A study on variations in the properties of Cottonseed biodiesel due to addition of Diesel

Kiran Raj Bukkarapu
Department of Mechanical engineering
VFSTR University
Guntur, Andhra Pradesh, India

Sivaji Kundla
Department of Mechanical engineering
VFSTR University
Guntur, Andhra Pradesh, India

***Abstract*— Cottonseed oil being a renewable fuel, can replace the conventional diesel fuel in a diesel engine. But its high viscosity makes it less feasible in the engine and hence cottonseed biodiesel was obtained by transesterification process. However, finding the biodiesel also more viscous and denser than diesel, an attempt to improve its properties by blending it with diesel, was done. In this regard, biodiesel-diesel blends were prepared in different volume proportions and the basic fuel properties like density, kinematic viscosity, flash point and fire point of the blends were determined. By increasing diesel content in the biodiesel, kinematic viscosity of the fuel decreased, thus, improving the atomization characteristics. Higher the diesel content, lesser is the flash point and thus an improvement in the ignition characteristics can be expected. However, blends with diesel content less than 20% possess flash point greater than 93`C and hence can be ruled out from being used, as per ASTM D93. Correlations were developed to predict the properties of the blend, given the percentage of diesel blended. These correlations were validated using different blends other than those used to develop them.**

Keywords- Biodiesel; flash point; fire point; kinematic viscosity; density.

I. INTRODUCTION

It is a well known fact that the conventional fossil fuels in use, would get extinct in near future. Vegetable oils were found to be an appreciable alternative to conventional diesel both in terms of availability and emissions [1-6]. But, the high viscosity, high density, polyunsaturated content and the poor calorific value of the vegetable oils ended up in poor performance of the diesel engine [7, 8]. Poor spray characteristics like increased penetration, narrow spray angle are due to high viscosity of the vegetable oils [7, 9]. The high viscosity of the biodiesel can be reduced by adopting the following processes: pyrolysis, transesterification, micro-emulsification. Among these, transesterification is the widely used method to reduce the viscosity of the vegetable oils [1, 10]. It is a process in which triglycerides are converted to mono-glycerides by allowing then to react with an alcohol like methanol/ethanol in the presence of a catalyst [11-16]. Thus, a biodiesel is mono alkyl esters of long chain fatty acids [13, 14, 17].

Fuel is injected on volume basis in a diesel engine and thus a denser fuel indicates higher fuel consumption. Based on the fatty acid composition of biodiesels, their densities vary and they are found to be denser than diesel.

The ability of a fuel to flow through the fuel injectors and split into fine particles is influenced by its kinematic viscosity [5]. A fuel which is less viscous would lead to excessive wear of the engine while its high viscosity would end up in poor atomization [1]. Hence, kinematic viscosity of a fuel is an important parameter to be studied about.

Flash point of a fuel indicates how quick it gets ignited [5]. A fuel with high flash point would be less volatile in nature, leading to increased ignition delay. The fire point is the minimum temperature at which the fuel vapors will continue burning after being ignited even after the removal of the ignition source.

Biodiesel is advantageous to diesel in terms of its availability, higher flash point, negligible sulfur presence, reduced CO (carbon monoxide) and HC (unburnt hydro carbons) emissions [18]. Higher viscosity and higher density along with poor calorific value contribute to the negative characteristics of a biodiesel [19].

Thus, biodiesel can be blended with diesel to improve its properties and make it comparable to diesel. Apart from studying the effect of diesel addition to biodiesel on its properties, relationships predicting the properties with diesel percentage as input have been determined.

II. METHODOLOGY

Refined cottonseed vegetable oil was purchased from a local market and was analyzed based on density at 25 `C (ASTM D4052) and kinematic viscosity (ASTM D445). Methanol (purity> 99.8%), n-hexane, sodium hydroxide (85%, pellets) were supplied by a local vendor. Methanol was added to cottonseed oil, preheated to 60`C, in 6:1 ratio with 1% of sodium hydroxide as catalyst [2] and stirred at a speed of 500 rpm for 6 hours. The mixture was then allowed to settle in a separation flask for glycerin recovery. The processed cottonseed biodiesel was blended with No.2 Diesel in different volume proportions. The samples prepared were named as D0 (Neat cottonseed biodiesel), D10, D20…up to D100 (Neat diesel). Ostwald's U-tube glass viscometer was used to determine the kinematic viscosity of each sample at 313K, which was calibrated using distilled water. Density measurements were made using a pycnometer of 25mL capacity, at a temperature of 313K, calibrated using distilled water. Cleveland's open cup apparatus was used to determine the flash point and fire point of the prepared samples, as specified by ASTM. The uncertainty for all the measurements is between 0.5-1.5 percent for three separate determinations.

III. RESULTS AND DISCUSSION

The measured density (ρ), kinematic viscosity (ν), flash point (FlP) and fire point (FiP) of the eleven samples (including neat fossil diesel and neat cottonseed biodiesel) prepared are given in Table 1.

TABLE 1 Density, Viscosity, flash point and fire point measurements of eleven samples

S. No	Blend sample	Density (gm/cm^3)	Kinematic viscosity (mm^2/s)	Flash point (`C)	Fire point (`C)
1	D0	0.862	4.68	135	140
2	D10	0.858	4.37	110	115
3	D20	0.852	4.10	95	100
4	D30	0.849	3.77	87	93
5	D40	0.844	3.61	74	79
6	D50	0.839	3.28	65	70
7	D60	0.833	3.22	63	67
8	D70	0.826	3.06	61	66
9	D80	0.818	2.95	58	63
10	D90	0.799	2.71	54	59
11	D100	0.796	2.60	52	57

A. *Effect of diesel percentage on Density of cottonseed biodiesel*

Density of neat cottonseed biodiesel (D0) is higher than that of diesel (D100), as shown in Table 1. However, it can be pulled down by blending it with diesel. It is noticed that, higher the diesel content, lower will be the density of the blend, as shown in Figure 1.

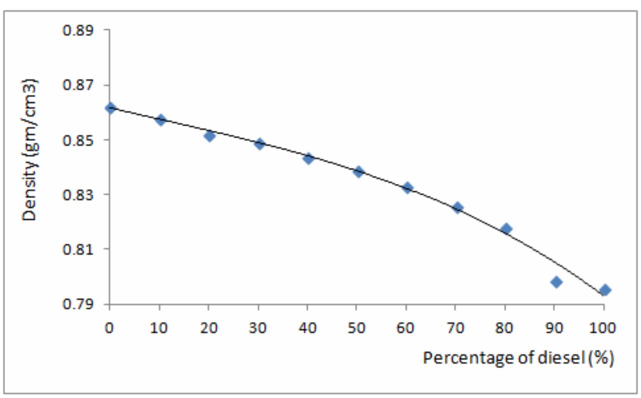

Figure 1 Variation of density with varying diesel percentage.

Density of the blend is related to percentage of diesel blended (R^2 = 0.9884) as

$$\rho = -4E\text{-}08x^3 + 1E\text{-}06x^2 - 0.0004x + 0.8617 \qquad (1)$$

To validate the equation (1), a sample with 15% cottonseed biodiesel and 85% diesel (D85) was prepared and the properties were determined. The experimental density of D85 is 0.802 gm/cm^3 and the value predicted using the given relation is 0.810 gm/cm^3. As the density of fuel was decreased by increasing the diesel content, the viscosity also found to decrease and they are related as (shown in Figure 2).

$$\nu = 518.91\ \rho^2 - 831.07\ \rho + 335.43 \qquad (2)$$

Validation of equation (2) whose coefficient of regression is 0.9846, is done using D85 whose experimentally determined viscosity is 2.81mm^2/s and the predicted one being 2.67mm^2/s.

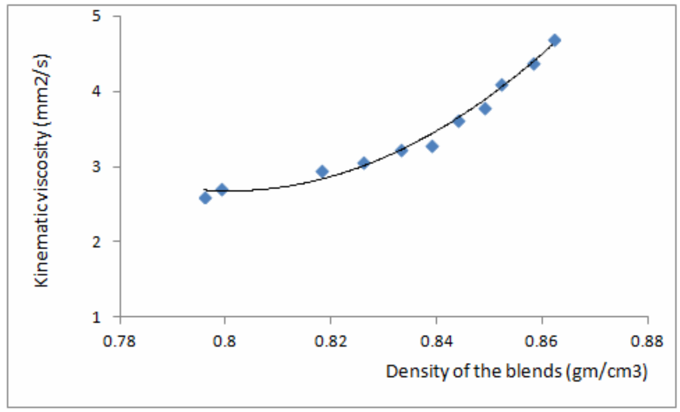

Figure 2 Variation of viscosity with varying density.

B. *Effect of diesel percentage on Kinematic Viscosity of cottonseed biodiesel*

The kinematic viscosity of cottonseed methyl esters (4.68mm^2/s) is found to be nearly double the kinematic viscosity of diesel (2.60mm^2/s). However, blending the neat cottonseed biodiesel with diesel could help in making it less viscous, as shown in Table 1. The variation in viscosity of the biodiesel by adding diesel to it in different proportions can be seen in Figure 3. Kinematic viscosity of the cottonseed biodiesel-diesel blend is related to the percentage of diesel added (R^2 = 0.9747) as follows

$$\nu = -0.0202x + 4.5041 \qquad (3)$$

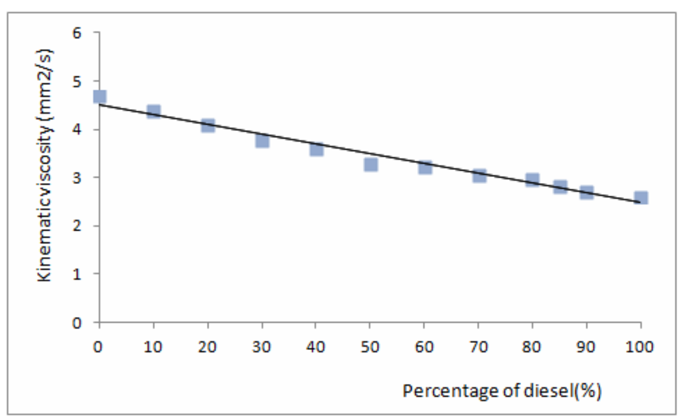

Figure 3 Variation of kinematic viscosity with varying diesel percentage.

The kinematic viscosity of D85 was found to be 2.81mm^2/s, while the value predicted using equation (3) was 2.79mm^2/s, which confirms the validity of the equation (3). Viscosities of the blends were calculated using Arrhenius, Bingham, Kendall & Monroe [20] equations and compared to those predicted using equation (3) in Table 2.

Arrhenius equation: $\log \nu_{blend} = x_{v1} * \log \nu_1 + x_{v2} * \log \nu_2$ (4)

Bingham equation: $1/ \nu_{blend} = x_{v1} / \nu_1 + x_{v2} / \nu_2$ (5)

Kendall & Monroe: $\nu_{blend}^{1/3} = x_{v1} * \nu_1^{1/3} + x_{v2} * \nu_2^{1/3}$ (6)

Where, x_{v1} and x_{v2} are the volume fractions of diesel and biodiesel respectively. ν_1 and ν_2 are kinematic viscosities of neat diesel (2.60mm^2/s) and neat biodiesel (4.68mm^2/s) respectively.

TABLE 2 Comparison of predicted kinematic viscosities of the blends

S. No	Equations to predict	Kinematic viscosity of D85
1	Arrhenius equation	2.83
2	Bingham equation	2.79
3	Kendall & Monroe	2.86
4	Equation (3)	2.79
5	Experimental value	2.81

C. *Effect of diesel percentage on Flash point of cottonseed biodiesel*

The flash point of neat cottonseed biodiesel is found to be 135`C. According to ASTM D93, the maximum limit for a fuels flash point is 93`C and hence neat biodiesel cannot be used. However, adding diesel to it would help but apparently, addition of diesel upto 20% could not help in getting down the value within the acceptable limits. The relation (R^2 = 0.984) between diesel percentage and the flash point of the sample is given as equation (7).

$$FlP = 0.0101x^2 - 1.7472x + 129.71 \quad (7)$$

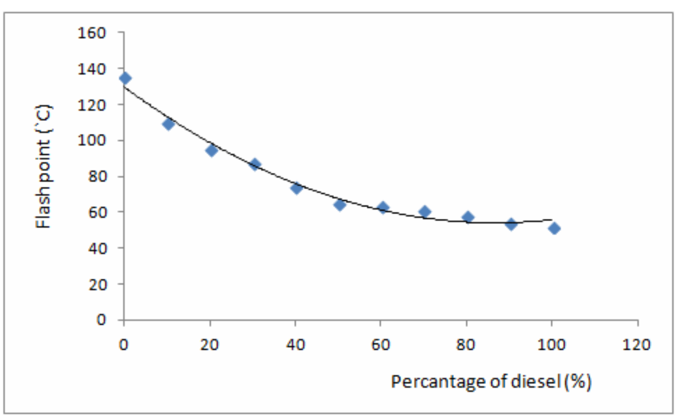

Figure 4 Variation of flash point with varying diesel percentage.

Equation (7) is validated using D85 whose experimental flash point is 55`C and that predicted using the above equation is 54.17`C.

D. *Effect of diesel percentage on Fire point of cottonseed biodiesel*

As the diesel percentage increased the fire point of the sample also decreased, as shown in Figure 5. The relation between diesel percentage and the fire point of the sample is given as (R^2 = 0.9842)

$$FiP = 0.0101x^2 - 1.7535x + 134.9 \quad (8)$$

Equation (8) is validated using D85 whose experimental fire point is 60`C and that predicted using the above equation is 58.9`C.

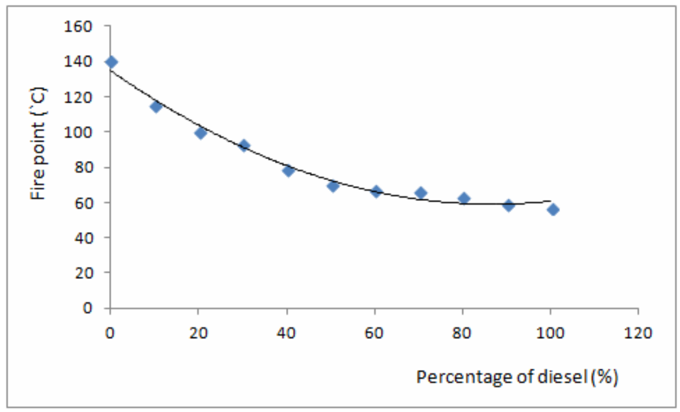

Figure 5 Variation of fire point with varying diesel percentage.

IV. CONCLUSIONS

The following conclusions can be drawn from the study

1) It is noticed that, higher the diesel content in the blend, lower will be the density of the blend.

2) The values of kinematic viscosity predicted using the proposed equation (3) were comparable to already established Arrhenius, Bingham and Kendall & Monroe equations.

3) Blending cottonseed biodiesel with diesel helped in pulling down its flash point within the acceptable limit of 135`C as per ASTM D93.

4) Blending has decreased the flash point of biodiesel which is advantageous in terms of volatility viz.,. ignition delay but disadvantageous in terms of fuel portability.

5) Equations have been developed to calculate the properties of cottonseed biodiesel and diesel blend, given the diesel percentage blended with the biodiesel.

REFERENCES

[1] Amit Sarin, Biodiesel: Production and Properties, RCS publishing, 2012, ISBN 978-1-184973-470-7.

[2] Murat K, Gokhan E, Murat H, The effects of preheated cottonseed oil methyl ester on the performance and exhaust emissions of a diesel engine, Applied Thermal Engineering 28 (2008) 2136–2143.

[3] Ekrem Buyukkaya, Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics, Fuel, 89 (2010) 3099-3105.

[4] Tony Saba, Jane Estephane, Bilal El Khoury, Maroulla El Khoury, Mahmoud Khazma, Henri El Zakhem, Samer Aouad, Biodiesel production from refined sunflower vegetable oil over KOH/ ZSM5 catalysts, Renewable Energy, 90 (2016) 301e306.

[5] Seid Reza Amini-Niaki, Ahmad Ghazanfari, Comparison of fuel and emission properties of petro diesel and sunflower biodiesel prepared by optimized production variables, Fuel, 109 (2013) 384–388.

[6] Mert Gülüm, Atilla Bilgin, Measurements and empirical correlations in predicting biodiesel-diesel blends' viscosity and density, Fuel, 199 (2017) 567–577.

[7] D. Darnoko and M. Cheryan, 'Kinematics of palm oil transesterification in a batch reactor', (JAOCS), 2000, 771 1263.

[8] S. Bari, C. W. Yu and T. H. Lim, "Effect of fuel injection timing with iste cooking oil as a fuel in a direct injection diesel engine". January 2004, Vol. 218, 93-104.

[9] E. H. Pryde, "Utilization of commercial oil seed crops", (JAOCS), 1983, 60, 1557.

[10] B. K. Barnwal and M. P. Sharma, "Prospects of biodiesel production from vegetable oils in India", Renewable and Sustainable Energy Reviews 9 (2005) 363–378.

[11] Demirbas, A. Biodiesel processing. Fuel 1998;77(9-10):1117 e 20.

[12] Demirbas, A. A direct route to the calculation of heating values of liquid fuels by using their density and viscosity measurements. Energy Conservation Management 2000;41(15):1609 e 14.

[13] B. K. Barnwal and M. P. Sharma, Prospects of biodiesel production from vegetable oils in India, Renewable and Sustainable Energy Reviews 9 (2005) 363–378.

[14] S. Kent Hoekman, Amber Broch, Curtis Robbins, Eric Ceniceros, Mani Natarajan, Review of biodiesel composition, properties, and specifications, Renewable and Sustainable Energy Reviews 16 (2012) 143– 169.

[15] Yusuf Ali & M. A. Hanna, Alternative Diesel Fuels From Vegetable Oils, Bioresource Technology 50 (1994) 153-163.

[16] Gabriella P.A.G. Pousa, Andre´ L.F. Santos, Paulo A.Z. Suarez, History and policy of biodiesel in Brazil, Energy Policy 35 (2007) 5393–5398.

[17] Demirbas A, Conversion of biomass using glycerin to liquid fuel for blending gasoline as alternative engine fuel. Energy Conservation Management 2000;41:1741–8.

[18] Oliveria L. E, Da Silva M. L. C. P., Relationship between cetane number and calorific value of biodiesel from Tilapia visceral oil blends with mineral diesel, Renewable energy and power quality journal, ISSN 2172-038 X, No. 11, March 2013.

[19] NwadikeIsioma, Yahaya Muhammad, O'Donnell Sylvester, Demshemino Innocent, Okoro Linus, Cold Flow Properties and Kinematic Viscosity of Biodiesel, Universal Journal of Chemistry 1(4): 135-141, 2013.

[20] Ioanna-Panagiota Kanaveli, Maria Atzemi, Evripidis Lois, Predicting the viscosity of diesel/biodiesel blends, Fuel 199 (2017) 248–263.

AUTHORS PROFILE

First Author:

Kiran raj bukkarapu

Assistant Professor

Department of Mechanica engineering

VFSTR University

Additional Author:

Sivaji Kundla (Final year B. Tech)

Department of Mechanica engineering

VFSTR University