Comparison of Linear Regression and ANN of Fish Oil Biodiesel Properties Prediction

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Abstract: The straight fish oil based biodiesel is used as fuel in CI engines by adjusting physical properties such as density and viscosity and increasing the temperature. In the present study, the variation of density and viscosity of fish oil based biodiesel blend with temperature are studied. The volumetric fraction of biodiesel in the range of 10 to 100% is added with diesel and change in the properties of viscosity and densities are investigated. From the experimental results, density (ρ) and kinematic viscosity (ʋ) of fish oil are synchronized with diesel properties at B40 at 40-50ºC. Artificial Neural Network (ANN) and linear regression modeling are employed for predicting the density and viscosity of fish oil biodiesel blends. For training the ANN, 60% of data has been used a training set, 30% of data has been used a testing set and the remaining 10% of total data has been used for validation. It is observed that the MAPE (Mean Absolute Percentage Error) obtained from the ANN is only 5.27% whereas in the regression prediction the error is 23.9%. Hence, it is established that ANN gives the best performance over regression analysis and found suitable for predicting the biodiesel properties with better accuracy. Thus, it eliminates instrumental usage and man-hours.

Key Words: Fish Oil Biodiesel Blends, Density, Kinematic Viscosity, ANN and Linear Regression Model.

LIST OF ABBREVIATION

ANN Artificial Neural Network
AAD Absolute Average Deviation
B Blends of biodiesel
CI Compression Ignition
CO Carbon Monoxide
CO2 Carbon Dioxide
CN Cetane Number
GA Genetic Algorithm
GRNN Generalized Regression Neural network
GMD Geometric Mean Diameter
HC Hydro Carbon
MAPE Mean Absolute Percentage Error
MSE Mean Squared Error
KV Kinematic Viscosity
FP Flash Point
PUF Polyurethane Foam Insulation
R2 regression coefficient
SR Symbolic regression
SPSS Statistical Package for the Social Sciences
kHz kilo Hertz
MSV Mean Square Value
Notation

| Symbol | Description       |
|--------|-------------------|
| $\rho$  | Density           |
| $m$    | mass              |
| $v$    | volume            |
| $\nu$  | Kinematic viscosity |

1. Introduction

The demand for petroleum and environmental pollution are increasing rapidly due to an average annual growth rate in the world population. It becomes a necessity to search for alternative fuels, which are renewable. Developing and developed countries need alternative fuels for future generations and new technologies for controlling and reducing emissions. In recent years, researchers have put good efforts for identifying sustainable energy resources and have stated that biofuel derived from renewable source is the best alternative fuel for engines. Biodiesel has been one of the most promising alternative fuels in CI engine. Daming Huang et al. [1] have reviewed that the biodiesel plays an important role in sustainable energy resources. From world research, new development and various techniques are adopted for sustainable energy sources. In this view, biodiesel gives the best alternative as a renewable fuel to regulate the emission.

Abdurahman et al. [2] have studied the effects of the emissions derived from the vehicles by using diesel fuel as fuel in engines. As per the Kyoto protocol 1997, the gradual increase of CO$_2$ emission in the environment is the important factor for choosing renewable fuel. Instead of petrol and diesel, natural gas as the fuel in CI engine also reduced the CO$_2$ emission effectively. The main effect of using the diesel usage in CI engine is NOx and particulate emission which is feared to health hazardous. From 2005 onwards the engines are followed by Euro-4 norms and 2008 Euro-5 norms of engines are forced to follow or regulate the CO, HC, NOx and particulate matter. Linus et al. [3] have studied that biodiesel is one of the assured alternative fuels in CI engine that can be produced from plants or animal oils that regulate the emission. Oxygenated content of biodiesel is sculpture free, biodegradable, non-toxic, environmentally-friendly and suitable alternative fuel for CI engines. Jon Van Gerpen [4] has reviewed the usage of biodiesel and the study evidences that the usage of biodiesel controls the emission effectively. It can be produced from vegetable oils and animal fats by using transesterification, pyrolysis and ultrasonic assisted techniques. Due to some disadvantages of direct use of biodiesel such as harming of rubber hoses and continuously changing of the filter in an engine, biodiesel can add at particular ratios such as 20 to 50% without any modification of engine.

Tate et al. [5] have stated that some special instruments are needed to measure the properties of biodiesel above 60°C of temperature and suggested for measuring the kinematic viscosity with the help of saybolt viscometer. Okullo et al. [6] have introduced the new instrument that is used for measuring the viscosity, density and surface tension at temperatures up to 300°C and it gives some useful data. Their study concludes that the physical properties of biodiesel are slightly identical with diesel.

Bernat Esteban et al. [7] experimental study reveals that viscosity and density are the two important properties for fuel in CI engines. Their study describes the use of vegetable oil as the fuel in diesel engine and measures the viscosity and density of vegetable oil up to 140°C and it concludes that the preheating of vegetable oil at 120°C the properties of oil coincide with the diesel oil.

Seung Hyun Yoon et al. [8] have performed the experimental analysis of biodiesel at the temperature range from 0 to 200°C. The various properties of biodiesel such as viscosity, density and specific gravity are measured with blended diesel. Their study concludes that specific gravity, density and kinematic viscosity increases with increasing blend ratio of biodiesel with diesel and decreasing with increasing temperature.

Mohammed Jibril et al. [9] have studied the properties of jatropha oil derived biodiesel, neem oil based biodiesel and automotive gas oil. From this investigation, jatropha-based biodiesel properties such as flash point, specific gravity, density, cloud point and pour point are as an acceptable range with automotive gas oil. But these properties are higher from neem oil derived biodiesel.
Aida Dominguez-Saez et al. [10] have investigated two predictive models (ANN and GA) for engine running at transient condition fuelled with animal fat. The pollutants from the engine were predicted by using ANN and SR. $R^2$ value obtained from the ANN model for CO$_2$, NOx, particle number concentration in accumulation mode, particle number concentration in nucleation mode and GMD were 0.91, 0.78, 0.87, 0.4 and 0.81, respectively. $R^2$ value obtained from the SR prediction of same pollutants is 0.91, 0.82, 0.87, 0.41 and 0.82. From this investigation, simpler regression is more accuracy than Artificial neural Network other than prediction of NOx emission.

Solomon et al. [11] have reviewed the 55 feedstocks of biodiesel as an input parameter and four ANN decided to predict the properties of Cetane Number, Kinematic viscosity, Flash Point and density of biodiesel from the Fatty Acid Composition. The prediction accuracy of CN (96.69%), KV (95.80), FP (99.07%) and density (99.40%) and the average absolute deviation (AAD) of the networks are CN (1.637%), KV (1.638%), FP (0.997%) and density (0.101%).

Ilamathi et al. [12] have studied the NOx emission from 210 MW capacities of a pulverized coal-fired boiler and the study predicts with the help of Artificial Neural Network (ANN) and genetic algorithm (GA) that is the optimization level of input operating techniques to reduce NOx emission in flue gas from the boiler. Their study concludes that ANN is the best tool for predicting the NOx emission from a tangentially fired boiler.

Xiangzan Meng et al. [13] have reviewed 105 biodiesel samples that are collected from the literature and the data is predicted with the help of ANN. Results obtained from this study indicates that ANN is a powerful tool to predict the biodiesel kinematic viscosity at 313 K with MSE of 0.009 and compares the Knothe–Steidley method with the Ramírez-Verduzco method.

Ramadhas et al. [14] have studied the Prediction of cetane number by using the currently available techniques and it has comparatively discussed the ANN prediction tool. Their study also presents the application of multilayered forward, radial base, GRNN and recurrent method for cetane prediction. Finally, their study reduces the time, laboratory experiment usage, and possibly predicts the biodiesel properties with the help of ANN tool. Ceyla Özgür et al. [15] have experimentally studied the density and viscosity of cotton biodiesel at different temperatures condition with the help of ANN and Linear regression. It is indicated that the ANN tool is the best tool for predicting the data without the need for experimental usage and time-consuming process.

From the literature survey, it is concluded that the authors of the previous studies have done experimental and numerical prediction of biodiesel properties on many kinds of fuel, but very few authors (Solomon O et al, Ramón Piloto-Rodriguez et al, Nematizade et al, Roman Balabin et al, ceyla ozgur et al) compare the prediction of biodiesel properties data with ANN and Linear regression. From this work, fish oil based biodiesel density and viscosity variation with temperature is identified and the results of the experimental works are predicted by using ANN and linear regression. None of the authors is concentrating on the properties of fish oil based biodiesel at different temperature condition. Some special instruments are needed to measure the viscosity and density at the temperature at above 60°C and below atmospheric temperature. In the present experimental investigation, the circulating bath set up has been introduced for heating and cooling purpose, this technique is new while comparing with the previous studies.

### 2. Methodology

From this study, fish oil-based biodiesel is produced from crude fish oil by using ultrasonic transesterification technique. This investigation measures the biodiesel density and viscosity at a varying temperature of 10°C to 90°C with a blending range of biodiesel and diesel at the range of B10 to B100 in the interval of 10% volume fraction by using newly introduced circulating bath set up. The measured experimental density and viscosity values are predicted with the help of ANN and linear regression model and the best models are suggested to measure the biodiesel properties prediction. This work also investigates that in which temperature and blending range of biodiesel properties coincide with the diesel properties.

#### 2.1. Biodiesel production
Crude Fish Oil is purchased from Arbee Fish Oil Company, Kottayam, Kerala. This crude oil is directly used for this study without any modification and it is shown in figure 1. Potassium Hydroxide is used as the catalyst and Methanol (95% pure) has been purchased from the local chemical stores. Biodiesel transesterification technique, ultrasonic bath sonicator was used for time minimization purpose. Figure 2 shows the 1.5L (H) capacity of Ultrasonic Bath Sonicator and it operates at room temperature and atmospheric pressure. This sonicator consists of 250 ml flask; inbuilt heating with reflux condenser arrangement to increase the reaction temperature and it brings back the condensed methanol to the flask. Transesterification of raw oil with methanol and Potassium hydroxide were carried at room temperature of 25°C under 40 kHz Ultrasonic Irradiation. In this reaction process, the molar ratio (methanol to oil) is 9:1, potassium hydroxide is 1.5% of weight and a reaction time of 30 min. After successful completion of this transesterification process, procured crude ester was allowed to cool at room temperature and pressure and further, it was allowed to the separation process. Due to this separation process, glycerol was settled at the bottom and the less dense biodiesel settled on the top of the glycerol. The two phases are separated by using a separating funnel. The methyl ester layer was purified by gently washing it with hot distilled water (at about 60°C) until the washing water had a pH value similar to that of distilled water. The methyl-ester layer is then dehydrated with magnesium oxide (1gm MgO / 200 ml biodiesel). The MgO is mixed with biodiesel and this mixture is gently stirred for about 20 minutes for removing the moisture content from the biodiesel. Figure 3 shows the photography of glycerol separated from the pure biodiesel and this biodiesel is used for this study.
2.2 Test fuel:
Test fuel for this study is biodiesel from trash fish oil. For this study, test fuel is in the range from 10% to 100% by an interval of 10% volume fraction of biodiesel that is blended with diesel. Biodiesel blend with diesel is stirred and ensured for proper mixing. This mixing is kept at room temperature.

2.3 Experimental measurement:
The circulating bath set up that maintains the temperature range of 10-120°C for oil and 10-100°C for water as the medium of heat exchange with the uncertainty of ± 2°C is used for this work. Ostwald viscometer and pycnometer are also used to measure the viscosity and density of diesel blended biodiesel. Figure 4 shows the photography of circulating bath set up, which consists of two chambers. The inner chamber is made of stainless steel and the outer chamber is made of mild steel sheets. Inner space in between the wall is tightly packed with a PUF insulation to avoid thermal losses. The chamber is provided with a top opening cover made of stainless steel and provided with a handle and evaporating coils are kept at the rear side in between the inner and outer chamber. Air-cooled Condenser and accessories are provided at the lower portion of the bath. Circulating Pump is supplied with inlet and outlet Ball Valve and By-Pass Valve for regulating the Built-in control panel that accommodates indicating Switch lamps; digital Temperature Controller, Relay, etc are also provided at the lower portion of the chamber for operational convenience.

The circulating bath is filled with fluid and the fluid gets cooled / heated by using the refrigerating & heating unit. Vertical tubes are fitted in the bath and outlet of the fluid from the bath is pumped to an inlet of the tube. Whenever the bath is heated, the tube inside the fluid also gets heated. Biodiesel is filled with viscometer and pycnometer. The viscometer and pycnometer are inserted inside the tube. These two instruments are to be used for measuring the density and viscosity of biodiesel at various temperature ranges. Figure 5 shows photographs of the experimental apparatus. This figure reveals that the tubes mounted on the circulating bath and hold the pycnometer and viscometer. The biodiesel is heated with the help of heat transfer between tube and viscometer and pycnometer. Digital Temperature Controller is used to control the temperature and shows the temperature level. After the steady state reaches or heating is achieved; the readings are taken from the pycnometer and viscometer. The temperature is also checked inside the tube through ordinary thermometer with an accuracy of ± 1°C.

In this investigation for measuring the density and viscosity, the temperature range from 10°C to 90°C at the interval of 10°C and the blends of tested fuel of B10 to B100 at the interval of 10% volume fraction are carried out. The fluid used for this experiment is water and the viscometer and pycnometer are cleaned whenever test fuels are changed.
2.4. **ANNs**

ANN is the method of solving the problem like a human brain which consists of many neurons connected in a collection node called layers. ANN can solve the difficult problem with the help of the Black box Method having multiple input and output. The NeuroShell2 software package was used to construct the ANN models for this study. This approach involves the determination of the best network structure. The structure of the network consists of inputs, hidden layer, and an output layer. Biodiesel blend and temperature is the input layer, weights and transfer functions such as linear, tanh, tanh15, symmetric logistic, gaussian are the hidden layers and biodiesel density and viscosity are the output layers of this structure.

### 2.4.1. **ANN Characteristics:**

ANN consists of three important characteristics which include an input layer, hidden layer, and an output layer. Input layer carrying input data, in this work biodiesel + diesel blend and temperature as the feed data for the input layer. In the hidden layers transfer function and algorithms are developed by the system. The following formula is helpful to find the number of hidden layers present in the node which can be calculated.

\[
\text{Number of hidden layers} = 0.5 \times (\text{input} + \text{output}) + \text{number of training patterns} \tag{1}
\]

In this hidden layer, every layer is linked to every previous layer in the hidden layer which gives the best fit in the system. Activation functions or transfer functions are attached between two neural networks. Figure 6 indicates the typical representation of ANN architecture. In the output layer density and viscosity are two biodiesel properties for this study.

### 2.4.2. **Performance of ANN**

It is a kind of excellent statistical tool to predict or interpolate the data. Each system needs to measure the performance, in the same way as some performance characteristics are available in the ANN tool such as statistical regression value ($R^2$), correlation coefficient ($r$), mean square value (MSV) and Mean Square Error Value (MSE). The measurement between actual and predicted value is called the correlation coefficient, and the range of -1 to +1. If the $r^2$ value is a negative value, it will give a negative linear relationship and if the $r^2$ value is positive it will give a positive linear relationship. The square root of the difference between actual and predicted value is called the mean squared error (MSE). Difference between actual and predicted value is called mean absolute value (MAV).
2.5. Linear models

Multiple linear regression model is a statistical linear approach and this modelling is predicted the data with the help of the relationship between the dependent and independent variables. In the present study, the following equation (2) is developed to estimate the fuel properties of density and viscosity at the different composition of biodiesel blends with diesel.

\[ Y = a + bx_1 + bx_2 \]  

Where, 
\[ Y = \text{Dependent variable, } a, b_1, b_2 = \text{Constant, } x_1 = \text{Independent variable 1, } x_2 = \text{Independent variable 2} \]

3. Results and discussion

3.1. Effect of Biodiesel Fraction and Temperature on Density and viscosity

The density of the biodiesel is measured at various temperatures for different biodiesel-diesel blends. Table 1 shows the density variation of fish oil based biodiesel-diesel blends. The biodiesel-diesel blends have the density varying from minimum of 786.8 kg/m³ for 10% biodiesel fraction at 90°C to a maximum of 894 kg/m³ at 100% biodiesel fraction at 10°C. The density of the blend is increasing with an increase in the biodiesel volume fraction. Biodiesel density depends upon the volume of fraction and temperature. Whenever the temperature increases the density is decreased and with the decreasing volume fraction, the density gets decreased [7, 8]. A High density of biodiesel may affect the droplet size, Spray cone angle, spray tip penetration [17]. Figure 7 shows the variation in density with respect to temperature for different Biodiesel- Diesel blends. It is revealed that the density decreases with increase in temperature for the biodiesel-diesel blends B10-B100. Pure diesel is purchased from the local dealer and its density value of 30°C is 839 kg/m³ and a kinematic viscosity at the same temperature is 3.6 mm²/s at 40°C. In this experimental analysis results indicate that the biodiesel blends with diesel at B40 at 50°C and matches as with diesel density value.

![Diagram](image_url)
| Temperature(°C) | B10   | B20   | B30   | B40   | B50   | B60   | B70   | B80   | B90   | B100  |
|----------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| 10             | 844.3 | 847.5 | 853.7 | 863.9 | 874.1 | 878.2 | 882.2 | 886.2 | 890   | 894.1 |
| 20             | 838.8 | 837   | 847.99| 857.73| 867.4 | 871.3 | 875.2 | 879.1 | 883   | 886.9 |
| 30             | 831.3 | 831.5 | 841.1 | 850.7 | 860.2 | 864.04| 867.84| 871.64| 875.4 | 879.4 |
| 40             | 826.7 | 826   | 836.6 | 846.2 | 855.8 | 859.14| 862.28| 865.4 | 868.5 | 872.4 |
| 50             | 820.8 | 819.5 | 830.5 | 839.5 | 848.5 | 852.34| 856.18| 859.9 | 863.8 | 865.2 |
| 60             | 812.5 | 813   | 822.5 | 832   | 841.4 | 844.7 | 848   | 851.3 | 854.6 | 857.9 |
| 70             | 804.2 | 806.5 | 815.19| 823.89| 832.6 | 836.5 | 840.3 | 844.1 | 847.9 | 850.7 |
| 80             | 795.8 | 800   | 808   | 816   | 823.5 | 827.4 | 831.42| 835.4 | 839.3 | 843.5 |
| 90             | 786.8 | 789.4 | 798.33| 806.13| 814.5 | 818.66| 822.82| 826.98| 831.4 | 836.3 |

Fig. 7 Variation in Density with Temperature for various Biodiesel-diesel Blends

Table 2 narrates how the viscosity of various biodiesel with diesel blends at different temperatures. The biodiesel kinematic viscosity increases with increasing biodiesel blend fraction and decreasing with increasing temperature. The kinematic viscosity of the biodiesel blended with diesel has a minimum value of 1.528 mm²/s at 10% biodiesel fraction at 90 °C and a maximum value of 10.55 mm²/s at 100% biodiesel at 10°C. Figure 8 shows the various temperature ranges with respect to biodiesel blends and it shows that viscosity increases with increasing blends and decreases with increase in temperature [7, 8]. In this experimental venture, the result shows that kinematic viscosity value of B40 at 40°C matches with diesel value.
Table 2. Variation in kinematic viscosity of Biodiesel - Diesel blends with various temperatures

| Temperature(°C) | B10 | B20 | B30 | B40 | B50 | B60 | B70 | B80 | B90 | B100 |
|----------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|------|
| 10             | 5.513 | 6.37 | 6.87 | 7.37 | 7.8 | 8.35 | 8.9 | 9.45 | 10.00 | 10.55 |
| 20             | 4.097 | 4.277 | 4.577 | 4.877 | 5.24 | 5.474 | 5.708 | 5.942 | 6.176 | 6.41 |
| 30             | 3.523 | 3.51 | 3.81 | 4.11 | 4.39 | 4.55 | 4.72 | 4.88 | 5.03 | 5.233 |
| 40             | 2.909 | 2.966 | 3.166 | 3.366 | 3.54 | 3.66 | 3.78 | 3.9 | 4.02 | 4.143 |
| 50             | 2.590 | 2.676 | 2.876 | 3.076 | 3.35 | 3.45 | 3.45 | 3.48 | 3.5 | 3.529 |
| 60             | 2.262 | 2.386 | 2.606 | 2.826 | 3.06 | 3.07 | 3.075 | 3.082 | 3.086 | 3.091 |
| 70             | 2.002 | 2.062 | 2.282 | 2.502 | 2.61 | 2.628 | 2.708 | 2.788 | 2.868 | 2.70 |
| 80             | 1.742 | 1.738 | 1.863 | 1.998 | 2.15 | 2.18 | 2.21 | 2.24 | 2.27 | 2.3 |
| 90             | 1.528 | 1.532 | 1.652 | 1.772 | 1.9 | 1.906 | 1.912 | 1.918 | 1.924 | 1.93 |

Fig. 8. Variations in kinematic viscosity with Temperature for various Biodiesel- diesel Blends

Table 3. ANN Training and testing section of fuel specification

| Fuel | Fuel description | Data type | Data (%) viscosity and density |
|------|------------------|-----------|--------------------------------|
| B100 | Pure Biodiesel   | Testing data | 30% |
| B90  | 90% biodiesel+ 10% diesel |  |  |
| B80  | 80% biodiesel+ 20% diesel |  |  |
| B70  | 70% biodiesel+ 30% diesel | Training data | 60% |
| B60  | 60% biodiesel+ 40% diesel |  |  |
| B50  | 50% biodiesel+ 50% diesel |  |  |
| B40  | 40% biodiesel+ 60% diesel |  |  |
| B30  | 30% biodiesel+ 70% diesel |  |  |
| B10  | 10% biodiesel+ 90% diesel |  |  |
| B20  | 20% biodiesel+ 80% diesel | Validation data | 10% |
3.2 Experimental result with ANN comparison:

3.2.1. *Experimental vs ANN Predicted kinematic viscosity value:*

The main advantage of using neuroshell-2 ANN tool is that the data sets are made manually. 60% of experimental data were taken for training, 30% of total data were taken for testing purpose and 10% of validation data. Figure 9 shows that the experimental data coincides with ANN predicted viscosity data. $R^2$ value for this experimental trial is produced as 0.99. It indicates that predicted value using the ANN method is similar to the experimental value.

![Experimental vs ANN Predicted kinematic viscosity value](image)

Fig. 9 Test results of ANN for kinematic viscosity prediction

3.2.2. *Experimental vs ANN Predicted density value:*

Figure 10 shows that experimental density values match with ANN predicted value and it is depicted that density decreases with increasing temperature. $R^2$ value from this theoretical trial is 0.98. It clearly shows that predicted value is coinciding with the experimental value. Table 3 indicates training, testing and validation data used for ANN study.

![Experimental vs ANN Predicted density value](image)

Fig. 10 Test results of ANN for density prediction

3.3. *Experimental results with linear regression Predicted value:*

Table 5 gives the coefficient value obtained from a linear regression model by using SPSS tool.
3.3.1. Experimental vs linear regression Predicted viscosity value:

Figure 11 indicates that linear regression predicted viscosity value does not match with the experimental value. $R^2$ value obtained from the model is 0.801. Table 4 indicates that MAPE (%) from the linear regression for kinematic viscosity prediction is 23.9% and ANN predicted value is 4.51%.

![Experimental vs linear regression predicted value](image1)

Fig. 11 Test results of linear regression for kinematic viscosity prediction

3.3.2. Experimental vs. linear regression predicted density value

Figure 12 shows how the test results of B20 at corresponding temperature experimental results are compared with the linear regression model. The predicted density value does not match with the experimental value. As per the theoretical result, $R^2$ value is 0.98 and MAPE (%) from the linear regression model is 5.2%.

![Experimental vs linear regression predicted value](image2)

Fig. 12 Test results of linear regression for density prediction
Table 4. MAPE values of test section

|        | Viscosity value | Density value |
|--------|-----------------|---------------|
| ANN    | 4.51            | 0.27          |
| LR     | 23.9            | 5.2           |

Table 5. Linear regression coefficients

| Kinematic Viscosity | Density |
|---------------------|---------|
| Y = kinematic viscosity | Y = density |
| Y = a₁+b₁x₁+b₂x₂ | Y = a₁+b₁x₁+b₂x₂ |
| a₁, b₁, b₂ = Constant | a₁ = 6.067, b₁ = 0.017, b₂ = -0.066 |
| x₁ = Temperature (°C) | a₁ = 848.649, b₁ = 0.561, b₂ = -0.715 |
| x₂ = Blend ratio (% volume) | |

4. Conclusion

In this study, experimental and numerical investigation of density and viscosity of fish oil biodiesel with diesel blends with varying fraction and at different temperature have been carried out by using newly introduced circulating bath set up. From this investigation, it is seen that biodiesel density and kinematic viscosity decrease with increasing temperature and increases with increasing of biodiesel blend with diesel. Results from this experimental investigation shows that the preheating of B40 fish oil biodiesel at 40-50°C, density and kinematic viscosity of biodiesel matches with diesel value. This study indicates that by adjusting the temperature of biodiesel the properties can be matched with conventional diesel properties.

By comparing with linear regression and ANN of a numerical investigation of fish oil biodiesel blends with diesel, R² obtained from the linear regression and ANN for density prediction is 0.98 and 0.98 and for viscosity, the prediction is 0.801 and 0.99. MAPE (%) from the linear regression and ANN for kinematic viscosity prediction is 23.9% and 4.51% and density prediction is 5.2% and 0.27%. Comparison with linear regression Artificial Neural Network (ANN) gives better performance for predicting the fuel properties.

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