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Original Research Article

Determination of the fuel properties of cottonseed oil methyl ester and its blends with diesel fuel

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Abstract

In this study; density, kinematic viscosity, calorific value, flash point and water content of methyl ester produced from cottonseed oil (CO) were determined under varying blend ratio with ultimate euro diesel fuel, also density and kinematic viscosity were investigated at different temperatures. Six different fuel blends (3%, 5%, 10%, 25%, 50% and 75% by volume blending with diesel), cottonseed oil methyl ester (COME), cottonseed oil and diesel were used for experiments. Density of samples was measured 0-93^{o}C interval with 5^{o}C increments and kinematic viscosity of samples was measured 298.15-373.15 K interval with 5 K increments. All of the measurements were performed at 20^{o}C room temperatures. It is found that; density, kinematic viscosity, calorific value, flash point and water content of cottonseed oil are 921.50 kg/m^3, 31.347 mm^2/s, 39.278 MJ/kg, 237^{o}C and 232.90 mg/kg, respectively. For cottonseed oil methyl ester, they are 884.75 kg/m^3, 4.713 mm^2/s, 39.254 MJ/kg, 171^{o}C and 499.19 mg/kg, respectively. The densities of each fuel sample decreased linearly with increasing temperature. But the kinematic viscosities of each fuel sample decreased exponentially with increasing temperature. In addition experimental results, the most commonly used prediction models were used to calculate the density and kinematic viscosity varying with temperature and blend ratio. Also calorific value, flash point and water content were correlated.

Keywords: Cottonseed oil, cottonseed oil methyl ester, blends, fuel property, density, kinematic viscosity, prediction

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1. Introduction

Continuously rising energy prices, decreasing fossil resources and because of the fact that environmental problems caused by them, the interest in alternative energy sources is increasing with each passing day in the world. Renewability, lower air pollutant and more economic profits are the advantages of the alternative fuels compare to fossil fuels [1]. Natural gas, propane, ethanol, methanol, hydrogen and vegetable oil are the most prevalent alternative fuels. Alcohols and vegetable oils are promising substitutes for diesel fuel. Through alcohols have good volatility, they have low cetane number and hence engine modification is necessary if alcohols are used as fuels in diesel engine. On the other hand, vegetable oil is a renewable and can be easily produced. It has properties similar to those of diesel fuel [2].

One of the biggest problem of using vegetable oils as a fuel source is high viscosity and density values. Transesterification is one of the major ways to decrease its viscosity and density. On the other hand, viscosities of biodiesels produced by a transesterification method are approximately two times more than viscosity of diesel fuel [3]. Transesterification is a chemical reaction in which alcohol reacts with the triglycerides of fatty acids in presence of a catalyst. The stoichiometric ratio for transesterification reaction requires three moles of alcohol and one mole of triglyceride to yield three moles of fatty acid ester and one mole of glycerol. Higher molar ratios result in greater ester production in a shorter time [4]. Various catalysts such as alkali, acid and enzymes have been used for transesterification reaction [5-9].

Biodiesel is a renewable, clean diesel fuel, which is made from fatty acid methyl or ethyl esters. These esters are made from vegetable oils, animal fats, algae oils or waste oil used in cooking or industry. Biodiesel may be produced from various seed oils. These include, but are not limited to, sunflower, canola, hemp, cottonseed, corn, safflower and coconut containing oil. Biodiesel is a fuel, which can be used directly in diesel engines without any modification or with a small modification [10].

One of the benefits in the use of biodiesel as fuel is the fact that has the potential to reduce the level of pollutants and probable carcinogens. In addition, biodiesel has become attractive because it is biodegradable. Other advantages of biodiesel compared to diesel include their higher flash point, also is non-toxic, and essentially free of sulfur and aromatics. Furthermore, it improves remarkably the lubricity of diesel in blends [11].

Among the fuel properties kinematics viscosity, density and heating value are the most important parameters that affect the engine performance and the emission characteristics. One of the major shortcomings of the biodiesels when used in a diesel engine is the detrimental effects caused by the high viscosity of fuel [12]. The higher viscosity of biodiesel fuel compared to diesel makes it an excellent lubricity additive. On the other hand, the high viscosities of biodiesel fuels are reportedly responsible for premature injector fouling leading to poorer atomization [13]. The density of the diesel fuel is also a very important parameter, since other crucial performance parameters of engine such as cetane number and heating value have been correlated against it. In addition, the density values have also been used to measure the amount fuel in fuel system by volumetric method. The variation of the density affects the power and the fuel spray characteristics during fuel injection and combustion in cylinder [12].

It is important to know the basic properties of biodiesel-diesel blends. Some of these properties are required as input data for predictive and diagnostic engine combustion models. Additionally, it is necessary to know if the fuel resulting from the blending process meets the standard specifications for diesel fuels. Given the difficulty of obtaining the basic properties of the blend by measurement, the ability to calculate these properties using blending or mixing rules is very useful [14]. The relationship of the fatty acid composition of the vegetable oils methyl esters, their viscosity, surface tension and atomization characteristics was determinated by Allen (1998) [15]. To predict the viscosity of biodiesel, a novel topologic index was developed by Shu et al. (2007) and the viscosity of biodiesel is predicted by using regression analysis [16].

The objective of this paper is to report on the experimentally determined of the fuel properties like density, kinematic viscosity, calorific value, water content and flash point of transesterified biodiesel based on cottonseed oil methyl ester and its blends with diesel fuel considering the effect of blend ratio (0-100%). In addition experimental results, predicting models were used for temperature dependent density and kinematic viscosity for fuels.

2. Material and Method

2.1. Methyl Ester Production from Cottonseed Oil (CO)

The biodiesel used in this experimental work was transesterified fatty acid methyl ester of cottonseed oil (CO) and was purchased from local market in Adana, Turkey. The transesterification process was performed with methyl alcohol and in base-catalyzed with sodium hydroxide (NaOH). The details of the transesterification process used in this experiment were given in Figure 1.

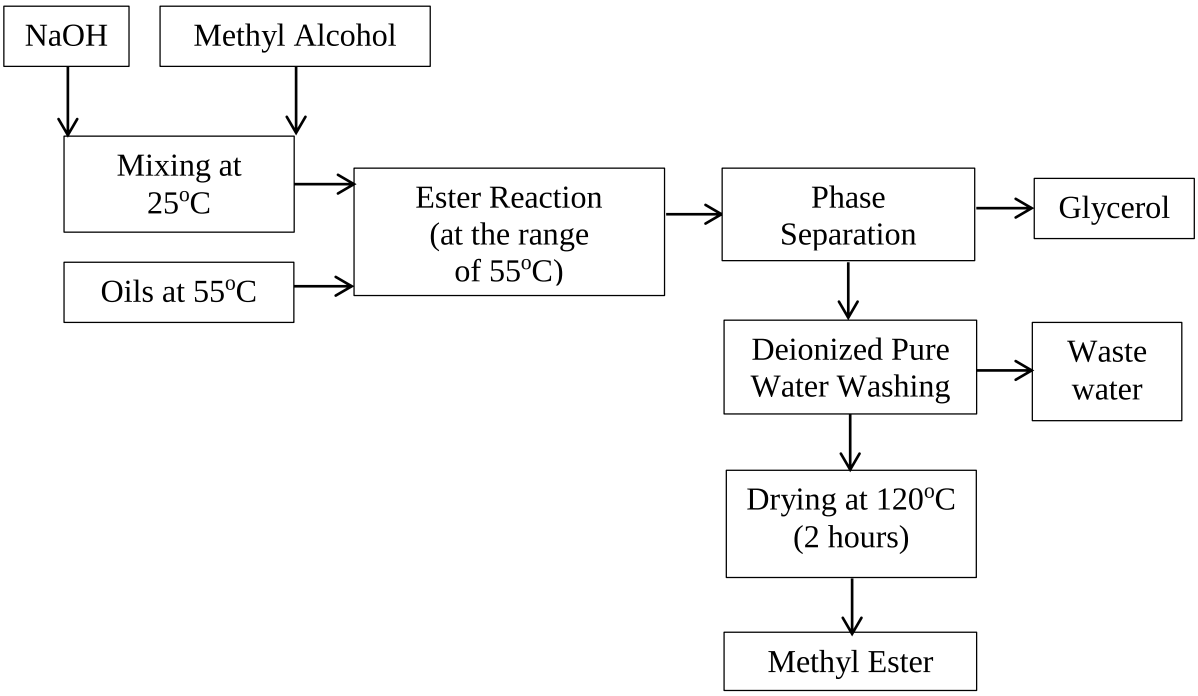

Figure 1. The flow diagram of methyl ester production process

In this study, pure biodiesel (cottonseed oil methyl ester) was indicated as B100, diesel was indicated as B0. The cottonseed oil methyl ester and diesel fuels were blended different proportion and fuel blends were indicated as B3, B5, B10, B25, B50 and B75.

2.2. Preparation of the Fuel Blends

Methyl ester can be used on its own, or by mixing with diesel at any proportion. When mixing diesel and cottonseed oil methyl ester, first 97%, 95%, 90%, 75%, 50% and 25% diesel was put in, than respectively, 3%, 5%, 10%, 25%, 50% and 75% methyl ester was added. The blends were tried to be made homogenous first with laboratory type VELP Scientifica brand DLS F20100155 model mixer at 1500 l/min, then with IKA ULTRA-TURRAX brand T 25 digital model homogenizer at 24000 1/min, for 7.5 minutes each, for a total of 15 minutes [17]. Following this B3, B5, B10, B25, B50 and B75 blends were obtained.

2.3. Experimental Procedure

2.3.1. Kinematic Viscosity

For kinematic viscosities of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels at 298.15-373.15 K temperature range, Polyscience brand 7306A12E model metering device with ±0.05 K temperature sensitivity and ±0.5 K reading validation was used. The device can perform kinematic viscosity metering in accordance with ASTM D 445 standard. Before each fuel samples measurement, the device has been set to the temperature to be measured, and then it was heated. In order to eliminate the residues inside the glass measuring tube dipped into the device, toluene-acetone-ethanol blends have been prepared to clean it. A clean, dry air flow has been applied to eliminate the residues of the dissolver. The fuel with the viscosity to be measured has been placed into the glass metering tube and it was heated for 10 minutes for the temperature of the fuel to reach the temperature to be measured. Glass metering tube works on reverse flow principle. There is a wide mass (balloon) on the glass metering tube. The balloon has been filled with the help of a pendant switch, left to reverse flow, and the flow duration has been measured with a chronometer from the measurement line intervals and then these have been multiplied to the coefficients of certain temperatures of the glass metering tube to determine the kinematic viscosities. For each fuel samples, reading of the kinematic viscosity was measured 3 times and then averaged to report in this study.

2.3.2. Density

The densities of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels at 0-93^oC temperature range, Kem Kyoto brand DA-645 model metering device with ±0.00005^oC temperature sensitivity and 0.00000 to 3.00000 g/cm^3 measuring intervals was used. The device can perform density calculation at measuring temperature, specific gravity (t/4) calculation for water density at 4^oC and specific gravity (t/t) calculation for water density at measuring temperature metering in accordance with ASTM D 1250 and ISO 12185 standards. Before each fuel samples measurement, the device has been set to the measuring temperature, and then it was heated. In order to eliminate the residues inside the device tube cleaned with ethanol or acetone. A clean, dry air flow has been applied automatically to eliminate the residues of the dissolver. In order to wet the inner walls of the device, before measurements, 2 mL of the samples were passed through the density cell. The measurements cell was refilled with a fuel sample before every measurement was taken. Then, the cell was set up at measuring temperature and it was filled with 2 mL fuels. After the measurement completed the cell was automatically and slowly heated at measurement temperatures which are 0 to 93^oC at a step of 5^oC, then measurement was repeated. For cottonseed oil methyl ester, measurements was taken only for temperatures higher than the freezing point, the range of density measurements for these was 10-93^oC. For each fuel samples, reading of the density was measured 3 times and then averaged to report in this study.

2.3.3. Calorific Value

For calorific values of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels IKA brand C200 model bomb calorimeter device was used. For measuring, the amount of fuel (~0.1 g) was combusted inside the calorimeter bomb which was filled with oxygen for full combustion with adequate pressure (~30 bars), filled bomb calorimeter was put in the device and surrounded by an adequate amount of normal water (~2000 mL at 18-25^oC±1^oC). The heat of combustion was transferred to the water and measured thorough the temperature rising in the calorimeter. The device is given the calorific value such as MJ/kg unit. The device can performed calorific value in accordance with EN 61010, EN 50082, EN 55014 and EN 60555 standards. For each fuel samples, reading of the calorific value was measured 3 times and then averaged to report in this study.

2.3.4. Water Content

For water contents of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels Kem Kyoto Electronics brand Karl-Fischer Moisture Titrator MKC-520 model device was used. The measurement interval of the device is 10 μg to 100 mg and the measurement temperature is between 5-35^{o}C. Before the measurement, the device was opened and started pre-titration process. After that, the sample was taken about 3-5 mL from homogenous fuels with clean injector 3 times and these were sent to the waste cup, and then the sample was taken into the injector and was measured the weight of the sample+injector. After the pre-titration process finished, the sample was sent to the device and weight of the empty injector was measured. When the device wanted the full and empty weight of injector, the measurements were entered, and the device gave the water content such as ppm (mg/kg) unit. For each fuel samples, reading of the water content was measured 3 times and then averaged to report in this study.

2.3.5. Flash Point

For flash points of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels Rapid Tester brand RT-1 model device was used and it was measured the flash point between -30 - +300^{o}C. The device can perform flash point in accordance with ASTM D3243, 3278, 3828, IP303 ve ISO 3679, 3680 standards. Before each fuel samples measurement, in order to eliminate the residues inside the experimental cup, cover and other parts of the device toluene-acetone-methanol blends was applied to clean it. A clean, dry air flow has been applied to eliminate the residues of the dissolver. If the flash points of the measuring samples lower than 100^{o}C, 2 mL sample is put in the device. If the flash points of the measuring samples higher than 100^{o}C, 4 mL sample is put in the device. After that, the cover was closed and the device was opened. The flash point of the samples was found and the temperature was decreased about 5^{o}C. Each 1^{o}C temperature increasing, the absolute flash point was determined. For each fuel samples, reading of the flash point was measured 3 times and then averaged to report in this study.

3. Results and Discussion

3.1. Fuel Properties of Cottonseed Oil Methyl Ester-Diesel Blends

The fuel properties of cottonseed oil, B100 and of the diesel used as reference were given in Table 1.

As seen in Table 1. density, kinematic viscosity, flash point, calorific value and copper strip corrosion of cottonseed oil methyl ester were found by Ref. 10 as 884.00 kg/m^3, 4.650 mm^2/s, 95^{o}C, 39.260 MJ/kg and 1a, respectively. Khan and Shrivastava (2013) was found density, kinematic viscosity, flash point, calorific value and copper strip corrosion of cottonseed oil methyl ester as 880.00 kg/m^3, 5.561 mm^2/s, 190^{o}C, 40.830 MJ/kg and 1a, respectively [18]. Our study for cottonseed oil methyl ester showed that density, kinematic viscosity, flash point, calorific value and copper strip corrosion are 884.75 kg/m^3, 4.173 mm^2/s, 171^{o}C, 39.254 MJ/kg and 1a, respectively. So the fuel properties of the cottonseed oil methyl ester were showed that it is suitable for ASTM D 6751 and TS 2EN 14214 standards.

Karaosmanoglu et al. (1999) was found the density, kinematic viscosity, flash point, calorific value and copper strip corrosion of cottonseed oil as 925.10 kg/m^3, 35.8 mm^2/s, 242^{o}C, 36.500 MJ/kg and 1a, respectively [19]. In our study, the density, kinematic viscosity, flash point, calorific value and copper strip corrosion of cottonseed oil are found as 921.50 kg/m^3, 31.347 mm^2/s, 237^{o}C, 39.278 MJ/kg and 1a, respectively.

The cottonseed oil density was decreased from 921.50 kg/m^3 to 884.75 kg/m^3 and kinematic viscosity was decreased from 31.347 mm^2/s to 4.713 mm^2/s with transesterification process. The density and kinematic viscosity of the cottonseed oil methyl ester is higher than the diesel fuel about 1.07 and 1.78 times, respectively.

Density can be defined as the mass of an object divided by its volume. The experimental data were correlated as a function of biodiesel fraction by empirical linear equation. These equations, obtained from regression analysis by using the measured values, were used for estimating the density [20]. The measured density values for each fuel are given Figure 2.

Fig. 2 shows that the density is related with temperature and blend ratio. Other researches were indicated this relationship linearly. If the temperature increases, the density decreases linearly. Furthermore, if the methyl ester blend ratio increases, the density increases linearly because of the fact that the density of cottonseed oil methyl ester is higher than the density of diesel fuel approximately 7.450%.

The cottonseed oil methyl ester has high freezing point, so the densities were not measured at 0 and 5°C. But it was not affected the fuel blends density because of the diesel fuel property.

Table 1. Fuel properties of diesel, B100 and cottonseed oil

Fuels	Density at 15°C (kg/m^3)	Kinematic viscosity at 40°C (mm^2/s)	Flash point (°C)	Water content (mg/kg)	Calorific value (MJ/kg)	Copper strip corrosion (3h at 50°C)
Euro Diesel	823.41	2.641	59	36.757	45.082	1a
B100	884.75	4.713	171	499.19	39.524	1a
B100 [10]	885.00	4.650	95	-	39.260	1a
B100 [18]	880.00	5.561	190	0.015 (v/v%)	40.830	-
CO	921.50	31.347	237	232.90	39.278	1a
CO [19]	925.10	35.8	242	Absent (wt%)	36.500	1a

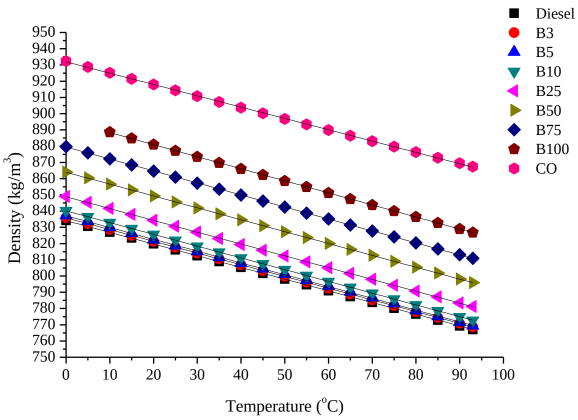

Figure 2. Measured density values of fuels

A possible method for predicting the density of the biodiesel blends should be given by Verduzco et al. (2011) [11] at fixed concentration.

$$\rho = AT + B \qquad (1)$$

Where T is the temperature in °C, A and B are the adjustable parameters. The correlation coefficients of the above equation for each fuel were given in Table 2.

As seen in Table 2. It is clear from the correlation coefficients and regression square values Eq. 1 fits the density values excellent and it is not needed to apply high degree equations.

Table 2. The correlation coefficients of Eq. 1 for each fuel

Fuels	A	B	R^2
B0	-0.72169	834.23893	0.99999
B3	-0.72195	835.83591	0.99999
B5	-0.72650	837.13951	0.99993
B10	-0.72404	840.13492	0.99999
B25	-0.72752	848.81940	0.99998
B50	-0.73161	863.94223	0.99999
B75	-0.73880	879.48805	0.99999
B100	-0.74289	895.79081	0.99999
CO	-0.69701	931.91254	0.99994

The error (%) of the calculated density values of each fuel is given Fig. 3. Fig. 3 shows that B5 has the maximum errors, diesel fuel and

B3 have the minimum errors at different temperatures.

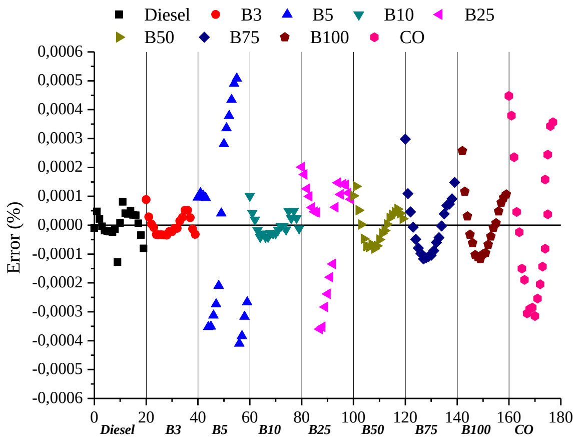

Figure 3. Error of calculated density values

The general form of the equation as a function of the biodiesel fraction is given by Alptekin and Canakci (2008) [20].

$$\rho = Ax + B \tag{2}$$

Where A and B are coefficients and x is the biodiesel fraction. The experimental density values at 15°C of fuel blends are given Fig. 4. The regression square value of the Eq. 2 for cottonseed oil methyl ester-diesel blends is 0.99959. It shows that the equation is so good and not need to use high degree equation. As seen in the Fig 5. The maximum and minimum errors are in B100 and B10, respectively.

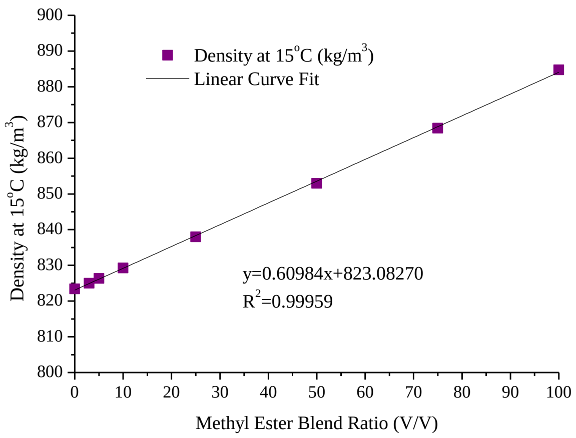

Figure 4. Experimental density values of fuel blends at 15°C

$$\varphi_B = \sum_{i}^{n} x_i \varphi_i \tag{3}$$

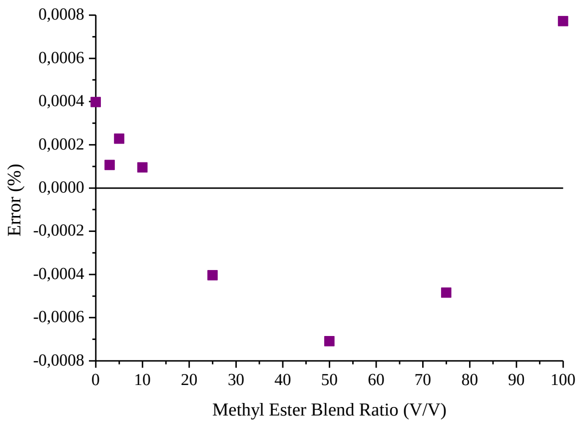

Figure 5. Error of density prediction model of Eq. 2

Where φ_B is the property of the blend and φ_i is the respective property of the i^{th} component. Using volume fraction instead of molar fraction, Eq. 3 for a binary mixture takes the form of an arithmetic volume average:

$$\rho = V_1\rho_1 + V_2\rho_2 \tag{4}$$

Where ρ is the density of the biodiesel blend, ρ_1 and ρ_2 are the density of the pure biodiesel and diesel in kg/m^3, respectively. V_1 and V_2 are the volume percentage of the pure biodiesel and diesel, respectively [14]. The errors of the fuel blends calculated from Kay's mixing rule is given Fig. 6, B3 and B10 have good calculated results compare to other fuel blends.

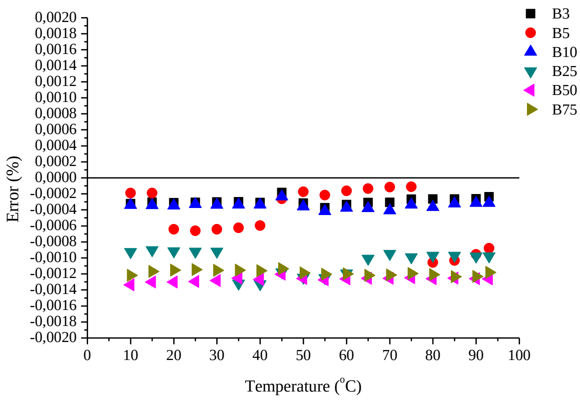

Figure 6. Error of calculated density values with Kay's mixing rule

Viscosity is the property of a fluid by virtue of which it offers resistance to flow. The viscosity of a biodiesel is higher than the viscosity of diesel fuel and some researchers have reported that the biodiesel viscosity can be up to 1.6 times that of diesel at 40°C. This ratio increases especially when the temperature is below 25°C. Blending of the biodiesel with diesel and pre-heating of the biodiesel improves the viscous characteristics significantly [12]. The measured kinematic viscosity values for each fuel are given Fig. 7. As seen in the Fig. 7, diesel fuel has the lowest viscosity and cottonseed oil has the highest viscosity.

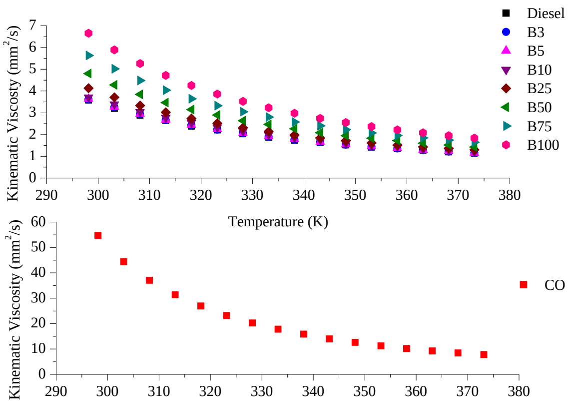

Figure 7. Measured kinematic viscosity values of fuels

The viscosities of fuels are not changed linearly with temperature. So the researchers were developed a lot of models for prediction of viscosity. The most common use of models is Andrade and Grunberg-Nissan. Andrade model can be used for prediction the viscosity of fuels with temperature and Grunberg-Nissan model can be used for prediction the viscosity of blending fuels. Andrade equation of the form [21-23]:

$$\eta = e^{A+\frac{B}{T}} \tag{5}$$

Where η is kinematic viscosity (mm^2/s), A and B are coefficients and T is temperature in K. The correlation coefficients of the Eq. 5 for each fuel sample were given in Table 3. As the temperature increased, the average intermolecular forces also decreased which in turn reduced the resistance to flows and resulted in lower viscosity [24]. Based on experimental data, regression correlations for each fuel sample are given in Table 3. B10 showed the maximum and CO showed the minimum R^2 values as 0.99936 and 0.99828, respectively.

Table 3. The correlation coefficients of Eq. 5 for each fuel

Fuels	A	B	R^2
B0	-4.58517	1741.82715	0.99888
B3	-4.55677	1736.68152	0.99905
B5	-4.55304	1737.59215	0.99907
B10	-4.41476	1704.77008	0.99936
B25	-4.57102	1780.75380	0.99892
B50	-4.59558	1832.63325	0.99912
B75	-4.62012	1887.59418	0.99886
B100	-4.69538	1959.83742	0.99911
CO	-6.27779	3054.75140	0.99828

The error (%) of the calculated kinematic viscosity values of each fuel is given Fig. 8.

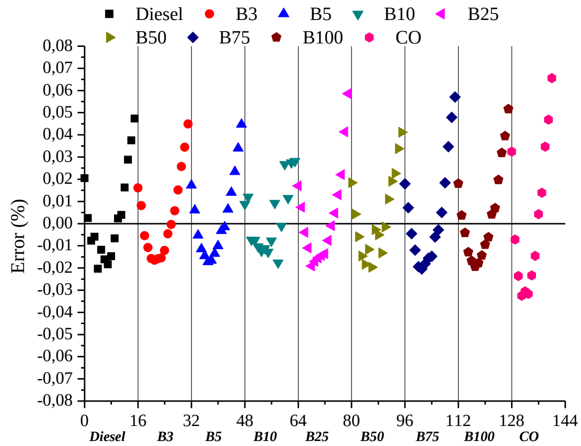

Figure 8. Error of calculated kinematic viscosities

The viscosity of biodiesel can be estimated from well-known mixing laws such as the Grunberg-Nissan which were originally proposed by Arrhenius [25]. The equation is expressed as:

$$ln(\eta_B) = x_1 \ln(\eta_1) + x_2 \ln(\eta_2) \tag{6}$$

Where η_B is the kinematic viscosity (mm^2/s) of the blend, η_1 and η_2 are the kinematic viscosity (mm^2/s) of the components 1 and 2, x_1 and x_2 are the mass or volume fractions of components 1 and 2. Error of calculated kinematic viscosity values with Eq. 6 was given in Fig. 9.

Calorific value (CV) is the amount of heat produced by the complete combustion of a material or fuel. The ultimate analysis of a vegetable oil provides the weight percentages of carbon, hydrogen, and oxygen.

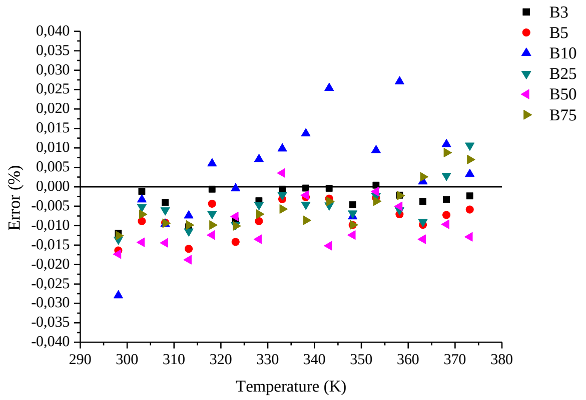

Figure 9. Error of calculated kinematic viscosity values with Eq. 6

The carbon, hydrogen, and oxygen contents of various common vegetable oils are 74.5 to 78.4, 10.6 to 12.4, and 10.8 to 12.0 wt%, respectively. The HHV of vegetable oils ranges from 37.27 to 40.48 MJ/kg. The HHVs of various vegetable oils vary by <9% [26]. The low heating value of biodiesel implies the need of more fuel injected into the engine in order to gain the same output power. The experimental data are correlated by [27] with empirical linear equation of the form:

$$CV = Ax + B \qquad (7)$$

Where A and B are coefficients and x is the biodiesel fraction. The experimental results of calorific value for cottonseed oil methyl ester and its blends with diesel have been given in Fig 10.

The experimental data shows that diesel has the highest calorific value with 45.407 MJ/kg and it decreases linearly with blending methyl ester. The error of the calculated calorific values is given Fig. 11.

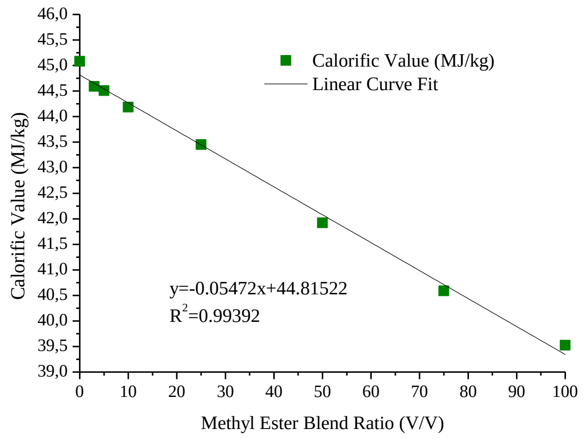

Figure 10. Measured calorific values of fuels

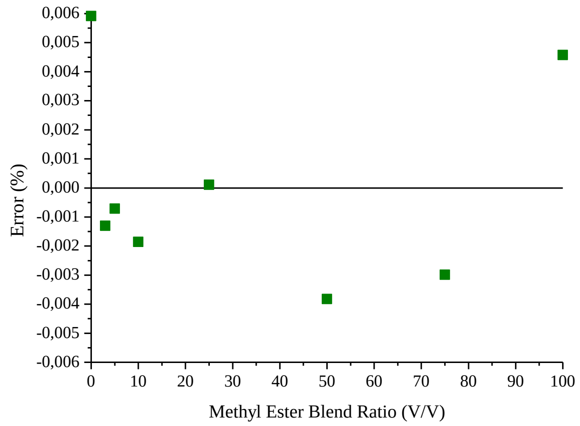

Figure 11. Error of calculated calorific values with Eq. 7

The flash point values of vegetable oil methyl esters are much lower than those of vegetable oils [26]. In this study, as the flash point of cottonseed oil is 237°C, the flash point of cottonseed oil methyl ester is 171°C. The experimental flash points are correlated by 3rd degree polynomials of the form:

$$T_{flash} = Ax^3 + Bx^2 + Cx + D \qquad (8)$$

Where T_{flash} is the flash point (°C) of the fuel, A, B, C and D are coefficients and x is the biodiesel fraction. Experimental values show that B100 has the highest flash point as 171°C and diesel fuel has the lowest flash point as 60°C. But blending fuels were not shown linear regression with biodiesel addition. It is clearly shown in Fig. 12. So Eq.8 is developed for flash point prediction, the regression square value is 0.99290. The error values of the Eq. 8 are given in Fig. 13.

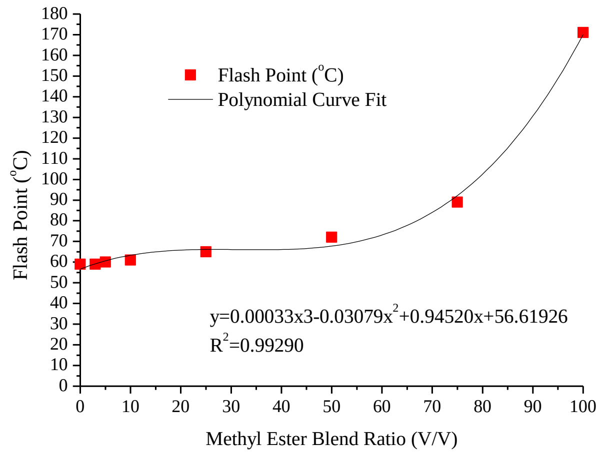

Figure 12. Measured flash points of fuels

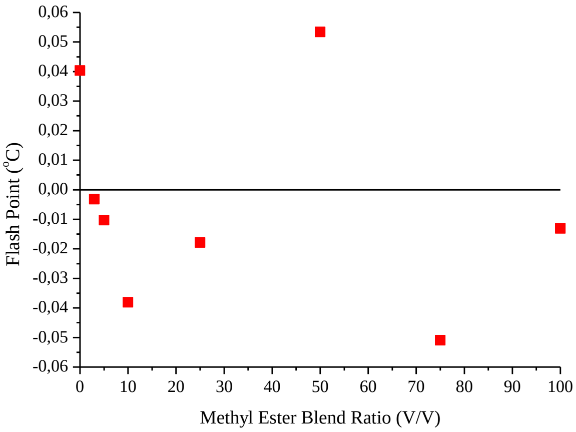

Figure 13. Error of calculated flash points with Eq. 8

The water content of a fuel is required to accurately measure the net volume of actual fuel in sales, taxation, exchanges, and custody transfer [26]. The experimental water contents are correlated by linear of form:

$$WC = Ax + B \qquad (9)$$

Where *WC* is the water content (mg/kg) of the fuel, *A* and *B* are coefficients and *x* is the biodiesel fraction. The water content relationship between biodiesel fractions are given Fig. 14, it is linear with blend ratio. When the Eq. 9 is used for prediction the water content of fuel, the error values of the model are given Fig. 15.

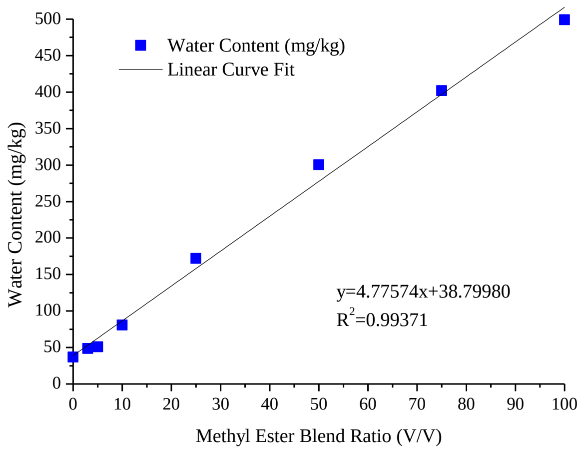

Figure 14. Measured water contents of fuels

4. Conclusions

Recently, decreasing fossil based energy sources and their negative impact on the environment have increased the interest towards renewable energy sources. One of the renewable energy sources is biodiesel.

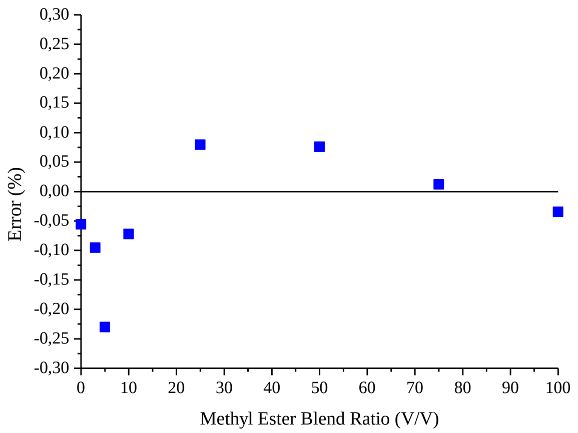

Figure 15. Error of calculated water contents with Eq. 9

Density, kinematic viscosity, calorific value, flash point and water content are important and basic properties of biodiesel fuel. In this study, methyl ester was produced transesterification method from cottonseed oil and was blended with diesel fuel. Then fuel properties of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels were investigated, also prediction models were applied for density and kinematic viscosity. Based on the experimental and prediction results of this study, the following conclusions were drawn:

- The density of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels decreases linearly with increasing temperature.
- The density of blend fuels increases linearly with increase the pure biodiesel blend ratio. Because, the density value of pure biodiesel was found 7.450% higher than diesel fuel.
- The kinematic viscosity of CO, B100, B75, B50, B25, B10, B5, B3 and diesel fuels decreases exponentially with increasing temperature.
- The kinematic viscosity of blend fuels increases with increase the pure biodiesel blend ratio. Because, the density value of pure biodiesel was found 4.713 mm^2/s and it is 1.7 times higher than diesel fuel.
- The calorific value of fuels decreases linearly with blend ratio. The calorific value of the B100 was found 12.329% lower than diesel fuel.

- The flash point of fuels increases with blend ratio but not linearly. The flash point of the B100 was found 171°C and it is 2.85 times higher than diesel fuel.
- The water content of fuels increases approximately linearly with blend ratio. The water content of the B100 was found 499.19 mg/kg and it is 57 times higher than diesel fuel.
- All of the density and kinematic viscosity equation models showed the excellent results compare to the experimental data.
- Calorific value equation showed that R^2 is 0.99665 and B50 has the maximum error.
- Flash point equation showed that R^2 is 0.98664 and B50 has the maximum error. This will be improved with increasing the degree of the equation.
- Water content equation showed that R^2 is 0.99366 and diesel has the maximum error.

The density, kinematic viscosity, calorific value, flash point and water content prediction models can be used for estimate the fuel properties of cottonseed oil, cottonseed oil methyl ester and its blends with diesel fuel.

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