Journal of Multidisciplinary Engineering Science and Technology (JMEST)
ISSN: 2458-9403
Vol. 3 Issue 12, December - 2016

Predict The Physical And Chemical Properties Of Biodiesel Produced From Various Sources Using The Fatty Acid Profile

Mohammad Tohidipour
Department: Chemical Engineering
South Tehran Branch,
Islamic Azad University
Tehran, Iran
M.tohidipour@gmail.com

Feryal Nosratinia
Department: Chemical Engineering
South Tehran Branch,
Islamic Azad University
Tehran, Iran
F_Nosrati@azad.ac.ir

Mehdi Arjmand
Department: Chemical Engineering
South Tehran Branch,
Islamic Azad University
Tehran, Iran
M_arjmand@azad.ac.ir

***Abstract*—In this study, the relationship between the physical and chemical properties of biodiesel with its chemical composition was examined. For this purpose, biodiesel was produced from 10 animal and vegetable oils and fats sources (sunflower oil, soybean, olive, palm, waste, chicken fat, lamb fat, peanuts, corn and canola). Samples produced in the laboratory were tested for physical and chemical properties and their cetane number, cloud point and pour point were examined and fatty acid profile of these 10 types of biodiesel produced was determined by the GC device. Using the proposed models for the relationship between the chemical composition of biodiesel with physical and chemical properties, physical and chemical properties of biodiesels produced were estimated and compared with the laboratory data. The results of this study and comparison with experimental and laboratory results indicated that Su and Liu model have the best results in determining the cetane number, Su and Liu relationship for cold flow properties of biodiesel to pour point and Sarin et al relationship for cloud point provide more fairly accurate results. Also, the neural network modeling was used for other comparison that neural network model provided a good estimate.**

Keywords—Biodiesel, Physical and chemical properties, Modeling, Fatty acid profile, neural network

I. INTRODUCTION

Biodiesel is a renewable and biodegradable fuel which is obtained from vegetable oil or animal fat. This fuel can be blended with gasoline and to be used in gasoline-fueled cars. The positive results of using biodiesel in reducing air pollution has been confirmed by valid international organizations. Biodiesel is a clean fuel and diesel fuel alternative that this green fuel such as gasoline and oil, can be used in any combustion - compression engine. Biodiesel maintains gasoline's capacity and scope of work. The growth of plants containing oil is associated with carbon dioxide. Therefore, biodiesel has a carbon wheel package that dramatically reduces carbon dioxide [1].

Physical and chemical properties of biodiesel are important in determining its characteristics and providing relevant models. In previous works, the sheer volume of studies is devoted to designing and producing biodiesel from various sources, but there are fewer laboratory data on the forecast of physicochemical characteristics of this fuel, and usually validity of the presented models has been measured with a limited number of data.

The parameters examined in this study include cetane number, cloud point and pour point that the produced samples were tested in the laboratory of physical and chemical properties and fatty acid profile of these 10 types of biodiesel produced was determined by the GC device. Details related to each of these parameters are discussed below.

II. BIODIESEL SYNTHESIS

In this study, the method of transesterification with alkaline catalysts which is most common and most commercial biodiesel production method was used. This process is similar to the hydrolysis process, with the difference that alcohol is replaced instead of water. For this purpose, molecules of oil or fat composition participates with an alcohol such as methanol or ethanol in the presence of a catalyst and hydrocarbon chain in the oil is replaced by OH alcohol. As a result, esters with new molecular structure called methyl or ethyl esters fatty acids is produced which has a great similarity with diesel [2].

III. TRANSESTERIFICATION REACTION AND THE PRODUCTION OF BIODIESEL

In the transesterification reaction, an alcohol (methyl / ethyl alcohol) reacts with oil and produces (methyl / ethyl ester) biodiesel. After reaction, two liquid phases are produced, one methyl / ethyl ester and the other glycerin that the two phases can be separated by density difference. For the main reaction

and biodiesel production, after the preparation of the oil, first methoxide solution (solution containing the catalyst and methanol) should be prepared. For this purpose, solid potassium hydroxide was dissolved in methanol; cetane number was measured by Cetan-IM manufacturing Co. Metrics (Russia) according to ASTM D-613 standards.

IV. Cetane number

Cetane number (CN) is an attribute of fuel combustion quality. Since biodiesel is mainly composed of long-chain hydrocarbons (without plugs or aromatic structures), it usually has a higher cetane number than diesel and increase the amount of mixing (level B) increases cetane number of the mixture.

Biodiesel derived from materials with a high content of saturated fatty acids (such as bovine fat and palm oil) have higher cetane number compared to fuel produced from less saturated materials (such as soybean oil and canola oil). The effect of cetane number of alcohol branches used in the production is very low. Cetane number of pure FAME increases with chain length, but when complex mixtures FAME is investigated, the effect faded. FAME cetane number varies with the amount of unsaturated. Increasing the amount of unsaturated follows the increase of cetane number. There is no significant relationship between cetane number with cetane index (CI) and also CI and the amount of unsaturated with iodine value (IV). These observations suggest that CI values reported in previous studies were unreliable and highlighted the problem of lack of a suitable method for calculating CI [3].

V. Prediction method of cetane number of biodiesel

Assuming the existence of linear dependence between chain length and cetane number of fatty acids and considering the effect of double bonds, a relationship including three factors has been presented: 1- methyl-octane cetane number index (shortest ester chains in the study) 2- development of cetane number index that fatty acid esters chain increases by two carbon atoms 3- development of cetane number index due to the presence of a double bond in the molecule. Establishing connection between these factors and laboratory data, an equation to estimate the FAME cetane number using the number of carbon atoms and double bonds was presented as follows:

$$CN_{FAME} = 58.1 + 2.8\left(\frac{n_{c,i}-8}{2}\right) - 15.9n_{DB,i} \quad (1)$$

$$CN_{BDF} = \sum_i x_i CN_{FAME,i} \quad (2)$$

Which $n_{c,i}$ the number of carbon atoms, nDB,i the number of double bonds in the fatty acid chain but i , X_i mole fraction of $FAME_i$-th, $CN_{FAME,i}$ cetane number of pure $FAME_i$ -th existing in biodiesel and CN_{BDF} is the cetane number of biodiesel.

Similarly in another study, to estimate the cetane number, the law of ideal mixing with a cetane number of pure FAME including methyl palmitate [C 16: 0], methyl Asytrat [C 18: 0], methyl oleate [C 18: 0] and methyl linoleate [C 18: 2] and the weight fraction as a weighting function have been used [4].

$$CN_{BDF} = \sum_i x_{wi} CN_{FAME,i} \quad (3)$$

That in this relation X_{wi} and N_{FAME} respectively are defined weight fraction and cetane number of pure FAME.

Gopinath to estimate the cetane number of FAME achieved an important relation. By studying the previous methods, they found that these methods can be used only for separate FAMEs. To improve the forecasting the FAME mixed cetane number, they proposed multiple linear regression model based on the weight percent of some fatty acids in biodiesel [5].

$$CN_{BDF} = 62.2 + (0.017L) + (0.074M) + (0.115P) + (0.177S) - (0.103O) - (0.279LI) - (0.366LL) \quad (4)$$

That in the above equation, L weight percent of lauric acid, M weight percent of myristic acid, P weight percent of palmitic acid, S weight percent of stearic acid, O weight percent of oleic acid, LI weight percent of linoic acid and LL is weight percent acid and linoleic acid.

Ramirez also provided a semi-empirical relation to estimate the cetane number of each fatty acid and reported the average relative deviation (ARD %) 95.5 percent for it [6]

$$\varphi_i = 7.8 + 0.302M_i - 20N \quad (5)$$

φ_i cetane number of methyl ester, M_i molar weight of methyl ester i and N is the number of double bonds of methyl ester. Similar to viscosity prediction method and according to simplicity of Chang method and modifying the parameters of the model considering the laboratory data, Su and Liu developed following equation to estimate the cetane number of biodiesel rather than pure FAMEs based on the weighted average number of carbon atoms N_C, and the weighted average number of double bonds N_{DB}.

$$CN_{BDF} = 3.930N_C - 15.936N_{DB} \quad (6)$$

VI. Cloud point

First, temperature of the test samples was come to at least 14 degrees Celsius higher than the potential cloud point i.e. 20 ° C. Transparent test samples inside the test container were poured up to place of the mark. Span of test container was tightly closed by cork in which thermometer is located.

VII. Pour point

Pour point test was performed with the same device measuring the cloud point by ASTM D-97 standard. In order to obtain a profile of fatty acids in raw oil and biodiesel synthesized, gas chromatography (GC), Claus GC model Manufacturing Co. Perkin-

Elmer (America) in Bioenergy Research Center of Tarbiat Modarres University was used. To determine percent conversion of methyl esters and the weight percent of fatty acids, respectively, the following formula were used:

$$(\%C) = \frac{\sum A_I - A_{IS}}{A_I} \times \frac{C_{IS} \times V_{IS}}{m} \quad (7)$$

$$C_i = \frac{A_I}{\sum A} \times 100 \quad (8)$$

In the above equations, C , conversion percentage of methyl esters produced (%), $\sum A$ the total area under the peaks ($\mu V.s$), A_{IS} the area under the peak related to internal standard ($\mu V.s$), C_{IS} concentration of internal standard solution (mg/ml) , C_i the fatty acid weight percent (%), A is the area under peak related to fatty acids.

VIII. Results

In this section, experimental results including fatty acid profile, cetane number, cloud point and pour point as well as conversion percentage of methyl esters on biodiesels synthesized with plant and animal origin will be reported and examined and then predictive relations and models of some properties can be expressed.

Conversion percentage of methyl ester of sunflower oil, soybean, canola, olive, waste oil, corn oil, peanut oil, palm oil, chicken fat and lamb fat is shown in Figure 1. The highest percentage of conversion is related to soybean oil by 95.84% and the lowest at 81.22% is owned by waste oil. Low percentage of waste oil conversion rate is probably due to the presence of water, moisture and impurities in the raw oil. It should be also considered that kitchen cooking oil is produced from different vegetable oils and often a mixture of oils. Looking at the chart, we see that vegetable oils have a higher conversion rate than animal fats.

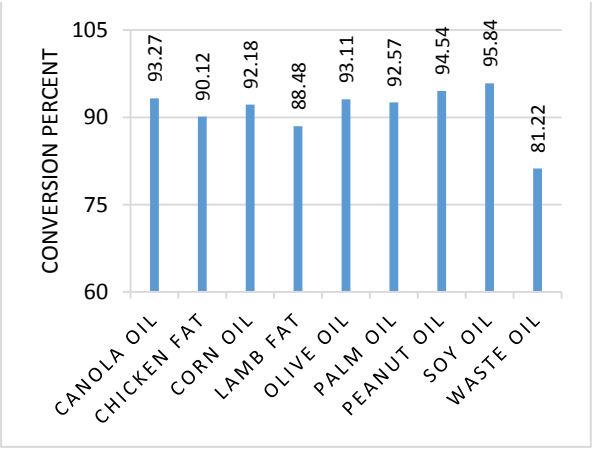

Fig. 1. *conversion percentage of plant and animal oils into methyl ester*

Composition and frequency percentage of fatty acids in biodiesel from oils and fats, along with the advent of each are shown in the Tables. In the case of sunflower, the first compound in 16.05 minutes with 6.73 frequency percentage is related to the palmitic acid (C16: 0). The highest frequency percentage dedicates to linoleic acid (C18: 2) with 58.85 percent and the lowest frequency percentage to C20: 0 with 0.29, and the first composition for soybean oil in 16.05 minutes with frequency percentage 10.13 is related to palmitic acid (C16: 0). The highest frequency percentage dedicates to linoleic acid (C18: 2) with 55.12 percent and the lowest frequency percentage to C20: 1 with 0.23. The first composition for rapeseed oil in 16.04 minutes with frequency percentage 3.95 is related to palmitic acid (C16: 0); the highest frequency percentage dedicates to oleic acid (C18: 1) with 66.14 percent and the lowest frequency percentage to C16: 1 with 0.14. The first composition in olive oil in 16.06 minutes and frequency percentage 12.98 is related to palmitic acid (C16: 0); the highest frequency percentage allocates to oleic acid (C18: 1) with 67.64 percent and the lowest frequency percentage to C22: 1 with 0.26.

Also similar cases were examined about the chicken fat and results showed that the first composition in 14.08 minutes with a frequency percentage 0.41 is related to mysteric acid (C14: 0); the highest frequency percentage allocates to oleic acid (C18: 1) with 46.55 percent and the lowest frequency percentage to C17: 0 with 0.07. The results about the lamb fat showed that the first composition in 9.52 minutes with frequency percentage 0.09 is related to caprylic acid (C8: 0); the highest frequency percentage dedicates to oleic acid (C18: 1) with 39.92 percent and the lowest frequency percentage to C12: 0 with 0.07.

Table 1. Fatty acid profile of biodiesel produced from sunflower oil

Fatty acid	%Wt	Time(min)
Palmitic acid 16:0	6.73	16:05
Stearic acid C18:0	3.40	18:06
Oleic acid C18:1	29.51	18:28
Linoleic acid C18:2	58.85	18:32
Linolenic acid C18:3	0.61	18:56
Arachidic acid C20:0	0.29	19:43
Behenic acid C22:0	0.61	20:23
Total	100	

Table 2. fatty acid profile of biodiesel produced from soybean oil

Fatty acid	% Wt	Time (min)
Palmitic acid C16:0	10.13	16:05
Stearic acid C18:0	3.25	18:02
Oleic acid C18:1	21.22	18:22
Linoleic acid C18:2	55.12	18:55
Linolenic acid C18:3	9.11	19:14
Arachidic acid C20:0	0.33	19:31
Gondoic acid C20:1	0.23	20:48
Behenic acid C22:0	0.28	22:02
Erocic acidC22:1	0.33	22:53
Total	100	

Table 3. fatty acid profile of biodiesel produced from olive oil

Fatty acid	% Wt	Time (min)
Palmitic acid C16:0	12.98	16:06
Palmitoleic acid C16:1	0.91	16:27
Stearic acid C18:0	2.59	18:08
Oleic acid C18:1	67.64	18:35
Linoleic acid C18:2	13.47	18:57
Linolenic acid C18:3	0.89	19:40
Arachidic acid C20:0	0.58	20:24
Erocic acid C22:1	0.26	20:47
Lignoceric acid C24:0	0.68	25:53
Total	100	

Table 4. biodiesel produced from rapeseed oil fatty acid profile

Fatty acid	% Wt	Time (min)
Palmitic acid C16:0	3.95	16:04
Palmitoleic acid C16:1	0.14	16:26
Stearic acid C18:0	2.17	18:09
Oleic acid C18:1	66.14	18:30
Linoleic acid C18:2	18.57	18:59
Linolenic acid C18:3	6.19	19:41
Arachidic acid C20:0	0.74	20:20
Gondoic acid C20:1	1.23	20:45
Behenic acid C22:0	0.29	22:51
Erocic acid C22:1	0.58	23:19
Total	100	

Composition and frequency percentage of fatty acids in biodiesel from corn oil with the advent of each are shown in the Table below. The first composition in 9.54 minutes at a frequency percentage 0.04 is related to caprylic acid (C8: 0); the highest frequency percentage dedicates to linoleic acid (C18: 2) with 45.32 percent and lowest frequency percentage to C8: 0 with 0.04. And for peanuts, the first compound in minutes 9.05 with frequency percentage 0.02 is related to caprylic acid (C8: 0); the highest frequency percentage dedicates to oleic acid (C18: 1) with 57.18 percent and lowest frequency percentage to C8: 0 with 0.02. In the case of palm oil, the first composition in 15.12 minutes with a frequency percentage 10.21 is related to palmitic acid (C16: 0); the highest frequency percentage dedicates to oleic acid (C18: 1) with 55.12 percent and the lowest frequency percentage to C22: 0 with 0.10. And for waste oil, the first composition in 14.28 minutes with a frequency percentage 0.1 is related to palmitic acid (C14: 0); the highest frequency percentage dedicates to linoleic acid (C18: 2) with 33.38 percent and the lowest frequency percentage to C14: 0 with 0.10.

Table 5. fatty acid profile of biodiesel produced from lamb fat

Fatty acid	% Wt	Time (min)
Caprylic acid C8:0	0.09	9:52
Capric acid C10:0	0.14	10:20
Lauric acid C12:0	0.07	12:38
Myristic acid C14:0	3.14	14:11
Myristoleic acid C14:1	1.18	14:45
Pentadecanoic acid C15:0	1.22	15:07
Palmitic acid C16:0	21.48	16:07
Palmitoleic acid C16:1	3.48	16:25
Heptadecanoate acid C17:0	1.27	16:45
Stearic acid C18:0	14.04	18:07
Oleic acid C18:1	39.92	18:35
Linoleic acid C18:2	2.12	18:57
Linolenic acid C18:3	0.58	19:45
Arachidic acid C20:0	0.41	19:59
Behenic acid C22:0	0.45	23:35
Unknown	10.41	-
Total	100	

Table 6. fatty acid profile of biodiesel produced from chicken fat

Fatty acid	% Wt	Time (min)
Myristic acid C14:0	0.41	14:08
Myristoleic acid C14:1	0.12	14:45
Palmitic acid C16:0	26.01	16:02
Palmitoleic acid C16:1	6.33	16:28
Heptadecanoate acid C17:0	0.07	16:58
Stearic acid C18:0	6.59	18:05
Oleic acid C18:1	46.55	18:30
Linoleic acid C18:2	12.61	18:57
Linolenic acid C18:3	0.42	19:43
Arachidic acid C20:0	0.39	20:47
Unknown	0.50	-
Total	100	

Table 7. fatty acid profile of biodiesel produced from corn oil

Fatty acid	% Wt	Time (min)
Caprylic acid C8:0	0.04	9:54
Capric acid C10:0	1.02	10:15
Lauric acid C12:0	0.05	11:48
Myristic acid C14:0	0.26	12:50
Myristoleic acid C14:1	1.54	14:02
Pentadecanoic acid C15:0	0.56	14:38
Palmitic acid C16:0	17.54	16:01
Palmitoleic acid C16:1	1.16	16:28
Heptadecanoate acid C17:0	0.45	16:49
Stearic acid C18:0	2.53	17:52
Oleic acid C18:1	25.12	18:08
Linoleic acid C18:2	45.32	18:41
Linolenic acid C18:3	3.18	18:58
Arachidic acidC20:0	1.03	21:01
Behenic acid C22:0	0.20	22:46
Total	100	

Table 8. The fatty acid profile of biodiesel produced from peanut butter

Fatty acid	% Wt	Time (min)
Caprylic acid C8:0	0.02	9:05
Capric acid C10:0	0.78	10:15
Lauric acid C12:0	0.04	11:48
Myristic acid C14:0	0.80	12:50

Myristoleic acid C14:1	0.07	14:02
Pentadecanoic acid C15:0	0.21	14:38
Palmitic acid C16:0	9.05	16:01
Palmitoleic acid C16:1	2.54	16:28
Heptadecanoate acid C17:0	0.32	16:49
Stearic acid C18:0	2.10	17:52
Oleic acid C18:1	57.18	18:08
Linoleic acid C18:2	25.67	18:41
Linolenic acid C18:3	0.25	18:58
Arachidic acid C20:0	0.85	21:01
Behenic acid C22:0	0.12	22:46
Total	100	

Table 9. fatty acid profile of biodiesel produced from palm oil

Fatty acid	% Wt	Time (min)
Palmitic acid C16:0	10.21	15:12
Palmitoleic acid C16:1	1.50	16:21
Heptadecanoate acid C17:0	1.27	16:54
Stearic acid C18:0	6.41	17:32
Oleic acid C18:1	55.12	18:32
Linoleic acid C18:2	23.87	18:50
Linolenic acid C18:3	0.41	19:06
Arachidic acid C20:0	1.11	19:48
Behenic acid C22:0	0.10	21:01
Total	100	

Table 10: Biodiesel produced from waste vegetable oil fatty acid profile

Fatty acid	% Wt	Time (min)
Myristic acid C14:0	0.1	14:28
Palmitic acid C16:0	21.0	16:24
Stearic acid C18:0	3.70	18:27
Oleic acid C18:1	32.05	18:29
Linoleic acid C18:2	33.38	18:49
Linolenic acid C18:3	2.20	19:58
Arachidic acid C20:0	0.22	20:50
Behenic acid C22:0	2.25	23:57
Lignoceric acid C24:0	4.22	27:24
Nervonic acid C24:1	0.8	28:29
Total	100	

The measurement results of cetane number and the cloud point and pour point for 10 samples of biodiesel produced from different oils in accordance with ASTM D613 standard have been reported in Tables 11 and 12. The results show that the highest amount is related to palm oil and sunflower oil is the lowest.

Table 11. The test results for 10 samples cetane number of biodiesel produced from various oils

Sample Name	**Cetane Number**
Sunflower oil	49
soybean oil	50
Canola oil	53
olive oil	52
Chicken fat	50
lamb fat	50
corn oil	51
Peanut oil	54
Palm oil	66
Waste oil	51

Table 12. cloud point and pour point test results for 10 different samples of biodiesel produced from oil

Sample Name	Cloud Point °C	Pour Point °C
Sunflower oil	+6	-2
soybean oil	+8	-3
Canola oil	+8	-3
olive oil	+5	-2
Chicken fat	+8	-3
lamb fat	+9	-1
corn oil	+7	-2
Peanut oil	+5	-3
Palm oil	+7	-2
Waste oil	+4	-4

Oher studies have been done on determining the cold flow properties of biodiesel. The relationships that have linked cold flow properties of biodiesel to methyl esters of free fatty acids can be defined as follows:

$CP=-0.576(U_{FAME}) + 48.255 \quad (0<U_{FAME} \leq 84)$ (9)

$PP= -0.626(U_{FAME}) + 45.594 \quad (0<U_{FAME} \leq 84)$ (10)

$CFPP=-0.561(U_{FAME}) +43.967 \quad (0<U_{FAME} \leq 84)$ (11)

With regard to above relations and also using the obtained data, Table 13 and 14 was prepared which shows a comparison of the results obtained from experimental data and theoretical relations with the help of average relative deviation (ARD %). To assess the relations provided, the average relative deviation (ARD %) was used which is calculated and reported in accordance with the following formula:

$$ARD\% = \frac{\sum_i^n |x_{experimental,i} - x_{theoretical,i}|}{x_{experimental,i}} \times \frac{100}{N} \quad (12)$$

Table 13. Results of the relationship between theory and laboratory data to pour point of biodiesel

Sample name	Laboratory data	Su and Liu model	Sarin et al. Model
	Pour point	*Pour point*	*Pour point*
Sunflower oil	-2	-2.55	-2.28
soybean oil	-3	-2.37	-2.27
Canola oil	-3	-2.76	-2.28
olive oil	-2	-2.18	-2.27
Chicken fat	-3	-1.47	-2.27
lamb fat	-1	-0.92	-2.27
corn oil	-2	-2.08	-2.27
Peanut oil	-3	-2.63	-2.27
Palm oil	-2	-1.96	-2.27
Waste oil	-4	-0.38	-2.27
AARD%		23.28	32.27

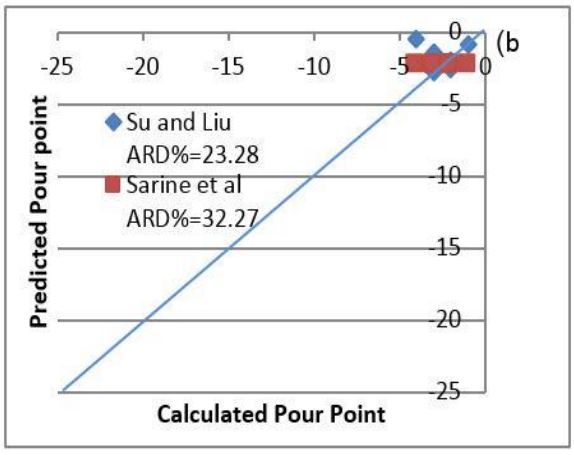

Figure 2. Pour point Su and Liu model and also Sarin et al model

Table 14. Results of the relationship between theory and laboratory data to pour point of biodiesel

Sample name	Laboratory data	Su and Liu model	Sarin et al. Model
	Cloud Point	*Cloud Point*	*Cloud Point*
Sunflower oil	6	5.14	4.82
soybean oil	8	5.03	4.78
Canola oil	8	5.32	4.77
olive oil	5	4.94	4.78
Chicken fat	8	3.97	4.79
lamb fat	9	0.63	4.80
corn oil	7	4.38	4.78
Peanut oil	5	4.75	4.78
Palm oil	7	4.93	4.78
Waste oil	4	5.26	4.79
AARD%		33.26	27.90

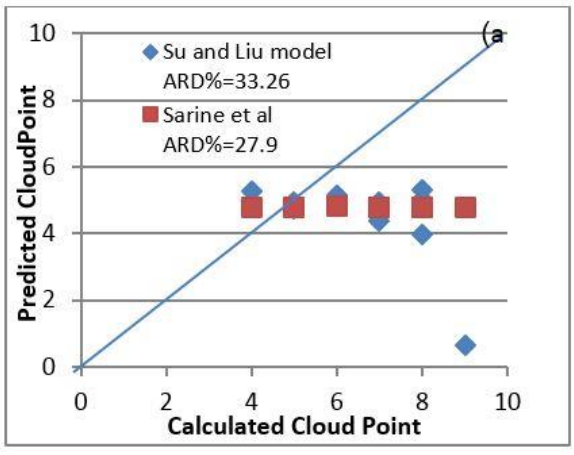

Figure 3. Cloud point Su and Liu model and also Sarin et al model

In the case of cetane number, Kelp Feinstein (1982) provided an equation to estimate the cetane number of FAME using the number of carbon atoms and double bonds by establishing relationship between three factors cetane number index of methyl octane (the shortest ester chains), development of cetane number index that the fatty acid ester chain increases by two carbon atoms, and development of cetane number index due to the presence of a double bond in the molecule and laboratory data.

$$CN_{FAME}=58.1+2.8(\frac{n_{c,i}-8}{2})-15.9n_{DB,i} \quad (13)$$

$$CN_{BDF}=\sum_i x_i\ CN_{FAME,I} \quad (14)$$

Which nc,i the number of carbon atoms, nDB,i the number of double bonds in the fatty acid chain but i, Xi mole fraction of $FAME_i$ -th, $CN_{FAME,i}$ cetane number of pure $FAME_i$ -th existing in biodiesel and CN_{BDF} is the cetane number of biodiesel.

According to simplicity of Chang method and modifying the parameters of the model considering the laboratory data, Su and Liu developed following equation to estimate the cetane number of biodiesel rather than pure FAMEs based on the weighted average number of carbon atoms N_C, and the weighted average number of double bonds N_{DB}.

$$CN_{BDF}=3.930N_C-15.936N_{DB} \quad (15)$$

Using the law of ideal mixing with a cetane number of each pure FAME including methyl palmitate [C 16: 0], methyl Asytrat [C 18: 0], methyl oleate [C 18: 0] and methyl linoleate [C 18: 2] and the weight fraction as a weighting function, Clement (1996) offered the following relation:

$$CN_{BDF}=\sum_i x_{wi}\ CN_{FAME,I} \quad (16)$$

Which in this equation, X_{wi} and N_{FAME} are respectively defined as weight fraction and cetane number of pure FAME.

Chang and Liu (2010) in their study presented a linear relationship based on the weighted average of the number of carbon atoms and the number of double bonds of the methyl ester as following equation.

$$CN_{FAME}= 4.201\ Nc-20.077N_{DB}+2.005 \quad (17)$$

That in this relation, CN_{FAME} methyl ester cetane number, N_C number of methyl ester carbon atoms and N_{DB} the number of methyl ester double bonds are defined.

Given the above and models presented, a comparison between the results of experimental data and theoretical models have been proposed in Table 15. As can be seen, Su and Liu model has the lowest deviation from experimental data, and then the Clement' model is in the second rank and eventually, Chang and Liu model had the greatest deviation. In Figure 4-6 , correlation graphs of these data are plotted.

Table 14. Results of the relationship between theory and empirical data for cetane number of biodiesel

Sample Name	Lab. data	Clement model	Sue and Liu Model	Zhang and Liu Model
Sunflower oil	49	48.26	46.58	47.26
soybean oil	50	46.53	44.69	44.93
Canola oil	53	52.41	50.98	52.74
olive oil	52	56.15	54.21	56.96
Chicken fat	50	58.41	55.12	58.51
lamb fat	50	60.43	52.49	56.58
corn oil	51	43.80	41.05	40.61
Peanut oil	54	53.86	51.65	53.81
Palm oil	66	55.00	53.05	55.50
waste oil	51	55.12	53.65	56.12
ARD%		9.43	8.75	10.06

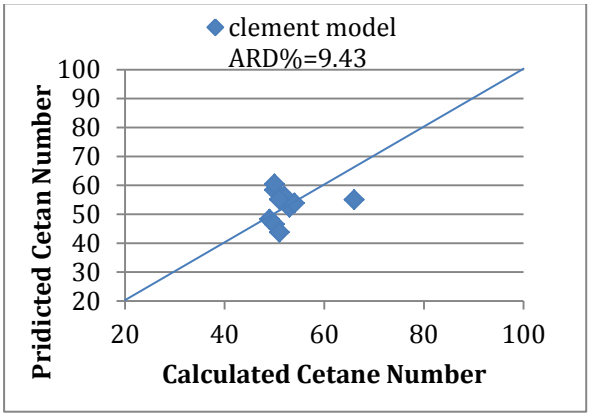

Figure 4. Cetane number calculated with experimental data using Clement model

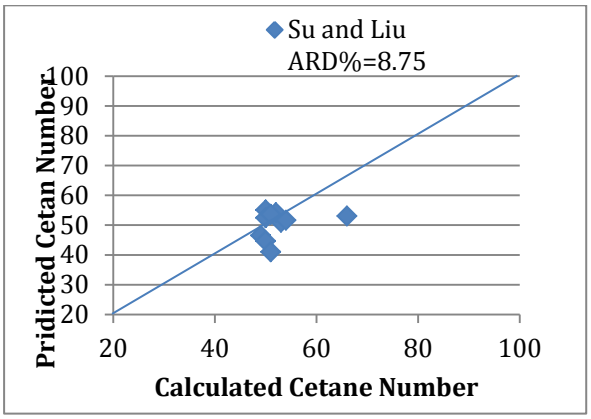

Figure 5. Cetane number calculated with experimental data using Su and Liu model

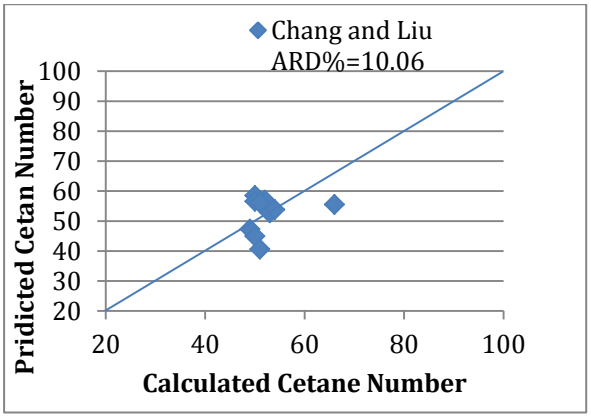

Figure 6. Cetane number calculated with experimental data using Chang and Liu model

IX. NEURAL NETWORK MODELING

Figure 7 shows neural network modeling results for experimental data of this study using the experimental data of other researchers (7-10) for cloud point. In this model which its code is written with MATLAB software, the model was compared with the data of other researchers and has been verified with the data of this research and the results show that the model error is R = 0.963.

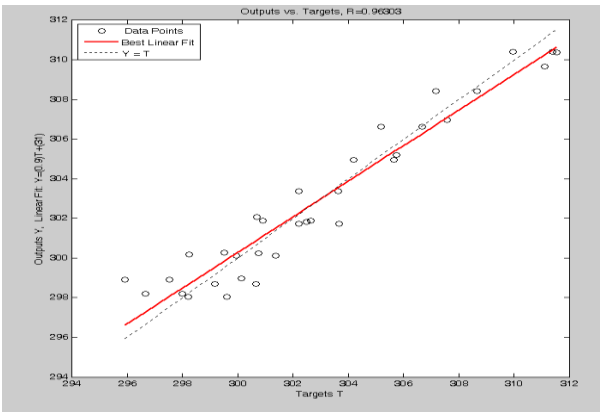

Figure 7: Graph Y = T to compare the output data of neural network model and experimental data with the model error for cloud point

Also Figure 8 shows neural network modeling results for experimental data of this study compared to

the experimental data of other researchers (54) for cetane number that the model error is R = 0.901.

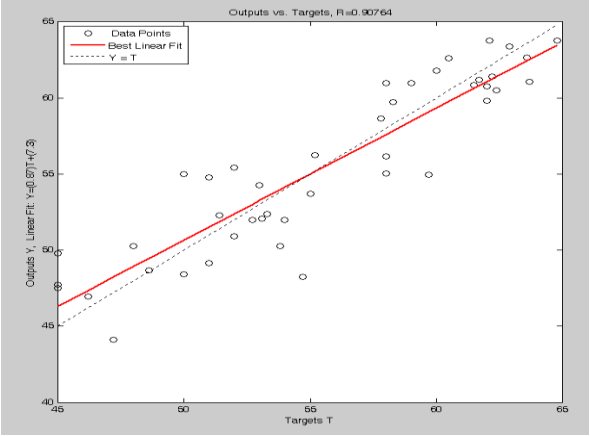

Figure 8: Graph Y = T to compare the output data of neural network model and experimental data for cetane number

As well as, Figure 9 shows page graph of fatty acids and cetane number of neural network model:

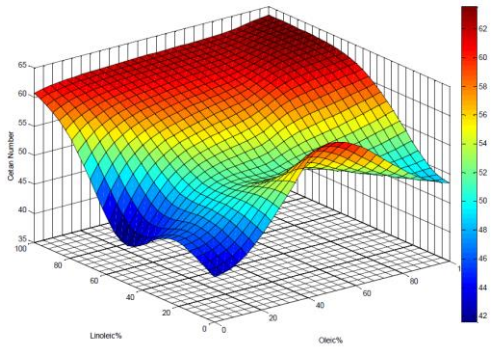

Figure 9. Page graph of fatty acids and cetane number of neural network model

The model input is weight percent of oleic and linoleic acids, and its output is cetane number. The reason for using the acids as model input is that major weight fraction of acids constituting biodiesel are these two types of fatty acids.

X. Conclusion

Designers of biodiesel production processes require to identify and measure biodiesel components properties or a mixture of them and on the other hand, cost of laboratory measurements are sometimes very high. Therefore, methods of forecasting and estimating the properties can be a good alternative to laboratory measurements. This research attempted to examine the relationships and theoretical models available in the scientific literature, in addition to report of experimental data obtained from 10 types of biodiesel produced from plant and animal different sources (including sunflower oil, soybean, canola, olive, waste oil, corn oil, peanut oil, palm oil, chicken fat and lamb fat), and it to be compared with experimental data obtained. In this regard, it can be concluded that efficiency of methyl esters production was greater in the production of biodiesel from vegetable oils, because these oils compared to animal and waste oils have a better quality in terms of the amount of free fatty acids and water and other impurities and thus, the efficiency of biodiesel production is higher than of them. By examining the various theoretical models to predict the biodiesel properties, it was found that Su and Liu model have the best results in determining the cetane number, Su and Liu relationship for cold flow properties of biodiesel to pour point, and Sarin et al relationship for cloud point provide more fairly accurate results.

XI. Refrences

[1] Atapour, Mehdi, and Hamid-Reza Kariminia. "Characterization and transesterification of Iranian bitter almond oil for biodiesel production." Applied Energy 88, no. 7 (2011): 2377-2381.

[2] Alptekin, Ertan, and Mustafa Canakci. "Determination of the density and the viscosities of biodiesel–diesel fuel blends." Renewable Energy 33, no. 12 (2008): 2623-2630.

[3] Klopefenstein, W. E. (1982). "Estimation of Cetane Index for Esters of Fatty Acids." J. Am. Oil Chem. Soc 12(59): 531-533.

[4] Gopinath, A., S. Puhan, et al. (2009). "Relating the cetane number of biodiesel fuels to their fatty acid composition: a critical study." Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering 223(4): 565-583.

[5] Ceriani, Roberta, Cintia B. Gonçalves, Juliana Rabelo, Marcel Caruso, Ana CC Cunha, Flavio W. Cavaleri, Eduardo AC Batista, and Antonio JA Meirelles. "Group contribution model for predicting viscosity of fatty compounds." Journal of Chemical & Engineering Data 52, no. 3 (2007): 965-972.

[6] Vicente, G., M. Martınez, et al. (2004). "Integrated biodiesel production: a comparison of different homogeneous catalysts systems." Bioresource technology 92(3): 297-305.

[7] Movagharnejad, Kamyar, and Maryam Nikzad. "Modeling of tomato drying using artificial neural network." Computers and electronics in agriculture 59, no. 1 (2007): 78-85.

[8] Nazari, Ali Ghafari, and Masoud Mozafari. "Simulation of structural features on mechanochemical synthesis of Al2O3–TiB 2 nanocomposite by optimized artificial neural network." Advanced Powder Technology 23, no. 2 (2012): 220-227.

[9] Xu, Wei, Lingbo Zhang, and Xingsheng Gu. "Soft sensor for ammonia concentration at the ammonia converter outlet based on an improved particle swarm optimization and BP neural network." Chemical Engineering Research and Design 89, no. 10 (2011): 2102-2109.

[10] Khayet, M., and C. Cojocaru. "Artificial neural network modeling and optimization of desalination by air gap membrane distillation." Separation and Purification Technology 86 (2012): 171-182.