International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Assessment of Physical & Chemical Properties of Biodiesel of Sunflower Oil & Peanut Oil

Aakriti Thakur*

Indira Gandhi Delhi Technical University for Women , Kashmere Gate, New Delhi-110006
Email: thakur.aakriti05@gmail.com

Abstract

This paper presents the comparative testing results of a four stroke, four cylinder multi-fuel diesel engine and its 5%, 10% and 15% sunflower oil and peanut oil blends with Diesel fuel. This study aims to define the requirements for biodiesel production by the esterification process, testing its quality by determining some parameters such as density, kinematics viscosity, high heating value, cetane number, flash point, cloud pint and pour point and comparing it to Diesel fuel.

Keywords: Biodiesel; Sunflower Oil; Peanut Oil; Diesel; Physical Properties; Chemical Properties; Physio-Chemical Properties.

1. Introduction

During the last years, the consumption of energy has increased a lot due to the change in the life style and the significant growth of population. This increase of energy demand has been supplied by the use of fossil resources, which caused the crises of the fossil fuel depletion, the increase in its price and the serious environmental impacts as global warming, acidification, deforestation, ozone depletion. As fossil fuels are limited sources of energy, this increasing demand for energy has led to a search for alternative sources of energy that would be economically efficient, socially equitable, and environmentally sound.

----

* Corresponding author.

Two of the main contributors of this increase of energy demand have been the transportation and the basic industry sectors, being the largest energy consumers. Bio-fuels appear to be a solution to substitute fossil fuels because, resources for it will not run out (as fresh supplies can be re-grown), they are becoming cost wise competitive with fossil fuels, they appear to be more environmental friendly and they are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available. Bio-fuels appear to be more environment friendly in comparison to fossil fuels considering the emission of greenhouse gasses when consumed. Examples of those gasses are carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O). The objective of our project is to study the prospects and opportunities of introducing vegetable oils as fuel in diesel engines. Vegetable oils present a very promising scenario of functioning as alternative fuels to fossil diesel fuel. The properties of these oils can be compared favourably with the characteristics required for IC engine fuels. Fuel-related properties are reviewed and compared with those of conventional diesel fuel. Biodiesel is an alternative fuel for diesel engines that is produced by chemically reacting a vegetable oil or animal fat with an alcohol such as methanol. The reaction requires a catalyst, usually a strong base, such as sodium or potassium hydroxide, and produces new chemical compounds called methyl esters. It is these esters that have come to be known as biodiesel .To overcome problems of high viscosity associated with neat vegetable oils (triglycerides) as bio fuels; the oil or fat is either cracked, blended with low viscosity solvents or converted to methyl esters. Such methyl ester fuels are already in commercial production in Europe, with rapeseed and sunflower oils being the major feedstock, and to a limited extent in the USA, with soybean oil being the major feedstock. In India also some of the companies like Naturol (Kakinada, A.P, India), Southern on line, (Hyderabad, A.P, India) are using Palm oil and Fish oil respectively for the production of bio diesel. The driving forces behind the search for bio diesel fuels in the United States and Europe are mainly environmental concerns. Vegetable oil and animal fat based bio diesel fuels, as methyl esters, have the following advantages and disadvantages over diesel fuel.

2. Literature Review

The inventor of the diesel engine [1] used peanut oil as a diesel engine fuel or demonstration at the 1900 World Exhibition in Paris. Speaking to the Engineering society at St. Louis, Missouri, in 1912, Diesel said, ―the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become in course of time as important as petroleum and the coal tar products of the present times. The author of [2] describes a new type of sunflower oil expeller for extracting sunflower oil to be used in diesel engines as fuel. They conducted experiments to determine the filterability of dewaxed sunflower oil at various temperatures, pressures and percentage of diesel fuel in Blends. The writer in [3] conducted tests using 100% palm oil on direct injection four-stroke 70 kW diesel-generator. The results proved that a diesel-generator set can be adapted to run with palm oil. Increasing the palm oil temperature the performance and endurance of the diesel generator increases compared to operation in ambient conditions. The deposits on the cylinder head presented high levels when the engine operated with palm oil heated at 50°C and acceptable levels when heated at 100°8C (almost similar to the operation with diesel oil).However, other engine modifications are required to improve lubricating oil degradation, performance, emissions and reach a more efficient combustion. ABEBE focused on the development of heterogeneous catalysts for biodiesel production from high free fatty acid (FFA) containing Jatropha curcas oil (JCO). Solid base and acid catalysts were prepared and tested for transesterification in a batch reactor under mild reaction conditions. Mixtures of solid base and acid catalysts were also tested for single-step simultaneous esterification and transesterification. More soap formation was found to be the main problem for calcium oxide (CaO) and lithium doped calcium oxide (LieCaO) catalysts during the reaction of jatropha oil and methanol than for the rapeseed oil (RSO). CaO with Li doping showed increased conversion to biodiesel than bare CaO as a catalyst. La2O3/ZnO, La2O3/Al2O3 and La0.1Ca0.9MnO3 catalysts were also tested and among them La2O3eZnO showed higher activity. Mixture of solid base catalysts (CaO and LieCaO) and solid acid catalyst (Fe2(SO4)3) were found to give complete conversion to biodiesel in a single-step simultaneous esterification and transesterification process. The author in [4] conducted experiments on sunflower oil and recommended incorporating dual fuel pre-heater for durability improvements of diesel engines. The durability of the engine increased through the prevention of engine operation at low load and low speed conditions, reduced exposure time off fuel injection system at very high temperature conditions during transition process from high to light loads and elimination off fuel injection of oil during shut down period. The writer in [5] conducted experiments using 100% sunflower oil, 100% peanut oil, 50% of sunflower oil with diesel and 50% of peanut oil with diesel. A comparison of the engine performance was presented. The results showed that there was an increase in power and emissions. Another study [6] used sunflower oil to run the engine and it was reported that it performed well. Blends of sunflower oil with diesel and safflower oil with diesel were used by [7] for his experimentation. He demonstrated the least square regression procedure to analyze the long-term effect of alternative fuel and I.C. engine performance. The author of [8] used electric oil expeller for the extraction of crude oil. Base catalyzed transesterifiction process is applied for optimum yield (80%) of biodiesel. Fuel properties of sunflower oil biodiesel were compared with American Society for Testing and Materials (ASTM). Engine efficiency of biodiesel with reference to power, efficiency and consumption of biodiesel blends (B100, B20 and B5) were determined. It was concluded that sunflower oil is one of the option for biodiesel production at a large scale depending on its mass cultivation .The writer in [9] conducted two tests in Chicago using bio-diesel as an alternative fuel for in-service motor coaches. This was an exploratory investigation to determine the effect of fuel on the engine performance characteristics and infra- structure needed to use this fuel. The testing proved that the bio-diesel could be used as a feasible alternative fuel. The author in [9] conducted experiments by using rapeseed oil in diesel engines. The introduction of 5% of RME led to a reduction in the volumetric efficiency around 0.4%. It has been reported that, even after a 71,50,000 km run by vehicles no abnormal aging was observed. The increase in NOx and decrease in HC were detected. The increase of noise and smoke level occurrence during cold [10] prepared emulsion of53% sunflower oil, 13.3% ethanol and 33.4% butonal. This emulsion had a viscosity of6 .3 centistokes at 40 vC, a cetane number of25. Lower viscosities and better spray patterns were observed with an increase in the percentage of butanol. The author in [11] conducted experiments on sunflower oil and recommended incorporating dual fuel pre-heater for durability improvements of diesel engines. The durability of the engine increased through the prevention of engine operation at low load and low speed conditions, reduced exposure time of fuel injection system at very high temperature conditions during transition process from high to light loads and elimination of fuel injection of oil during shut down period. Samaga operated a single cylinder water-cooled dual fuel engine using sunflower oil and groundnut oil. The performance characteristics obtained are comparable to that of diesel. He suggested some remedies to the practical problems encountered in the dual fuel operation of I.C. engines. Periodic cleaning of the nozzle tip is necessary to ensure adequate spray characteristics. Starting and stopping with diesel oil while running with vegetable oil eliminates filter clogging. Bio-diesel produced from vegetable oil is of higher unsaturated fatty acids and bio-diesel from animal fats is of higher content in saturated fatty acids. The author in [12] presented the results of a parametric study of the transesterification reaction variables that included temperature, molar ratio of alcohol to oil, type of catalyst, and the degree of refinement of the oil. They observed that the reaction proceeded to completion in 1 h at 60 8C but took 4 h at 32 8C. The author in [13] present a research work on biodiesel to find out the optimum compression ratios, better performance blend & lesser exhaust gas temperature at different blends of laxmitaru oil on C.I. engine. In this project test were carried out with the diesel & blend of Laxmitaru oil in proportion 10, 20, 30,40,50,70 and 100%. The engine performances were tested on Variable Compression Ratio (VCR) Diesel Engine as per ASTM standard. The performance parameters were tested like Brake specific fuel consumption, Brake power, Brake thermal efficiency at different load & variable compression ratio. The author in [14] discusses the economic aspects of processing of sun flower oil to be used as fuel for diesel engines. The writer in [15] explains the jatropha, soybean, ground nut, castor bean oils as diesel fuel substitute in Thailand and also discusses the economic spect of these vegetable oils. The author in [16] studied the properties of different vegetable oils and modified hybrid fuels for automotive applications and reported that vegetable oils have acceptable cetane numbers (35–45), high viscosity (50 cSt), high carbon residue, high flash points (220–285° C) and pour points (-6 to -12 °C) and appreciable heating value (88–94% of Diesel fuel), low sulfur content (<0.02% by wt.) and contain gumming impurities. Bhanodaya. The author in [17], used pongamia oil and its blends in a diesel engine to evaluate the best blend and optimum fuel injection pressure. The test results with 20% pongamia oil and 80% diesel blends at 200 bar fuel injection pressure were quite encouraging. The writer in [18] explains the relationship between combustion induced mechanical noise and cetane number. In case of vegetable oils the correlation between combustion noise and cetane number does not hold good. While operating the engine with vegetable oils 2 dBA, (A standard for noise measurement that takes into consideration the human ear's sensitivity to certain frequencies) reduced noise levels were observed and 1 to 5 dBA, increased noise levels in case of biodiesels were observed. The writer in [19] conducted droplet combustion studies by a convective mass transfer theory using Palm Oil, Soybean oil and Rice bran oil with diesel fuel to measure the carbon monoxide emission levels from the engine by prediction and experimental methods. It was also found that 5-10% of the vegetable oil mixed in diesel reduced excessive carbon monoxide emissions. The author in [20] developed an experimental and analytical method to study the oxidizability of extra-virgin olive oil, olive oil, sunflower seed oil, soybean oil, maize oil, peanut oil, rapeseed oil, grape seed oil, hazelnut oil, rice oil and four different kinds of oils for frying, using thermo gravimetric analysis (TGA). The author in [21] conducted experiments with crude sun flower oil, pea nut oil soybean oil degummed soybean oil and 50% of above oils with diesel fuels as blend respectively. Carbon deposits on the fuel injector, fuel injection pump leakage and higher fuel consumption were observed with crude vegetable oil operation. Thermal efficiency was 1 to 2% lower compared to diesel fuel operation. 1 to 2% lower NOx, CO and HC were reported and 1 to 2 % higher particulate emissions were observed with vegetable oil operation. The writer in [22] evaluated torque of diesel engines using fuel consumption measurement, exhaust gas temperature measurement and engine governor control lever position measurement and feels that the governor control position measurement is the most appropriate to determine the torque of a diesel engine.

3. Characteristics of oils or fats affecting their suitability for use as biodiesel

In the Laboratory, CI-Engines were designed to run with Bio-diesel as fuel, alternative to Petroleum diesel. The analyzed properties of Biodiesel were closer to that of Diesel. Because a large variation in properties of tested fuel may lead to erratic running of engine and may cause damage to the engine system along with poor performance. The following are some of the properties analyzed:

1. ***Calorific Value or Heat of Combustion*** – Heating Value or Heat of Combustion, is the amount of heating energy released by the combustion of a unit value of fuels. One of the most important determinants of heating value is moisture content. Air-dried biomass typically has about 15-20% moisture, whereas the moisture content for oven-dried biomass is negligible. Moisture content in coals varies in the range 2-30%. However, the bulk density of most biomass feed stocks is generally low, even after densification between about 10 and 40% of the bulk density of most fossil fuels. Liquid bio fuels however have bulk densities comparable to those for fossil fuels.

2. ***Viscosity*** – Viscosity refers to the thickness of the oil, and is determined by measuring the amount of time taken for a given measure of oil to pass through an orifice of a specified size. Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps, resulting in leakage or increased wear. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion, increased exhaust smoke and emissions.

3. ***Density*** – Is the weight per unit volume. Oils that are denser contain more energy. For example, petrol and diesel fuels give comparable energy by weight, but diesel is denser and hence gives more energy per liter.

4. ***Flash Point*** - The flash point temperature of a fuel is the minimum temperature at which the fuel will ignite (flash) on application of an ignition source. Flash point varies inversely with the fuel's volatility. Minimum flash point temperatures are required for proper safety and handling of diesel fuel.

5. ***Melt Point or Pour Point*** - Melt or pour point refers to the temperature at which the oil in solid form starts to melt or pour. In cases where the temperatures fall below the melt point, the entire fuel system including all fuel lines and fuel tank will need to be heated.

3.1. Procedure

3.1.1 .Methods of Biodiesel Production

Considerable efforts have been made to develop vegetable oil derivatives that approximate the properties and performance of the hydrocarbon-based diesel fuels. The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. The viscosity of vegetable oils, when used as diesel fuel, can be reduced in at least four different ways:

(1) Dilution with hydrocarbons (Blending)

(2) Emulsification

(3) Pyrolysis (Thermal cracking)

(4) Transesterification (Alcoholysis).

Transesterification is the most common method and leads to mono alkyl esters of vegetable oils and fats, now called bio-diesel when used for fuel purposes. Transesterification is otherwise known as alcoholysis. It is the reaction of fat or oil with an alcohol to form esters and glycerin. A catalyst is used to improve the reaction rate and yield. Among the alcohols, methanol and ethanol are used commercially because of their low cost and their physical and chemical advantages. They quickly react with triglycerides and NaOH and are easily dissolved in them. To complete a transesterification process, 3:1 molar ratio of alcohol is needed. Enzymes, alkalis or acids can catalyze the reaction, i.e. lipases, NaOH and sulphuric acid, respectively. Among these, alkali transesterification is faster and hence it is used commercially. A mixture of vegetable oil and sodium hydroxide (used as catalyst) are heated and maintained at 650C for 1 hour, while the solution is continuously stirred. Two distinct layers are formed, the lower layer is glycerin and the upper layer is ester. The upper layer (ester) is separated and moisture is removed from the ester by using calcium chloride. It is observed that 90% ester can be obtained from vegetable oils.

3.2. Biodiesel Production

The commencement of the production process depends upon the type of oil employed, and whether it is fresh oil used oils from the catering industry. In the case of the latter, a titration process takes place, the result of which determines the proportions of methanol to potassium hydroxide used in the preparation of the reaction catalyst. The following are the steps required for the production of Bio Diesel:

- ***Titration***: This process is carried out to determine the amount of Potassium hydroxide that would be required. This process is the most crucial and the most important stage of Bio- Diesel manufacturing Titration method for determining how much catalyst needed to neutralize the fatty acids in the used vegetable oil.

  a. Dissolve 1 gram of KOH in 1 liter of distilled water.

  b. Dissolve 1 ml of into 10ml isoprophyl alcohol.

  c. With an eyedropper, set the pH to 8-9 by adding phenolphthalein drop by drop. You will see an eventual rise in the ph level.

  d. Record the quantity of Naoh solution added until the colour of the oil changes pink and holds for at least 5 seconds (this represents a pH in the range of 8 to 9).

- Titration to determine the Excess Catalyst

1. Burette solution: KOH solution -1000ppm
2. Pipette solution: 1 ml of used vegetable
3. Solvent: 10 ml iso propyl alcohol
4. Indicator: Phenolphthalein.
5. End point: Appearance of pink color

Table 1: Titration value for sunflower oil

serial no:	Initial reading(ml)	Final reading(ml)	Volume used(ml)
1.	50	46.90	3.1
2.	50	46.80	3.2
3.	50	46.80	3.2

Table 2: Titration value for peanut oil

Serial no.:	Initial reading(ml)	Final reading(ml)	Volume used(ml)
1.	50	46.60	3.4
2.	50	46.80	3.2
3.	50	46.80	3.2

Calculations:

Since we are using NaOH as titrating solution thus,

Average (titration solution) + 5.5 = (3.2 + 5.5)gm/litre =8.7 gm/litre

For 500 ml of sunflower oil = 8.7gm/litre *0.5=4.35grams

For peanut oil, Average +5.5 =(3.3 +5.5)gm/litre =8.8 gm/litre

- ***Preparation of Potassium Methoxide***

1. Carefully pour the NaOH into 20% methanol.
2. Agitate the mixture until the KOH is completely dissolved in the methanol.

- ***Heating and Mixing***

The potassium methoxide solution prepared is mixed with oil. The residue is heated in between 120ºF to 1300ºF after which it is mixed well using a stirrer at 300 rpm. Continue mixing the contents. Carefully pour the potassium methoxide and shake vigorously for 15 minutes.

- ***Settling and Separation***

After mixing the liquid, it is allowed to cool down. After the cooling process, the bio fuel is found floating on the top while the heavier glycerin is found at the bottom. The glycerin is easily separated by allowing it to drain out from the bottom. In this way pure Bio Diesel is prepared:

1. Allow the glycerin to settle
2. Settle the mixture overnight.
3. The successful chemical reaction between the oil, alcohol, and the catalyst will have broken down the oil into several layers.
4. The top layer will be biodiesel, chemically called an Ester, the next layer may contain soap, and the bottom layer will be glycerin.

- ***Washing***

Biodiesel and glycerin will separate due to density difference. Glycerin and unreacted catalyst will sink to the bottom and can be easily drained .After separation of biodiesel it must be washed with hot water to remove unreacted methanol and potassium hydroxide.

- ***Removing Water***

All the water contained in the residual gangue is removed which makes the reaction faster. The water is easily removed by boiling the liquid at 500C for some time.

Blending

This section focuses on blending B100 with petroleum diesel to make B5, but the approach is similar for other blend levels, such as B10 or B15. As discussed in the previous sections, the performance properties of B100 can be significantly different from those of conventional diesel. Blending biodiesel into petroleum diesel can minimize these property differences and retain some of the benefits of B100. B20 is popular because it represents a good balance of cost, emissions, cold weather performance, materials compatibility, and ability to act as a solvent. B10 is also the minimum blend level that can be used for Epact compliance for covered fleets.

Blends:

B-0: it refers to 100% Diesel

B5: it means that it contains 5% sunflower oil/peanut oil i.e. for 1 Litre, 50ml of sunflower or peanut blends and 20ml of methanol and 950 ml of diesel similarly for 10% and 15% blends.

B10: it means that it contains 10% sunflower oil/peanut oil.

B15: it means that it contains 15%sunflower oil/peanut oil.

Different blends of biodiesel were prepared for further study of properties:

950ml diesel + 50ml sunflower oil = 5% sunflower oil-diesel solution

900ml diesel + 100ml sunflower oil = 10% sunflower oil-diesel solution

850ml diesel + 150ml sunflower oil = 15% sunflower oil-diesel solution

950ml diesel + 50ml peanut oil = 5% peanut oil-diesel solution

900ml diesel + 100ml peanut oil = 10% peanut oil-diesel solution

850ml diesel + 150ml peanut oil = 15% peanut oil-diesel solution

4. Testing of Physio-Chemical Properties

4.1. Method used of testing the Viscosity

Apparatus used:

1. *Viscometer:* Calibrated, glass capillary type, capable of measuring kinematic viscosity within the limits of precision are acceptable.

2. *Viscometer Holders*: To enable the viscometer to be suspended in a similar position as when it was calibrated. The proper alignment of vertical parts may be confirmed by using a plumb line.

Methodology:

The time was measured in seconds for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving heat and at a closely controlled temperature. The kinematic viscosity is the product of the measured flow time and the calibration constant of the viscometer.

4.2. Method used of testing the Flash point

The sample was heated at a slow, constant rate with continual stirring. A small flame was directed into the cup at regular intervals with simultaneous interruption of stirring. The flash point is the lowest temperature at which application of the test flame causes the vapour above the sample to ignite.

4.3. Method used of testing the Pour point

In the determination of pour point, the sample was heated and then cooled at a specified rate. It was examined at intervals of 3ºC for flow characteristics. The lowest temperature at which the oil was observed to flow was noted and recorded as the pour point of the material.

4.4. Heating value or Heat of combustion

Heating value or Heat of combustion is the amount of heating energy released by the combustion of a unit value of fuels. The most important determinants of the heating value are the moisture content. It is because of this, that the purified Biodiesel is dried. The moisture content of the Biodiesel is low and this increases the heating value of the fuel. A bomb calorimeter is a type of constant-volume calorimeter used in measuring the heat of combustion of a particular reaction. Bomb calorimeters have to withstand the large pressure within the calorimeter as the reaction is being measured. Electrical energy is used to ignite the fuel; as the fuel is burning, it will heat up the surrounding air, which expands and escapes through a tube that leads the air out of the calorimeter. When the air is escaping through the copper tube it will also heat up the water outside the tube. The temperature of the water allows for calculating calorie content of the fuel. The calorimeter gives the value of the high heating value or the GROSS (or higher) calorific value for a fuel. The net calorific value is then obtained by subtracting the latent heat of the water present from the gross calorific value. The latent heat of vaporization of water is 2.5 MJ/kg.

5. Results

Table 3: Tested results for Sunflower Oil Biodiesel

Fuel Type	Gross Calorific Value	Density	Viscosity	Pour point	Flash point
5% Sunflower Oil	11225	827	4.38	-19.7	74.2
10% Sunflower Oil	10892	833	4.27	-18.9	77.9
15% Sunflower Oil	10911	836	4.12	-18.4	79.1

Table 4: Tested results for Biodiesel

Fuel Type	Gross Calorific Value	Density	Viscosity	Pour point	Flash point
5% Peanut Oil	11218	825	3.78	-20.3	71.8
10% Peanut Oil	11023	828	3.92	-19.4	73.5
15% Peanut Oil	10890	831	4.07	-19.8	78.1

Table 5: Properties of Diesel

Properties	Values
Density at 20°C, Kg/m³	837
Cetane number	50
Lower Calorific Value, MJ/Kg	43
Kinematic viscosity at 40°C, mm2/s	2.6
Boiling point	180-360
Latent heat of evaporation, kJ/Kg	250
Oxygen, % wt	0
Stoichiometric air-fuel ratio	15
Molecular weight	170

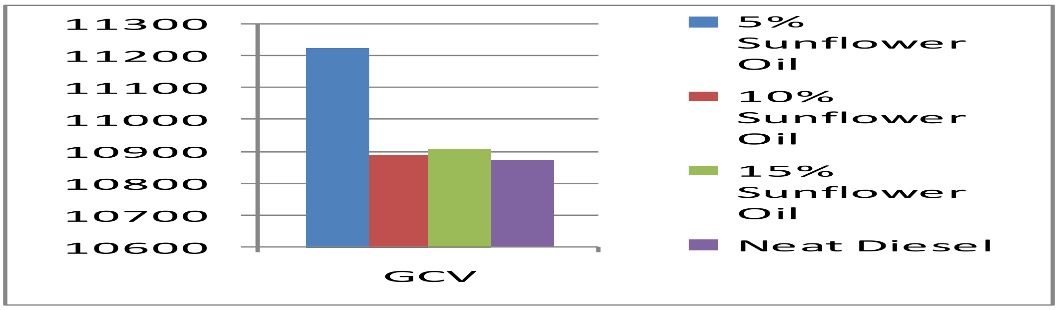

Figure 1

Comparison of Properties of Sunflower Oil Biodiesel with neat diesel:

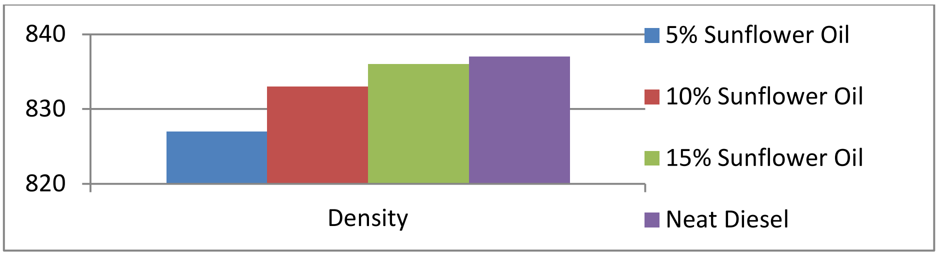

Figure 2

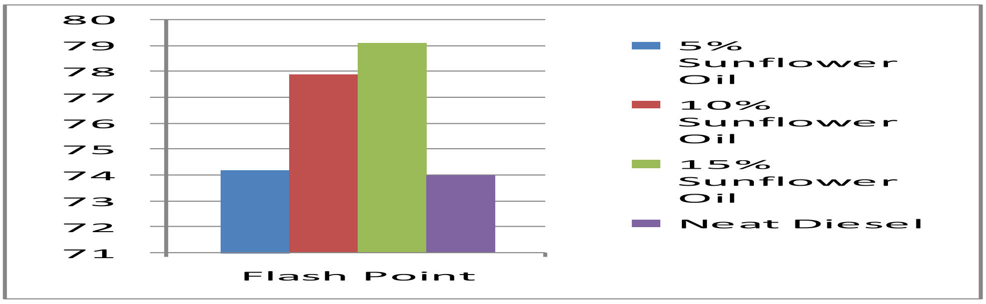

Figure 3

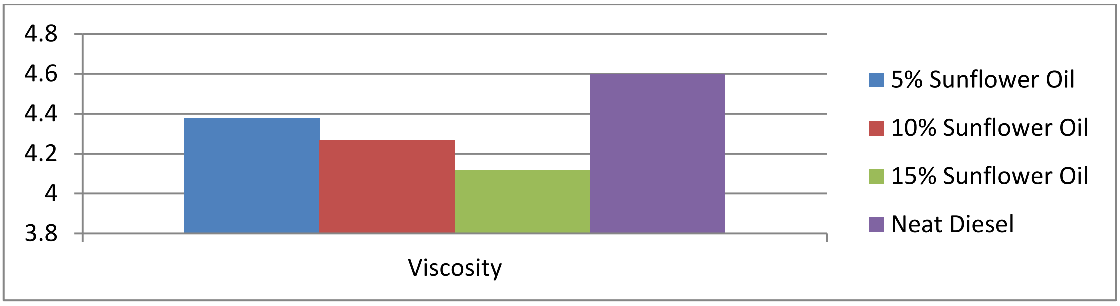

Figure 4

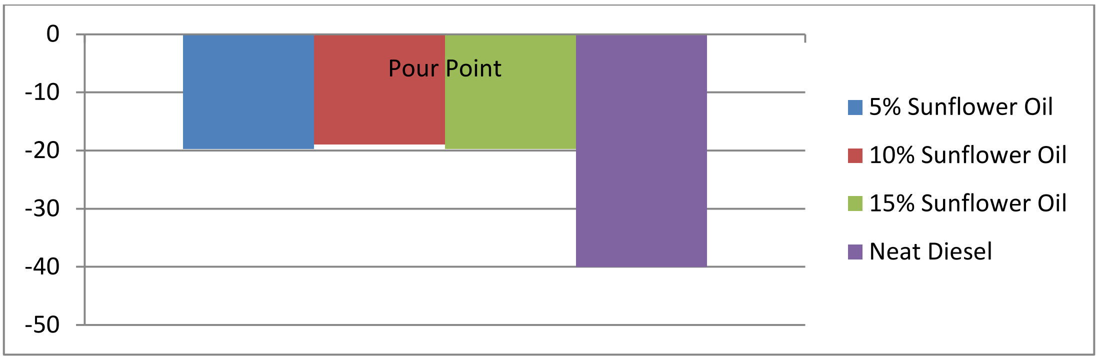

Figure 5

Comparison of Properties of Peanut Oil Biodiesel with neat diesel:

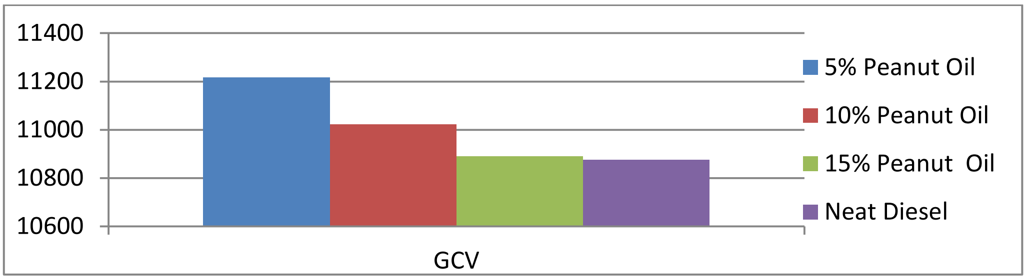

Figure 6

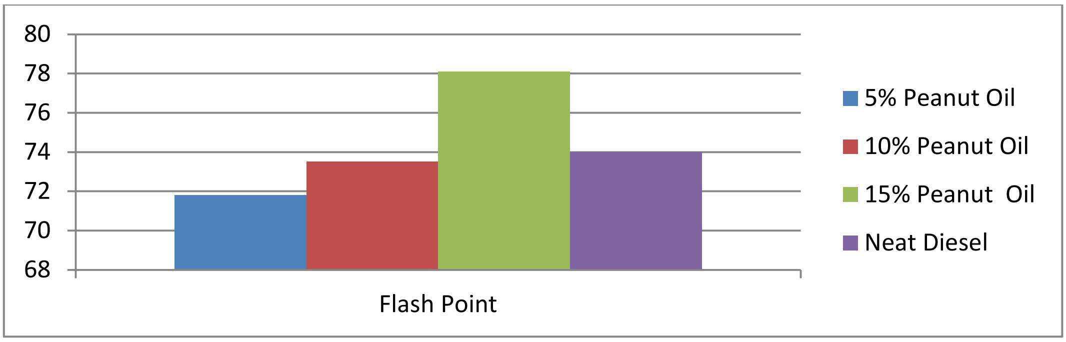

Figure 7

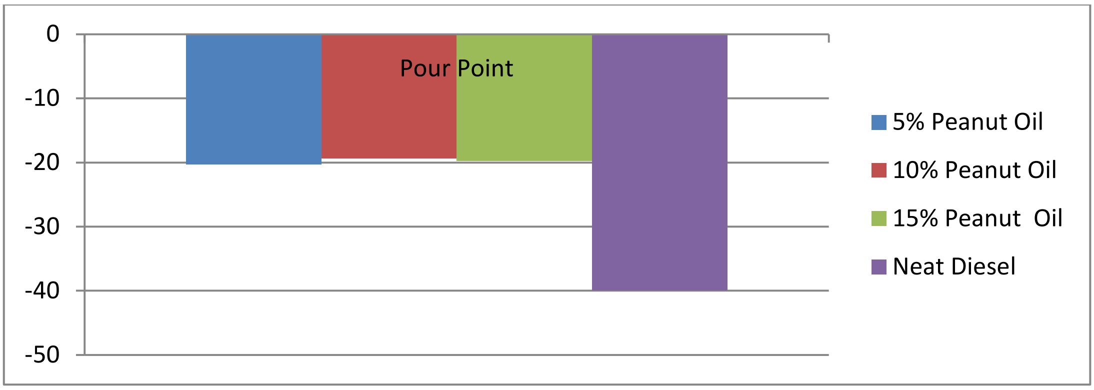

Figure 8

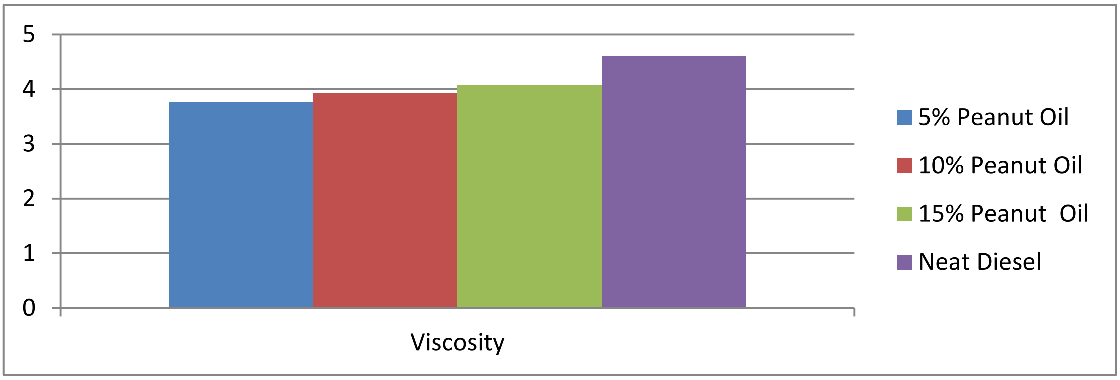

Figure 9

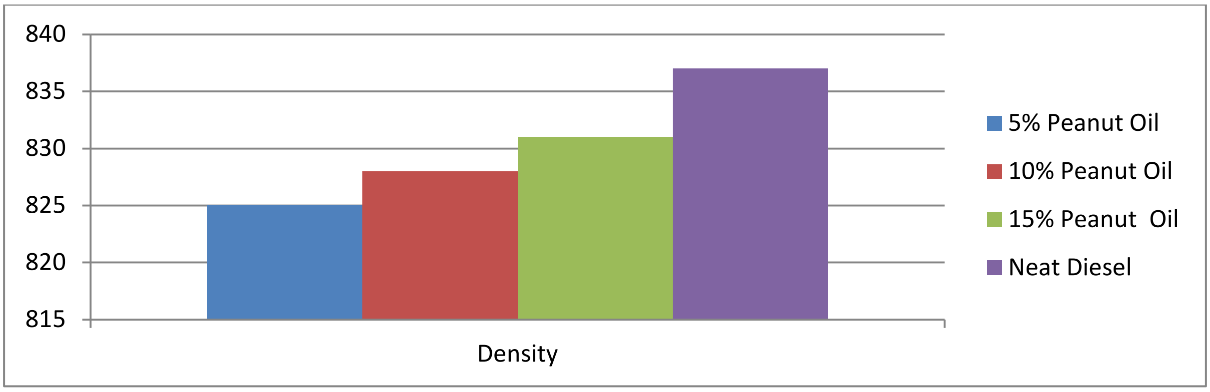

Figure 10

6. Future Scope

In this research we have just performed the study of physical and chemical properties of the biodiesel blends. However, there is still a need to study the engine performance using these blends and also study the smoke and exhaust composition using these blends.

Only these studies once performed can reassure that we can use these biodiesels in our day to day life.

References

[1] Rudolf Diesel,: www.wikepedia

[2] Backer,L.F., Jacobsen,L. and Olson,J.C., 'Farm-Scale Recovery and Filtration Characteristics of Sunflower Oil for Use in Diesel Engines', JAOCS, Vol.60, No.8, 1983, Page No.1558-1560.

[3] Silvio et al. "Performance of a diesel generator fuelled with palm oil', fuel 81(16):2097-2102 • November 2002 with 841 Reads DOI: 10.1016/S0016-2361(02)00155-2.

[4] Mariusz Ziejwski, Goettler J., 'Design modifications for durability improvements of diesel engines operating on plant oil fuels', SAE 921630, 1992.

[5] Barsic NJ, Humke H. 'Performance and emission characteristics of a naturally aspirated diesel engine with vegetable oil', SAE 810262, 1981.

[6] Rosa Radu. 'The use of sunflower oil in diesel engines', SAE 972979, 1997.

[7] Zeiejerdki K, Pratt K. 'Comparative analysis of the long term performance of a diesel engine on vegetable oil', SAE 860301, 1986.

[8] Mushatq Ahmad, Shoaib Ahmed, Fayyaz-Ul-Hassan, Muhammad Arshad, Mir Ajab Khan, Muhammad Zafar and Shazia Sultana, ' Base catalyzed transesterification of sunflower oil Biodiesel', African Journal of Biotechnology Vol. 9(50), pp. 8630-8635, 13 December, 2010.

[9] Christopher W. 'The practical implementation of bio-diesel as an alternative fuel in service motor coaches', SAE 973201, 1997.

[10] Czerwinski J. 'Performance of D.I. Diesel engine with addition of ethanol and rapeseed oil', SAE 940545, 1994.

[11] Mariusz Ziejewski. and Hans, J.Goettler., 'Comparative Analysis of the Exhaust Emissions for Vegetable Oil Based Alternative Fuels', SAE 920195, 1992, Page No.65-73.

[12] Freedman, B., Pryde,E.H. and Mounts,T.L., 'Variables Affecting the Yields of Fatty Esters from Transesterified Vegetable Oils', JAOCS , Vol.61, No.10, 1984, Page No.1638-1643.

[13] Dipak virkar, sachin pisal, 'characterization of biodisesl on vcr engineInternational Journal of Informative & Futuristic Research (IJIFR) Volume - 4, Issue -2, October 2016 Continuous 38th Edition, Page No: 5202-5210.

[14] Delmer, L.Helgeson. and Leroy, W.Schaffner, 'The Economis of on-farm processing of sunflower oil'. U.S. Department of Commerce, l;Iureau of the Census, 1978 Census of Agriculture, Preliminary

Report, North Dakota, Washington, D.C., October 1980. (Farms with sales of $2,500 or more were used).

[15] Dunn,P.D. and Wasan Jompakdee. 'The Use of Vegetable Oils as a Diesel Fuel', Substitute in Thailand', Vol.3, 1993, Page No.44-49.

[16] Goering,C.E., Schwab, A.W., Daudhtery,M.J., Pryde, E.H. and Heakin.A.J . 'Fuel properties of eleven vegetable oils', Trans. of ASAE, Vol. 25(46), 1982; Page No.1472–7.

[17] Bhanodaya Reddy,G., Reddy,K.V. (Retd.). and Ganesan,V.'Utilization of Non-Edible Vegetable Oil in Diesel Engine'. XVII NCICEC, 2001, Page No.211-214.

[18] Chan,C.M.P., Moncrieff,I.D. and Pettitt,R.A. 'Diesel Engine Combustion Noise With Alternative Fuels', SAE 820236, 1983, Page No.948-958.

[19] Wibulswas,P., Chirachakhrit,S., Keochung,U. and Tiansuwan,J. 'Combustion of Blends Between Plant Oils and Diesel Oil', Renewable Energy, Vol. 16, 1999, Page No. 1098-1101.

[20] Coni, E., Podesta, E. and Catone, T. 'Oxidizability of different vegetables oils evaluated by thermo gravimetric analysis', Thermochimica Acta, Vol.418, 2004, Page No.11–15.

[21] Humke,A.L. and Barsic,N.J. 'Performance and Emissions Characteristics of a Naturally Aspirated Diesel Engine with Vegetable Oil Fuels-(Part 2)'‖, SAE 810955, 1982, Page No.2925-2935.

[22] Eduardo, G.de Souza. and Luig, F.Milanez. 'Indirect Evaluation of the Torque of Diesel Engines'‖, ASAE, Vol.31, No.5, 1988, Page No.1350-1354.