Calorific value and density for Palm based biodiesel and Petro-diesel Blends

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ABSTRACT

For the study, the pure palm oil based biodiesel is not suitable to use as fuel in petro-diesel engine. Therefore, the palm based biodiesel is blended with commercially available petro-diesel. Biodiesel is potential alternative for the currently conventional petro-diesel. Blend behavior is analyzed using various properties like density, viscosity, calorific value, refractive index, flash point, cetane number, carbon residue, as per ASTM standard operating procedure. Density is important flow property for pumping of fuel in petro-diesel engine, so it is beneficial to develop correlation for density at entire biodiesel volume fraction range.

In present study, density is examined at various temperatures (298 K, 308 K, 313 K, 318, 323 K) for the different blends of palm based biodiesel to the petro-diesel using specific gravity bottle. The data is obtained and studied for estimation of empirical equation. Empirical equation is developed and compared with the equation like kay equation, newton equation, Dale-Gladstone equation, eykman equation these equations are available in literature and the accuracy of calculated values using these models was calculated by root mean square prediction difference method (RMSPD).

The calorific value is determined for the various blends of palm based biodiesel and petro-diesel. For the various proportion of biodiesel B0, B05, B10, B15, B20, B25, B30, B35, B40, B45, B50, B55, B60, B65, B70, B75, B80, B85, B90, B95 and B100. The empirical equation is developed for the calorific value and compared with the literature equations and calculated the accuracy of calculated values using root mean square prediction difference method (RMSPD).

Key words: *Biodiesel Blend, Density, Calorific Value*

1. INTRODUCTION

From vegetable oils and animal fat through transesterification process in presence of catalyst the reaction takes place for triglycerides and mono alcohol to produce biodiesel (monoester) and glycerine as by-product. The use of biodiesel blend with petro diesel is an emerging alternative source for the conventional diesel fuel. Biodiesel is defined as a mixture of mono-alkyl esters of saturated and unsaturated fatty acid [1].

It is advantageous to use biodiesel as fuel as it will reduce the pollution. Bio-fuels are renewable resource. We can utilize the alternative fuel without extra or no modifications in the current diesel engine. Depending upon feedstock, vegetable oil and mono alcohol, the properties are highly influenced. Before the commercial use of these blends, we need to understand the behavior of the blend with the parameters variations. Behavior of the blend can be estimated with the determination of the various properties like density, viscosity, flash point, pour point, carbon residue, Calorific value, etc [2,3].

Density is an important property of fuel for compression ignition engines. It is worth noting that fuel density increases with the increase in the percentage of biodiesel in the blend. Reheating of biodiesel before injection could be done to overcome the problem of higher fuel density by taking advantage of the high temperature of the engine exhaust gas [4].

In the present study we have discussed the calorific value and density for the binary mixture of the biodiesel with petro-diesel blends. The experimental data has been generated. With the present study we have developed the empirical equation which can predict the density of the biodiesel with dependence on volume fraction of

biodiesel. To the best of our knowledge, few data were presented in literature regarding calorific value and density of palm based biodiesel and its blend [8-10].

The experimental data was utilized to verify the predictive capacity of different proposed equations:

Kay equation [9,10]:

$$D_m = v_1 D_1 + v_2 D_2 - - - - - - - (1)$$

Newton equation [9,10]:

$$D_m^2 - 1 = \sum_{i=1}^{n} \{vi(D_i^2 - 1)\} - - - - - (2)$$

Dale-Gladstone equation [9,10]:

$$D_m - 1 = \sum_{i=1}^{n} \{vi(Di - 1)\} - - - - - (3)$$

Eykman equation [9,10]:

$$\frac{D_m - 1}{D_m + 0.4} = \sum_{i=1}^{n} \left(vi \times \frac{Di - 1}{Di + 0.4} \right) - - - - - (4)$$

D_m=density of a mixture
V_1=volume fraction of petrol-diesel
V_2= volume fraction of palm based bio diesel
D_1=density of a petro-diesel
D_2=density of palm based bio diesel

The accuracy of predictive models was estimated with Root Mean Square Prediction Difference (RMSPD) [9,10].

$$RMSPD = 100 \times \sqrt{\frac{1}{n} \times \sum_{i=1}^{n} \left[\frac{Y_{Cal,i} - Y_{exp,i}}{Y_{exp,i}} \right]^2} - - - - - (5)$$

Where,Y_{Cal} andY_{exp} are the calculated and experimental values respectively, and n is the no. of experimental data.

2. Materials:

For the current study, we have analyzed the samples of biodiesel based on palm based bio diesel. The biodiesel is mixed with the petro-diesel with different proportions. The palm based biodiesel is obtained from the supplier whereas the diesel is obtained from the local supplier.

3. Experimental work:

3.1 Density:

The mixture of biodiesel with diesel fuel were prepared by volume percentage of biodiesel 0%, 5%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%, 55%, 60%, 65%, 70%, 75%, 80%, 85%, 90%, 95% and 100%. All the mixtures are completely miscible. Density of a blend at various temperature of different volume fraction was measured by specific gravity bottle using constant temperature water bath [5].

3.2 Calorific value:

Calorific value of petro-diesel and biodiesel blend was measured by using bomb calorimeter. First of all, water bath was filled with 2000 ml of distilled water. The blend of Palm based Biodiesel and petro-diesel blend samples of different proportionate were taken in crucible in the range of 0.9 gm to 1.1 gm. 5-8 cm of Nichrome wire was cut and tied up between two electrodes. A cotton thread was also tied up on the wire. The wire was submerged in to the sample in crucible. The bomb was properly sealed. It was tighten and water locked in the upper and lower part of the bomb to make it leakage proof. The bomb was pressurized up to 20-25 atm with oxygen. The bomb was placed into water bath in the calorimeter; the electrodes were connected to the bomb and to the sparking unit. The cover of calorimeter was closed. The motor connected with pulley and stirring was started with the careful placement of thermometer inside the water bath. Temperature reading was set on zero initially of the thermocouple. The bomb was ignited by pressing the ignition button and holds it down for 2-5 seconds. The temperature was begun to rise within 20 seconds after fired. The temperature was recorded in every 15 seconds until the temperature reading stabilized and then being to fall. The motor was shut down. The thermometer and the stirrer were carefully raised and remove from the bath and bomb. The pressurized gas was released slowly from the bomb and then bomb was opened. Any unburned fuse wire was carefully removed and cleaned the apparatus.

4. Results and Discussion:

4.1 Density:

Table 1: Experimental value of palm based biodiesel blend

	Density (kg/m^3)				
Blend %	**298 K**	**308 K**	**313 K**	**318 K**	**323 K**
00	817.00	813.00	810.20	806.20	803.60
05	819.00	816.20	814.60	810.80	808.20
10	821.60	819.20	816.80	814.20	812.40
15	823.40	821.60	819.60	815.80	813.80
20	825.00	823.20	822.20	819.60	816.00
25	827.80	825.70	823.70	822.40	819.60
30	829.30	827.50	826.10	824.20	821.80
35	832.00	829.70	827.80	825.80	823.00
40	834.80	832.60	829.20	827.40	824.60
45	836.40	834.80	832.00	829.80	826.80
50	839.80	836.40	833.60	831.60	829.60
55	842.40	838.30	834.80	832.40	830.60
60	844.60	840.60	837.80	835.20	832.60
65	847.30	843.10	840.60	837.80	835.60
70	850.30	847.20	842.80	839.80	838.00
75	856.40	853.00	848.60	843.20	840.80
80	860.40	856.20	851.60	846.00	842.60

85	865.00	859.60	855.20	849.00	846.80
90	868.00	861.40	858.60	853.00	849.60
95	871.00	864.40	861.00	857.40	851.60
100	875.00	869.60	865.80	861.60	858.60

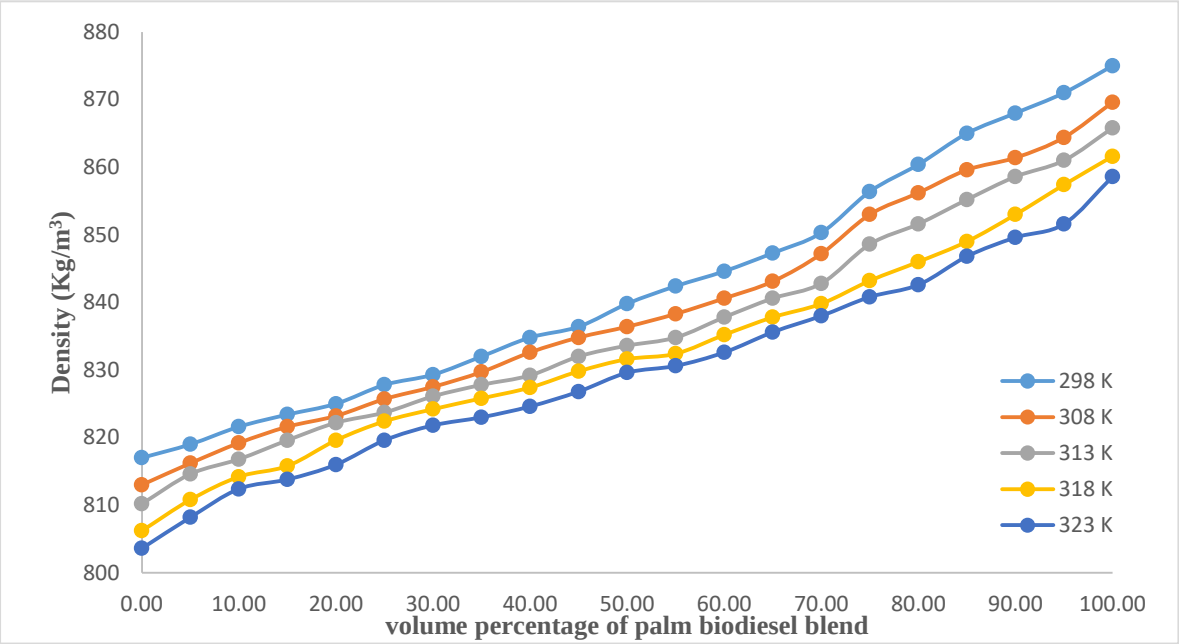

Fig-1: Density of blend at different temp.

The experimental values were utilized to verify the predictive capacity of models as presented in Table 2 to Table 6.

Table 2: Density using various models at 298K

Blend %	**Expt.Value (Kg/m^3)**	**Calculated Values of Density using equations (Kg/m^3)**			
		[1]	**[2]**	**[3]**	**[4]**
0	817.00	817	817	817	817
5	819.00	819.9	819.99	819.9	819.63
10	821.60	822.8	822.98	822.8	822.28
15	823.40	825.7	825.95	825.7	824.96
20	825.00	828.6	828.92	828.6	827.67
25	827.80	831.5	831.87	831.5	830.41
30	829.30	834.4	834.82	834.4	833.17
35	832.00	837.3	837.75	837.3	835.96
40	834.80	840.2	840.68	840.2	838.78
45	836.40	843.1	843.59	843.1	841.63

50	839.80	846	846.49	846	844.50
55	842.40	848.9	849.38	848.9	847.41
60	844.60	851.8	852.27	851.8	850.35
65	847.30	854.7	855.14	854.7	853.32
70	850.30	857.6	858.01	857.6	856.31
75	856.40	860.5	860.86	860.5	859.34
80	860.40	863.4	863.71	863.4	862.41
85	865.00	866.3	866.54	866.3	865.50
90	868.00	869.2	869.37	869.2	868.63
95	871.00	872.1	872.19	872.1	871.80
100	875.00	875	874.99	875	875
RMSPD(%)		**0.5774**	**0.6185**	**0.5774**	**0.4550**

Table 3: Density using various models at 308K

Blend %	**Expt. Value (Kg/m^3)**	**Calculated Values of Density using equations (Kg/m^3)**			
		[1]	**[2]**	**[3]**	**[4]**
0	813.00	813	813	813	813
5	816.20	815.8	815.92	815.83	815.57
10	819.20	818.7	818.83	818.66	818.16
15	821.60	821.5	821.73	821.49	820.78
20	823.20	824.3	824.63	824.32	823.43
25	825.70	827.2	827.51	827.15	826.10
30	827.50	830	830.38	829.98	828.80
35	829.70	832.8	833.24	832.81	831.53
40	832.60	835.6	836.09	835.64	834.28
45	834.80	838.5	838.94	838.47	837.06
50	836.40	841.3	841.77	841.3	839.87
55	838.30	844.1	844.59	844.13	842.70
60	840.60	847	847.41	846.96	845.57
65	843.10	849.8	850.21	849.79	848.46
70	847.20	852.6	853.01	852.62	851.39
75	853.00	855.5	855.80	855.45	854.34

80	856.20	858.3	858.57	858.28	857.33
85	859.60	861.1	861.34	861.11	860.35
90	861.40	863.9	864.10	863.94	863.40
95	864.40	866.8	866.85	866.77	866.48
100	869.60	869.6	869.59	869.6	869.6
RMSPD(%)		**0.3670**	**0.4013**	**0.3670**	**0.2726**

Table 4: Density using various models at 313K

Blend %	**Expt. Value (Kg/m^3)**	**Calculated Values of Density using equations (Kg/m^3)**			
		[1]	**[2]**	**[3]**	**[4]**
0	810.20	810.2	810.2	810.2	810.2
5	814.60	812.98	813.07	812.98	812.72
10	816.80	815.76	815.93	815.76	815.28
15	819.60	818.54	818.78	818.54	817.86
20	822.20	821.32	821.62	821.32	820.46
25	823.70	824.1	824.45	824.1	823.09
30	826.10	826.88	827.27	826.88	825.74
35	827.80	829.66	830.08	829.66	828.42
40	829.20	832.44	832.88	832.44	831.12
45	832.00	835.22	835.67	835.22	833.85
50	833.60	838	838.46	838	836.61
55	834.80	840.78	841.23	840.78	839.40
60	837.80	843.56	843.99	843.56	842.21
65	840.60	846.34	846.75	846.34	845.06
70	842.80	849.12	849.50	849.12	847.93
75	848.60	851.9	852.23	851.9	850.83
80	851.60	854.68	854.96	854.68	853.76
85	855.20	857.46	857.68	857.46	856.72
90	858.60	860.24	860.40	860.24	859.71
95	861.00	863.02	863.10	863.02	862.74
100	865.80	865.8	865.79	865.8	865.8
RMSPD(%)		**0.3895**	**0.4213**	**0.3895**	**0.3025**

Table 5: Density using various models at 318K

Blend %	Expt. Value (Kg/m^3)	Calculated Values of Density using equations (Kg/m^3)			
		[1]	[2]	[3]	[4]
0	806.20	806.2	806.2	806.2	806.2
5	810.80	808.97	809.06	808.97	808.72
10	814.20	811.74	811.91	811.74	811.26
15	815.80	814.51	814.75	814.51	813.83
20	819.60	817.28	817.58	817.28	816.42
25	822.40	820.05	820.40	820.05	819.04
30	824.20	822.82	823.21	822.82	821.68
35	825.80	825.59	826.01	825.59	824.35
40	827.40	828.36	828.80	828.36	827.05
45	829.80	831.13	831.58	831.13	829.77
50	831.60	833.9	834.35	833.9	832.52
55	832.40	836.67	837.12	836.67	835.29
60	835.20	839.44	839.87	839.44	838.10
65	837.80	842.21	842.62	842.21	840.93
70	839.80	844.98	845.36	844.98	843.79
75	843.20	847.75	848.08	847.75	846.68
80	846.00	850.52	850.80	850.52	849.60
85	849.00	853.29	853.51	853.29	852.55
90	853.00	856.06	856.22	856.06	855.54
95	857.40	858.83	858.91	858.83	858.55
100	861.60	861.6	861.59	861.6	861.6
RMSPD(%)		**0.3545**	**0.3769**	**0.3545**	**0.3048**

Table 6: Density using various models at 323K

Blend %	Expt. Value (Kg/m^3)	Calculated Values of Density using equations (Kg/m^3)			
		[1]	[2]	[3]	[4]
0	803.60	803.6	803.6	803.6	803.6

5	808.20	806.35	806.4391	806.35	806.1031
10	812.40	809.1	809.2682	809.1	808.6296
15	813.80	811.85	812.0874	811.85	811.1801
20	816.00	814.6	814.8969	814.6	813.7549
25	819.60	817.35	817.6967	817.35	816.3544
30	821.80	820.1	820.487	820.1	818.9789
35	823.00	822.85	823.2679	822.85	821.6289
40	824.60	825.6	826.0393	825.6	824.3048
45	826.80	828.35	828.8015	828.35	827.007
50	829.60	831.1	831.5545	831.1	829.736
55	830.60	833.85	834.2985	833.85	832.4921
60	832.60	836.6	837.0334	836.6	835.2759
65	835.60	839.35	839.7595	839.35	838.0878
70	838.00	842.1	842.4767	842.1	840.9284
75	840.80	844.85	845.1852	844.85	843.7979
80	842.60	847.6	847.885	847.6	846.6971
85	846.80	850.35	850.5763	850.35	849.6264
90	849.60	853.1	853.259	853.1	852.5862
95	851.60	855.85	855.9334	855.85	855.5773
100	858.60	858.6	858.5994	858.6	858.6
RMSPD(%)		**0.3456**	**0.3656**	**0.3456**	**0.3046**

With the increase in temperature the Density of biodiesel-diesel blend decreases.

It is observed that maximum error in the models is 0.6185 %. It is very good accuracy for the predicting Density.

From the current experimental study, we have developed the correlation for the temperature and volume fraction of biodiesel to the Density. The correlation can be utilized to determine the Density of biodiesel at any temperature and any volume fraction of biodiesel mixture at any degree of blending.

The correlation for prediction of Density for binary biodiesel blend is [6]:

$$\ln D_m = 6.5817 - 0.0007 \times v_1 + \frac{36.008}{T} + \frac{0.4191 \times v_1}{T} - - - - - - - - (6)$$

D_m is the Density of blend
v_1 is the volume fraction of biodiesel,
T is absolute temperature.

Table 7: RMSPD for correlation as per equation (6)

Temperature, K	298	303	308	313	323
RMSPD (%)	**0.3527**	**0.2345**	**0.2535**	**0.2760**	**0.2778**

The accuracy of the prediction is evaluated and the error is calculated as Root Mean Square Prediction Difference (RMSPD). The maximum error registered was 0.3527%.

4.2 Calorific value:
Experimental values of calorific value at different volume fractions are presented in figure 2

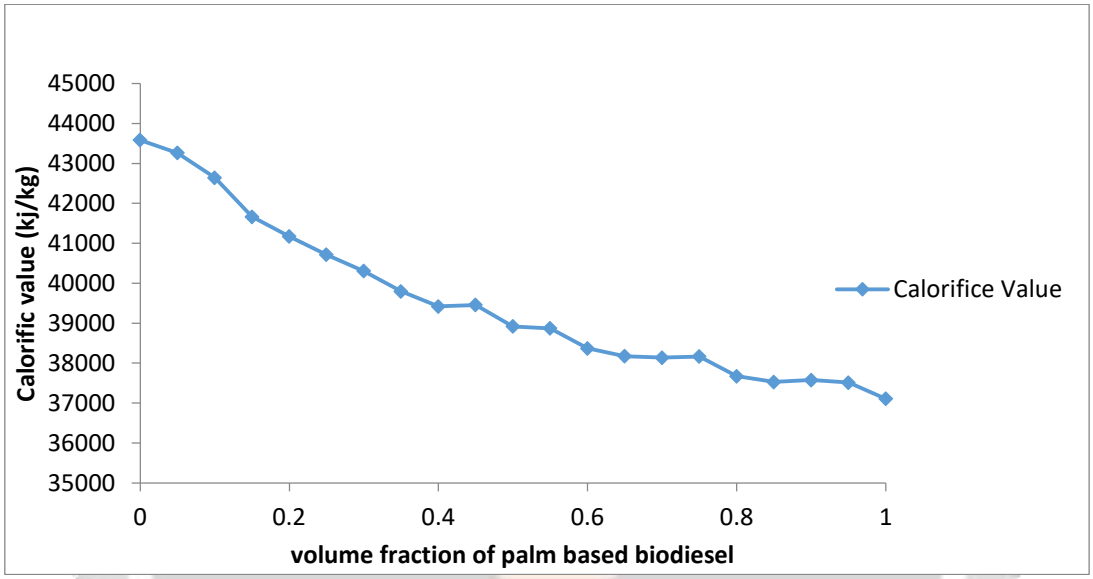

Fig- 2 Calorific value of different blends

The experimental values were utilized to verify the predictive capacity of models as presented in Table 8.

Table 8: Calorific value at various volume fractions

Blend %	**Expt. Value (KJ/kg)**	**Calculated Values of Calorific value using equations (KJ/kg)**			
		[1]	**[2]**	**[3]**	**[4]**
0	43584	43584	43584	43584	43584
5	43265	43260	43283	43260	43176
10	42642	42936	42980	42936	42779
15	41664	42612	42675	42612	42394
20	41171	42288	42368	42288	42018
25	40714	41964	42058	41964	41652
30	40304	41640	41746	41640	41296
35	39799	41317	41432	41317	40948

40	39420	40993	41115	40993	40609
45	39456	40669	40796	40669	40279
50	38918	40345	40475	40345	39956
55	38872	40021	40150	40021	39641
60	38371	39697	39823	39697	39333
65	38174	39373	39494	39373	39033
70	38137	39049	39162	39049	38739
75	38165	38725	38826	38725	38452
80	37671	38401	38488	38401	38171
85	37527	38077	38147	38077	37896
90	37576	37753	37803	37753	37627
95	37511	37429	37456	37429	37363
100	37105	37105	37105	37105	37105
RMSPD(%)		**2.4661**	**2.7312**	**2.5009**	**1.8113**

With the increase in blend ratio the calorific value of biodiesel-diesel blend is decreases.

It is observed that maximum error in the models is 2.7312 %. It is very good accuracy for the predicting Calorific value.

From the current experimental study we have developed the correlation for the volume fraction of biodiesel to the Calorific value. The correlation can be utilized to determine the Calorific value of biodiesel at any volume fraction of biodiesel mixture at any degree of blending.

The correlation for prediction of Calorific value for binary biodiesel blend is [7]:

$$C_v = 6199.3 \times v_i^2 - 12329 \times v_i + 43573 - - - - - - - - (7)$$

C_v is the Calorific value of blend
v_i is the volume fraction of biodiesel

using the equation (7) we predicted calorific value for different blends and for The accuracy of the prediction is evaluated and the error is calculated as Root Mean Square Prediction Difference (RMSPD). The error for predicted model is 0.4621%.

5. Conclusion

From the present study it was found that with increase in the volume fractions of biodiesel in the blends, the density of the blends increase and with increase in the temperature the density of the blends decrease. For the calorific value with increase in the volume fractions of biodiesel in the blends, the calorific value decrease. Also from the experimental data we developed correlation for prediction of the density of different blends at different temperatures and also we developed correlation for prediction of calorific value at different volume fractions and compared with literature correlation and measure the accuracy of correlation using RMSPD. These two properties are used to determine the optimum blend ratio for palm based biodiesel petro-diesel blends.

6. Acknowledgment

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