

BIO-DIESEL - A BETTER SUBSTITUTE FUEL FOR DIESEL ENGINES.

¹ Dr Arvind Lal ,

¹ Faculty , Department of Engineering Materials,
Indian Railways Institute of Mechanical and Electrical Engineering (IRIMEE) , Jamalpur, India-811214

Abstract : In the present paper, an attempts have been made to use non-edible vegetable oils such as Jatropha and polanga (calophyllum inophyllum) for the production of biodiesel by the process of triple stage transesterification. The produced biodiesel and its blends with diesel were tested for their use as green substitute fuel for diesel engines. The production of both the bio-diesel was optimized and the effect of molar ratio of methyl alcohol to oil, reaction time, catalyst amount and reaction time were optimized during the transesterification process. To judge the quality of bio-diesel as per ASTM D 6751, different experimental investigations such as viscosity, flash point, density and pour point etc were carried out and compare its with diesel, several blends of bio-diesel with diesel and near bio-diesel. The formation of Jatropha oil methyl ester (JOME B100) and Polanga oil methyl ester (POME B100) by base-catalyzed transesterification required optimum volumetric ratio of 9.7:1 and 10.5:1 of methyl alcohol for every litre of triglyceride, which was sufficient to give 93% and 87% yields of esters respectively. The maximum conversion efficiency during base catalyzed transesterification was achieved at 0.85% and 1% of KOH for polanga and jatropha oil for the reaction duration of 2 hours of esters yield respectively .The biodiesel and their blends with diesel displayed higher densities, viscosities, flash points and lower calorific values as compared to diesel .All these tests for characterization of biodiesel demonstrated that the properties are in close agreement with diesel,making it a potential candidate for diesel engines.

IndexTerms - Bio-diesel, jatropha oil, polanga oil, Transesterification, free fatty acid (FFA), IRIMEE.

1. INTRODUCTION.

Biodiesel is a renewable liquid fuel coming from biological raw materials (vegetable oils) and have been proved to be a good substitute for diesel in the transportation and agriculture sector. It is a mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats produced by process of transesterification in which oil is reacted with monohydric alcohol in presence of catalyst [1] hence , biodiesel is gaining worldwide acceptance as a solution to environmental problems, energy security, reducing imports, rural employment and improving agricultural economy. Biodiesel is made from virgin or used vegetable oils (both edible & non edible) and animal fats through transesterification and is a diesel substitute and requires very little or no engine modifications [2,3]. The use of biodiesel results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. It is an oxygenated biodegradable and environmental friendly fuel with similar flow and combustion properties and low emission to fossile fuel [4,5].It has almost no sulphur, no aromatics and has about 10% built-in oxygen, which helps it burn fully. Its higher cetane number improves the combustion.[6]

Vegetable oils appears to be an attractive feedstock [7] for three main reasons. Firstly, it is a renewable resource that could be sustainably developed in the future. Second, it appears to have formidably positive environmental properties resulting in no net release of carbon dioxide and very low sulphur content. Third, it appears to have significant economic potential provided that fossil fuel prices increase in the future [3]. Its plantation, seed collection, oil extraction, transesterification, blending, storage and transport will create employment opportunities for a large number of people, particularly the tribals and the poor, and will help rehabilitate unproductive and wastelands and save precious foreign exchange by substituting imported crude. Thus, biodiesel development by itself could become a major poverty alleviation programme for the rural poor apart from providing energy security to the country in general and to the rural areas in particular and upgrading the rural non-farm sector.

In view of the escalating problems of energy (fuel) crisis, environmental degradation and the potential of biodiesel being adopted as an alternative fuel for diesel engines, the present work aims at characterization of locally available non-edible vegetable oils from tree based oilseeds of jatropha and polanga , optimization of production process variables and quality assessment of biodiesel, evaluation of physico-chemical properties of biodiesel and their blends with diesel.

2. MATERIALS AND METHODS.

2.1 . Characterization of feedstock for biodiesel.

Depending on the climate and soil condition different nations are looking into different vegetable oils for diesel fuel substitute. Worldwide, the feedstocks for biodiesel production in greatest supply are soybean oil, palm oil, sunflower oil, rapeseed oil, coconut oil, etc. which are edible in Indian context. Since edible oil demand is higher than its domestic production, it is not desirable to divert these oils for production of biodiesel in India. Being a tropical country, India is rich in forest resources having a wide range of trees, which yield a significant quantity of oil seeds. Thus, development of biodiesel from locally available non edible oil seeds which are low in cost is a more rational basis. The potential of jatropha oil [8-10] and karanja oil [11-13] as a major source of fuel for the biodiesel industry is recognized. There is no doubt that the production of oil seeds can be stepped up once

they are being adopted for regular use in diesel engines. Considering the huge rates of their consumption and consumption pattern, it is clear that vegetable oils at best can provide only a partial replacement.

Ramadhas et al.^[14] developed a double stage process for producing biodiesel from high free fatty acid rubber seed oil. The oil was treated with 0.5% sulphuric acid along with 200 ml methanol per litre of oil in the first stage for reducing FFA to about 2% followed by alkaline catalyzed transesterification in the second stage. They found that excess addition of acid often darken the product. The maximum ester conversion was achieved at very high reaction temperature and viscosity of biodiesel was nearer to diesel. In the proposed paper, investigation have been undertaken to find out suitable production process for biodiesel derived from non-edible oils such as jatropha (*Jatropha curcas*) and polanga (*Calophyllum inophyllum*). Moreover, any study have hardly been carried out to investigate, in totality.

2.2 Materials & its composition.

In the present study, two different varieties of non-edible oils were procured from different sources for production of biodiesel. Jatropha oil was collected from Chattisgarh, Biofuel Development Authority (CBDA), Yasosiddh Bhawan, 48, Masonut Sector1, Shankar Nagar, Raipur, Chattisgarh whereas Polanga oil was collected from Indian Railways Diesel Shed, Kharagpur.

The fatty acid composition as determined by gas chromatograph. and other physico-chemical properties of jatropha and polanga oil is presented in Table 1. It was observed that the free fatty acid (FFA) content of polanga oil (as determined by titration method) was more than 4% except Jatropha oil as shown in Table 1.

Table 1: fatty acid composition and important properties of jatropha and polanga oil.

S.No.	Property of oils	Jatropha oil (<i>Jatropha curcas</i>)	Polanga oil (<i>Calophyllum inophyllum</i>)
1.	Fatty acid composition (%) i) Palmitic acid C _{16:0} ii) Stearic acid C _{18:0} iii) Oleic acid C _{18:1} iv) Linoleic acid C _{18:2} v) Linolenic acid C _{18:3}	16.0 6.5 43.5 34.4 0.8	12.01 12.95 34.09 38.26 0.3
2.	Specific gravity	0.920	0.896
3.	Viscosity (cSt) at 40°C	18.2	71.98
4.	Flash point (°C)	174	221
5.	Acid value (mgKOH/gm)	3.8	44
6.	Free fatty acid % FFA	1.9	22

In good quality feed stock oils, the acid value should be minimum (<8 mg KOH/gm). Increase in acid value should be taken as an indicator of oxidation of the oil which may lead to gum and sludge formation besides corrosion. It is observed from the Table 5.1 that acid value of polanga oil is more than 8 mg KOH/gm i.e. FFA is greater than 4%. The yield of esterification process decreases considerably if FFA is greater than 4%. It has been found that the alkali catalysed transesterification process, though much faster, low in cost and offers mild reaction conditions, is not suitable to produce esters from feedstock having FFA greater than 4% due to presence of moisture leading to soap formation and lack of phase separation. Saponification is an undesirable reaction which affects the yield.

2.3 Experimental set up for biodiesel production:

Initially, experiments were conducted in the laboratory set up at Indian Railways Institute of Mechanical and Electrical Engineering (IRIMEE), Jamalpur. The biodiesel reactor consists of heating mantle, reaction glass flask and mechanical stirrer. The working capacity of the reaction flask was 1 litre. It consisted of three necks one for stirrer, and other for condenser and inlet for reactants as well as for the thermocouple to observe the reaction temperature. The important variables that influence transesterification conversion were oil temperature, reaction temperature, reaction duration, ratio of alcohol (methanol) to oil sample, catalyst type and concentration and mixing intensity. The variable parameters were optimized in the test set up of 1 litre capacity reactor and the optimized parameters were used for production of larger quantity of biodiesel in a 5 litre capacity per batch as shown in Fig 1 at IRIMEE, Jamalpur.



Fig-1 Bio-diesel plant.

2.4 Preparation of biodiesel (Different stages)

The first stage for lab scale preparation of biodiesel from the feedstocks was zero catalyzed transesterification. This stage resulted in lowering the acid value of these oils and is presented in Table 2

Table 2 FFA content after zero-catalysed transesterification.

S.No.	Name of oil	Acid value after first stage (mg KOH/gm)	FFA (%)
1.	Jatropha	3.2 mg KOH/gm	1.6
2.	Polanga	29 mg KOH/gm	14.5

It is seen from the table that jatropha, oil has FFA content of less than 4% but polanga had FFA of 14.5%. Thus it was essential to reduce the FFA content in polanga oil. This necessitated extra step (acid catalysed transesterification) for polanga oil in which the lower layer of zero-catalysed transesterification was treated with anhydrous sulphuric acid as catalyst and methanol for four hours. Extra FFA of polanga oil was converted to Triglycerides during the second stage of transesterification. The final FFA of the polanga oil mixture which consisted of mono-ester (biodiesel), di-esters, triglycerides and FFA, was found to be 2.1%. Experimentally, it was optimized that 0.65% by volume of the H_2SO_4 acid and an oil to methanol volumetric ratio of 7.5:1 gave the maximum conversion efficiency of FFA to glycerides and thereby reducing the acid value of the product of the second stage below 4 mg KOH/gm. The optimized duration of the reaction was 4 hours. Thus the second stage resulted in further lowering of the acid value of polanga oil as shown in Table 3.

Table 3: FFA content after acid-catalyzed transesterification of polanga oil

Name of oil	Acid value after second stage	% FFA
Polanga oil	4.2 mg KOH/gm	2.1

Third and final stage of transesterification process is the base catalysed transesterification. It is observed from the experiments conducted for base-catalysed transesterification that an optimum oil to methanol volumetric ratio of 10.5:1 and 0.85% by weight of KOH was found to give the maximum polanga oil methyl ester (POME) yield leading to 87% of ester yield for a reaction duration of 125 minutes. The formation of Jatropha oil methyl ester (JOME) by base-catalysed transesterification requires optimum oil to methanol volumetric ratio of 9.7:1 and 1% by weight of KOH was found to yield the maximum of jatropha oil methyl ester (JOME) , leading to 93% of ester yield for a reaction duration of 100 minutes at a temperature of 66°C. Table 4. shows the optimized parameters for biodiesel production from jatropha and polanga oil.

Table 4: Optimized parameters for biodiesel production from jatropha and polanga oil.
1st Stage (zero-catalysed transesterification)

S.No.	Parameters	Jatropha oil	Polanga oil
1.	Feedstock oil (litre)	1	1
2.	Methanol (ml/litre of oil)	350	350
3.	Toluene (ml/litre of oil)	4	5
4.	Ortho phosphoric acid (ml/litre of oil)	4	5
5.	Reaction duration (minutes)	120	120
6.	Reaction temperature (°C)	66	66
7.	Stirring speed (RPM)	450	450
8.	Settling time (minutes)	90	120
9.	FFA (%)	1.6	14.5

2nd Stage (acid-catalysed transesterification)

S.No.	Parameters	Jatropha oil	Polanga oil
1.	Methanol (ml/litre of oil)	-	75
2.	Sulphuric acid (ml/litre of oil)	-	6.5
3.	Reaction temperature (°C)	-	55
4.	Reaction duration (minutes)	-	240
5.	Stirring speed (RPM)	-	300
6.	Settling time (minutes)	-	120
7.	FFA (%)	-	2.1

3rd Stage (base-catalysed transesterification)

S.No.	Parameters	Jatropha oil	Polanga oil
1.	Oil to Methanol ratio (v/v)	9.7:1	10.5:1
2.	% KOH (w/v)	1	0.85
3.	Reaction temperature (°C)	66	66
4.	Reaction duration (minutes)	100	120
5.	Yield %	93	87

2.4.1 Zero-catalysed transesterification (Removal of organic matter and gum):

The first stage removes the organic matters and other impurities present in the samples of jatropha and polanga oil using reagent. The presence of impurities creates problems in the yield and in phase separation between the glycerine and esters. This necessitates the pretreatment of procured vegetable oils in the first stage. This is a zero-catalysed transesterification in which mixture of raw vegetable oil, methanol, ortho-phosphoric acid and toluene was stirred at a constant speed and temperature for 0.5 hours to 4.0 hours. 1 litre of oil was mixed with 350 ml of methanol, 5 ml of toluene and 5 ml of ortho-phosphoric acid as a reagent. Toluene helps in dissolving the organic matter with methanol and separating it from the neat oil along with impurities. Different methanol to oil ratio in % volume basis (6% to 40%) and reaction times (0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 hours) were used to investigate for the optimization and their influence on the acid value of raw vegetable oils. The mixture was stirred in air tight reaction flask for 2 hours at 66°C. The heating set up should be just above the boiling point of the alcohol (66°C) to accomplish the reaction. The speed of the stirrer was kept the same for all test runs at 400 rpm. The reactions were carried out with continuous stirring. The product from the first stage was allowed to settle and complete phase separation was visualized. The upper layer which consisted of methanol-water fractions, organic matter, gum, toluene and other impurities were separated from the lower layer. The acid value of the lower layer, which was raw material for the second stage was further measured.

2.4.2 Acid-catalysed transesterification:

Anhydrous sulphuric acid (98.4%) was used as catalyst in the acid-catalysed transesterification. The product of the first stage was mixed with various proportions of anhydrous sulphuric acid starting from 0.1% (v/v) along with methanol in volume basis and stirred at a temperature of 55°C with reaction time of 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5 and 4.0 hours. The stirring speed was maintained at 300 rpm for all the experiments.

2.4.3 Alkaline-catalysed transesterification:

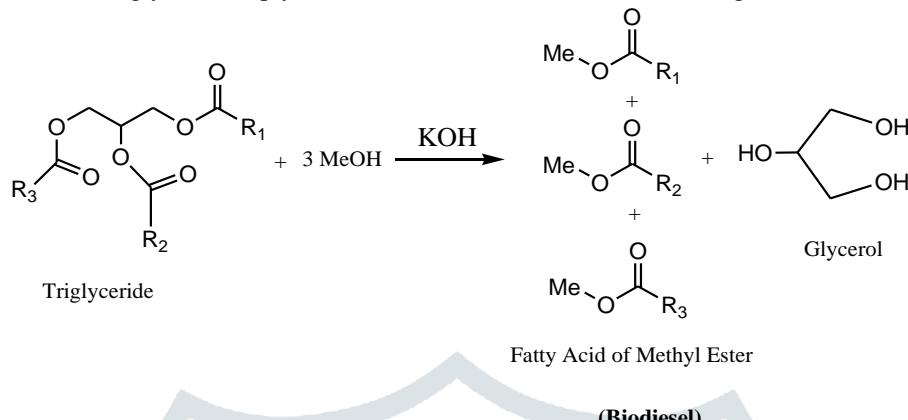
The product of the second stage (pure triglycerides) was transesterified to monoesters of fatty acids (biodiesel) using alkali catalyst KOH in the third stage. The second stage product i.e. pure triglycerides having less than 4% FFA, was used in the third stage. When the reaction was complete, the products were allowed to settle in two layers. The lower layer contained the impurities and glycerol. The top ester layer was separated and purified using warm distilled water. After washing, the final

product was heated to 110° C for 15 minutes in the oven to remove water and was stored in air tight jar for further use. This resulted in a clear light liquid with density and viscosity close to petro-diesel.

2.5 Bio-diesel reaction.

The chemical reaction for the base catalyzed Bio-diesel production is given below.

Once the reaction is complete after adding Metoxide (30 minutes) as in case of Karanj oil, two major products Bio-diesel on the top & glycerin at the bottom. The glycerin simply drained off from the bottom of the settling vessel.



R₁, R₂ and R₃ indicates the fatty acids chain associated with the oil which are largely Palmitic, stearic, oleic and linoleic acids (other are present in small amounts) etc for naturally occurring oils and fats. Bio-diesel is produced from the vegetable oils by converting the triglyceride oils to methyl (Or ethyl) esters with a process know as transesterification. In this process the oil react with alcohol to release three ester chains. From the glycerin backbone of each triglyceride. The reaction requires heat and a strong base catalyst (KOH) to achieve complete conversion of vegetable oil into the separated ester and glycerin. The Glycerin can be further purified for sale to the pharmaceutical and cosmetic industries. The mono-alkyl esters become the Bio-diesel, with the lower viscosity of the original vegetable oil.

Lee et al. [15] studied the effect of bulk modulus of biodiesel and observed that speed of sound and bulk modulus have a significant effect on the fuel injection system and combustion. They reported that the speed of sound, density and bulk modulus of biodiesel being greater than diesel fuel affect the engine's injection timing and combustion delay, thus altering the combustion timing and combustion rate. The combustion timing changes can cause exhaust emissions and performance different from the optimized settings chosen by engine manufacture.

3. Results and discussion.

3.1 Characterization of biodiesel from jatropha and polanga oil.

The fuel properties of JOME and POME and their blends in comparison with that of diesel are shown in Table 5. Most of the fuel properties of JOME and POME and their blends are comparable to those of diesel. The present results obtained show that the transesterification process improved the fuel properties of the virgin with respect to density (Kg/m³), viscosity (cSt), calorific value (MJ/kg), flash point (°C) and pour point (°C). The comparison of these properties with those of diesel used in Indian railways [16] as per IS:1460/2005 shows that methyl esters of jatropha and polanga have relatively closer fuel property values to that of diesel. Hence, no hardware modifications are required for handling these fuels (biodiesel and their blends) in the existing engine.

Table 5: Properties of biodiesel (JOME and POME)

S.No.	Fuel	Density (kg/m ³ at 25°C)	Viscosity (cSt) at 40°C	Calorific value (MJ/kg)	Flash point (°C)	Pour point (°C)	Cloud point (°C)
		ASTMD 1298	ASTMD445	ASTMD240	ASTMD93	-	ASTMD2500.
1.	Diesel	840	2.87	44.0	76	3.1	6.5
2.	JOMEB 100	873	4.23	42.6	148	4.2	10.2
3.	POMEB 100	869	3.99	41.3	111	3.6	10.8

The calorific values of all the biodiesels was measured using Parr calorimeter and are found to be lower than that of diesel because of their oxygen content. The presence of oxygen in the biodiesel helps for complete combustion of fuel in the engine. The flash point was determined with the help of closed cup pensky marten's apparatus. The flash point of all the biodiesels is lowered by transesterification but it is still higher than that of diesel. Addition of a small quantity of biodiesel with diesel increases the flash point of diesel. Hence it is safer to store compared to diesel.

The properties of biodiesel are compared with ASTM biodiesel standards. The tested properties of methyl esters of oils under study are found to be in reasonable agreement with ASTM 6751.

3.2 Preparation of biodiesel blends and their physico-chemical properties

Biodiesel blends with standard diesel fuel (HSD) were prepared and noticed that blending improved the thermal tolerance of the fuel by decreasing the pour point. Blending must always be considered at the biodiesel manufacturing site prior to storage. Several techniques are available for blending of biodiesel with diesel. Since biodiesel has a higher specific gravity than diesel fuel therefore, blending can be achieved by splashing the biodiesel on the top of diesel. This technique is known as splash blending. Water contamination is undesirable as it promotes biological growth in the stored blends however; biodiesel/diesel fuel blends will not separate upon exposure to water. The synthesized biodiesel from two different oil sources namely jatropha oil biodiesel (JOME B100), and polanga oil biodiesel (POME B100) were tested for their physico-chemical properties as per ASTM D-6751 in the Diesel-Shed Laboratory of Indian Railways, Jamalpur. After testing of biodiesels (JOME B100 and POME B100) their blends with diesel were prepared in varying proportions by volume (JOME B20, JOME B40, JOME B60, JOME B80, POME B20, POME B40, POME B60 and POME B80) using splash blending technique and their physical and chemical properties were also determined and listed in Table 6. The ratio of 80% diesel and 20% jatropha oil biodiesel also termed as "JOME B20", indicates 20% level of jatropha oil biodiesel by volume in the blend.

Table 6. Properties of blended biodiesel

S.No.	Biodiesel blend	Density (Kg/m ³) at 25°C	Calorific value (MJ/kg)	Viscosity (CSt) at 40°C	Flash point (°C)	Pour point(°C)	Cloud point (°C)
1.	JOME B20	852	43.7	3.02	88	3.3	6.9
2.	JOME B40	854	43.5	3.41	97	3.4	7.1
3.	JOME B60	860	43.0	3.64	119	3.6	7.6
4.	JOME B80	866	42.9	3.98	131	3.9	8.3
5.	POME B20	852	43.1	2.98	86	3.0	7.8
6.	POME B40	854	42.8	3.30	91	3.2	8.5
7.	POME B60	860	42.3	3.61	96	3.4	10.6
8.	POME B80	862	41.9	3.72	111	3.6	10.8

The densities (as determined using hydrometers of different range) of different blends of biodiesels B20, B40, B60, B80 and B100 of jatropha, and polong biodiesels are compared with diesel. The densities of the blends were found to increase with the increasing concentration of biodiesel in the blend. However, the density of the blends B20 and B40 of jatropha and polong biodiesels were found to be much closer to diesel as compared to the blends B60, B80 and B100 and hence the blends up to B40 may be considered as an alternative fuel to diesel based on the property of density. Larger deviation in the density is observed with blends B60, B80 and B100.

Similar trends were observed in the kinematic viscosity of the biodiesels measured by kinematic viscometer. The kinematic viscosity (at 40°C) of blends B20, B40, B60, B80 and B100 are higher than the viscosity of diesel. The kinematic viscosity of the blends was also found to increase with the increasing concentration of biodiesel in the blend of jatropha and polong biodiesel. However, the kinematic viscosity of blends B20 and B40 were found closer to the kinematic viscosity of diesel compared to B60, B80 and B100.

The calorific value of Jatropha and Polong biodiesels were found to be lower than the calorific value of diesel. The calorific value of the blends of biodiesel decreases with the increasing concentration of biodiesel in the blend.

The flash points of biodiesels increased with increase in blend percentage. Higher flash point of blends of biodiesel indicates safe storage and handling of these oils without any fire hazards.

4. Conclusions:

Based on the experimental investigations with special reference to triple stage transesterification process, the following conclusion can be drawn.

1. Biodiesel is an attractive option for the substitute fuel of petro-diesel because of their desirable properties. It can be produced from locally available vegetable oils through a chemical reaction known as transesterification.
2. Transesterification is a low cost process which brings about a change in the molecular structure of the vegetable oil molecules, thus bringing down the levels of viscosity, density and unsaturation of vegetable oil.
3. It has been observed that biodiesel production from feedstocks with high FFAs (Free Fatty Acids > 4%) is extremely difficult using alkaline catalyzed transesterification process. This is because the alkaline catalysts react with FFAs to

form soap that prevents separation of glycerin and ester. Thus a two step esterification for jatropha and a triple stage transesterification for polanga oil are developed to convert the high FFA oils to its esters. The first step (zero catalyzed transesterification) reduces the FFA content of the oil to less than 2% for jatropha. The second step (acid catalyzed transesterification) reduces the FFA content of polanga oil to less than 2%. The third step (alkaline catalyzed transesterification) converts the products of the first step for jatropha oil and the products of the second step for polanga oil to its mono-esters and glycerol.

4. The effects of alcohol to oil volume, catalyst amount and reaction duration are analyzed in each step of the process. Excess addition of sulphuric acid darkens the product. It has been observed that the conversion efficiency is strongly affected by the amount of alcohol. The volumetric ratio of 9.7:1 and 10.5:1 of alcohol favours the completion of alkaline catalyzed transesterification process in 100 and 120 minutes for the formation of jatropha oil methyl ester (JOME B100) and polanga oil methyl ester (POME B100), which is sufficient to give 93% and 87% yield of ester respectively.
5. The density and viscosity of vegetable oil gets drastically reduced after esterification. The density and viscosity of biodiesel were very close to petroleum diesel oil.
6. The flash point and cloud point of biodiesel are greater than that of diesel and calorific value is slightly lower than that of diesel.
7. Three step transesterification method reduces the overall production cost of biodiesel as it uses cheap, unrefined non-edible vegetable oil.
8. The addition of biodiesel to diesel fuel changes the physico-chemical properties of the blends. With the increase of biodiesel concentration in diesel-biodiesel blends, the kinematic viscosity, flash point and fire point of the blends increase.

All these tests for characterization of biodiesel oil demonstrated that the important properties of bio-diesel are in close agreement with the diesel making it a potential candidate for the application in diesel engines.

ACKNOWLEDGEMENT

The author would like to acknowledge Director, IRIMEE to grant for conducting this research at IRIMEE, Jamalpur.

REFERENCES

1. Zhang, Y., M.A. Dube, D.D. McLean and M.Kates, 2003. Biodiesel production from waste cooking oil: 2. Economics assessment and sensitivity analysis. *Bioresource Technol.*, 90:229-240.
2. Gerhard, V., 1983. Performance of Vegetable oils and their monoesters as fuels for diesel engines. SAE paper No. 831358.
3. Peterson, C., Reece, D.L. Hammond, D.L. Cruz, R. and Thompson, J., 1992. "A comparision of ethyl and methyl esters of vegetable oils as diesel fuel substitute", *Proceedings of Alternative Energy Conference, ASAE*, 99-110.
4. Altin, Recep, selim Cetinkaya and Huseyin Serdar yucesu,2001. The potential of using vegetable oil fuels as diesel engines. *Energy Conversion and Manage.*,42(5):529-538.
5. Fukuda, H., A. Kondo and H. Noda, 2001. Biodiesel fuel production by transesterification of oils. *J. Bioscience and Bioengineering*, 92(5):405-416.
6. Canaki, M., The potential of restaurant waste lipids as biodiesel feedstocks. *Bioresource Technology*. (98); 2007: 183-190
7. Peterson, C.L., 1986. Vegetable oil as a diesel fuel: Status and research priorities, *Trans. ASAE*, 29 (5), 1413-1422.
8. Berchmans, H.J. and Hirata S. 2008. Biodiesel Production from Crude Jatropha Cureas L. Seed oil with a high content of free fatty acids. *Bioresource Technolgy*, 99, 1716-1721.
9. Ramesh D. and Sampathrajan A., 2008. Investigations on performance and emission characteristics of diesel engine with Jatropha biodiesel and its blends. *Agricultural Engineering International: the CIG RE. Journal. Manuscript EE 07013 Vol. X.*
10. Pramanik K., 2003. Properties and use of Jatropha curcus L. and diesel fuel blends in compression ignition engine. *Renewable Energy*, 28, 239-248.
11. Srivastava P.K. and Verma M., 2007. Mehyl ester of Karanja oil as an alternative renewable source energy. *Fuel* (87) pp. 1673 – 1677.
12. Sharma Y.C. and Singh B., 2007. Development of biodiesel from Karanja, a tree found in rural India *Fuel*, doi: 10.1016/J. Fuel. 2007 08.001.
13. Karmee S.K. and Chadha A., 2005. Preparation of biodiesel from crude oil of Pongamia pinnata. *Bioresource Technology*, 96, 1425-1429.
14. Ramodhas, A.S., Muraleedharan, C. and Jayaraj S., 2005. Performance and emission evaluation of a diesel engine fuelled with methyl esters of rubber seed oil. *Renewable Energy*, Vol. 20,1-12.
15. Lee C.S., Park, S.W. and Kwon, S., 2005. An experimental study on the atomization and combustion characteristics of biodiesel blended fuels. *Energy and Fuels*, 19: 2201-2208.
16. Lal,A.,Gupta,A.K.,kumar,A.,and yadav,N.K.,2010.Waste cooked oil as an alternative feed stock for bio-diesel production in Indian Railways,Asian J.researchChem,4(6):942-945.