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## Physicochemical Characteristics And Fuel Performance Of (Castor-Linseed Biofuel)-Petroleum Fuel Mixture

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**Abstract**

In this study, the physicochemical characteristics and fuel performance of castor-linseed biofuel were studied in different mixing ratio by petroleum fuel. Firstly, the properties of the mixed castor oil biofuel-linseed oil biofuel were investigated including: density, specific gravity, viscosity, boiling point, pour point, cloud point, flash point, fire and smoke points. The change in the studied properties by gradual addition of the prepared biofuel to petroleum fuel was investigated and correlated to several factors. The study showed the ability of mixing castor-linseed mixed biofuel and petroleum fuel up to 30% (biofuel) with the stability of the required properties of the final fuel to be in accordance with the ASTM fuel specifications.

*Keywords: Castor oil; linseed oil; biofuel; fuel properties; petroleum diesel.*

### 1. Introduction

Petroleum diesel is the most common type of diesel fuel. It is produced by fractional distillation of crude oil between 200 and 350 $^{o}C$ at atmospheric pressure, resulting in a mixture of carbon chains that typically contain between 8 and 21 carbon atoms per molecule. Petroleum-derived diesel is composed of about 75% saturated hydrocarbons (primarily paraffin including *n*-, *iso*-, and cyclo-paraffins), and 25% aromatic hydrocarbons (including naphthalenes and alkyl benzenes). The average chemical formula for common diesel fuel is $C_{12}H_{23}$, ranging approximately from $C_{10}H_{20}$ to $C_{15}H_{28}$. Petroleum is a useful chemical substance for many important purposes, but it is also a nonrenewable resource with a highly toxic composition. It poses significant problems when used in huge volumes throughout the industrialized world. Biodiesel is an alternative fuel similar to conventional diesel **[1]**. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil **[2]**. The chemical composition of biodiesel is methyl or ethyl esters of long chain fatty acids. The transesterification reactions of castor oil and linseed oil with ethanol and methanol as transesterification agents in the presence of several classical catalytic systems were studied. The study indicates that biodiesel can be obtained by transesterification of castor oil and linseed oil using either ethanol or methanol as the transesterification agent. Similar yields of fatty acid esters may be obtained following ethanolysis or methanolysis **[3]**. However, the reaction times required to attain similar yield are very different, with methanolysis being much more rapid **[4]**. Non-edible oil can be diluted with petroleum diesel to reduce its viscosity and improve the performance of the engine. This method does not require any chemical process. Therefore, blending of 20–25% vegetable oil to petroleum diesel

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has been found to give good results for diesel engine. De and Panua **[5]** analysed the performance and emission characteristics of pure petroleum diesel, castor, linseed oils and Castor, linseed oils-diesel blended fuels with various blend ratios in engine laboratory single cylinder, four-stroke, direct injection diesel engine. They showed that various parameters such as thermal efficiency, $SO_x$ and $NO_x$ emissions are very close to petroleum diesel for lower Castor, linseed concentrations **[6]**. However, for higher Castor, linseed concentrations, the performance and emissions were much inferior to petroleum diesel. In order to decrease the cost and gases emission during ignition of petroleum fuel, biofuel is mixed with it in a different mixing ratio. In this study the influence of mixing biofuel obtained from castor oil and linseed oil with petroleum fuel and the total characteristics of the obtained petroleum fuel-biofuel were studied..

## 2. Materials and methods

### 2.1. Materials

Castor oil (C) and linseed oil (L) were extracted from castor seeds via hydraulic pressing, NaOH, methanol and petroleum diesel were obtained from commercial market.

### 2.2. Methods

#### 2.2.1. Preparation of biofuel using C and L by transesterification reaction

Castor oil biofuel (EC) and linseed oil biofuel (EL) were obtained from transesterification of their oils using methanol as described by **Negm et al., [7]**.

#### 2.2.2. Purification of castor oil fatty acid methyl ester (FAME) and linseed oil fatty acid methyl ester (FAME)

The purification of the two fatty methyl esters of castor oil and linseed oil was performed by neutralization of the used catalyst (sodium methoxide) by adding diluted sulfuric acid equivalent to the used sodium methoxide. Two formed layers have been produced in the separating funnel; the upper one contained the obtained EC-FAME and EL-FAME and the excess methyl alcohol. While the lower layer, contained the produced glycerol from the transesterification reaction. The upper layer washed by distilled water three times and then kept overnight over anhydrous sodium sulphate.

#### 2.2.3. Samples preparation

Castor oil and linseed oil were symbolized as C and L, respectively; while their corresponding biodiesels were EC and EL. The mixtures of biodiesels used were formed of different ratios from EC and EL ranging between 1:9 (EC:CL) to obtain the mixed biodiesels formulations (ECL1-9). ECL1-9 formulations were blended by petroleum diesel in four mixing ratio of 5%, 10%, 20%, 40% to obtain B1-4, respectively.

#### 2.2.4. Petroleum diesel-biofuels (ECL-FAME) specification

The properties of the prepared esters mixtures and the blends were studied according to standard test methods **[8]**: viscosity (ASTM D-445), density (ASTM D-4052), carbon residue (ASTM D-189), ash content (ASTM D-4530), sulphate content (ASTM D-874), pour point (ASTM D-97), flash point (ASTM D- 92).

## 3. Results and Discussion

### 3.1 Characterization of ECL biofuel-petroleum diesel mixtures

The advantages of biodiesel over diesel fuel are higher combustion efficiency, higher cetane number and higher biodegradability and less carbon monoxide emissions. Along with the inherent advantages of biodiesel, the disadvantages of using biodiesel are worth mentioning. The disadvantages of biodiesel include slightly higher $NO_x$ emissions, cold start problems, lower energy content, higher copper strip corrosion and fuel pumping difficulty resulting from higher viscosity. Currently, biodiesel is expensive to produce than diesel, which appears to be the primary factor in preventing its more widespread use. Current worldwide production of vegetable oil and animal fat is not enough to replace liquid fossil fuel use **[9]**. These reasons gave rise to the increasing importance of blends of other fuels like diesel fuel and bio-ethanol with biodiesel.

#### 3.1.1 Density

The density is an important property which is directly reflected on the weight of the fuel. Lower fuel weight, by other meaning, lower density fuel is preferable than higher density. This is because higher density fuel has higher weight and consequently cause more potential on the engines, especially aviation engines. In general, densities of biodiesel fuels are slightly higher than those of petroleum diesel. It has been reported that Biodiesel density is also affected by chain length, which leads to lower fuel density **[10]**. Increasing the concentration of the used to biofuel in the mixture with petroleum diesel in B4 mixture decreases the density of the obtained ECL-petroleum diesel considerable to reach 0.9057 g/cm[3]. Increasing the amounts of ECL9 to 90% in B4 decreases the density of the obtained ECL-petroleum diesel blend considerably to reach 0.8369 g/cm[3]. That indicates the increasing of the used to biofuel in the mixture with petroleum diesel and also increasing of EC amount decreases the density of the obtained ECL-petroleum diesel. As a result, the densities of the obtained ECL-petroleum diesel mixtures were comparatively low **(Figure 1).**

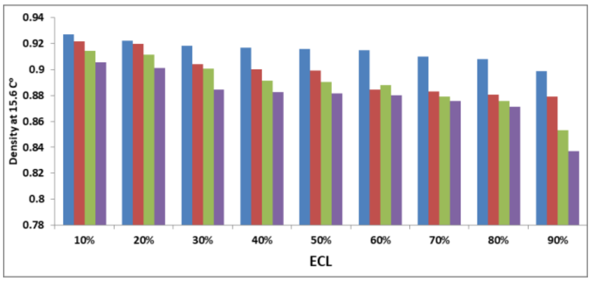


**Figure 1: Variation of density of ECL(1:9)-petroleum diesel (blue: B1, brown: B2, green: B3, violet: B4).**

### 3.1.2 Viscosity

Viscosity is an important characteristic for diesel and biodiesel fuels because it impacts the operation of components such as the fuel pump. Higher viscosity interferes with injector operation, resulting in poorer atomization of the fuel spray, and has been associated with increased engine deposits. All the biodiesels have viscosities significantly higher than diesel, which would be expected to have problems in this area on diesel engines. These reasons gave rise to the increasing importance of blending with other fuels like diesel fuel or bioethanol. Increasing the amount of the used EC ratio in ECL mixture from 10% (ECL1) to (ECL3) has a decreasing effect on the viscosity of the obtained biofuel B1-4. Increasing the EC biofuel amount increases the cracking extent of the fatty acid chains in the oil and consequently decreases the produced carbon chain length, which decreases their viscosity **[11] (Figure 2).**

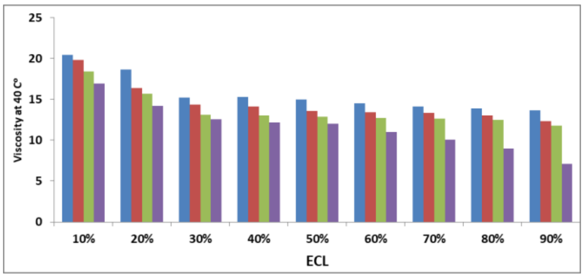


**Figure 2: Variation of kinematic viscosity of ECL(1:9)-petroleum diesel (blue: B1, brown: B2, green: B3, violet: B4).**

### 3.1.3 Boiling point

Boiling point of biofuel-petroleum diesel determines the point, at which it begins to boil, i.e., the change from liquid phase to vapor phase. This point is very important because it determines the ability to transport and save biofuel-petroleum diesel at thermal condition. Also, it determines the need of cooling during transportation. Low boiling point fuels cause problems during transportation due to the ability of ignition and forming vapours with critical fuel concentration. All the biodiesels have boiling point significantly higher than petroleum diesel. Because of the high values, biodiesels would be expected to have benefits in this area on diesel engines. Increasing the concentration of ECL in B1-4 blends decreases the boiling point of the obtained B1-4 blends considerably to reach 80 °C. Increasing the amounts of EC to 90% in ECL with petroleum diesel blend to 40% in B4 decreases the boiling point of the obtained ECL-petroleum diesel blends considerably to reach 60 °C. That indicates the increasing of ECL in the mixture with petroleum diesel decreases the boiling point of the corresponding B1-4 **(Figure 3)**.

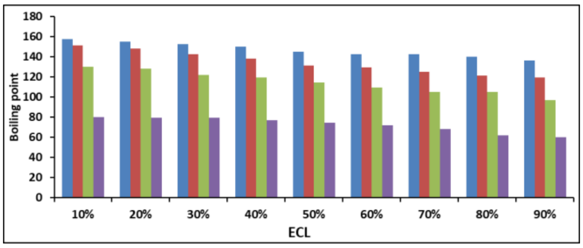


**Figure 3: Variation of boiling points of ECL(1:9)-petroleum diesel (blue: B1, brown: B2, green: B3, violet: B4).**

### 3.1.4 Pour point

Pour point is the temperature at which the biofuel-petroleum diesel starts to lose its fluidity due to the formation of crystals of the fatty acid methyl esters molecules. The crystal formation decreases the fluidity of the biofuel-petroleum diesel at the low temperature and at high crystalline aggregation, the biofuel-petroleum diesel lose its fluidity. The fluidity of the biofuel-petroleum diesel is very important property during transportation under ultimate cold climate. Therefore, pour point depressants are added to several petroleum products and biodiesel with high pour points to facilitate their transportation pipes. Increasing the concentration of ECL in ECL-petroleum diesel as in B4 decreases the pour point of the obtained ECL-petroleum diesel considerably to -12 °C. Increasing the amounts of EC in ECL9 decreases the pour point of the obtained ECL-petroleum diesel blends, especially B4 to -18 °C. That indicates the increasing in the concentration of ECL in B blends decreases the pour point of these blends to reach the maximum depression in B4, **(Figure 4)**.

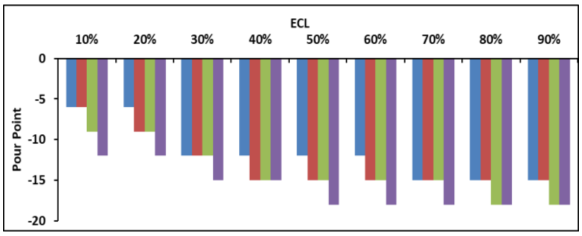


**Figure 4: Variation of pour points of ECL(1:9)-petroleum diesel (blue: B1, brown: B2, green: B3, violet: B4).**

### 3.1.5 Cloud point

Cloud point is the temperature obtained by cooling of biofuel-petroleum diesel at which a wax crystals start to appear in the liquid phase (nucleation). The biofuel-petroleum diesel at this temperature starts to be pale, while further cooling can change its liquid phase to waxy. The decrease in the temperature increases the wax crystals and also causes their agglomeration (crystal growth) **[11-13]**. It is clear from Figure 5 that increasing the concentration of ECL in the blends by petroleum diesel as in B4 decreases the cloud point of the obtained ECL-petroleum diesel blend considerably to -9 ºC. Increasing the amounts of EC to 90% (ECL-9) in the blend with petroleum diesel (B4-ECL-9) decreases the cloud point of the obtained ECL-petroleum diesel considerably to -15 ºC. That indicates the increasing the concentration of ECL in ECL-petroleum diesel and also increasing EC concentration in the blends decreases the cloud point of the biofuel-petroleum diesel. As a result, the cloud points of the obtained ECL-petroleum diesel blends were comparatively lower than ECL or petroleum diesel **(Figure 5)**.

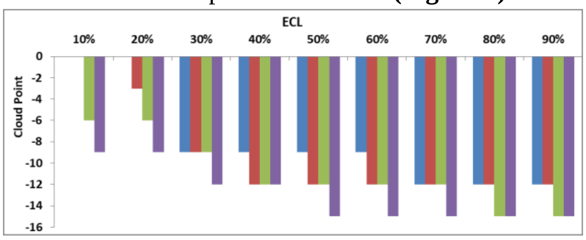


**Figure 5: Variation of cloud points of ECL(1:9)-petroleum diesel (blue: B1, brown: B2, green: B3, violet: B4).**

### 3.1.6 Flash, fire and smoke points

Fire point is the temperature at which the fuel starts to fire. It varies from one fuel to another and from one blend to another. The fire point is an important parameter determines the efficiency and usability of the fuel as diesel. The fire points of the biofuels are comparatively higher than the petroleum fuel due to the differences between the chemical structures of the two types. Biofuel is formed of fatty acids methyl esters, while petroleum diesel is formed of a mixture of hydrocarbons **[14]**. Blending of petroleum fuel by biofuel aims to decrease the cost and lowering the harmful gases emission. It is clear from the data listed in **Table 1** that the gradual increase in the abundance of EC in ECL formed the different blends B1-4 decreases the fire and smoke points considerably. ECL-1-B1-4 has fire point at 81 ºC and smoke point at 29 ºC. Increasing EC ratio in ECL-B1 decreases these two points to 45 ºC and 22 ºC. On the other hand, ECL9-B4 showed higher depression in both fire and smoke points to 31 ºC and 21 ºC. It is clear from **Table 1** that the fire and smoke points of the ECL-petroleum diesel blends are lower than ECL, and increasing the ratio of EC in ECL-B blends decreases these values considerably.

**Table 1: Variation of fire and smoke points of ECL1-9:B1-4 blends**

| Fuel blend | B1 | | B2 | | B3 | | B4 | |
|---|---|---|---|---|---|---|---|---|
| | Fire Point | Smoke Point | Fire Point | Smoke Point | Fire Point | Smoke Point | Fire Point | Smoke Point |
| **ECL-1** | 81 | 29 | 77 | 28 | 70 | 28 | 63 | 26 |
| **ECL-2** | 75 | 28 | 62 | 27 | 58 | 27 | 49 | 25 |
| **ECL-3** | 62 | 27 | 59 | 27 | 51 | 26 | 43 | 25 |
| **ECL-4** | 60 | 27 | 53 | 25 | 49 | 25 | 39 | 24 |
| **ECL-5** | 57 | 26 | 47 | 24 | 45 | 24 | 37 | 23 |
| **ECL-6** | 53 | 24 | 43 | 24 | 42 | 24 | 36 | 23 |
| **ECL-7** | 50 | 24 | 41 | 23 | 39 | 22 | 35 | 21 |
| **ECL-8** | 47 | 23 | 40 | 24 | 36 | 23 | 35 | 21 |
| **ECL-9** | 45 | 22 | 38 | 24 | 33 | 23 | 31 | 21 |

## 4. Conclusion

From the study, several concluding points can be extracted:

1- Increasing the ratio of EC in ECL-B blends enhances their physicochemical and fuel properties.

2- The gradual increase of ECL in the ECL-petroleum fuel blends B1-4 showed significant influence on the physicochemical and fuel properties of the blends within ASTM fuel specification.

3- The biofuel is recommended to be mixed with petroleum fuel up to 30% to decrease the cost and hazardous emissions, with similar performance compared to pure petroleum fuel.

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