INTRODUCTION

Waste to energy (WTE) technology is a promising way to transform the municipal solid waste (MSW) into the energy resource. According to Plastic Europe Market Research Group, the reported global production of plastic is 322 million tons (PEMARG) in which only United States individually contributes 250 million tons of municipal solid waste (MSW) (Staley, 2009) which generates numerous environmental problems. Pyrolysis is a thermal degradation process of organic materials which operated at very high temperature in oxygen less environment. On pyrolysis of plastic by mixing biomass causes the improvement in liquid product yield than the plastics pyrolyzed individually (Brebu, 2010). Co-pyrolysis of plastic waste with different biomass such as karanja & niger seeds (Shadangi, 2015), red oak (Xue, 2015), rice husk (Costa, 2014), almond shell (Önal, 2013), oil shell (Aboulkas, 2012), pine cone (Brebu, 2010), wood biomass (Sharypov, 2002), forestry biomass wastes (Paradel, 2009), ligno-cellulosic materials (Jakab, 2001) has been studied widely. Oxidative thermal degradation of the waste High Density Polyethylene (HDPE) and Low Density Polyethylene (LDPE) by mixing Jute fiber is a novel pathway to obtained high yield of liquid fuel from polyethylene waste (Dixit, 2016).

*Corresponding author: Savita Dixit
Department of Chemistry Maulana Azad National Institute of Technology, Bhopal India 462051

PHYSIOCHEMICAL PROPERTIES OF OIL<sub>JFWPB</sub>, RECOVERED BY THE OXIDATIVE THERMAL DEGRADATION OF THE MIXTURE OF HDPE, LDPE AND JUTE FIBER

Vijesh Verma., Savita Dixit* and Gajendra Dixit
Department of Chemistry Maulana Azad National Institute of Technology, Bhopal India 462051

A B S T R A C T

The Oil<sub>JFWPB</sub> was recovered by the oxidative thermal degradation of the mixture of HDPE, LDPE and Jute fiber. According to the GC/MS analysis, it was reported that chemically Oil<sub>JFWPB</sub> consisted of a phytol, two saturated fatty acids, two unsaturated fatty acids and two silica containing derivatives. Five blends of Oil<sub>JFWPB</sub> were prepared with Diesel (Reference fuel) and the basic physiochemical fuel properties such as Density, Viscosity, Kinematic Viscosity, Flash Point, Fire Point, Cloud Point, Pour Point and Calorific Value were determined by using ASTM methods.

MATERIAL AND METHOD

The Oil<sub>JFWPB</sub> was recovered by the oxidative thermal degradation of the mixture of HDPE, LDPE and Jute fiber (Dixit, 2016). The five blends of Oil<sub>JFWPB</sub> i.e. Oil<sub>JFWPB</sub>-10%, Oil<sub>JFWPB</sub>-20%, Oil<sub>JFWPB</sub>-30%, Oil<sub>JFWPB</sub>-40% and Oil<sub>JFWPB</sub>-50% were prepared with the Diesel (Reference fuel) for the determination of basic physiochemical fuel properties.

Figure 1 A: Diesel, B: Oil<sub>JFWPB</sub> C-G: prepared five blends, respectively
In this research work the five blends of OilJFWPB were prepared with Diesel (Reference fuel) and by following the ASTM methods the basic physicochemical properties of the blends were determined and compared with Diesel.

**Preparation and nomenclature of the blends of OilJFWPB with Diesel**

For the preparation of each blend, the appropriate fractions of OilJFWPB and Diesel were taken in a 1 Liter beaker by using measuring cylinder and then with the help of magnetic stirrer the mixture of OilJFWPB and Diesel were stir for 30 minutes, to make the uniform mixture of fuel. The actual picture of the OilJFWPB and their five blends with Diesel shown in Figure 1. Nomenclature and composition of the blends of OilJFWPB with Diesel were summarized in Table 1.

**Table 1 Nomenclature and composition of the blends of OilJFWPB**

| S.N. | Name of the blend | Fraction of OilJFWPB (ml) | Fraction of Diesel (ml) |
|------|-------------------|--------------------------|------------------------|
| 1.   | Diesel (Reference fuel) | 00 | 1000 |
| 2.   | OilJFWPB-10% | 100 | 900 |
| 3.   | OilJFWPB-20% | 200 | 800 |
| 4.   | OilJFWPB-30% | 300 | 700 |
| 5.   | OilJFWPB-40% | 400 | 600 |
| 6.   | OilJFWPB-50% | 500 | 500 |

**Standard methods**

The ASTM methods and apparatus which were used to determine the fuel properties summarized in Table 2.

**Table 2 Standard apparatus and methods for the fuel properties**

| S.N. | Fuel properties | Standards apparatus | ASTM methods |
|------|-----------------|---------------------|--------------|
| 1.   | Density (g/cm³) | Gay-Lussac specific gravity bottle | ISI 1448[P:32]:1992 |
| 2.   | Viscosity (m Pa S) | A N D Viscometer SV 10 | Digital Viscometer |
| 3.   | Viscosity (c S) | Redwood Viscometer No. 1 | ASTM D 445 |
| 4.   | Flash Point (°C) | Abel’s closed cup apparatus | ASTM D 93 |
| 5.   | Fire Point (°C) | Abel’s closed cup apparatus | ASTM D 93 |
| 6.   | Cloud Point (°C) | Cloud Point determination apparatus | ASTM D 2500 |
| 7.   | Pour Point (°C) | Pour Point determination apparatus | ASTM D 97 |
| 8.   | Calorific Value (MJ/Kg) | Digital Bomb Calorimeter | IS:1448[P:6]:1984 |

**RESULTS AND DISCUSSION**

**Chemical composition of the OilJFWPB**

According to the GC/MS analysis of OilJFWPB, in the Total ion chromatogram (Figure 2) the 14 major peaks were recorded in which seven chemical compounds (Table 3) were, a phytol identified as 3,7,11,15-Tetramethyl-2-hexadecen-1-ol (Figure 2 (B)), two saturated fatty acids, Methyl tetradecanoate and Pentadecanoic acid, 14-methyl- methyl ester (Figure 2 (C) & 2(E)), two unsaturated fatty acids, 7-Hexadecenoic acid, methyl ester, (Z) (Figure 2 (D)) and 9-Octadecenoic acid (Z)-, methyl ester (Figure 2 (F)) and 2
Physiochemical properties of oil_{jfwpb} recovered by the oxidative thermal degradation of the mixture of hdpe, ldpe and jute fiber

| Retention time | Compound name  | Fragmentation (m/z) | Molecular formula  | Molecular structure |
|----------------|----------------|---------------------|--------------------|--------------------|
| 15.25          | Methyl tetradecanoate | 242,199,143,74     | C_{17}H_{33}O_{2}  |                    |
| 16.78          | 3,7,11,15-Tetramethyl -2-hexadecen-1-ol | 296,278,249,193,179, 138,123,96,81,56 | C_{20}H_{36}O                  |                    |
| 17.17          | 7-Hexadecenoic acid, methyl ester, (Z) | 278,236,194,152,123, 110,95,82,74 | C_{17}H_{32}O_{2}            |                    |
| 17.43          | Pentadecanoic acid,14-methyl-, methyl ester | 270,227,213,185,171, 143,101,86 | C_{19}H_{34}O_{2}            |                    |
| 19.2           | 9-Octadecenoic acid (Z)-, methyl ester | 296,264,235,222,194,180,152,1 37,110,96,83,69 | C_{19}H_{36}O_{2}            |                    |
| 5.9            | Benzaldehyde,3-methoxy-4-[(trimethylsilyl)-, O-methyloxime | 281,253,223,207,191,149,119,1 04,73 | C_{19}H_{29}O_{2}NSi         |                    |
| 8.65           | 2,2'- Bis-(trimethylsilyl) benzhydryl ether methyl | 355,327,281,223,207,133, 89,73 | C_{20}H_{29}O_{2}Si          |                    |

silica containing derivatives (Figure 2 (G) & 2 (H)). On the basis of the molecular structure the tentative average chemical formula of the Oil_{jfwpb} can be calculated and obtained as C_{17.14}H_{31.14}O_{1.8}N (Silica not included) whiles the average chemical formula of Diesel is C_{17}H_{32}.

**Physiochemical properties of Oil_{jfwpb}**

**Density**
The variation in Density of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% and Diesel shown in Figure 3 (A), were 0.7751 g/ml, 0.7734 g/ml, 0.7717 g/ml, 0.7760 g/ml, 0.7683 g/ml and 0.7768 respectively. The Density of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% is decrease by 0.21%, 0.43%, 0.65%, 0.87%, 1.09% as compared to Diesel respectively. According to the physical properties of the blends, it was clear that Density decreases with increase of the fraction of Oil_{jfwpb} in each blend. Decrease in Density indicates that every blend getting lighter than Diesel respectively.

**Viscosity**
The variation in Viscosity of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% and Diesel shown in Figure 3 (B), were 3.6, 3.45, 3.34, 3.2, 3.05 and 3.66 respectively.

The Viscosity of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% are decreased by 1.63%, 5.73%, 8.74%, 12.56%, 16.66% as compared to Diesel. Decrease Viscosity indicates that every blend getting thinner than Diesel respectively.

**Kinematic Viscosity**
The variation in Kinematic Viscosity of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% and Diesel shown in Figure 3 (C), were 10.07, 9.09, 7.73, 5.93, 3.99 and 10.41 respectively. The Kinematic Viscosity of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% were decreased by 3.26%, 12.68%, 25.74%, 43.03%, 61.67% as compared to Diesel.

**Flash Point**
The variation in Flash Point of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% and Diesel shown in Figure 3 (D), were 48 °C, 42 °C, 32 °C, 30 °C, 29 °C and 58 °C respectively. The Flash Point of Oil_{jfwpb}-10%, Oil_{jfwpb}-20%, Oil_{jfwpb}-30%, Oil_{jfwpb}-40%, Oil_{jfwpb}-50% are decreased by 17.2%, 27.5%, 44.8%, 48.2%, 50% as compared to Diesel respectively.
Table 4 Physiochemical fuel properties of all the five blends of OilJFWPB with respect to Diesel

| S.N. | Name of the blend | Density at 31.2 °C (g/ml) | Viscosity at 25.5 °C (m Pa S) | Kinematic Viscosity | Flash Point (°C) | Fire Point (°C) | Cloud Point (°C) | Pour Point (°C) | Calorific Value (KJ/Kg) |
|------|-------------------|---------------------------|-------------------------------|--------------------|----------------|----------------|----------------|----------------|-----------------------|
| 1.   | Diesel            | 0.7768                    | 3.66                          | 10.41              | 58             | 66             | -11            | -20            | 45518.2               |
| 2.   | OilJFWPB-10%     | 0.7751                    | 3.60                          | 10.07              | 48             | 56             | 12             | 0              | 45296.4               |
| 3.   | OilJFWPB-20%     | 0.7734                    | 3.45                          | 9.09               | 42             | 53             | 10             | -2             | 45074.6               |
| 4.   | OilJFWPB-30%     | 0.7717                    | 3.34                          | 7.73               | 32             | 45             | 7              | -3             | 44852.8               |
| 5.   | OilJFWPB-40%     | 0.7700                    | 3.20                          | 5.93               | 30             | 39             | 4              | -5             | 44631.1               |
| 6.   | OilJFWPB-50%     | 0.7683                    | 3.05                          | 3.99               | 29             | 37             | 2              | -6             | 44409.1               |

Figure 3 Physiochemical properties of OilJFWPB. A: Density, B: Viscosity, C: Kinematic Viscosity, D: Flash Point, E: Fire Point, F: Cloud Point, G: Pour Point, H: Calorific Value respectively.
The variation in Pour Point of Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\%, Oil_{5}\% - 50\% and Diesel shown in Figure 3 (E), were 56 °C, 53 °C, 45 °C, 39 °C, 37 °C and 6°C. The Fire Point of Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\%, Oil_{5}\% - 50\% are decreased by 15.1%, 19.6%, 31.8%, 40.9%, 43.9% as compared to Diesel respectively. It was clear that flash and Fire Point decreases with increase of the fraction of Oil_{i}\% in each blend. Decrease in Density and Viscosity indicates that every blend getting lighter and thinner than Diesel respectively, hence the Flash and Fire Point of each blend also decreases.

Cloud Point
The variation in Cloud Point of Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\%, Oil_{5}\% - 50\% and Diesel shown in Figure 3 (F), were 12 °C, 10 °C, 7 °C, 4 °C, 2 °C and -11 °C respectively.

Pour Point
The variation in Pour Point of Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\%, Oil_{5}\% - 50\% and Diesel shown in Figure 3 (G), were 0 °C, -2 °C, -3 °C, -5 °C, -6 °C and -20 °C respectively.

Calorific Value
The variation in Calorific Value of Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\%, Oil_{5}\% - 50\% and Diesel shown in Figure 3 (H), were 45296.4 KJ/Kg, 45074.6 KJ/Kg, 44852.8 KJ/Kg, 44631.1 KJ/Kg, 44409.1 KJ/Kg and 45518.2 KJ/Kg respectively. The Calorific Value of Oil_{i}\% - 10\%, Oil_{i}\% - 20\%, Oil_{i}\% - 30\%, Oil_{i}\% - 40\%, Oil_{i}\% - 50\% are decreased by 0.48%, 0.97%, 1.46%, 1.94%, 2.43% as compared to Diesel respectively.

The characteristic basic physicochemical fuel properties of all the five blends of Oil_{i}\% i.e. Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\% and Oil_{5}\% - 50\% with respect to Diesel summarized in Table 4.

CONCLUSION
It was concluded that, for all the five blends i.e. Oil_{1}\% - 10\%, Oil_{2}\% - 20\%, Oil_{3}\% - 30\%, Oil_{4}\% - 40\% and Oil_{5}\% - 50\%;

1. The Density decreased by 0.21%, 0.43%, 0.65%, 0.87% and 1.09% as compared to Diesel.
2. The Viscosity decreased by 1.63%, 5.73%, 8.74%, 12.56% and 16.66% as compared to Diesel.
3. The Kinematic Viscosity decreased by 3.26%, 12.68%, 25.74%, 43.03% and 61.67% as compared to Diesel.
4. The Flash Point decreased by 17.2%, 27.5%, 44.8%, 48.2% and 50% as compared to Diesel.
5. The Fire Point decreased by 15.1%, 19.6%, 31.8%, 40.9% and 43.9% as compared to Diesel.
6. The variation in Cloud Point was 12 °C, 10 °C, 7 °C, 4 °C and 2 °C as compared to Diesel.
7. The variation in Pour Point was 0 °C, -2 °C, -3 °C, -5 °C and -6 °C as compared to Diesel.
8. The Calorific Value decreased by 0.48%, 0.97%, 1.46%, 1.94% and 2.43% as compared to Diesel respectively.

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