International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 10 | Oct 2018 www.irjet.net p-ISSN: 2395-0072

Transesterification of Waste Frying Oil for the Production of Biodiesel as Alternative Fuel for an IC engine

Dharmendra Kumar Tiwari[1], Sumit Kumar Prajapati[2]

[1]Teaching Assistant, M.Tech, JNU Jodhpur.
[2]Assistant Professor, Dept. Of Chemical Engineering, Dr. Ambedkar Institute of Technology for Handicapped, U.P., India

---

Abstract - *The purpose for the present study is to produce biodiesel from the used vegetable oil and tested on diesel engine. This study aims to define the requirements for biodiesel production by the esterification process, testing its quality by determining some parameters such as density, kinematics viscosity, high heating value, cetane number, flash point, cloud pint and pour point and comparing it to Diesel fuel, and the strategic issues to be considered to assess its feasibility, or Likelihood of succeeding. This analysis is useful either when starting a new business, or identifying new opportunities for an existing business. Therefore, it will be extremely helpful for taking rational decisions about the development of a biodiesel production plant. The properties of biodiesel are better than to diesel fuel as biodiesel shows high boiling point, cloud point, flash point and cetane number as well as lower the carbon residue, sulphur content and ash content. It also shows the moderate heating value as compare to diesel fuel. Therefore, biodiesel is rated as a realistic fuel as an alternative to diesel. This is due to the fact that the conversion of waste cooking oil into methyl esters through the transesterification process approximately reduces the molecular weight to one third, reduces the viscosity by about one-seventh, reduces the flashpoint slightly and increases the volatility marginally, and reduces pour point considerably.*

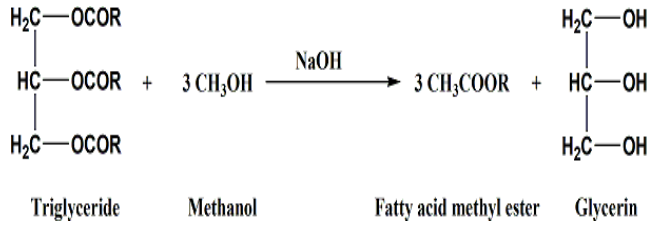
Key Words: Biodiesel, vegetable oil, Esterification, cetane number, flash point, carbon residue, sulphur content, ash content.

1. INTRODUCTION

Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. Over the last century, there has been more than 20 fold increase in the consumption of energy worldwide and all major sources excepting hydropower and nuclear electricity are the finite sources and therefore are likely to be exhausted in near future .The rapid increase in the consumption of fossil fuels is resulting into climate change which is considered as the most important environmental problem of the present century and the recent studies hence indicates that the emission of green house gases to the atmosphere have contributed to the increase in the global mean temperature by approximately 0.8 °C during the past century. The impact of climate change on the ecosystem and human societies has prompted to develop ecofriendly and infinite renewable sources like solar, wind, small hydro, biomass, etc .Renewable energy sources in general and biomass energy in particular is capable of reducing our dependency on foreign import there by increasing the security of energy supply. The ethanol and biodiesel are the two liquid bio fuels that can replace/substitute gasoline /diesel respectively.

Biodiesel can be obtained from a number of edible and non edible oil resources and major thrust is given for the utilization of non edible seed plant. The oil from these plants can be transesterified by suitable method depending on its FFA content for the production of biodiesel that can be used to operate a CI engine. The present paper attempts to review the work on the performance of diesel engine using biodiesel-diesel blends as well as blend of diesel with various oils. . According to Diya'uddeen et al. (2012)[1], the biodiesel can be defined as a monoalkyl ester of long chain fatty acids derived from a renewable lipid feedstock, such as vegetable oil or animal fat. If it is obtained from other sources are considered as II generation biodiesel (Pirozzi et al., 2013)[2].It is sulphur free, non-toxic and biodegradable; it reduces the emission of gas pollutants and global warming.

The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO2). Biodiesel is rapidly biodegradable and completely non-toxic, meaning spillages represent far less of a risk than fossil diesel spillages. Biodiesel has a higher flash point than fossil diesel and so is safer in the event of a crash. The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerin molecule as its base with three long chain fatty acids attached. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. A common product of the transesterification process is Rape Methyl Ester (RME) produced from raw rapeseed oil reacted with methanol.



2. MATERIALS AND METHODS

2.1 Substrate and glassware Used

- Waste vegetable oil (WVO)
- Large container for heating oil
- Stove burner or hot plate
- Sock filter(s)
- Scale
- KOH
- Weigh boats
- Distilled water
- 1.5 L beaker
- Funnel
- Burette
- Small (50 ml) flasks
- Graduated pipette

2.2 Preparation Procedures

The process of converting waste vegetable oil (WVO) to biodiesel is essentially the same as that of converting virgin vegetable oil. The recipe for making biodiesel from virgin vegetable oil, using base as a catalyst, is simple.

For Every 1L of vegetable oil, add 215ML of methanol, and 10 g of NAOH. In this lab, we will be starting with 500ml after that 1000 ml of vegetable oil. Here we are collected palm waste vegetables oil due to easy availability from restaurant, sweet shops, dhaba etc. with very low cost.

2.3 Filtration:

The frying process often introduces food particles to the oil, and the oil must be filtered before undergoing the transesterification reaction. We typically pre-filter the oil through a 25 micron sock filter. The filtration process should be performed in advance of a transesterification reaction.

2.4 Heating and Settling (Option)

In addition to food particles, foods introduce water to the fryer oil. We pre-heat our WVO to 70°C, which allows water (and additional food particles) to settle to the bottom of the vessel. Excess water and solid material will settle on the bottom of the oil container. Pre-heating should be started at least one day before a transesterification reaction.

2.5 Titration

When vegetables containing water are fried in hot oil, some of the water reacts with triglyceride molecules to form what are known as free fatty acids ((FFAs) FFAs are fatty acid molecules that are not bound to glycerin. These acids react with base catalyst to form soap effectively making less catalyst available for the transesterification of triglycerides to biodiesel. The result is a less complete transesterification reaction. Titration allows one to determine the concentration of acid in a known volume of WVO by neutralizing it with a reference solution (or titrant) of known base concentration in the presence of a pH neutral indicator. The following titration procedure has been popularized among biodiesel home brewers for its ease of use. Conveniently, the number of milliliters of reference solution needed to neutralize the analyte corresponds directly with the grams of additional base needed per liter to neutralize the FFAs in the WVO.

2.6 Calculation-

The amounts of methanol and NaOH required:
1 Liter vegetable oil ↔215 ml Methanol ↔10 g NaOH
Reagents: Waste vegetable oil and alcohol (methanol)
Products: biodiesel and glycerin
Catalyst: Sodium hydroxide (NaOH)

The transesterification reaction produces crude biodiesel. The product is considered crude because it is contaminated with methanol, base, glycerin, and soap.

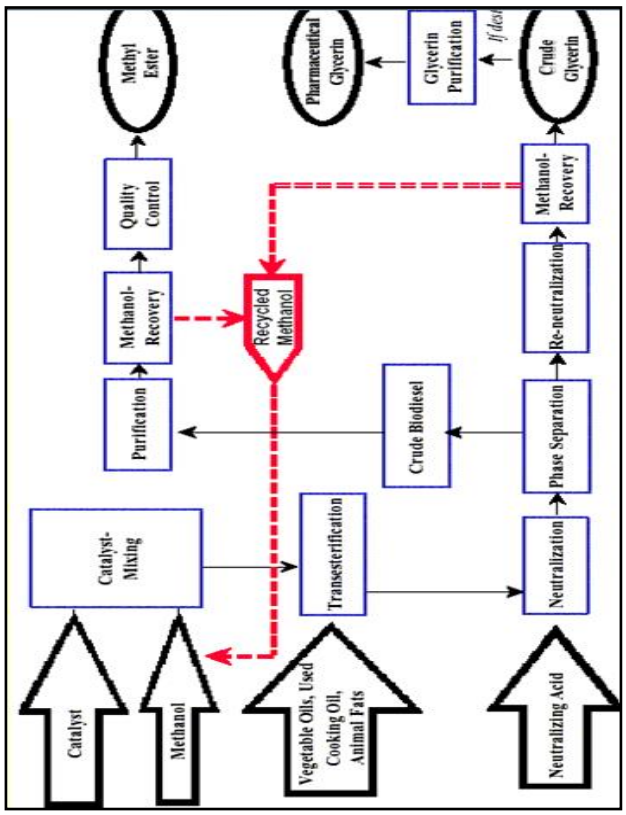


Fig.1: Flow chart of bio diesel processes

2.7 Alcohol and Catalyst

The catalyst is typically sodium hydroxide (caustic soda) or potassium hydroxide (potash). It is dissolved in the alcohol using a standard agitator or mixer reaction. The alcohol/catalyst mix is then charged into a closed reaction vessel and the oil or fat is added. The system from here on is totally closed to the atmosphere to prevent the loss of alcohol. The reaction mix is kept just above the boiling point of the alcohol (around 160 °F) to speed up the reaction and the reaction takes place. Recommended reaction time varies from 1 to 8 hours, and some systems recommend the reaction take place at room temperature. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. Care must be taken to monitor the amount of water and free fatty acids in the incoming oil or fat. If the free fatty acid level or water level is too high it may cause problems with soap formation and the separation of the glycerin by-product downstream.

2.8Separation

Once the reaction is complete, two major products exist: glycerin and biodiesel. Each has a substantial amount of the excess methanol that was used in the reaction. The reacted mixture is sometimes neutralized at this step if needed.

2.9 Alcohol Removal

Once the glycerin and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In others systems, the alcohol is removed and the mixture neutralized before the glycerin and esters have been separated.

2.10Glycerin-Neutralization

The glycerin by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerin.

2.11 Methyl Ester Wash

Once separated from the glycerin, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage.
This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to petro diesel.

2.12 Thin layer chromatography

A good way to check for impurities; how many different compounds are in a sample, very small quantities of the samples are placed on the special TLC plates. The plate is put in a container with a solvent or solvent mixture, the solvent runs up the plate and will separate the different kinds of molecules based on polarity differences and size differences. The mobile phase flows through the stationary phase and carries the components of the mixture with it. Different components travel at different rates. The stationary phase in this case is silica gel coated on a thin piece of rigid plastic.

2.13 Bomb calorimeter

In more recent calorimeter designs, the whole bomb, pressurized with excess pure oxygen (typically at 30atm) and containing a weighed mass of a sample (typically 1-1.5 g) and a small fixed amount of water (to saturate the internal atmosphere, thus ensuring that all water produced is liquid, and removing the need to include enthalpy of vaporization in calculations), is submerged under a known volume of water (ca. 2000 ml) before the charge is electrically ignited. The bomb, with the known mass of the sample and oxygen, form a closed system - no gases escape during the reaction. The weighed reactant put inside the steel container is then ignited. Energy is released by the combustion and heat flow from this crosses the stainless steel wall, thus raising the temperature of the steel bomb, its contents, and the surrounding water jacket. The temperature change in the water is then accurately measured with a thermometer. This reading, along with a bomb factor (which is dependent on the heat capacity of the metal bomb parts), is used to calculate the energy given out by the sample burn.

3. RESULT AND DISCUSSION

Table 1: Fuel properties of vegetables oils, methyl ester and its blends

	Fuel	Relative density	Kinematic viscosity	Calorific value (MJ/kg)	Flash point (°C)
1	Veg. oil	0.899	25.89	33.00	201
2	B100	0.874	9.012	38.15	185
3	B20	0.850	3.65	37.68	78
4	B40	0.856	4.53	36.99	82
5	B60	0.861	5.12	36.54	84
6	B80	0.864	5.95	35.98	90
7	Diesel	0.846	2.60	42.21	52

Table 2: Comparative data between diesel and biodiesel for fuels analysis are mentioned below

Fuel property	Diesel	Biodiesel	Unit
Fuel standard	ASTDM 975	ASTDM675I	
Low heating value	129050	117059	Btu/gal
Kinetamicviscosity@40 degc	1.3 - 4.1	1.9-6.0	mm^2/sec
Specific gravity@60degc	0.85	0.88	Kg/l
Density	7.079	8.682	Lb/gal
Water and sediment	0.05 max	0.05 max	% volume
Carbon	87	77	Wt%
Hydrogen	13	12	Wt%
Oxygen	0	11	-
Sulphur	0.0015	0.0024	Wt%
Boiling point	180to340	315 to 350	°C
Flash point	60 to 80	130 to 170	°C
Cloud point	-15 to 5	-3 to 12	°C
Cetane number	40 to 55	79.5 to 98.3	
Cetane improver	5000	More than 7000	Grams
Flash point (K)	471	459	350-356
Pour point (K)	286	266	263-267
Cetane number	50	55	41-45
Ash content (%)	0.007	0.005	0.007-0..009
Sulfur content (%)	0.09	0.07	0.42-0.55
Carbon residue (%)	0.44	0.36	0.36-0.42
Water content (%)	0.45	0.05	0.03-0.06
Higher heating value (MJ/kg)	42.20	42.96	45.96-46.98
Free fatty acid (mg KOH/g oil)	1.22	0.14	-
Iodine value	144.7	-	

Table 3: Comparison of properties of waste cooking oil, biodiesel from waste cooking oil and commercial diesel fuel

Fuel property	Waste vegetable oil	Biodiesel from waste vegetable oil	Commercial diesel fuel
Kinematic viscosity (mm^2/s, at 313 K)	38.8	5.12	1.9–4.1
Density (kg/L, at 288 K)	0.862	0.814	0.069 -0.081

The properties of biodiesel and diesel fuels, in general, show many similarities, and therefore, biodiesel is rated as a realistic fuel as an alternative to diesel. This is due to the fact that the conversion of waste cooking oil into methyl esters through the transesterification process approximately reduces the molecular weight to one third, reduces the viscosity by about one-seventh, reduces the flashpoint slightly and increases the volatility marginally, and reduces pour point considerably.

4. CONCLUSION

The present study emphasis on strategies such as that commercial food are used to make biodiesel but if there is a surplus of it, why not put the excess to better use. Not only does it match its rivals in energy output, it also reduces the damage done to the world. The production of biodiesel from waste vegetable oil offers a triple-facet solution: economic, environmental and waste management. The new process technologies developed during the last years made it possible to produce biodiesel from recycled frying oils comparable in quality to that of virgin vegetable oil biodiesel with an added attractive advantage of being lower in price. Thus, biodiesel produced from recycled frying oils has the same possibilities to be utilized.

ACKNOWLEDGEMENT

This research was supported by IIT Kanpur, MNIT Jaipur, UPTTI Kanpur and HBTI Kanpur. We thank our colleagues who provided insight and expertise that greatly assisted the research.

REFERENCES

[1] Diya'uddeen, B.H., Aziz, A.A., Daud, W.M.A.W. and Chakrabarti, M.H., 2012. Performance evaluation of biodiesel from used domestic waste oils: a review. *Process Safety and Environmental Protection*, *90*(3), 164-179.

[2] Pirozzi, D., Ausiello, A., Strazza, R., Trofa, M., Zuccaro, G. and Toscano, G., 2013. Exploitation of agricultural biomasses to produce II-generation biodiesel. *CHEMICAL ENGINEERING*, *32*.

[3] Nada, E.M., 2001. *The Manufacture of Biodiesel from the used vegetable oil* (Doctoral dissertation, Thesis submitted to the Faculty of Engineering at Kassel and Cairo Universities).

[4] Guider, T.P., 2008. *Characterization of Engine Performance with Biodiesel Fuels* (Doctoral dissertation, Lehigh University).Agarwal, A.K., 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. *Progress in energy and combustion science*, *33*(3), 233-271.

[5] Agarwal, A.K., 2005. Experimental investigations of the effect of biodiesel utilization on lubricating oil tribology in diesel engines. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, *219*(5), 703-713.

[6] Canakci, M. and Van Gerpen, J.H., 2003. Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel, and soybean oil biodiesel. *Transactions of the ASAE*, *46*(4), p.937.

[7] Kumar, G. and Kumar, A., 2013. Engine Performance Characteristics of Diesel Engine Using Mahua Biodiesel as Fuel. *International Journal of Current Engineering and Technology*, *3*(2), 424-427.

[8] Dwivedi, G., Sharma, M.P. and Jain, S., 2013. Diesel engine performance and emission analysis using biodiesel from various oil sources–Reviews. *Journal of Material and Environmental Science*, *4*, 434-447.

[9] Geyer, S.M., Jacobus, M.J. and Lestz, S.S., 1984. Comparison of diesel engine performance and emissions from neat and transesterified vegetable oils [Aldehydes]. *Transactions of the ASAE [American Society of Agricultural Engineers](USA)*.

[10] Kaplan, C., Arslan, R. and Sürmen, A., 2006. Performance characteristics of sunflower methyl esters as biodiesel. *Energy Sources*, *28*(8), 751-755.

[11] Gurunathan, B. and Ravi, A., 2015. Biodiesel production from waste cooking oil using copper doped zinc oxide nanocomposite as heterogeneous catalyst. *Bioresource technology*, *188*, 124-127.

[12] Karavalakis, G., Fontaras, G., Ampatzoglou, D., Kousoulidou, M., Stournas, S., Samaras, Z. and Bakeas, E., 2010. Effects of low concentration biodiesel blend application on modern passenger cars. Part 3: Impact on PAH, nitro-PAH, and oxy-PAH emissions. *Environmental Pollution*, *158*(5), 1584-1594.

[13] Canakci, M. and Van Gerpen, J., 1999. Biodiesel production via acid catalysis. *Transactions of the ASAE*, *42*(5), 1203.

[14] Park, Y.M., Lee, J.Y., Chung, S.H., Park, I.S., Lee, S.Y., Kim, D.K., Lee, J.S. and Lee, K.Y., 2010. Esterification of used vegetable oils using the heterogeneous WO 3/ZrO 2 catalyst for production of biodiesel. *Bioresource Technology*, *101*(1), S59-S61.

[15] Hossain, A.B.M.S. and Boyce, A.N., 2009. Biodiesel production from waste sunflower cooking oil as an environmental recycling process and renewable energy. *Bulgarian Journal of Agricultural Science*, *15*(4), 312-317.

[16] Çetinkaya, M., Ulusoy, Y., Tekìn, Y. and Karaosmanoğlu, F., 2005. Engine and winter road test performances of used cooking oil originated biodiesel. *Energy Conversion and Management*, *46*(7), 1279-1291.

[17] Lin, Y.C., Lee, W.J., Wu, T.S. and Wang, C.T., 2006. Comparison of PAH and regulated harmful matter emissions from biodiesel blends and paraffinic fuel blends on engine accumulated mileage test. *Fuel*, *85*(17), 2516-2523.

[18] Subramaniam, D., Murugesan, A. and Avinash, A., 2013. A comparative estimation of CI engine fuelled with methyl esters of punnai, neem and waste cooking oil. *International journal of energy and environment*, *4*(5), 859-870.

[19] Gopal, K.N., Pal, A., Sharma, S., Samanchi, C., Sathyanarayanan, K. and Elango, T., 2014. Investigation of emissions and combustion characteristics of a CI engine fueled with waste cooking oil methyl ester and diesel blends. *Alexandria Engineering Journal*, *53*(2), 281-287.

[20] Wang, R., Hanna, M.A., Zhou, W.W., Bhadury, P.S., Chen, Q., Song, B.A. and Yang, S., 2011. Production and selected fuel properties of biodiesel from promising non-edible oils: Euphorbia lathyris L., Sapium sebiferum L. and Jatropha curcas L. *Bioresource technology*, *102*(2), 1194-1199.

[21] Yusup, S. and Khan, M., 2010. Basic properties of crude rubber seed oil and crude palm oil blend as a potential feedstock for biodiesel production with enhanced cold flow characteristics. *Biomass and Bioenergy*, *34*(10), 1523-1526.

[22] Sharma, Y.C., Singh, B. and Upadhyay, S.N., 2008. Advancements in development and characterization of biodiesel: a review. *Fuel*, *87*(12), 2355-2373.

[23] Hossain, A.S., Salleh, A., Boyce, A.N., Chowdhury, P. and Naqiuddin, M., 2008. Biodiesel fuel production from algae as renewable energy. *American journal of biochemistry and biotechnology*, *4*(3), 250-254.

[24] Ikwuagwu, O.E., Ononogbu, I.C. and Njoku, O.U., 2000. Production of biodiesel using rubber [Hevea brasiliensis (Kunth. Muell.)] Seed oil. *Industrial crops and products*, *12*(1), 57-62.

[25] Sarin, R., Sharma, M. and Khan, A.A., 2010. Terminalia belerica Roxb. Seed oil: a potential biodiesel resource. *Bioresource technology*, *101*(4), 1380-1384.

[26] Jain, S. and Sharma, M.P., 2010. Prospects of biodiesel from Jatropha in India: a review. *Renewable and Sustainable Energy Reviews*, *14*(2), 763-771.

[27] Gogoi, T.K. and Baruah, D.C., 2011. The use of Koroch seed oil methyl ester blends as fuel in a diesel engine. *Applied energy*, *88*(8), 2713-2725.

[28] Kansedo, J., Lee, K.T. and Bhatia, S., 2009. Cerbera odollam (sea mango) oil as a promising non-edible feedstock for biodiesel production. *Fuel*, *88*(6), 1148-1150.

[29] Demirbas, A., 2007. Importance of biodiesel as transportation fuel. *Energy policy*, *35*(9), 4661-4670.

[30] Chapagain, B.P., Yehoshua, Y. and Wiesman, Z., 2009. Desert date (Balanites aegyptiaca) as an arid lands sustainable bioresource for biodiesel. *Bioresource technology*, *100*(3), 1221-1226.

[31] Hathurusingha, S., Ashwath, N. and Midmore, D., 2011. Provenance variations in seed-related characters and oil content of Calophyllum inophyllum L. in northern Australia and Sri Lanka. *New Forests*, *41*(1), 89-94

BIOGRAPHIES

Mr. D.K. Tiwari is the corresponding author of this research paper. He has done his M.Tech. from MNIT Jaipur and currently working as a Assistant Professor in Department of Mechanical Engineering at Dr. Ambedkar Institute of Technology for Handicapped, U.P., India

Mr. Sumit Prajapati has completed is M.Tech from HBTI Kanpur and currently working as a Assistant Professor in Department of Chemical Engineering at Dr. Ambedkar Institute of Technology for Handicapped, U.P., India