18	5.9
Fixed carbon	32.31	18.2	Nitrogen [N]	0.50	0.1
Ash	4.17	1.2	Oxygen [O]	8.33	46.9
	-	20	Others	3.69	-
Total	100	100	Total	100	100

2.2 Experimental section

Figure 2.1 shows the experimental set up of fixed bed pyrolysis unit. Its main unit is the reactor in which the feed material is heated from 350°C to 450°C by external heater. LP gas is used to heat up the reactor here. The inlet and outlet pipe are also connected to the condenser. A digital pyrometer is connected to the top of the reactor. The reactor and condenser are made of stainless steel for its less corrosiveness and high metallurgical limit. The reactor temperature is controlled manually by controlling the LPG supply in the burner through a gate valve. After every run the set-up was disassembled for feeding feed materials and for cleaning of tarry residue of yield attached. It was reassembled again for the next run and it was very difficult to make the system air tight in every joint. The liquid products were condensed inside the condenser chamber and stored into the liquid collector. On the other hand, gases were flared to the atmosphere. The reactor was cooled and bio chars inside the reactor were collected. By subtracting the weight of liquid and char from feedstocks the weight of gas product was determined. Several experimental runs were done by varying the operating conditions and every time the pyrolytic liquid was collected and measured. The proximate analysis was carried out according to the American Society for Testing Materials (ASTM) Standard D3172-73 (1984) test procedures for solid fuel and the ultimate analysis was carried out by an Elemental Analyzer of model EA 1108 according to the ASTM D3176-84 standard test procedures in Bangladesh Council of Science and Industrial Research (BCSIR) laboratory, Dhaka, Bangladesh. Some physical properties of pyrolytic liquids like density, viscosity, pour point, flash point and HHV were determined by using the following standard method: ASTM D189, ASTM D445, ASTM D97, ASTM D92 and ASTM D240 respectively. The calorific value of the pyrolysis oil was measured using an oxygen bomb calorimeter.

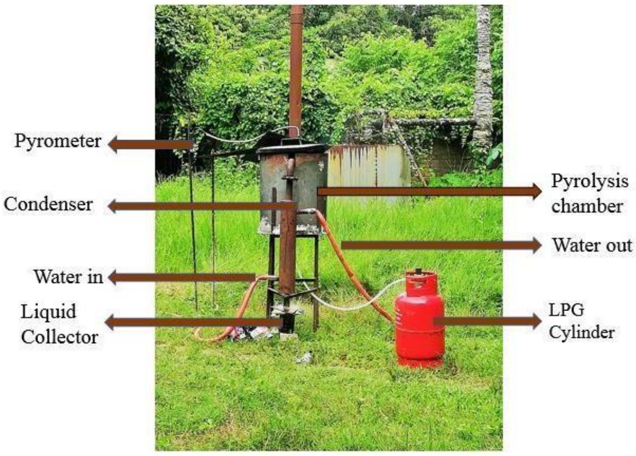

Fig. 2.1. Experimental section of the co-pyrolytic unit.

3. Results and discussion

The obtained major pyrolytic yields are presented in figure 3.1. It is clear from Fig. 3.1 that the maximum pyrolytic liquid (50 wt. %) and minimum char (32 wt. %) and gas (18 wt. %) were produced from 80% scrap tires and 20% saw dust.

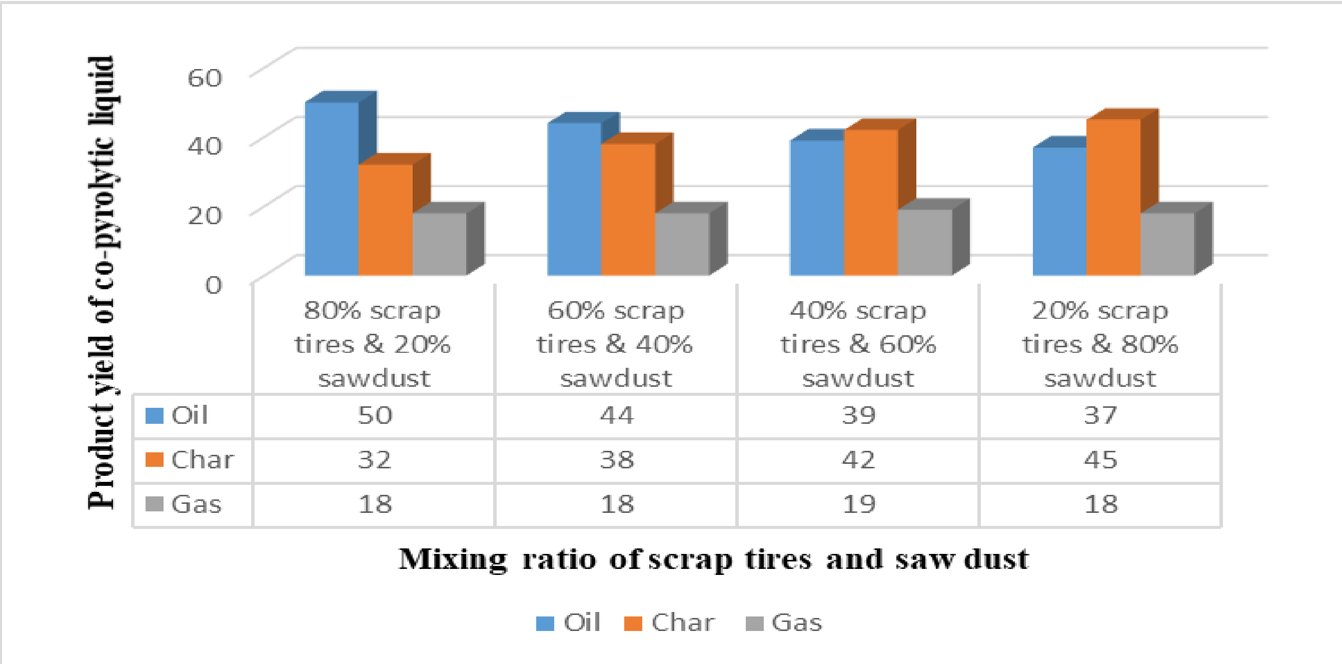

Fig. 3.1. Pyrolysis product yield distribution for different blends of scrap tires and sawdust.

On the other hand, the minimum liquid (37 wt.%) and maximum char (45 wt.%) and gas products (18 wt.%) were obtained from 20% scrap tires and 80% sawdust. Finally without any hesitation it can be said that, the amount of pyrolytic oil increases as well as the char and gas products decreases with the increase of scrap tires in the feedstock blends.

4. Analysis of fuel properties of the product liquids

The oil obtained from co-pyrolysis of scrap tires and sawdust was characterized in terms of density, viscosity, calorific value, pour point and flash point. The storage and utilization of the co-pyrolytic oil is greatly influenced by the moisture content in the feed stocks and pyrolysis conditions. The water content of the pyrolytic oil usually varies from 15 to 30 wt. %, depending on the initial moisture content in the feed stocks [6]. The variation of density with wt. % variation of scrap tires and sawdust in the blend is shown in Fig.4.2. From Fig.4.2, the highest density of the pyrolytic oil was obtained from 20% scrap tires and 80% sawdust and it was 1125 kg/m^3. As the wt. % of sawdust increases in the blend, the density of the pyrolytic oil is also increases. Similarly, from table 4.1, the minimum viscosity (7.60 cSt) of the co-pyrolytic liquid was obtained from 80% scrap tires and 20% sawdust. The increase of the wt. % of sawdust in the blend increases the viscosity of the pyrolytic liquid. The Fig. 4.1 represents the variation of calorific value with the wt. % variation of scrap tires and sawdust in the blend. The highest calorific value (38.5 Mj/kg) was obtained from 80 wt. % scrap tires and 20 wt.% sawdust feedstock's blend. The wt.% increases of sawdust in the feedstock blend decreases the calorific value of the liquid. Besides, from figure 4.2, it is clear that the density of co-pyrolytic liquid increases with the percentage of saw dust increases in the feedstocks. The fuel properties of the co-pyrolysis liquid are compared with various petroleum products are presented in Table 4.1.

Table 4.1. Pyrolytic oil comparison with various conventional fuel.

Properties	**80% scrap tire & 20% saw dust**	**60% scrap tire & 40% saw dust**	**40% scrap tire & 60% saw dust**	**20% scrap tire & 80% saw dust**	**Diesel [7]**	**Palm oil[8]**	**Heavy Fuel Oil**	**Gasoline[9]**
Viscosity at 30°C (cSt)	7.60	11.42	8.05	12.44	2.61	41	-	<1
Density (kg/m^3)	855	875	900	1125	827	830	980	710-790
H.C.V (MJ/Kg)	38.50	36	34	29	45.18	22.10	42	47.70
Specific gravity	0.855	0.875	0.90	1.125	0.83	-	0.98	-
Pour point (^{O}C)	<-6.3	<-6.3	<-6.3	<-4	-33 to -15	20	-	-
Flash point (^{O}C)	79	81	83	88	60-80	250	-	-45

The comparison of pyrolytic liquid obtained from co-pyrolysis of scrap tires and sawdust with conventional fuel indicates its suitability whether it can be used as alternative fuel or not. The density of co-pyrolytic liquid was found lower than that of petrol, diesel and other alternative fuels. Besides, the viscosity of the co-pyrolytic liquid was higher than that of diesel and gasoline fuels but lower than the palm oil. The blends 80 wt. % scrap tires and 20 wt. % sawdust have the lower viscosity (7.60 cSt) which is considered as more suitable for handling and transporting of the liquid. Again the HCV of the co-pyrolytic liquid is lower than the conventional fuels. The maximum HCV of the co-pyrolytic liquid of the scrap tires and sawdust was 38.5 MJ/kg.

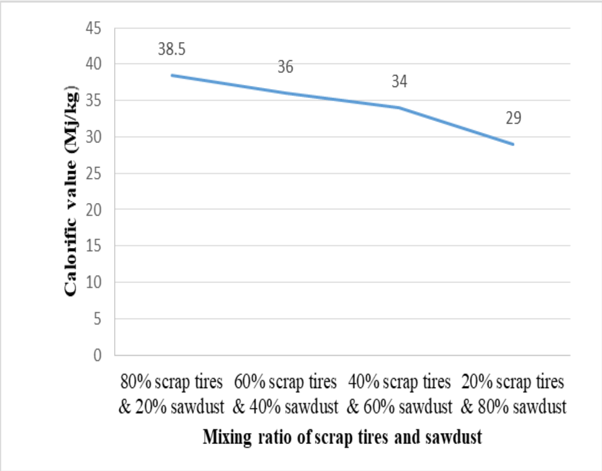

Fig. 4.1. Variation of calorific value with mixing ratio of scrap tires and sawdust.

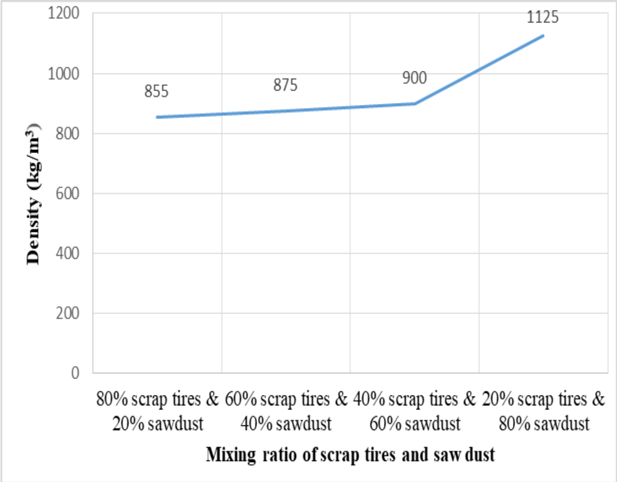

Fig.4.2. Variation of density with mixing ratio of scrap tires and saw dust.

In co-pyrolysis product yields depends mostly on temperature at which the decomposition of feed material is maximum. In order to obtain the effect of temperature the experiment was done at several temperatures such as 300°C,350°C, 400°C,450°C and 500°C. Feed size was in the range 600 µm to 4 mm and running time was 120 minute. Experiment was done at a mixing ratio of 80% scrap tire with 20% saw dust. In each experiment 1.5 kg of feed material is used. The figure 4.3, below represents effect of temperatures. From the figure it is clear that the decomposition rate is maximum at 450°C. In this temperature weight percentage of oil is 48%, char is 34% and gas 18%.The percentage of gas in increasing & char is decreasing with increasing of temperature. Feed size is considered as an important parameter in co-pyrolysis. Product yields depends mostly on feed size. For this experiment, feed size was 600 µm, 1.18mm, 2.36mm and 4mm. In each experiment 1.5 kg feed materials was used which contains 80% scrap tires and 20% saw dust. The optimum running temperature was 450°C and running time was 120 minute. The figure 4.4 represents the effect of feed size on product yields. From the figure, it is clear that for feed size 2.36mm, the percentage of pyrolytic oil is maximum. With increasing feed size percentage of gas decreases and char increases.

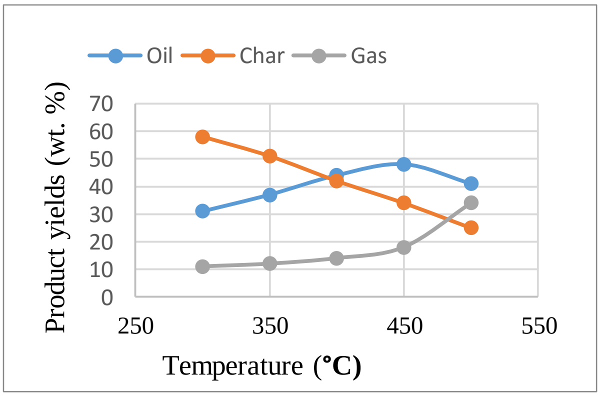

Fig.4.3. Effect of temperature on product yields for particle size 600 µm to 4 mm.

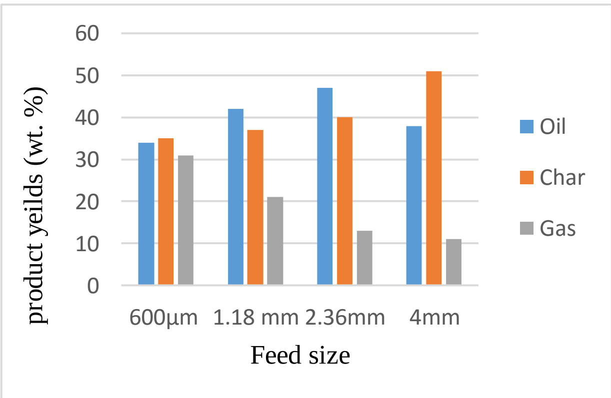

Fig.4.4. Effect of feed size on product yields at temperature 450°C and running time was 120 minute.

5. Conclusion

The wt. % variation of scrap tires and saw dust has a great influence on the product yield as well as FOECE. In this study about six experimental runs were made by varying the proportion of the feed materials. The liquid product yield increases while the char and gases product decreases with the increase of the wt. % of scrap tires in the feed stock blends. The maximum liquid yield 50 wt. % was obtained from the feed stock blends 80% scrap tires and 20% saw dust, at a reactor temperature 380ºC for zero N_2 gas flow. A temperature 380ºC is suggested as the best co-pyrolysis temperature for the co-pyrolysis of scrap tires and sawdust. The maximum calorific value of the pyrolytic liquid was 38.5 Mj/kg, obtained from co-pyrolysis of 80% scrap tires and 20% sawdust. The temperature of the reactor was considered as a major operating parameter for liquid and char products. We tried to maintain the temperature around 400°C for dry feed materials. From the results it can be said that by applying various treatment the obtained co-pyrolytic liquid can be used as a potential sources of renewable energy sources.

6. References

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