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PRODUCTION AND CHARACTERIZATION OF SCRAP TYRE PYROLYSIS OIL AND ITS BLEND

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ABSTRACT
Scrap tyre is considered for fixed bed pyrolysis. Scrap tyre was selected based on its availability, physical and thermal behavior. The major components of the system were fixed bed reactor, gas-preheating chamber, liquid condenser and ice-cooled liquid collectors. Nitrogen gas was used to maintain inert atmosphere in the reactor bed where pyrolysis reaction takes place. Liquid and char were separately collected. The feedstock was heated from 400°C to 550°C in the reactor. The operating temperature was monitored by a pyrometer. The maximum amount of liquid and condensate yields was obtained at 450°C for 5-7 cm size of feedstock with running time of 75 minutes. The product yields were liquid 61%, char 30% and gas 9%. The liquid obtained was filtrated and blended with conventional diesel fuel and characterized separately and finally compared with conventional pure diesel fuel. The physical properties, calorific value, elemental (CHNOS) analysis and chemical composition using Fourier Transform Infra-red spectroscopy (FTIR) of the oil and its blend were determined.

Keywords: Scrap Tyre, Pyrolysis oil, Blend, Fuel characteristics.

1. INTRODUCTION
Energy is the strategic input necessary for socio-economic developments. It is helping meeting basic human needs. Actually, energy propels the society. The standard of living is correlated with per capita energy consumption. The more the energy is consumed the higher the standard of living is considered. In the year 2100, the world population is expected to be more than 12 million and it is estimated that the demand for energy would increase by five times the current demand [4]. Thus, the demand of energy will continue to outstrip its supply. As a result, engineers, scientist and technologist are searching for new, alternative and promising source of energy . Scrap tyre represent an important source of alternative potential energy, fuel and value-added chemicals, which is abundantly available all over the world including Bangladesh.

There are different sources of energy. Some are renewable and others are nonrenewable. About 85% of the total global energy demand is fulfilled with the non-renewable fossil fuel [3]. Though the present stock of fossil fuel is so enormous that it will not end at the end of the next hundred years; however, it will be exhausted at last. Thus, for the future generation it is necessary to keep reserve of non-renewable energy source. Energy is used for domestic use, agriculture, industry, and commerce, transport and in almost every spare of life. A developing country like Bangladesh needs progressively increasing amount of energy for its men and machines, to move forward to prosperity and modernization. In recent years, there has been a resurgence of global interest in renewable energy sources from organic solid wastes. Organic solid wastes are globally available throughout the world. Under such circumstances, man has to find out some source of energy for his survival and to meet considerable part of energy demand in future. In this context, organic substance is one of the promising sources of energy [5]. Organic solid waste is considered to be pyrolysed in this study to get liquid oil as an alternative fuel. Pyrolysis is a new emerging technology for producing liquid fuel from organic solid waste by thermochemical conversion technology [2]. The liquid oil is easily transported, can be burnt directly in the power plant, can possibly be injected into the flow of conventional petroleum refinery, burnt in a gas turbine or upgraded to obtain light hydrocarbons for transport fuel[1].Thus the most promising thermochemical conversion technology currently appears to be the production of liquid oil by pyrolysis. This pyrolysis oil may provide a new dimension in the alternative fuel technology as a renewable source.

2. MATERIALS AND METHODS
The scrap tyre was collected locally at Rajshahi, Bangladesh. The feedstock was ground and sieved to the size of 1-4 cm and 5-7 cm, and finally was oven dried for 24 hours at 110^{o}C prior to pyrolysis.

2.1 Characterization of Scrap Tyre
For the purpose of investigating the suitability of scrap tyre locally available for the pyrolysis process in order to obtain value- added liquid product, proximate

and ultimate analysis has been considered. Important parameters such as volatile matter, moisture, fixed carbon and ash content of the feedstock essential to examine the suitability for pyrolysis process can be obtained from proximate analysis. Ultimate analysis in terms of carbon, hydrogen, nitrogen, oxygen and sulphur (CHNOS) constant is important in order to make necessary material balance of each component. Table 1 shows the proximate and ultimate analysis of the solid scrap tyre.

Table 1. The proximate and ultimate analysis of the solid scrap tyre

Proximate analysis	(wt%)	Ultimate analysis	(wt%)
Volatile matter	62.70	Carbon (C)	80.30
Fixed carbon	32.31	Hydrogen (H)	5.18
Moisture content	0.82	Oxygen (O)	10.13
Ash content	4.17	Nitrogen(N)	-
		Sulphur (S)	-

2.2 Experimental

Scrap tyre was pyrolysed continuously in an externally heated stainless steel fixed bed reactor system with nitrogen as a carrier gas. The main components of the system are fixed bed reactor, gas preheating chamber, reactor feeder, liquid condenser and ice-cooled liquid collectors. The effective length of the reactor is 340 mm and it is 76 mm in diameter. The Schematic diagram of the fixed bed pyrolysis reactor system is shown in Fig 1. A cylindrical biomass heater is used to heat the reactor and the gas pre-heating chamber. Varying the supply of air by means of air blower, the temperature of the reactor is controlled. Nitrogen gas was supplied in order to maintain the inert atmosphere in the reactor and to dispose of the vapor product in the reactor. Maximum amount of liquid product was obtained at 450°C. Pyrolysis product produced in the reactor passed through the liquid condenser and the condensed liquid was collected in the liquid collector. The noncondensed gas was flared to the atmosphere.

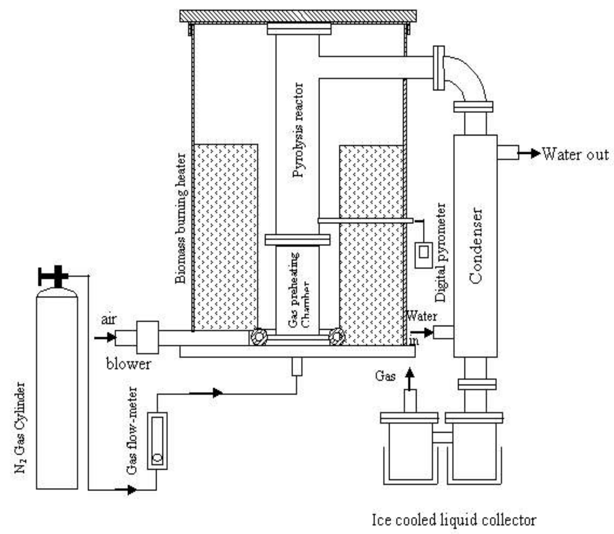

Fig 1. The schematic diagram of fixed bed pyrolysis apparatus.

3. BLEND OF SCRAP TYRE PYROLYSIS OIL WITH DIESEL FUEL

At first scrap tyre pyrolysis oil was filtrated to reduce tar and other impurities. Blend procedure was held in percent by volume. In this study, respectively 3%, 5%, 7%, 10% scrap tyre pyrolysis oil and 97%, 95%, 93%, 90% diesel fuel were used for blend. After blend it was shaked sufficiently and kept in the container for two days. Afterward, it was found that mixture was homogeneous and no layer was found. Thus, blend was successfully done.

4. ANALYSIS OF PRODUCT OIL AND ITS BLENDS

4.1 Physical and Chemical Analyses

The pyrolysis oil at the maximum liquid yield condition was characterized for its physical and chemical properties. These properties were determined according to the American Society of Testing Materials (ASTM) standard test methods. The properties determined were : kinematic viscosity, density, p^H value, flash point, fire point, higher and lower heating value. The elemental analysis of the oil was conducted at Analytical Research Division of BCSIR, Dhaka. The elemental composition of the derived oil was determined using a (CHNS) elemental analyzer of model EA1108. Oxygen was calculated by difference. Table 2 shows the physical and chemical analysis of scrap tyre oil and its blends.

Table2: Characteristics of scrap tyre pyrolysis oil and its blend

Analysis	Diesel fuel	Pyrolysis oil	3% pyrolysis oil+ 97% diesel	5% pyrolysis oil+ 95% diesel	7% pyrolysis oil+ 93% diesel	10% pyrolysis oil+ 90% diesel
Elemental Analysis (wt%)						
Carbon	84	80	-	-	-	-
Hydrogen	13.2	6.33	-	-	-	-
Nitrogen	--	--	-	-	-	-
Sulphur	--	--	-	-	-	-
Ash	0.02	0.06	-	-	-	-
Oxygen	0.01	13.8	-	-	-	-
Kinematics Viscosity(cSt at 38 °C)	4.3	4.8	4.35	4.4	4.48	4.55
Density (kg/m^3)	840	971	847	861	887	893
Specific gravity	0.93	1.08	0.94	0.96	0.99	0.99
p^H value	6.54	4.11	6.0	5.9	5.65	5.17
Flash point (°C)	69	40	62	63	63	64
Fire point (°C)	74	50	66	68	69	69
H.H.V (MJ/kg)	45.5	41.7	44.7	44.1	43.9	43.8
L.H.V (MJ/kg)	44.2	32.7	43.9	43.6	43.4	43

4.2 Compositional Analysis

Table 2 and Table 3 represent chemical composition analysis of scrap tyre oil and its blends. The functional group compositions of the pyrolysis oil were analyzed by Fourier Transform Infra-Red Spectroscopy (FTIR) to identify the basic compositional groups. The FTIR instrument of model SHIMADZU FTIR 4500 and an on-line pen plotter were used to produce the ir-spectra of the derived oils. The standard ir-spectra of hydrocarbons were used to identify the functional group of the components of the derived oils. The test was conducted in the laboratory of the Department of Chemistry of Rajshahi University.

Table 3: The FTIR functional groups and the indicated compounds of pyrolysis oil.

Frequency range (cm^{-1})	Group	Class of compound
3000 - 2800	C-H stretching	Alkanes
1775 - 1680	C=O stretching	Ketones, Aldehydes, Carboxylic acid
1680 – 1575	C≡C stretching	Alkanes
1575 – 1425	- NO_2	Nitrogenous Compound
1425 – 1325	C–H bending	Alkanes
1300 – 1175	C–O stretching O–H bending	Primary, Secondary and tertiary alcohols, phenol, esters and ethers.
1150 – 1000	C–H bending	Alkanes
950 – 875	C≡C stretching	Alkynes
900 - 650		Aromatic compounds

Table 4: The FTIR functional groups and indicated compounds of 10% blend of scrap tyre with Diesel.

Frequency range (cm^{-1})	Group	Class of compound
2775 - 2700	- NO_2 stretching	Nitrogen, Oxygen compound
2700 - 2500	C– H stretching	Aldehydes
1640 – 1570	C = C stretching N –H bending	Aromatics
1200 - 1125	C – O stretching O – H bending C – H bending	Alkane, Aromatics Alcohols (primary, secondary, tertiary), esters, ethers.
975 - 940	C ≡ C stretching	Alkynes

5. RESULTS AND DISCUSSION

5.1 Characteristics of Scrap Tyre

From the characterization study it may be concluded that the scrap tyre has high volatile content (62.71% by wt.), which is suitable for pyrolysis conversion of organic solid wastes to liquid product. Moisture content is low which favors for liquid fuel production.

5.2 Product Yields

The products obtained from the pyrolysis of scrap tyre were liquid, char and gas. The liquid obtained from scrap tyre was single-phase dark brownish color product of acrid smell. The liquid product was collected in two ice-cooled collectors in series. The char was collected from the reactor and the gas was flared to the atmosphere.

5.3 Effect of Reactor Temperature

The yields obtained from different experimental run at different reactor bed temperature have been presented in Figs 2 and 3 respectively. At lower bed temperatures the liquid yields were lesser in comparison to that at an intermediate temperature. However, the char yield was higher at lower temperature and this was found to be decreasing with increasing temperature. The gas yield was lower at lower temperature with a trend of increasing with increasing temperature. The maximum liquid yield was obtained at an intermediate temperature of 450°C. The reason behind this is that the lower temperature was not sufficiently high enough for the pyrolysis devolatilization reaction to take place completely rendering reduced amount of liquid and gaseous products. Again the higher temperature was causing secondary cracking reaction of the vapors yielding more gas at the cost of the liquid product yield.

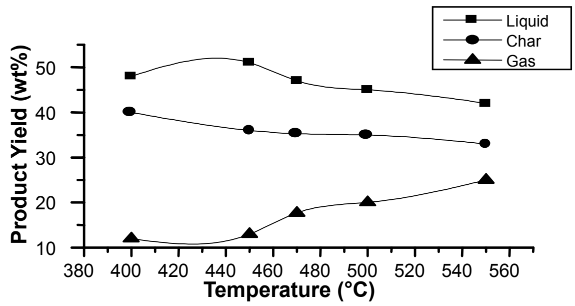

Fig 2. Effect of temperature on Product yields for particle size of 2-4 cm.

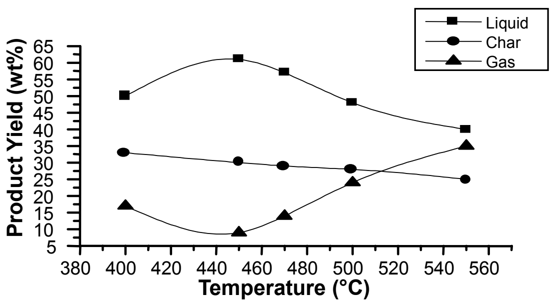

Fig 3. Effect of temperature on Product yields for particle size of 5-7 cm.

5.4 Effect of Feed Size

Figs 4, 5 and 6 show the liquid, char and gas yield

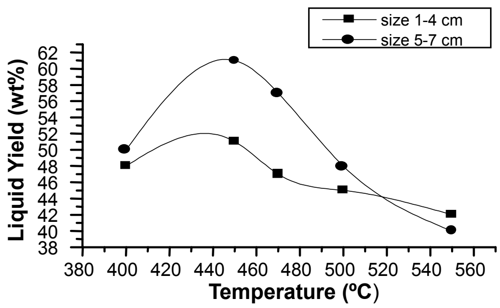

Fig 4. Effect of feed particle size on the liquid yield for pyrolysis of scrap tyre.

of two different feedstock size respectively. The highest liquid yield is found from the larger size particle (5-7cm).

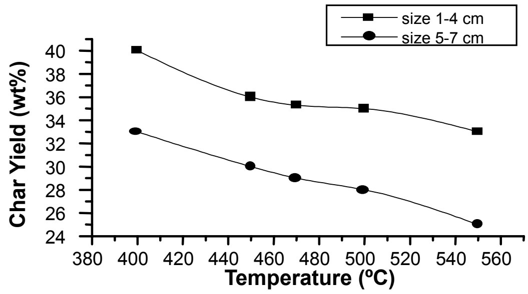

Fig 5. Effect of feed particle size on the char yield for pyrolysis of scrap tyre

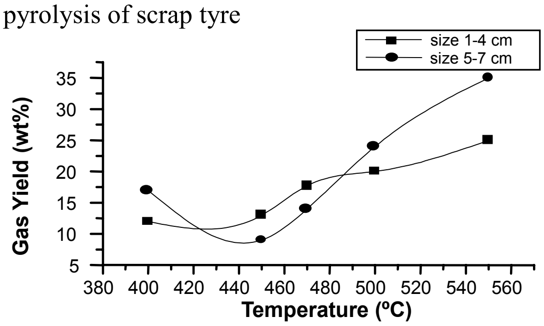

Fig 6. Effect of feed particle size on the gas yield for pyrolysis of scrap tyre

The maximum liquid yield from smaller feed was lower due to the fact that the smaller feed was blown out of the reactor in a shorter time, too quick for the total devolatilization to be completed. The char product were high for smaller feedstock.

5.5 Effect of Running Time

The effect of variation of running time on liquid yield is presented in Fig 7. From the plotted result, it is shown that liquid yield increased with the running time. After 90 min experimental run liquid yield was 62% and was constant with increase of running time. In more than 90 minutes the volatile contents in the feedstock was fully disposed of.

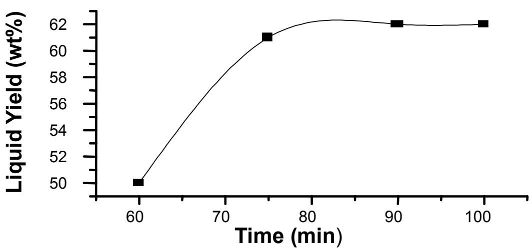

Fig 7. Effect of running time on liquid yield for pyrolysis of scrap tyre.

6. CONCLUSION

Fixed bed pyrolysis of scrap tyre had given maximum liquid yield of 61% of feed at a reactor temperature 450°C where the size of feedstock was 5-7 cm. The pyrolysis oil was single phase liquid product. The heating value of the oil was quite high almost similar to diesel fuel. After blending with diesel the fuel properties improved significantly.

7. REFERENCE

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8. NOMENCLATURE

Symbol	Meaning
LHV	Lower heating value
HHV	Higher heating value
ASTM	American society of testing materials
cSt	Centistokes
pH	Negative logarithm of hydrogen ion concentration
O-H	Hydroxyl stretching
C-H	Carbon hydrogen stretching and bending
C=O	Carbonyl stretching
C=C	Carbon carbon double bonding stretching
C≡C	Carbon carbon triple bonding stretching
$-N_2O$	Nitrogen dioxide stretching
C-O	Carbon oxygen stretching
FTIR	Fourier transform infrared