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Effect of blending ratio on the properties of sunflower biodiesel

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Abstract

Biodiesel has been generally accepted as a suitable replacement for petrol diesel. Since biodiesel cannot entirely replace petroleum-based diesel fuel in meeting the energy need of the increasing global population, the blending of biodiesel with petrol diesel can proffer solution. The blending of biodiesel with petrol diesel helps to improve diesel fuel properties and also reduces carbon dioxide emission into the atmosphere in considerable amounts during combustion. Sunflower biodiesel was blended with petrol diesel in different ratios 10:90 and the flash point, density and kinematic viscosity properties of the different blends were determined. The viscosities, flashpoints and density of the different blends were very suitable and conformed to ASTM D6751.

1. Introduction

With an estimated world population of over 6 billion people, issues surrounding energy are of great concern and shall continue to be [6]. Fossil fuels account for 78.4% of total world energy consumption [7]. Because of the environmental and sustainability challenges associated with fossil fuel usage [12, 13], several sources are currently being explored for a suitable alternative to conventional fossil fuels. Among the several alternatives, biodiesel is a promising source of future energy. This is because of its fossil fuel-like properties and sustainable and eco-friendly characteristics [8]. Biodiesel is a non-fossil alternative diesel fuel defined as the mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fat. It consists of long-chain alkyl esters and is made by reacting lipids with alcohol, producing fatty acid esters.

Among the several sources of biodiesel, vegetable oil has been most researched [9, 17]. This is because of its' advantages [10, 11]. An example of a vegetable plant that has gainedconsiderable attention as a potential feedstock for biodiesel production is the sunflower plant. Sunflower (Helianthus annus L.) of the Compositae family which is used for the production of edible oil. It is widely recognized in Africa, Europe, and America because of its varied uses [5]. It is cultivated on approximately 23 million hectares in about 40 countries of the world [14,15]. Sunflower has received much attention as a viable source of biodiesel because it can be grown in different parts of the world and the oil content of its seed is about 52% [16], among other reasons. Several studies have considered the preparation of biodiesel from sunflower oil [2,4,16].

Naureen et al, (2015) [4] investigated the preparation of biodiesel from sunflower seed oil through a base-catalyzed trans-esterification with methanol, using sodium hydroxide as a catalyst. The prepared biodiesel was then characterized for the properties of density, dynamic and kinematic viscosities, flash point, and other properties. The density, dynamic viscosity, kinematic viscosity, and flash point of the sunflower biodiesel were found to be 0.86gcm^{-3}, 5.321cp, 4.719mm^{2}s^{-1} and 183^{0}C respectively. Similarly, Ilkilic and Oner (2017) [2]

produced biodiesel fuel from sunflower oil. They found that the physical properties of petrol diesel and biodiesel were close, though the flash point, cetane number and viscosity of the produced biodiesel were higher than those of the petrol diesel. Though seed oil can be used directly as diesel in diesel engines without engine modification [2], the high viscosity of the oil needs to be reduced by trans-esterification to make it more suitable for use in diesel engines [6]. However, none of these studies has considered the processes of preparation and blending of sunflower biodiesel with petrol diesel, as well as their respective and blends characterization.
For this reason, the blending of sunflower oil with petrol diesel at different ratios is been investigated. Some researchers (in 2016) blended sunflower oil with petrol diesel at proportions of 10% and 20% of the vegetable oil. The blend with 20% sunflower oil was found within the ASTM standard. Then they concluded that sunflower oil at that ratio was more suitable in the use of sunflower blend as an alternative petrol diesel source. Furthermore, Muralidharan and Vasudevan (2011) [3] compared petrol diesel and sunflower biodiesel blend of 20%, 40%, 60% and 80%. They also examined the effect of the blends on the performance, emission, and combustion characteristics of a variable compression ratio engine. When experimented in the compression ratio engine, they observed a reduction of CO, hydrocarbon, and an increase in nitrogen oxide emissions. Thepreparation and blending of sunflower biodiesel with petrol diesel, as well as their respective blends characterization need to be examined. To this end, this study has investigated the blending of sunflower biodiesel with petrol diesel in ratios ranging from 10 to 90. The viscosity, flash point, density of the different blends have been determined.

2. Material and Methods

2.1. Determination of sunflower oil FreeFatty Acid (FFA)

10ml of Benzene was added to 10ml of Ethanol with 1.14g of the oil. The mixture was swirled and immediately titrated against 0.1mole of KOH with four (4) drops of phenolphthalein until a pale and permanent pink colour was observed. The acid value was calculated using the expression below:

$$AcidValue = \frac{X(56.1)N}{M}$$

Where N = Molarity

M = Mass of oil

X = S – B

S = Sample titer value   B = Blank titer value

The Free Fatty Acid (FFA) content was calculated using the expression below:

$$FFA = \frac{Acid\ Value}{2}$$

2.2. Production of Biodiesel from Sunflower oil
Sunflower biodiesel was produced by of trans-esterification reaction with methanol. 500g of oil was weighed into a 1000ml boiling flask. This was placed on a constant temperature magnetic stirrer and set to heat to 65^{o}c with the temperature sensor probe connected into the heating oil inside the flask to stabilize the temperature of the oil constant. The heated oil was added 76ml of methanol (8: 1-mole ratio) containing 1wt% of NaOH catalyst. The reacting mixture was then immediately connected with reflux condenser to prevent the methanol from vaporizing off the reaction. The mixture was allowed to react for 30 minutes after which the resulting product was poured into a 1000ml separating funnel and was then allowed to settle and separate into two layers of biodiesel and glycerol. Separation of products out of the funnel was done after 24 hours and the denser glycerol was observed to settle at the bottom and was withdrawn through the drain at the bottom of the funnel

2.3. Phase Separation and Purification of Biodiesel

1. Separation of Glycerol from Biodiesel

The mixture of biodiesel and glycerin obtained from the transesterification reaction was placed in a beaker and allowed to settle. The glycerin solidifies after some time and since the biodiesel and the glycerin are in different phases, a phase separation takes place. The biodiesel is then separated from the glycerin by decantation.

2. Washing of Biodiesel

The biodiesel was mixed with a certain volume of water and placed in a separating funnel. After some time, the water which had dissolved some of the impurities in the biodiesel settled at the bottom of the separating funnel and was drained off. This procedure was repeated multiple times until the wash water had a clear appearance, signifying that there were no more impurities in the biodiesel.

3. Characterization of biodiesel

The flash point was determined using Pensky Martens closed cup tester. The kinematic viscosity was determined using the capillary viscometer tube. The density of the biodiesel was determined by taking the weight of the biodiesel in grammes with a weighing balance, and measuring the volume with a measuring cylinder. The ratio of the oil in grammes to the volume of the biodiesel in centimeter cube is the density of the biodiesel in gramme per centimeter cube.

3. Results and discussion

The density is measured for all samples at the temperature of 40ºC. The density results aretabulated according to percentages of biodiesel in the sample. Figure 1 shows densities (g/cm^3) of biodiesel samples at different percentages.The relationship between density and biodiesel percentage at 40 ºC is given in Figure 1.

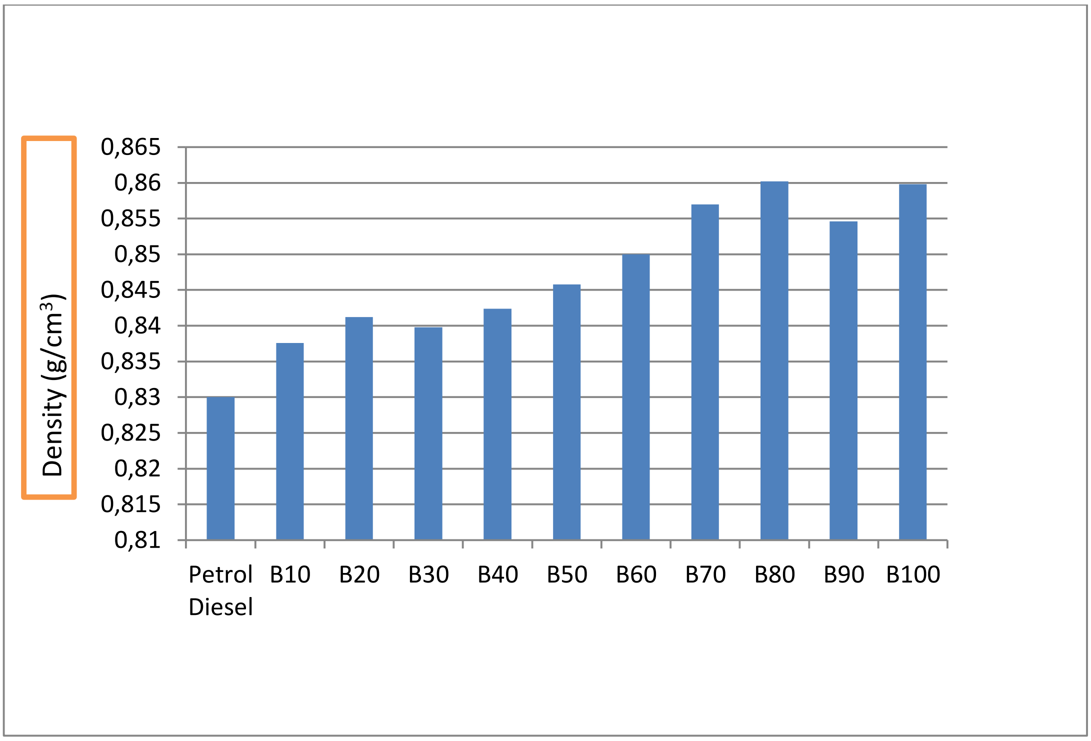

Figure 1 Graph of Petrol diesel, Biodiesel and Biodiesel blends versus Density

A graph of density in comparison to biodiesel blends is shown in Figure 2. The maximum measured value of biodiesel density at 40 ºC is 0.8602g/cm3 for B80 biodiesel blend and the minimum value at 40 ºC is 0.8300gm/cm3 for petrol diesel so the range is (0.8300-0.8602)(g/cm^3). The density of the biodiesel blends increased from B10 to B80.

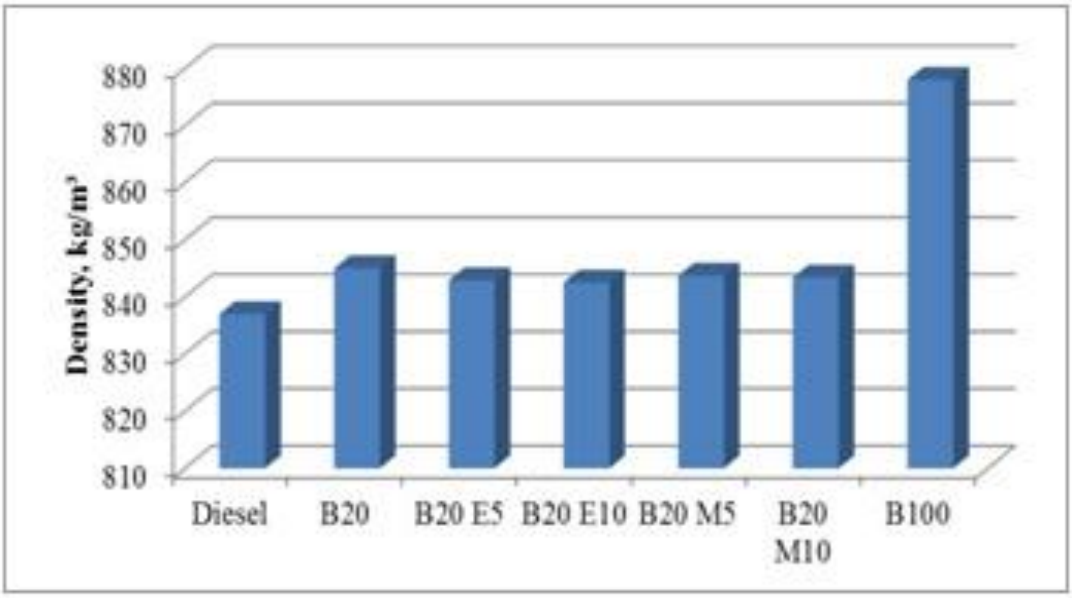

Figure 2: Graph of Density versus Biodiesel Blend (Hafizil, 2013)

The density shows a linear proportional relationship with the percentage of biodiesel. It is clearly shown that the rise of the biodiesel content in the fuel blend increases the density of the fuel. Density is an important biodiesel parameter, with an impact on fuel quality. Predicting density is of high relevance for a correct formulation of an adequate blend of raw materials that optimize the cost of biodiesel fuel production while allowing the produced fuel to meet the required quality standards but it should be considered that the density of biodiesel is affected by the sources of raw material (feedstock) in their production.

Flash Point Results

The flash point was measured for three samples at the operating condition and the overall results given in Table 1, while a graphical representation is shown in Figure 3. The maximum flash point is 128ºC measured for B100 biodiesel sample, and the minimum is 72 ºC measured for petrol diesel. The results obtained coincide with standards. The flash points were measured as a function of the percentage of biodiesel, the results emphasized that the flashpoints increase as the percentage of biodiesel increases in the sample. The fundamental reason for the requirement of flash point measurements is to assess the safety hazard of a liquid or semi-solid concerning its flammability and then classifies the liquid into a group. The lower the flash point temperature, the greater the risk and since blending of the biodiesel with fossil diesel help to increase the flash point hence the need to encourage the blending of biodiesel with fossil diesel.

Table 1: Relationship between biodiesel blends and flashpoints

Biodiesel Blend	Flashpoint(ºC)
Petrol Diesel	72
B50	88
B70	105
B80	108
B90	119
B100	128

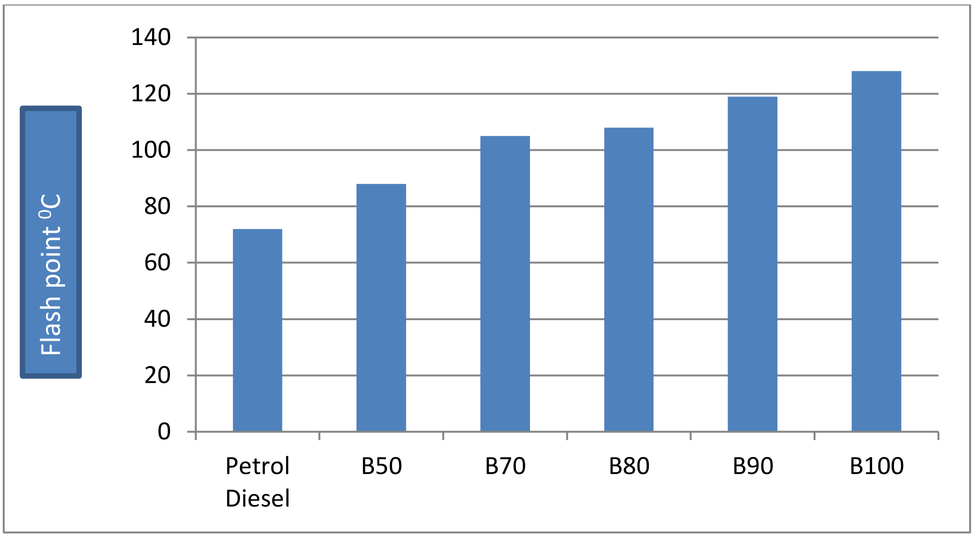

Figure 3 Graph of Petrol Diesel, Biodiesel and Blends versus Flash point

Viscosity Results

The results obtained are within the range of ASTM D6751. From the above result, it is seen that the values of the various blends will be safe to run the diesel engine. This further substantiates sunflower oil as a good feedstock for biodiesel production. Kinematic viscosity is one of the important physical properties of the fuel which influences the performance and efficiency of the engine as shown in Table 2. Viscosity affects the flow properties of the fuel which has an impact on the size of the droplets of the fuel during fuel injection. The higher viscosity forms the larger droplets lead to incomplete combustion of the fuel and exhaust emission become more. The biodiesel has slightly higher viscosity compared to petroleum diesel. Therefore, the blend of biodiesel with petroleum diesel in different proportions is used in the internal combustion engines to keep the viscosity and other properties within the desired standards.

Table 2: Measured values of dynamic and kinematic viscosity at 40 ºC

Biodiesel Blend	Kinematic Viscosity at 40^0C(mm^2/s)	Dynamic Viscosity at 40^oC(mm^2/s)
Petrol Diesel	1.92	1.60
B10	2.32	1.94
B20	2.39	2.00
B30	2.65	2.22
B40	2.74	2.30
B60	2.98	2.54
B70	2.49	2.13
B80	2.50	2.15
B90	2.52	2.15
B100	2.15	1.85

The kinematic viscosity of biodiesel blends is observed to vary with volume per cent of the blend components as shown in Figure 4. The knowledge of the variation of viscosity with change in volume per cent of blend components is the basic requirement to maintain the minimum standards of the fuel.

Discussion on the Gas Chromatograph Results

The sunflower oil was analyzed with Gas Chromatography Mass Spectrophotometer for its' fatty acid composition as shown in Figure 6. The result of the characterization is presented in Table 3. The biodiesel was also analyzed with Gas Chromatography Mass Spectrophotometer as shown in Figure 5 and found to contain a higher amount of linoleic acid methyl ester. Linoleic acid methyl ester being unsaturated will enhance the usage of sunflower biodiesel in cold regions of the world. This implies that sunflower oil is a good feedstock for the production of biodiesel. The viscosities and flash points of the various biodiesel blends obtained in this study are also promising. The analysis of both oil and biodiesel blends obtained in this study are in conformity with standards ASTM D6751 [18].

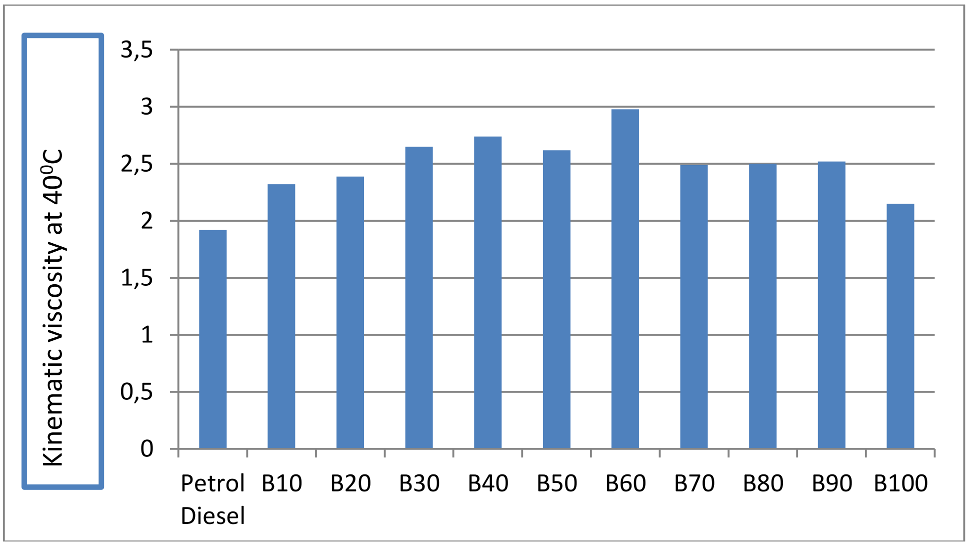

Figure 4: Graph of Petrol diesel, Biodiesel and Biodiesel blends versus Viscosity

Table 3: lesFatty acid and their profi

Fatty Acids	Percentage Present
Palmitic Acid	25.066
Linoleic acid	49.514
Stearic acid	2.700
Gadoleic acid	7.912
Eicosanoic acid	4.343
Hydrofol acid	7.100
Heneicosanoic acid.	3.365

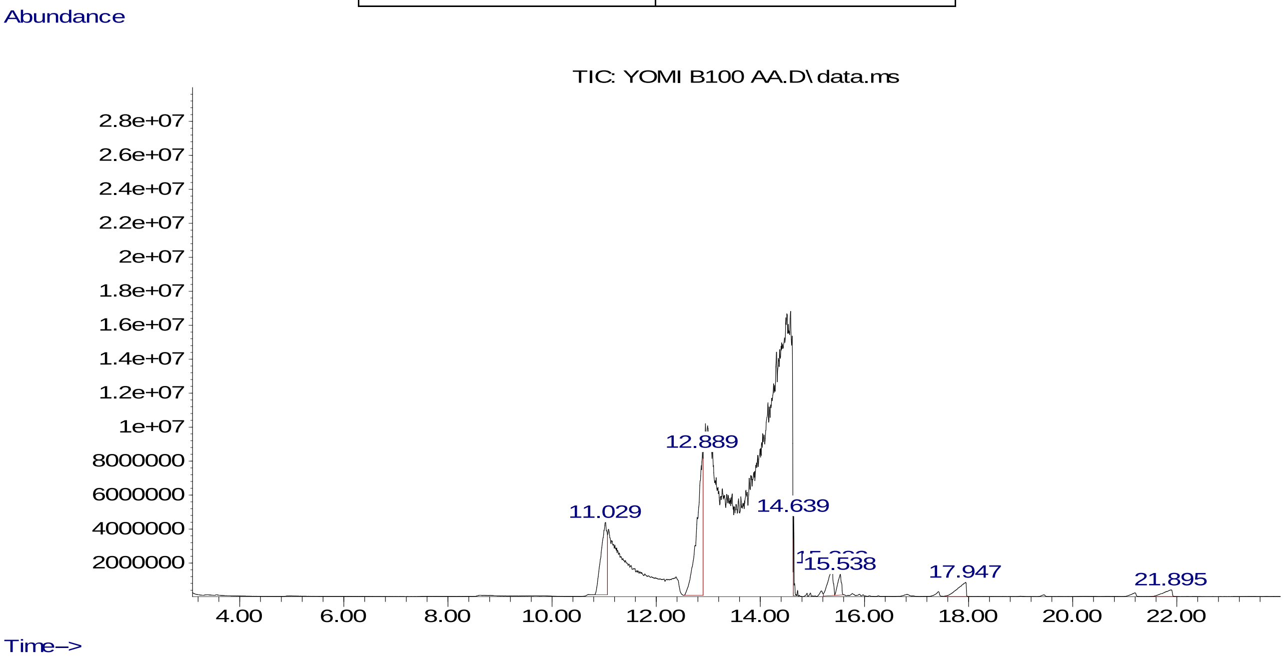

Figure 5 : Chromatogram of Biodiesel

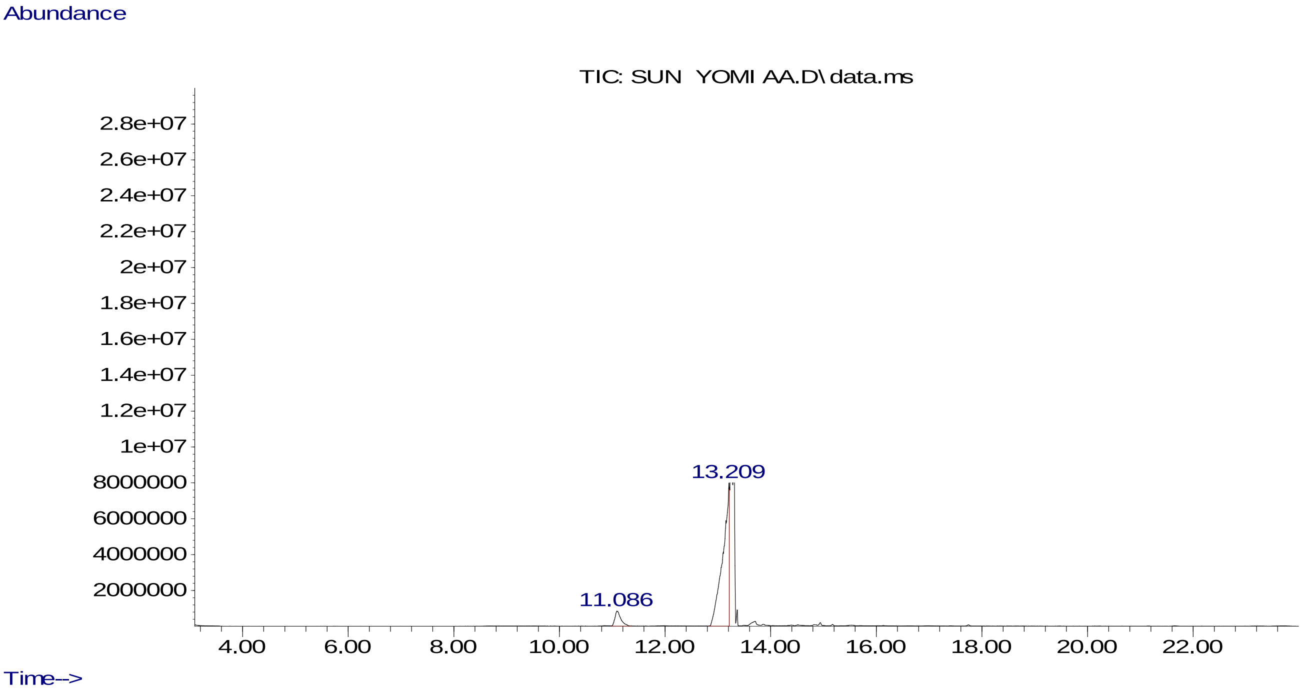

Figure 6 : Chromatogram of sunflower oil

Conclusion

The effect of blending ratio on the performance of sunflower biodiesel blend with petrol diesel has been reported. The sunflower oil was analyzed for its acid value and free fatty acid content and it was found to have an acid value of 2.7066 and an FFA content of 1.35. The composition of the methyl ester content of the sunflower oil was 100% in total conversion. From these results, the density, flashpoint and viscosity of the two samples (petrodiesel and biodiesel) had close values, though they were slightly altered as a result of the blending. The significance of these results is that sunflower oil can be used as an excellent replacement of petrol diesel for diesel production.

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