Advances in Bioresearch
Adv. Biores., Vol 7 (1) January 2016: 44-52
©2015 Society of Education, India
Print ISSN 0976-4585; Online ISSN 2277-1573
Journal's URL:http://www.soeagra.com/abr.html
CODEN: ABRDC3
ICV Value 8.21 [2014]

Advances in Bioresearch

ORIGINAL ARTICLE

Producing the Biodiesel by Combination of Olive Oil and Chicken Fat using Alkaline Catalysts

[1]Hossein Esmaeili, [2]Rauf Foroutan, [3]Mosayeb Zare Asl
[1]Faculty of Chemical Engineering, Islamic Azad University of Bushehr, Bushehr, Iran,
[2]Young Researchers and Elite Club, Bushehr Branch, Bushehr, Iran,
[3]Faculty of Engineering, Islamic Azad University, Iran
Email: esmaeili.hossein@gmail.com

ABSTRACT
With dwindling resources and rising global price of crude oil, the need for alternative fuels has been increasingly felt. One of the most important ones is biodiesel. Ethyl ester biodiesel is made out of vegetable oil, animal fat or renewable natural resources such as the herbal oils. In the current study, the combination of olive oil and chicken fat as the basic resource beside using a weight percentage of alkali catalyst (sodium hydroxide and potassium hydroxide), 60 min, molar ratio (1: 6) and using Trans-esterification process. In order to improve some properties of the produced biodiesel, it is landed with gasoline in different proportions (B25, B50, B75, and B100) and its properties such as flash point, kinematic viscosity, density, cloud point and distillation were analyzed and studied according to ASTM International D6751. According to the results, the properties of the produced biodiesel were in the standard range.
Keywords: *biodiesel, chicken fat, olive oil, alkali catalysts*

Received 10/09/2015 Accepted 19/11/2015

How to cite this article:
Hossein E, Rauf Foroutan, Mosayeb Zare A. Producing the Biodiesel by Combination of Olive Oil and Chicken Fat using Alkaline Catalysts. Adv. Biores., Vol 7 [1] January 2016: 44-52. DOI: 10.15515/abr.0976-4585.7.1.4452

INTRODUCTION

Following the oil crisis in 1970, some research was conducted on the alternative fuels for internal-combustion engines. These fuels were renewable, more accessible, and cleaner than fossil fuels [1]. Biodiesel is an alternative fuel which is produced from vegetable oils or animal fat [2]. Vegetable oil or animal fat including edible and inedible oils can be used for producing biodiesel. The biodiesel can also be made by raw materials. The raw materials can be vegetable oils such as soybean, cottonseed, coconut, palm, safflower, sunflower, castor oil and other vegetable oils, animal fat and waste edible oils [3]. Long-term production of biodiesel from crude edible oils may raise concerns [4], since these materials are consumed as food and long-term use of them may reduce the food resources for the world's population. Thus, the inedible oils resources have grabbed a great attention worldwide due to higher accessibility and not being used as food resources [4]. The waste edible oils, waste edible palm oil, animal oils such as chicken fat, duck fat, sheep and cow fat, and goat fat can be named among the inedible oils. The production of biodiesel from the raw oil increases the costs and prices of this fuel compared to oil-based fuel, since in case the edible oils are used for biodiesel production, 70-95% of the total cost and price of biodiesel is spent for the oil and base resources [13-15]. Thus, the inedible and waste oils are used to reduce the costs of biodiesel production.

There are several ways for producing biodiesel from vegetable oils and animal fat among which pyrolysis, dilution, micro-emulsion and trans-esterification process can be noted [16]. Biodiesel is mainly produced from raw oil materials through trans-esterification. The trans-esterification is a chemical reaction between the vegetable oils (mainly including triglyceride) and a short-chain alcohol (ethanol, methanol or propanol) and the biodiesel and glycerol are produced though the glycerol is a by-product [17]. Trans-esterification process is mainly accomplished with catalysts. Among the catalysts which are used in the trans-esterification process, homogeneous catalysts (alkali, acid and enzymes) and heterogeneous can be

named. In production of biodiesel through trans-esterification process, mainly the alkaline catalysts such as sodium and potassium hydroxide are used [18-20], since alkali catalyst are more efficient than other catalysts [21] and also they react at low temperatures and atmospheric pressure and have a higher yield in shorter times of reaction [22]. The alkali catalysts are used for oil resources with free fatty acids between 0.1% to 0.5% since if the amount of free fatty acids are higher than this amount, the soap will be produced as a result of trans-esterification process with alkali catalysts and the efficiency will be low. Also, the purification of the produced biodiesel in the process becomes more difficult. When the fatty acids of the used oil for producing the biodiesel are high (3.5-40%), other technologies should be used [23-24]. One of these technologies is usage of acid catalysts. Production of biodiesel with acid catalysts requires more time for reaction and thus it is not cost-efficient and they cannot compete with alkali catalysts for production of biodiesel on an industrial scale. For production of biodiesel from the oils with fatty acids higher than 0.5%, the reaction usually takes place at two stages. For the first stage, the acid catalysts are utilized and the reaction of the oil with the acid catalyst reduce the oil's free fatty acids and then at the second stage the combination of oil and produced ester with the presence of alkali catalysts is changed into biodiesel through tans-esterification process. This technology has been investigated several times and has proved to be efficient [25-26]. In addition to the composition of the used oil , other parameters such as the ratio of alcohol (methanol or ethanol) to oil, the temperature of reaction, the time of reaction, amount and the type of catalyst, the speed of blending the solution, purification process and washing the biodiesel are effective on production of biodiesel. After producing the biodiesel, it is combined with gasoline in different ratios in order to improve its properties [27-28].
In the current study, the chicken fat and olive oil were combined and treated by alkali catalysts such as potassium methoxide and potassium hydroxide for producing the biodiesel. Then, the produced biodiesel was combined with gasoline in different ratios and its properties such as Flash point, temperature of distillation point, density, and viscosity were determined and compared to those of gasoline.

MATERIAL AND METHODS

The Materials

In the current study, in order to investigate the feasibility of producing biodiesel from olive oil and chicken fat, firstly an amount of chicken fat was collected from Bushehr City's slaughterhouses and the olive oil was bought from the city shops. The alcohol used in the current study was methanol ($CH_3(OH)$) Which was purchased from Merck Company, Germany with a purity of 99.9 percent. The catalysts used in this study were potassium hydroxide (KOH), sodium hydroxide (NaOH)), and sodium sulfate (Na2SO4) which were all purchased from Merck Company.

The Extraction of Oil from Chicken Fat

Firstly, one kilogram of chicken fat was put inside a pot and it was heated and then one glass of water was added to it and regarding that a large proportion of chicken fat tissue is water and this water leads to reaction decomposition. The fats' temperature was raised to 100 °C and they were kept at this temperature until the water inside them evaporated. Then they were heated for another 7 hours until they were melted and the water inside the obtained oil entirely evaporated. Afterward, the obtained oil was passed through a filter in order to separate the unwanted objects from the oil as much as possible. After 24 hours, the water due to its higher density, was completely separated from the oil and it was collected at the bottom of the container.

Determination of the Composition of Olive Oil and Chicken Fat Fatty Acids and their Analysis

The composition of the fatty acids of the obtained oils was determined by Gas Chromatography (GC) device. The GC device model Varian cp-3800 which was equipped with FID detector and capillary column with a length of 30 meters was equipped with the following program for investigation of fatty acids. Helium was used as the carrier gas. Nitrogen gas flow (as Makeup), hydrogen and air were set 30 and 300 ml per minute, respectively. Required standards and necessary chemicals were purchased from Merck Germany. Firstly, the column's temperature was raised from 150° C to 220° C after 60seconds and it reached the speed of 10° per minute and remained in that condition for 2 minutes. Then, in the speed of 77°, its temperature was raised 235°C and it was kept at this temperature for 2 minutes. Afterward, with the same speed, the temperature was decreased to 225° C and remained for 1 minute, and finally with the speed of 10° per minute, the temperature was raised to 268°C and it was kept at this temperature for 30 minutes. After doing so, the composition of oil's fatty acids was obtained. The composition of fatty acids of the oil resources are provided in table 1.

Table 1: the composition of fatty acids of various oils and fats used for producing biodiesel as analysed by GC

Chicken fat	Olive oil	Molecular formula	Composition of fatty acid(%)
17.15	15.67	C16:0	Palmitic acid
4.15	2.83	C18:0	Stearic acid
25.81	24.95	C18:1	Oleic acid
7.49	13.29	C18:2	Linoleic acid
0.51	0.7	C18:3	Linolenic acid
0.49	0.01	C 14:0	Myristic acid

Testing Method

Tests esterification process was done in the presence of ethanol, the composition of olive oil and chicken fat, sodium hydroxide and potassium hydroxide catalyst, and water in optimized ratios. For conducting the test, different ratios of the oil's compositions as shown in table 3, were pre-heated in 60° C and after that, 1% weight of the catalysts (potassium hydroxide or sodium hydroxide) was added to the oil combination and afterward, the methanol with molar ratio 1-6 was added to the oil and the solution reacted with the oil for 60 minutes [30].

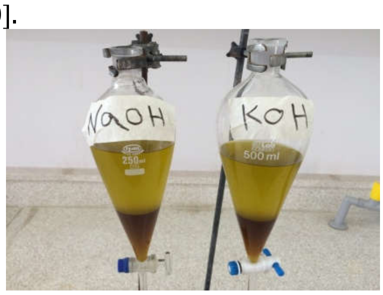

Figure 1: production of biodiesel and deposition of glycerin

Glycerin Separation

In the current study, the separation was done through deposition after the trans-esterification reaction. The rate of glycerin separation depends on the time period of separation and the more this time is, the higher the percentage of the separated glycerin from the biodiesel phase will be. About 90% of the glycerin in the biodiesel was separated from it in the initial 15 to 30 minutes; however 12 hours are needed for complete separation of glycerin.

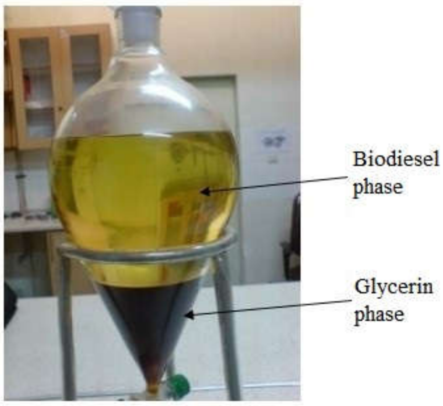

Figure 2: glycerin deposition by separation

Leaching Method

The most common method of biodiesel purification is the "wet" or "leaching" method. The leaching method is used to remove impurities such as methanol, biodiesel, soap, catalyst and residual glycerol. After separating the glycerol phase from the solution, the produced biodiesel is firstly washed by a 5% solution of acetic acid in order to dissolve the produced soap materials and phase it out from the solution phase. After several rinses with 5% acetic acid solution, the desired phase is repeatedly washed with distilled water with a temperature of 65 ° C in order for it to be completely neutral.

Purification by leaching method only requires two factors: water and time. The basis of the concept of leaching method is the utilization of water for increasing the concentration of biodiesel. The reason behind using water is that when the water combines with biodiesel, it collects and dissolves the inaccessible particles and removes it from the biodiesel and finally a pure biodiesel is obtained. In this method, a specific percentage of water is added to raw biodiesel and t purifies the biodiesel. When the water passes through the biodiesel fuel, it attacks impurities and dissolves them in itself. Then the contaminated water is drawn out at another stage. The process is repeated until the removed water is pure in terms of color. The leaching frequency depends on the quality of the oil and the precision of the process accomplishment. Two or three times of leaching is enough for the fresh oils with lower water and free fatty acids, however for waste oils, it is repeated 5 to 7 times. Transparency of waste water from leaching is a good criterion for completion of the work. The higher frequencies of leaching and lower amounts of water are preferred over lower frequencies of leaching with higher amounts of water [30].

Figure 3: leaching the produced biodiesel

Dry-cleaning Method

Leaching method has been more widely used in order to remove chemical contaminants and impurities in unprocessed biodiesel in the past. However, today, due to some economic problems such as high volumes of water and the large space (large tanks) needed and also some technical and environmental problems such as emulsification, high effluent volumes of sewage and longer processing time (frequency of leaching and drying the final product), the ten to n- cytosine-water purification methods on the agenda of many researcher and manufacturers in the industry is biodiesel. In the dry-cleaning method, water is replaced with ion exchanger resin or powder magnesium silicate and sodium sulfate in order to eliminate the maximum impurities. Nowadays, the both methods of dry-cleaning methods are being used in industrial factories (31). In this study, after neutralization, the product is poured into a beaker and about 10 grams of sodium sulfate is added to the solution it is blended for 40 minutes to absorb the water contained in the product. The resulting product is then filtered through the filter paper and vacuum pumps in order for the sodium sulfate to be separated from the solution. Following the filtration, biodiesel was poured into plastic bottles and was stored at room temperature. In the current study, all the reactions took place in the atmosphere pressure and for heating and blending the solution, the Yellow MAG HS7 heater equipped with mechanical blender was used.

RESULTS AND DISCUSSION

The Method of Determination of Optimum Condition for Producing the Biodiesel

In this study, the reaction firstly took place at 60°Cfor 60 minand1 wt% of catalyst (NaOH, KOH) (base oil)and methanol ratio of6.1. Also, all the reactions took place in the atmosphere pressure and for heating and blending the solution, the Yellow MAG HS7 heater equipped with mechanical blender with the rotation speed of 800rpmwas used, and all experiments were repeated twice.

The Properties and Attributes of the Diesel

Diesel fuel is a part of crude oil with brown color which contains distilled or residual components with the relative density of 0.87. Diesel fuels are classified based on their use as well as on a numerical rating. The American Society for Testing and Materials (ASTM) has provided this numerical classification from 1 to 6. The diesel fuel number 1 is defined for using in cold weather and the second type is the fuel that has lower volatility, most common in vehicles. Also, the third type of fuel is used in stationary units with lower-speed engines [32].

Table 2: the properties of diesel fuels based on ASTM standard

Fuel N.4	Fuel N.2	Fuel N.1	ASTM Standard D975
55	52	38	The minimum ignition temperature (℃)
0.05	0.05	0.05	The maximum amount of water and sediments (Volume,%)
	0.35	0.15	The maximum amount of remaining carbon (%)
0.01	0.01	0.01	Maximum ash (%)
-24 5.5	-4.1 1.9	-2.4 1.3	Kinetic viscosity 40℃ ($\times 10m^2/S$)
2.0	0.05	0.05	The maximum amount of sulfur
Deg3	Deg3	Deg3	The maximum amount of copper corrosion
40	40	40	Minimum cetane number

The properties of the three mentioned fuels based ASTM standard are provided in table 2.

The Properties and Attributes of Produced Biodiesel

To investigate the physical properties of biodiesel production, different compositions of olive oil and chicken fat, in different percentages (90-80-50-20-10), were prepared and the (10-90) percentage of chicken fat-olive oil with both KOH and NaOH catalysts produced the highest weight of the biodiesel which is mentioned in table 3. The biodiesel with different volume percentages (75, B50, B25B) is then blended and its properties were compared with pure gasoline (100B).

Table 3: the net weight of the produced biodiesel in different compositions of olive oil and chicken fat

The percentages of olive oil-chicken fat combination (%)	The weight of produced biodiesel (KOH)	The weight of produced biodiesel (NaOH)
20-80	162.5	172.56
80.20	181.06	187.2
50-50	170.56	180.3
10-90	155.06	160.1
90-10	56/187	190.5

The Physical Properties and Attributes of Produced Biodiesel and Mixing it with the Gasoline

Physical properties and attributes of biodiesel produced from a combination of olive oil and chicken fat with gasoline composition are reported in tables 4 and 5.

Table 4: The properties of produced biodiesel from combination of olive oil, chicken fat, and gasoline using KOH catalyst

Property	B25	B50	B75	B100
Flash point (°C)	92	130	175	192
Cloud point(°C)	-2	-1	2	6
Viscosity (mm^2/s)	4.1	4.2	5.2	6
Density (kg/m^3)	843	855	867	913
Distillation temperature(°C)	170	175	180	210

Table 5: the properties of produced biodiesel from combination of olive oil, chicken fat, and gasoline using NaOH catalyst

Property	B25	B50	B75	B100
Flash point(°C)	100	145	183	197
Cloud point(°C)	3	4	5	8
Viscosity (mm^2/s)	3.6	5	5.1	6.4
Density (kg/m^3)	843	861	876	878
Distillation temperature(°C)	188	175	180	210

Flash Point

The flash point is the temperature at which the fuel vapor and the air above it are in contact with each other start combustion. The flash point is a very important parameter for biodiesel and other fuels since this parameter indicates the fuel safety, conditions of storage and transportation (33). The flash point of biodiesel produced by the combination of olive oil and chicken fat, and gasoline is shown in Figure 4.

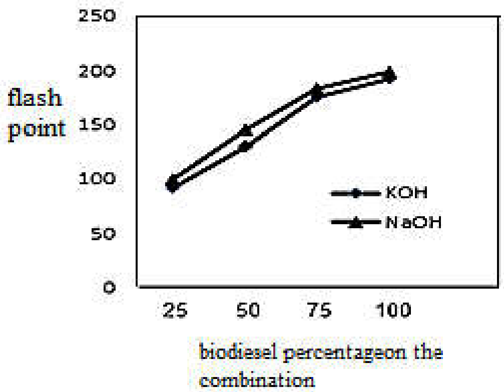

Figure 4: the effect of biodiesel percentage on the combination with gasoline for flash point

As indicated in this figure, with higher percentage of biodiesel in the combination with diesel fuel, the combustion temperature of the fuel composition will also increase, thus the increase in biodiesel percentage leads to increase in this property.

Cloud Point

The cloud point is among the heat-dependent parameters which affect the biodiesel usage in different weather and geographical conditions. By the share of biodiesel in the combinations increased, the cloud point had a rising trade in all of the samples, as it increased from -4°c in pure gasoline to 6°c in pure biodiesel with KOH catalyst and 8°c with NaOH catalyst. The cloud point of all the samples containing biodiesel was above that of gasoline which limits the use biodiesel combination fuel in cold weather (34). The clouds points of the produced biodiesel from combination of chicken fat and olive oil in pure state as well as combined with gasoline are shown in diagram 5.

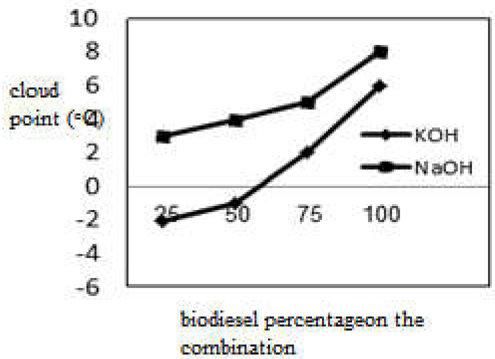

Figure 5: the effect of pure biodiesel-gasoline combination on cloud point (°C)

The Effect of Biodiesel on Fuel Viscosity

The kinematic viscosity is a very important and critical property of the engine's fuel. Kinematic viscosity plays an important role in fuel injection, mixing and combustion property. With the share of biodiesel increased, the fuels viscosity will also increase. The viscosity of pure diesel fuel is 1.9 mm 2/s, for pure biodiesel with catalyst KOH it is 8 mm^2/s, and for pure biodiesel with catalyst NaOH catalyst it is 6.4mm^2/s. Gasoline fuel plays the role of lubrication in some parts such as fuel injection pump and increasing the viscosity can be a useful factor to be considered in order to reduce wear and corrosion. The viscosity of the combination should be enough so it will not cause additional power consumption by the injector's pump for spraying it into the combustion chamber. The more the viscosity of the fuel is, the lower the possibility of its full atomization will be and soot particle emissions will increase [35]. The kinematic viscosity of biodiesel produced from chicken fat and olive oil combined with gasoline is shown in figure 6. As indicated in the figure, for all of the biodiesel percentages inside the combination, the amount of the fuel viscosity is within ASTM standard conditions.

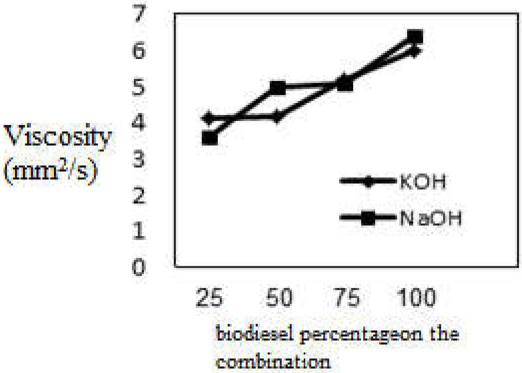

Figure 6: the effect of pure biodiesel-gasoline combination on viscosity (mm^2/s)

The Effect of Biodiesel on Fuel Density

Density is an important property of fuel since it affects the atomization of the fuel. Biodiesel, as compared to gasoline, is constituted from long hydrocarbon chains, thus by increasing the share of biodiesel in the combinations, the density also increases. The density of the pure gasoline increased from 860kg/m^3 to 913 kg/m^3 with KOH catalyst and 875kg/m^3 with NaOH catalyst for pure biodiesel (36). The effect of the amount and type of biodiesel combined with diesel on diesel fuel density properties is shown in Figure 7.

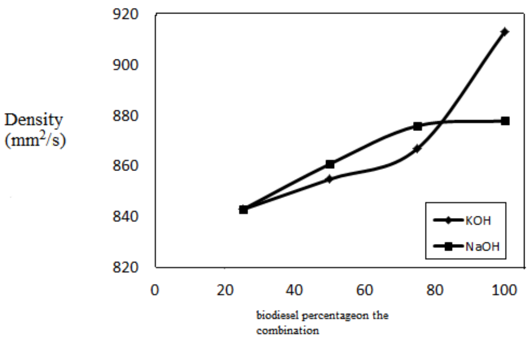

Figure 7: the effect of pure biodiesel-gasoline combination on density (mm^2/s)

The Effect of Biodiesel on Distillation Temperature

The results of measurement of distillation range indicated that by the increase in biodiesel share in combinative fuel, the distillation range also increases. The increase in average distillation temperature mean (B100) to (B25, B50, B75) is reason for superiority of biodiesels and increases their maintenance index. The reason behind the increase in distillation range is the increase in average length of H-C chain of biodiesel fuel and also increase in molecular weight of the fuel (37). The effect of the amount and type of biodiesel combined with diesel on diesel fuel distillation properties is shown in Figure 8.

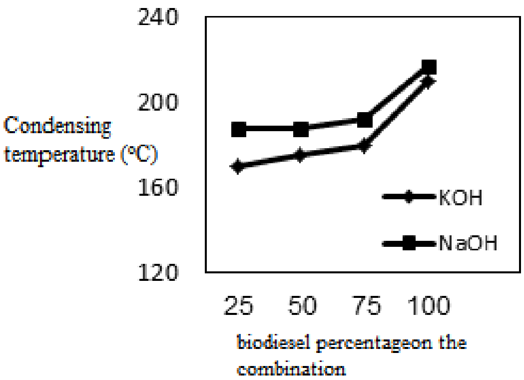

Figure 8: the effect of pure biodiesel-gasoline combination on distillation temperature (°C)

Comparing the Diesel and Biodiesel from Technical Viewpoint

The biodiesel has a lower density compared to common gasoline and due to this property. It should be noted that the amount of energy per one gallon or energy is measured per pound. It can be said that the energy deficits about10% comparing diesel fuels with biodiesel. In diesel engines, the rate of fuel viscosity in lower temperatures is very important when igniting. In this regard also biodiesel is weaker than diesel. The applied solution for solving this problem is adding a percentage of gasoline to biodiesel which is today considered [38]. Biodiesel is more efficient for the engine in combustion phase and it has been used as an additive for fuel from years ago since it increases the engine's smoothness and efficiency. Biodiesel is has mote smoothing property compared to diesel decrease the corrosion in vehicle. This fuel works as a mild solvent and reduces fouling in the vehicle's fuel tank, pipeline and fuel filters and consequently reduces machining costs besides increasing engine life. In the fuel production process, be it synthetic or extractive, some energy is consumed for purification, heating, or reaction. This energy is up to 4 times less than the energy needed for production of diesel fuel. It should be considered that oil, natural gas, and coal's resources are limited. Biodiesel can be effective in reducing the use of non-renewable fuels. Also the biodiesel life cycle is much shorter than that of fossil fuels. Another advantage of biodiesel is the high octane proportion, low sulfur content and high oxygen content that provides superior total combustion.

CONCLUSION

Biodiesel is a life-friendly fuel which is produced from different oil resources. In this study, for the production of biodiesel from a combination of olive oil and chicken fat was used as feedstock in the presence of alkaline catalyst.

The results showed that the percentage of chicken fat-olive oil with the ratio of 10-90 for both KOH and NaOH catalysts produced the highest weight of the biodiesel. Also, by increasing the percentage of biodiesel in the mixture; density and viscosity of fuel for proper engine performance and emissions reduction are improved.

REFERENCES

1. Canakci, M. (2007). Combustion characteristics of a turbocharged DI compression ignition engine fueled with petroleum diesel fuels and biodiesel. Bioresource Technology, 98: 1167–1175.
2. Knothe, G. (2005). Dependence of biodiesel fuel properties on the structure of fatty acid alkyl esters. Fuel Processing Technology. 86: 1059– 1070.
3. Widayat, Wibowo, A. D. K., Hadiyanto, (2013). Study on production process of biodiesel from rubber seed (*Hevea brasiliensis*) by in situ (trans) esterification method with acid catalyst. Energy Procedia. 32: 64 – 73.
4. Ong, H. Ch., Masjuki, H. H., Mahlia, T. M. I., Silitonga, A.S., Chong, W.T., Leong, K.Y., (2014). Optimization of biodiesel production and engine performance from high free fatty acid *Calophyllumino phyllum* oil in CI diesel engine. Energy Conversion and Management. 81: 30–40.
5. Meng, X., Chen, G., Wang, Y. H. (2008). Biodiesel production from waste cooking oil via alkali catalystand its engine test. Fuel processing technology, 89: 851-857.
6. Zhang, Y., Dube, M. A., McLean, D. D., Kates, M. (2003). Biodiesel production from waste cooking oil: 1. Process designand technological assessment. Bioresource Technology, 89(1): 1–16,
7. Omar, W. N. N. W., Amin, N. A. S. (2011). Optimization of heterogeneous biodiesel production from waste cooking palm oil via response surface methodology. biomass and bioenergy, 35: 1329-1338.
8. Marulanda, V. F., Anitescu, G., Tavlaridesa, L. L. (2010). Investigations on supercritical transesterification of chicken fat for biodiesel production from low-cost lipid feedstocks. The Journal of Supercritical Fluids, 54: 53–60.
9. Guru, M., Koca, A., Can, O., Cınar, C., Sahin, F. (2010). Biodiesel production from waste chicken fat based sources and evaluation with Mg based additive in a diesel engine. Renewable Energy, 35: 637–643.
10. Liu, K., Wang, R.(2013). Biodiesel production by transesterification of duck oil with methanol in the presence of alkali catalyst. Petroleum & Coal, 55 (1): 68-72.
11. Ali, A.S., Ahmad, F., Farhanand, M., Ahmad, M. (2012). Biodiesel production from residual animal fat using various catalysts. Pakistan Journal of Science, 64(4).
12. Chakraborty, R., Sahu, H. (2014). Intensification of biodiesel production from waste goat tallow using infrared radiation: Process evaluation through response surface methodology and artificial neural network. Applied Energy, 114: 827–836.
13. Zhang, Y., Dube, M.A., McLean, D.D., Kates, M. (2003). Biodiesel production from waste cooking oil: 2. Economic assessment and sensitivity analysis. Bioresource Technology, 90: 229–240.
14. Haas, M. J., McAloon, A. J., Yee, W. C., Foglia, T. A. (2006). A process model to estimate biodiesel production costs. Bioresource Technology, 97: 671–678.
15. Dorado, M. P., Cruz, F., Palomar, J. M., Lo´pez, F.J. (2006). An approach to the economics of two vegetable oil-based biofuels in Spain. Renewable Energy, 31: 1231–1237.

16. Azam, M. M., Waris, A., Nahar, N.M. (2005). Prospects and potential of fatty acid methyl esters of somenon-traditional seed oils for use as biodiesel in India. Biomass and Bioenergy, 29: 293–302.
17. Fernando, S., Karra, P., Hernandez, R., Kumar, S. (2007). Effect of incompletely converted soybean oil on biodiesel quality. Energy, 32: 844–851.
18. Gerpen, J. V. (2005). Biodiesel processing and production. Fuel Processing Technology, 86: 1097– 1107.
19. Srivastava, A., Prasad, R. (2000). Triglycerides-based diesel fuels.Renewable and Sustainable Energy Reviews, 4: 111-133.
20. Ma, F., Hanna, M. A. (1999). Biodiesel production: a review. Bioresource Technology, 70: 1-15.
21. Ma, F., Clements, L. D., Milford, H. (1998). The Effects of Catalyst, Free Fatty Acids, and Water on Transesterification of Beef Tallow. Industrial Agricultural Products Center – Publications & Information, 12.
22. Alia, E. N., Tay, C. I. (2013). Characterization of biodiesel produced from palm oil via base catalyzed transesterification. Procedia Engineering, 53: 7 – 12.
23. Zheng, S., Kates, M., Dube, M.A., McLean, D.D. (2006). Acid-catalyzed production of biodiesel from waste frying oil. Biomass and Bioenergy, 30: 267–272.
24. Schuchardt, U., Sercheli, R., Vargas, R. M. (1998). Transesterification of Vegetable Oils: a Review. Journal of Brazilian Chemical Society, 9(1): 199-210.
25. Charoenchaitrakool, M., Thienmethangkoon, J. (2011). Statistical optimization for biodiesel production from waste frying oil through two-step catalyzed process. Fuel Processing Technology, 92: 112–118.
26. Wang, Y., Ou, Sh., Liu, P., Zhang, Zh. (2007). Preparation of biodiesel from waste cooking oil via two-step catalyzed process. Energy Conversion and Management, 48: 184–188.
27. Kılıç, M., Uzun, B. B., Pütün, E., Pütün, A. E.(2013). Optimization of biodiesel production from castor oil using factorial design. Fuel Processing Technology, 111: 105–110.
28. Ramezani, K., Rowshanzamir, S., Eikani, M. H. (2010). Castor oil transesterification reaction: A kinetic study and optimization of parameters. Energy, 35: 4142-4148.
29. Bagherpoor, H., (2007). Modification of the reactor for producing the biodiesel.A thesis for master's degree, Tarbiat Modarres University
30. Ghobadian, B. Khatamifar, M. and Rahimi, H. (2005). Biodiesel fuel Production using transesterification of waste vegetable oils. The 4th International Conference on Intern Combustion Engines, Nov.16-18, Tehran iran.
31. Abbas Zade, M., (2010). Designing, building, and assessment of the biodiesel purification system. A thesis for master's degree.
32. Mahon L.L.J. (2004). DieselGenerator Handbook, Elsevier Butterworth Heinemann
33. R, AbdRabu, I. Janajreh, D. Honnery. (2013). Tran's esterification of waste cooking oil: Process optimization and conversion rate evaluation, Energy Conversion and Management, 65: 764-769.
34. Basheer Hasan Diya'uddeen, A.R. Abdul Aziz, W.M.A.W. Daud, M.H. (2012). Performance evaluation of biodiesel from used domestic waste oils: A review, Proc Safety and Environmental Protection, 90:164–179.
35. Canakci,M, Sanli, H. (2008). Biodiesel production from various feed stocks and their effects onthe fuel properties, Journal of Industrial Microbiology & Biotechnology, 35(5): 431-441.
36. Pedro Fe, M., Correia, J.N. IdalinaRaposo, João F., Mendes, RuiBerkemeier, Bordado, J.(2006). Production of biodiesel from waste frying oils, Waste Management, 26(5): 487-494.
37. Dorado, J. (2003). Emission evaluation of soybean derived biodiesel fuel. Southwest research institute study sponsored by the department of energy and university of Idaho. Presented at DOE biodiesel emission testing meeting, WA.
38. Boluri, F., (2011). Production of biodiesel.The Ministry of Industries and Mines, Tehran.