
Research article**Production of an alternative fuel from a blend of polypropylene wastes and *Jatropha* distillates for Oil Well drilling****Adegoke S.O^{1,*}, Falode O.A¹, Adeleke A.A², Ikubanni P.P² and Agboola O.O²**¹ Department of Petroleum Engineering, University of Ibadan, Ibadan, Oyo State, Nigeria² Department of Mechanical Engineering, Landmark University, P.M.B. 1001, Omu-Aran, Kwara State, Nigeria*** Correspondence:** Email: sfikayo@gmail.com.

Abstract: A fabricated ablative pyrolysis reactor was used to extract oil from polypropylene (PP) wastes and *Jatropha curcas* (JC). The oils extracted were distilled at a temperature range of 250–320 °C and the percentage of oil yield was recorded. The distilled oil from PP and JC were mixed in different ratios of 9:1, 4:1, 7:3, and 3:2, respectively. The flashpoint, pour point, cloud point, viscosity, and density of the mixtures were evaluated based on different ASTM standards. Fourier Transform Infrared (FTIR) spectroscopy was used to identify the functional groups in the samples. The results were compared with those of conventional diesel oil. The oil yields were 73% for PP waste and 43.2% for JP. The physicochemical properties of the 3:2 combination of PP/JC were the closest to the conventional diesel samples with a viscosity of 11.40 cst compared with 11.07 cst of diesel, the density of 0.892 g/cc compared with 0.8849 g/cc of diesel and cloud point of 0 °F compared with 25 °F of diesel. The statistical response optimiser gives the blend of polypropylene and *Jatropha* to be 3.12:2 PP/JC and 3:2 PP/JC for viscosity and density, respectively. It also shows consistency on the experimented result and the predicted responses. The FTIR of PP and JC distillates were similar to each other because of the presence of absorptions at 2982, 2940, 2856, 1462–1458 cm⁻¹ and the lowest absorption at 410 cm⁻¹. However, the major differences were the various visible absorptions at 1706, 1604, 1376–743/cm in JC oil. The blend of 3:2 PP/JC distillate was discovered to have great potential in the drilling industry based on their physicochemical properties when compared to diesel oil.

Keywords: Polypropylene; *Jatropha curcas*; alternative fuel; pyrolysis; renewable; environment

1. Introduction

A drilling engineer bore holes into the ground for the purpose of delineating the presence of oil. Various equipment ranging from machines capable of producing large torques such as pumps, motors, rigs and vessels are used [1,2]. Petrol (gasoline) and diesel utilised in the drilling industries are the major liquid transportation and machine fuels obtained from crude oil. Diesel has its source from fossil fuel, which is non-renewable and depleting at a fast rate. Nigeria is a blessed country because it hosts a large quantity of fossil fuel resources. It has a large reserve of crude oil, natural gas, tar sand, coal, and lignite. Nigeria has a proven crude oil reserve of over 36 billion barrels [3–5]. Crude oil also supplies aviation fuel for air transportation and kerosene for household and domestic purposes [3]. Hence, there is a need to proffer a safe alternative fuel to reduce many dependencies on the non-renewable resources [6–8]. Jahirul *et al.* [9] opined that biomass energy poses to be the third-largest global source of energy with up to 40–50% of energy usage in countries where there are massive forests which if utilised could boost rural development through industrialisation, investment, and trade. It could also create employment, raise domestic and international income leading to poverty eradication [4].

The use of various types of biomass as biofuel has been studied by several researchers [8] in which bio-ethanol and biodiesel were obtained to produce electricity and to serve as a replacement for diesel. Prasad *et al.* [6] blended two different biodiesels at different ratios (B10, B20, B30) and the investigated properties of the blend related to brake thermal efficiency and specific fuel consumption shows that B10 can be used as an alternative to diesel. Nedayali *et al.* [5] performed a similar experiment except that it was with different mixing ratio and concluded that B20 has the best brake thermal efficiency. Gonca *et al.* [10] studied the biodiesel percentage on engine and engine load performance by blending diesel and biodiesel. It was concluded that at an increase in engine load and a decrease in biodiesel percentage, the effective power increases constantly while the effective efficiency increases to a particular value before decreasing. However, no work has been done on the blend of polypropylene plastic waste with *Jatropha curcas* seed oil using a pyrolyser to proffer alternative to diesel fuel for powering drilling operations. Since plastic waste is a major component of municipal solid wastes, this work is important to curtail air and water pollution arising from the unrestrained act of burning and open burning of plastic waste [10,11]. The increase in plastic production was seen from the replacement of metals with plastics and even glass and paper are also been replaced with the use of plastics [12]. With this so much humongous use of plastic, the United Nations Environment Program (UNEP) estimate showed that 57% of plastics in Africa, 40% in Asia, and 32% in Latin America are not collected but being scattered or burnt by fire in the open [13]. This has led to different plastic-to-fuel or waste-to-energy technologies in recent years and even refuse-derived-fuel [14,15]. Plastic waste management methods include re-extrusion, mechanical recycling [16], chemical recycling (trans-esterification) [17,18], gasification [19], hydrogenation [16], and pyrolysis, which consists of thermal and catalytic pyrolysis [7,11,20]. Miandad *et al.* [21] defined pyrolysis as the disintegration of biomass to liquid bio-oil, bio-char, and vapor fractions by heating the sample biomass/plastic in an anaerobic environment to around 500 °C or above. Pyrolysis had been previously applied to biomass and reports showed that there were variations of the yield of

bio-oil from biomass in the range of 40 to 80% efficiency [18,20–23]. Patel and Patelb [24] revealed that pyrolysis of plastic could have a characteristic signature similar to diesel oil. However, the blend of plastic and JC has not been studied.

The use of vegetable oil for the production of bio-diesel because of biodegradability, less toxicity, and availability has also been reported [8,25]. Biomass such as rice straw, rice husk, energy crops such as *Jatropha curcas* is now being considered as independent source of renewable energy [14] as it is inedible and has 30–40% of oil content [26]. *Jatropha curcas* belongs to Euphorbiaceae family. It is a plant that is capable of thriving in tropical, subtropical and temperate zones such as in southeast Asia, India, Africa, central and south America. The chemical compositions of *Jatropha* seed oil include oleic, palmitic, stearic, linoleic acid. These substances are said to be poisonous, which makes it non-edible but a good source for biodiesel [26,27]. Recently, *Jatropha* has also been further advanced to lessen the reliance on fossil fuels in Africa. The government of Senegal in West Africa set up a plan of up to 321000 ha goal of *Jatropha* production. Similarly, a national plan was launched in Mali in 2004 to convert *Jatropha curcas* to fuel. Likewise, the government of Burkina Faso in collaboration with the National Union for the Promotion of *Jatropha* has begun several *Jatropha curcas* plantations for the production of biofuel [23,27]. The Kenya bio-diesel association started in 2008 to contribute to the growth of *Jatropha* methyl ester in the country and regulation was considered to grant a 3% biodiesel blending with traditional diesel fuel [12,18,28].

In this study, an alternative fuel from a blend of polypropylene wastes and *Jatropha* distillates for oil well drilling has been produced. Minitab 14 was used in this study to optimise methanol growth rate, temperature, and pH responses [29]. Therefore, in this study, a simplex centroid design was derived to fix the exact mixture blend that will give the desired density and viscosity. Minitab 14 uses the polypropylene and *Jatropha* stored models to estimate the predictor settings that optimises the values of both response factors. Individual desirability (d) evaluates how the settings optimise a single response while composite desirability (D) evaluates how the settings optimise a set of responses overall. Desirability has a value range of zero to one. One points out that the solution is perfect; zero indicates that one or more responses are outside their acceptable limits. Also, R-Sq (adj) and R-Sq are statistical calculations that help to validate a model [30,31]. Alimi *et al.* [30] stated that a good fit model must have the value of R-Sq close to 1 and R-Sq(adj) value close to R-Sq which is close 1 shows an alignment with measured and predicted response. In this study, blends of these two samples were considered useful to produce diesel oil alternative as both have been separately used as energy fuel. Therefore, *Jatropha curcas* seed and polypropylene plastic wastes were pyrolysed separately with a reactor, and the bio-oils produced were blended at four different ratios. The properties of the blended samples were compared with conventional diesel.

2. Materials and method

2.1. Materials

A 2.5 kg of polypropylene plastic wastes (PP) used in this study were carefully picked at the waste disposal bin in University of Ibadan metropolis and 1.5 kg of *Jatropha curcas* seeds was obtained at the University of Ibadan botanical garden.

2.2. Methods

2.2.1. Sample preparation

Jatropha curcas seed (1.5 kg) was sun-dried so that the epicarp can be easily removed. The undamaged seeds were selected, washed in water and sun-dried for 7 days (4 h/day) under 35–40 °C atmospheric temperature so as to reduce moisture content. The scrap of polypropylene plastic wastes (PP) was washed, sun-dried under similar conditions to other materials.

2.2.2. Description of the ablative pyrolyzer and oil extraction process

Pyrolysis was done using a fabricated ablative pyrolyzer with its setting shown in Figure 1. The reactor has an inner reactor chamber diameter of 27.1 cm and an outer diameter of 41.2 cm with a total reactor chamber volume of 40 liters. PP and JC were separately fed into the reactor chamber through the reactor opening. The influx of oxygen was prevented by using a tightly fitted lid to cover the opening of the reactor. Nitrogen gas was fed into the reactor to create an inert environment. The vapour line was connected to the condenser for heat exchange and condensation to take place. The condenser was prepared with the movement of chilled water at 200 mL/min in and out of the condenser internal space to prevent bio-oil loss. The bio-char discharge pipe was closed tightly to prevent oxygen from entering into the reactor to avoid combustion. The reactor was connected to a power source and set at 500 °C during the pyrolysis of JC while it was set at 550 °C for PP to produce bio-oil for further processing [32–34]. A round bottom flask was placed at the bottom of the condenser thimble for bio-oil storage while vapor which is non-condensable was collected in another chamber and flared. Water and oil were continuously collected via the vapour line for 4 h until flow ceased from the heating chamber. Then, the vapour line becomes cold which showed that the sample has completely burnt with only bio-char left in the chamber. The reactor was left for 8 h to cool before it was opened to discharge the bio-char.

2.2.3. Distillation of sample bio-oil

The distillation setup is presented in Figure 2. An 1800 W Lab-line Multi-unit extraction heater (Serial no 5000/5002; Model no: 0677) was used to distill the extracted sample. Each sample half-filled was poured into 500 mL pyrex round bottom flask to prevent the reflux of the liquid sample. This flask was placed on the heater and a collecting glass thimble was placed on top of the flask to collect the distilled samples. A water circulator effectively pumps already chilled water of about 4 °C sourced from a 10000 mL water trough into the condenser placed on top of the glass thimble. The process goes on until no distillate is seen to enter into the thimble. The temperature of distillation was taken from 250–350 °C in accordance with ASTM D86 standard [35].

2.2.4. Blending of distillate

The samples were collected separately in a container and blended as shown in Table 1. A total of 400 milliliters of PP and 100 milliliters of JC were used for the blend at 4 different ratios.

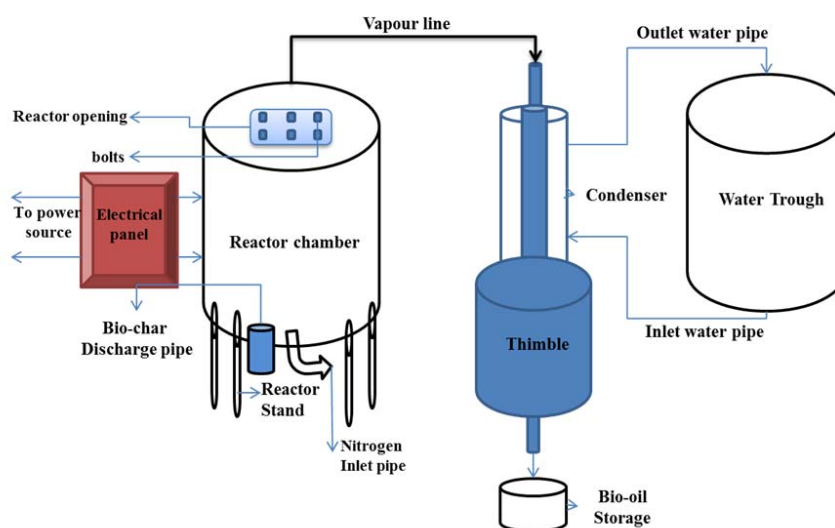


Figure 1. Schematic of the bio-oil extraction process using the fabricated pyrolysis reactor.

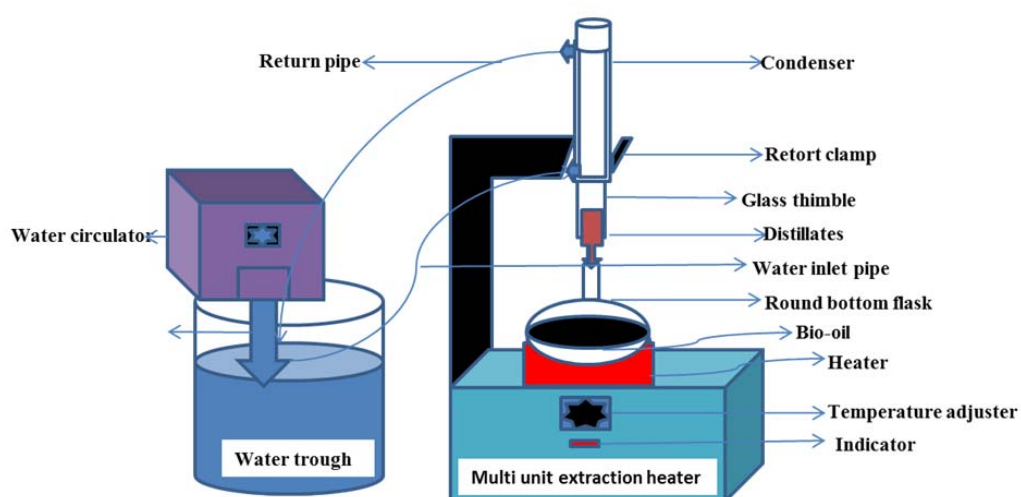


Figure 2. Distillation set up.

Table 1. Mixing ratio for the blended samples.

Sample ID	PP (mL)	JC (mL)	Total (mL)
90PP10JC	90	10	100
80PP20JC	80	20	100
70PP30JC	70	30	100
60PP30JC	60	40	100

2.3. Physico-chemical analysis

2.3.1. Determination of percentage bio-oil yield

The quantity of bio-oil yield for PP and JC was measured using a weighing balance (Serial no: 1119401867, PB3002-s model). The percentage of oil and char yield was calculated using the mass balance method as shown in Eqs (1) and (2) respectively while percentage gas yield was gotten by removing the addition of both oil and char from 100 (Eq 3)

$$\% \text{ oil yield} = \frac{ML}{MS} * 100 \quad (1)$$

$$\% \text{ Char yield} = \frac{MC}{MS} * 100 \quad (2)$$

$$\% \text{ Gas} = 100 - (\% \text{ oil yield} + \% \text{ Char yield}) \quad (3)$$

where ML is the mass of the bio-oil yield, MS is the mass of the sample and MC is the mass of the biochar

2.3.2. Density

The densities of the oil for the different blends of *Jatropha curcas* and polypropylene were obtained using a pycnometer. The pycnometer was used based on the recommendations of Khan *et al.* [25].

2.3.3. Viscosity

Viscosity was obtained using a viscometer (200 Kmax C12 model, USA) according to the ASTM D445 standard method [36]. About 5–10 mL of sample liquid was poured into the viscometer. Pipet filler was used to raise the liquid in the small-diameter U shaped opening of the viscometer past the upper marked line. A stopwatch was used to calculate the time (s) taken for the liquid to pass from the upper to the lower marked points. The viscosity of the oil was then calculated using Eq 4.

$$\text{Viscosity} = \text{Time (sec)} \times 0.10(\text{Viscosity constant}) \quad (4)$$

2.3.4. Design of experiment

The experiment was carried out based on mixture design shown in Table 2 as obtained from Minitab 14. The design was blocked with the run order followed for the experiment. The components (independent variable) used were Polypropylene (PP) and *Jatropha* (JC) with the lower and upper limit set at 0 and 100% respectively. The density and viscosity were set as the dependent variables. Numerical response optimiser of the Minitab 14 was used to obtain the optimum proportion of PP and JC to give the best response in terms of density and viscosity of the oil.

Table 2. Mixture experimental design obtained from Minitab 14.

StdOrder	RunOrder	Blocks	PP	JC	Density (g/cc)	Viscosity (cst)
1	1	1	100	0	0.747	4.11
2	2	1	90	10	0.747	4.277
3	3	1	80	20	0.748	6.107
4	4	1	70	30	0.748	8.21
5	5	1	60	40	0.892	11.4

2.3.5. Pour and cloud points

Pour and cloud points were obtained using a Cryostat (Model no: 94100-3V, Serial no: 1017543) based on a recommendation in Khan *et al.* [12]. The Cryostat measures up to -35°C . The Cryostat test jar containing the oil to be measured was loaded into the test bath which in turn was placed into the cryostat chamber. The chamber contains methanol which is the cooling fluid. The test jar has a rubber to protect the glass from breaking. The mark round the test jar depicts that the testing fluid must go over it. The power system was switched ON and left to work for 5 mins before loading. A thermometer was inserted in cork and placed on top of the test jar with its tip touching the testing fluid. The sample was observed until the oil turns cloudy; this temperature is taken for cloud point. The pour point measurement was taken after the sample turned solid and was inverted to allow normal atmospheric condition pouring. The temperature at this point is pour point.

2.3.6. Flash point

Seta Flash machine (Series 3, Model: 30000-0 U/Serial No: 1019937) was used to obtain the flashpoint according to the ASTM D93 standard [37]. The syringe was loaded with the sample fluid and injected into the sample cup through the filler orifice. The gas supply was switched ON and pilot and test jet were lighted. The shutter was opened and closed on a period of 2.5 sec until a blue halo or enlarged flame occur which shows the temperature of the sample is close to the flashpoint temperature. The second line of the display show flash and a popping sound was heard when the flame is dipped into the vapor space. The temperature at this point was recorded as the flashpoint.

2.3.7. FTIR spectroscopy analysis

The FTIR spectra of the PP and JC were obtained over a scan range of $400\text{--}4800\text{ cm}^{-1}$ at a resolution of 4 cm^{-1} on a Perkin Elmer FTIR Spectrometer 1725X. The KBr pellet technique was adopted. A drop of the liquid was placed on the face of a highly polished salt (KBr) in order to prepare samples for the analysis. Thereafter, another plate was put on top of the first plate to spread the liquid in a thin layer in between the plates, and then the plates were clamped together. The liquid spilled off the plate edges were cleaned off and then the sandwich plates were mounted onto the sample holders for IR analysis.

3. Results and discussion

3.1. Colour and odour of the bio-oil

Figure 3a and b showed that the colour of JC was dark red-brown and that of PP was blackish in nature. Both oils flow like a liquid at the point of condensation. The physical appearance of the bio-oil is dependent on the feedstock, micro-carbon, and the chemical composition of the bio-oil [9]. The colour obtained for this oil is in consonance with previous research works [9,12,15]. The colour of the bio-oil was also observed not to be far from that of diesel oil. The odour perceived from PP was similar to that of diesel oil though that of JC was distinctively different. JC has an acrid smoky smell, which may be due to the presence of low molecular weights of aldehydes and acids in biomass [9].

3.2. Percentage oil yield

Figure 3c represents the % yield of bio-oil, biochar and biogas from the JC and PP pyrolysis process. PP gave higher oil yield (73%) than JC (43.2%) while the char yield from JC (49.1%) was greater than PP (23%). The higher oil yield of PP may be traced to the higher content of stable hydrocarbon (aromatic C=C) compared with the abundant C-C bonds of JC [12]. By nature, biomass contains less stable C=C bond, more unstable OH group, and moisture content than hydrocarbon products. Biochar production is a function of the lignin composition of the biomass. Thus, a possible reason for the higher yield in JC bio-char than PP could be due to its higher lignin content [9]. Also, the pyrolysed oil becomes viscous as a result of the unstable nature of the oil; it goes through chemical and physical changes during storage, and volatile content are lost by the aging of the oil, thus reducing yield [9]. The results obtained in this study are in tandem with available literature [12,26,38]. The yield of biochar for *Jatropha curcas* (49.1%) was much higher than that what was obtained for polypropylene (23%). Also, the bio-oil yield for polypropylene (4%) was lower compared to *Jatropha curcas* (7.79%). It can be said that since more bio-oil was obtained from PP than JC, it generated lower bio-char and bio-gas compared to JC. The higher compositions of PP's lighter ends corroborate the lower yield of vapour compared to JC [21].

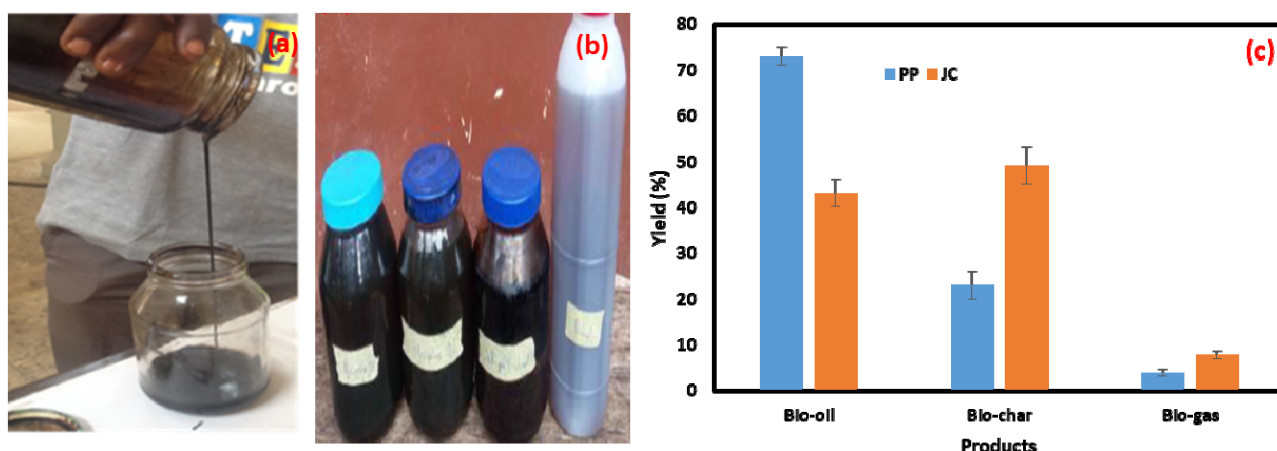


Figure 3. (a) Bio-oil of *Jatropha curcas* seeds; (b) Extracted oil from PP; (c) Oil, gas and char yields of polypropylene and *Jatropha curcas* seed.

3.3. Density and viscosity

Figure 4 shows the density and viscosity of the sample and the blends. The density and viscosity of JC were said to be high (15.6 cst and 0.956 g/cc) which is common with oil from biomass. This is because biomass is composed of fatty acid, carboxylic, and acetic acid [9]. However, PP recorded very low values (0.747 g/cc and 4.11 cst) corroborating the work of Khan *et al.* [25] (Figure 4). It was observed from Figure 4 that the density and viscosity of blends of 9:1 PP/JC, 4:1 PP/JC, 7:3 PP/JC were quite lower than the conventional diesel fuel but the properties of the 3:2 PP/JC blend was seen to be closer to the diesel oil. It was observed that as the quantity of the *Jatropha curcas* oil distillates was increased in the blend, the properties get closer to that of diesel oil. It is generally believed that the density from biomass origin is always higher due to fatty acid composition and the presence of contaminations [38]. The densities of 3:2 PP/JC blend and diesel oil were 0.892 and 0.885 g/cc, respectively. The density of biodiesel is higher than that of diesel fuel; this is because of the presence of high moisture and mass per unit volume [9,39]. 3:2 PP/JC gave the best properties that aligned with conventional diesel compared to others in this study. This blend will be useful in high-speed diesel engines with the presence of nitrate alcohol to improve its cetane content [9]. The viscosity of 3:2 PP/JC blend was 11.4 cst and it was slightly higher than that of conventional diesel fuel (11.07cst) used in this study. The viscosity of oil from biomass origin is always higher than those from fossil origin because of the presence of NO_x emissions, which usually occurs at temperatures above 930 °C [37]. This is an advantage because fuel leakages are reduced during injection as a result of high injection timing and increased combustion chamber pressure [9,39]. However, it should be noted that a very high viscosity can cause the destruction of the fuel pump, increase in exhaust smoke and poor combustion under certain conditions though, a very low viscosity can also cause reduced lubrication [40].

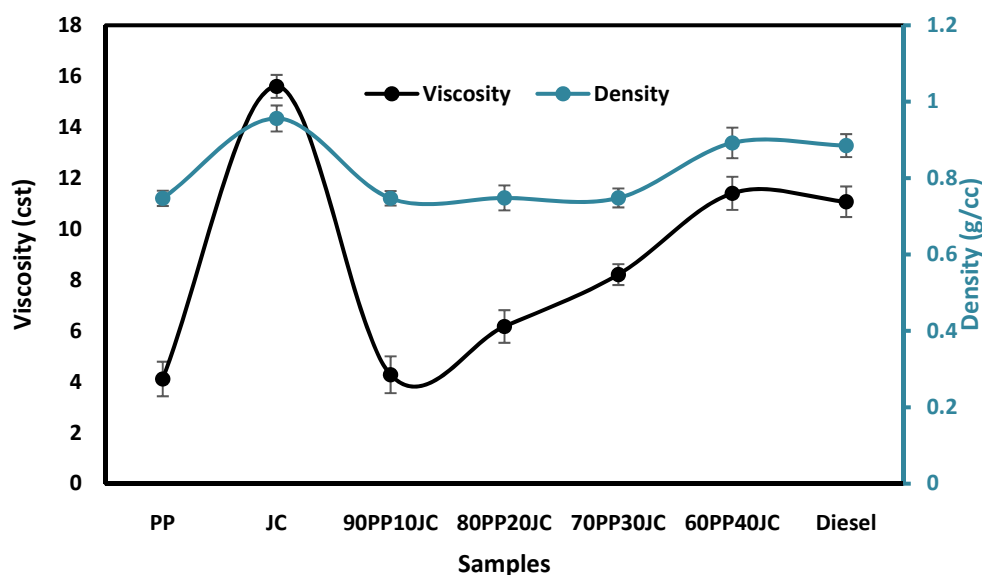


Figure 4. Viscosity and density of the raw samples and oil blends compared with conventional diesel.

3.4. Design of experiment result

The estimated regression coefficient for both the density and viscosity as a function of polypropylene and *Jatropha curcas* oil is shown in Table 3. For viscosity, the value of R-Sq was 99.78% with low P-value (polypro*Jatropha, P-value = 0.016) while the R-Sq (adj) was 99.55%. This shows an alignment between the experimented value and the predicted responses. Alimi *et al.* [30] stated that a good fit model must have the value of R-Sq close to 1 and P-value ≤ 0.05 . However, the density model shows R-Sq value of 85.72% while the R-Sq (adj) was 71.44%. More studies are recommended to be done to understand reasons for this. Figure 5 gives the response optimisation plot. The optimum viscosity yield (Figure 5a) of 11.07 cst was at 3.12:2 PP/JC with composite desirability of 1.0 indicating an excellent solution. Likewise, the optimum density yield (Figure 5b) of 0.87543 g/cc at 3:2 PP/JC and the composite desirability of 0.93163 were obtained indicating that the responses are within their acceptable limits. On a general note, the result generated for viscosity and the density is consistent (given from the statistical analysis).

Table 3. Estimated Regression coefficients for viscosity and density.

Term	Coef	SE Coef	T	P	VIF
Viscosity					
Polypropylene	3.92	0.1935	*	*	2.923
Jatropha	48.80	3.4469	*	*	84.351
Polypro*Jatropha	-43.58	5.4938	-7.93	0.016	96.714
S = 0.205559, Press = 0.709728, R-Sq = 99.78%, R-Sq (pred) = 98.12%, R-Sq (adj) = 99.55%					
Density					
Polypropylene	0.757	0.03262	*	*	2.923
Jatropha	2.265	0.58121	*	*	84.351
Polypro*Jatropha	-2.021	0.92637	-2.18	0.161	96.714
S = 0.0346616, Press = 0.0380402, R-Sq = 85.72%, R-Sq (pred) = 0.00%, R-Sq (adj) = 71.44%					

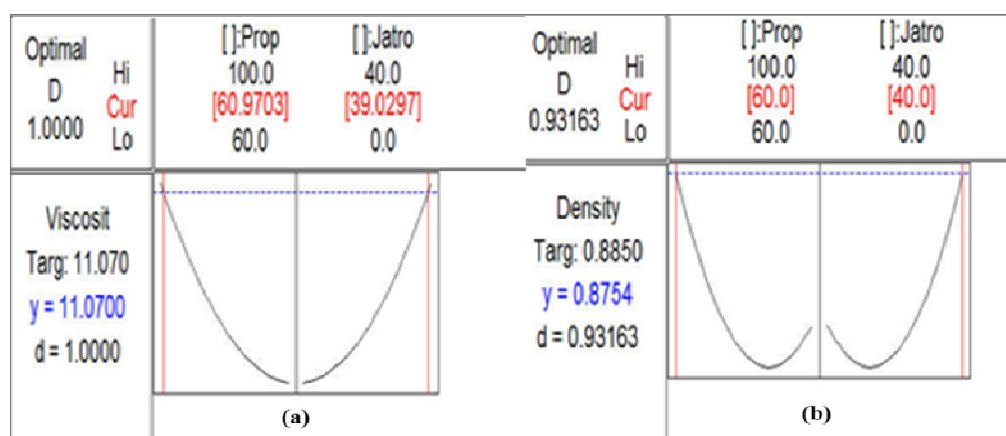


Figure 5. Response optimizer for (a) viscosity (b) density.

3.5. Cloud point, pour point and flash point

Table 4 presents the cloud, pour, and flashpoints of the samples used and blended oil samples compared with that of conventional diesel. While JC's cloud, pour and flash points gave 40 °F, 28 °F and 124 °C, respectively, PP's gave −5 °F, −20 °F and a very flammable flashpoint, respectively (Table 4). This depicts PP should be handled carefully and may not be good for transportation. However, the condition got to change when PP was blended with JC at 9:1, 4:1, 7:3 and 3:2, respectively. The lowest points were obtained for the 3:2 PP/JC which were 0, −10, 110 for cloud, pour, and flashpoints, respectively, which are the closest to diesel oil. The low cloud and pour points of the blends implied that they will remain liquid even at low temperatures [37]. Therefore, the reported pour point for the 3:2 PP/JC sample at −10 °F showed its ability to thrive even in hot temperate regions [12]. This makes it not possible for it to easily degrade during drilling even in high-temperature zone. Cloud point is the lowest temperature on cooling whereby the mixture of liquid in the whole system starts to become immiscible. This behavior makes them suitable for the cold season as they will still be clear at low temperatures [25,38]. Table 4 also shows that the blends except 3:2 PP/JC are very flammable compared to diesel. The high flash point could be due to the significant presence of C18:1 and C18:2 in the oil blend [38]. However, care should be taken when handling and transporting the bio-oil for low flashpoints because the lower the flashpoint, the greater the risk [9,12]. It can be implied from this study that there is a decrease in the flash point of *Jatropha* from 144 to 110 °C when polypropylene was added at 3:2 PP/JC. This means that flash point temperature could be affected by the presence of contaminants as they contain very high volatile contents. Flash point shows the lowest temperature at which the liquid can form air of ignitable mixture under specific conditions and the high flash point (110 °C) is good for safety and transportation. Therefore, the 3:2 PP/JC blend proves to be suitable for diesel engines because of the properties as shown in Table 4. The potential of 1:1 PP/JC blend though very flammable can be researched upon in the future.

Table 4. Physical cloud, pour and flash points of the raw oil and blended oil samples.

Samples	Cloud point (°F)	Pour point (°F)	Flash point (°C)
<i>Jatropha curcas</i>	40	28	144
Polypropylene	−5	−20	Very flammable
90PP10JC	−5	−20	Very flammable
80PP20JC	−2	−18	Very flammable
70PP30JC	−1	−11	Very flammable
60PP40JC	0	−10	110
Diesel	25	10	95

3.6. FTIR spectroscopy analyses

Figure 6 shows the FTIR spectra that present the functional groups of PP and JC distillates. Table 5 is a collection of the typical functional groups that may be present in the JC and PP samples. The JC oil signaled a broad absorption band at 3396/cm that describes the stretching and bending of O-H vibration which shows the presence of water molecules [26]. The FTIR of PP and JC distillates are similar to each other because of the presence of absorptions at 2982, 2940, 2856, 1462–1458/cm

and the lowest absorption at 410/cm but the major differences were the various visible absorption at 1706, 1604, 1376–743/cm in JC oil. The absorptions observed at 2940/cm for JC and 2982/cm for PP and 2856/cm for both oils show asymmetric and symmetric stretching vibrations of C-H in the CH₂ group with very strong intensity, respectively [26,38]. The absorption peaks in JC oil at 1706/cm show the presence of C=O stretching vibration of the carbonyl group. A stable C=C stretch of aromatic ring vibration position at 1606/cm for PP which informs the rationale behind higher oil yield for PP than JC with unstable C-C stretch [9,25]. The other similar peaks observed in JC and PP at 1462 and 1458/cm show the shear-type vibration of CH₂ group with medium intensity [39]. The absorptions at 1376/cm and 1268/cm of JC depict the stretching and bending vibration of CH₂ and CH₃ aliphatic group with medium intensity. The peak seen at 743/cm shows the bending out of plane, rocking vibration with medium intensity of CH₂ group [24,38]. On a general note, these functional groups demonstrated that there were alcohols, acids, and ester in the bio-oil which is why JC has an acrid smoky smell, high density, and viscosity [9,39]. The study further confirmed the presence of cellulose, hemicellulose, and lignin which are totally CHO chemical compounds within biomass [9,25,39].

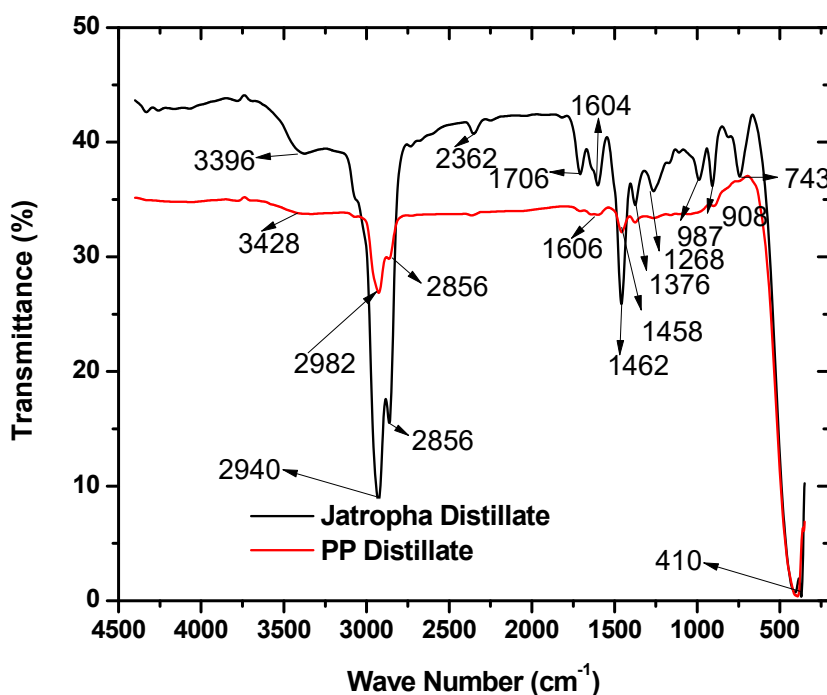


Figure 6. FTIR spectra of *Jatropha curcas* seed and PP distillates.

Table 5. The main functional groups for JC and PP samples.

Wave number (cm ⁻¹)	Compounds	Functional group
3600–3000 (s*)	OH stretching	Acid, methanol
2800–2970 (m*)	C–H _n stretching	Alkyl, aliphatic
1730–1700 (m)		Aromatic
1632 (m)	C=C stretching	Benzene ring
1613 (w), 1450 (w*)	C=C stretching	Aromatic skeletal mode
1470–1430 (s)	O–CH ₃	Methoxyl–O–CH ₃ acid
1440–1400 (s)	OH bending	
1402 (m)	CH bending	
1232 (s)	C–O–C stretching	Aryl-alkyl ether linkage
1215 (s)	C–O stretching	Phenol
743	CH ₂ bending	
410	C–I stretching	Halo compound

4. Conclusions

Experimental investigation on the use of animal or vegetable oils and municipal wastes to obtain high-quality alternative fuels through thermochemical conversion has attracted the attention of many researchers. This article fully describes the preparation and instruction process of distilled oil, and the optimised conditions. The fabricated vacuum pyrolyzer was utilised for the onward conversion of plastic wastes and biomass to oil/fuel at 500–550 °C. Plastic wastes yielded 73% while *Jatropha curcas* yielded 43.2% bio-oil. The 3:2 PP/JC oil blend distillates were discovered to have a great potential in the drilling industry considering their physicochemical properties such as density, viscosity, flash, pour and cloud points when compared to the conventional diesel fuel. From the statistical analysis, we see the consistency in the experimented result versus the predicted responses. Also, there was a resemblance in the FTIR spectrum of *Jatropha curcas* and polypropylene oil distillates at 2856 and 1458/cm peaks which made *Jatropha curcas* an energy potential biomass. This study has provided guidance to develop alternative fuels for the drilling industry. Other blends such as 50% plastic waste 50% *Jatropha curcas* seed oil and a higher proportion of *Jatropha* can be considered for study in the future.

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Conflict of interest

The authors declare that there is no conflict of interest.

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