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Full Length Research Paper

Mustard oil, an alternative Fuel: An experimental investigation of Bio-diesel properties with and without Trans-esterification reaction

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This paper presents an experimental investigates of the bio-diesel preparation from vegetable oil i.e. mustard oil. First time, the bio-diesel has been prerared by trans-esterification reaction or chemical process and blend in different proportion with diesel fuel. Again, without trans-esterification reaction, the mustard oil has been blended with diesel in different proportion of 20%, 30%, 40% and 50% and named as bio-diesel bland B20, B30, B40, and B50. The properties of the fuel i.e. density, viscosity, dynamic viscosity, carbon residue, flash point, fire point and calorific value of pure mustard and its blends have been carried out in the fuel testing laboratory. During the fuel and bio-fuel have been tested in the laboratory, different ASTM standards were maintained to findout the properties of the bio-diesel. The comperrison were made between the blended bio-fuels which was prepared with or without trans-esterification reaction.

Keywords: Heating value; Density; Dynamic viscosity; Specific gravity; Flash point; Fire point.

INTRODUCTION

Alternative fuel means the term refers to substances (excluding conventional fuels like gasoline or diesel) which can be used as fuels. Due to the energy crisis, the following factors have led to the increasing need for finding a feasible fuel alternative to conventional sources. Fossil sources are limited, and will eventually get used up. Only few countries have usable fossil reserves. This forces other nations to depend on them for energy. Countries want energy security and independence. Combustion of carbon-rich fuels leads to emissions like CO and CO2, which are harmful to the environment. More and more people are becoming environmentally-conscious and want a fossil fuel alternative (Radha, K. K., et al., 2011). The pressing need for a solution to the world's environmental and energy problems has led to a lot research to find a fossil fuel alternative. Alcohol-fuels like ethanol and methanol based substances are easy to produce. They are made from crops like corn, which is fermented to produce alcohol. But alcohols are highly corrosive, and require expensive metal, plastic and rubber replacements for existing parts to be used in cars (Kumar, S., et al., 2012; Nakpong, P., et al., 2010).

Bio-diesel refer to non-petroleum based substances which powers a diesel engine. Vegetable oils and used-fry-oil have been used as biodiesels, after being subject to some processing. They are effective alternatives to petro diesel, producing similar amounts of energy with lesser emissions. However, biodiesels are significantly more expensive than petro diesel, freeze solid in cold

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Corresponding author Email: azad_sgfl@yahoo.com weather, and cannot be produced in sufficient quantities to meet global demand. Hydrogen is the most promising fossil fuel alternative for the future. It's the most common element in the universe, and yields the highest amounts of energy on combustion. Also, hydrogen combustion produces only energy and water, so it's completely eco-friendly. Experts predict that by 2020, problems in production, storage and distribution of hydrogen would been solved, making it the best solution to the current energy crisis (Forhad, A., et al., 2010; Radwan, M. S., 2007; Berchmans, H. J., 2008).

Some of the typical option fuels include bio diesel, ethanol, butanol, chemically stored electricity (batteries and fuel cells), hydrogen, methane, natural gas, wood, vegetable oil, biomass, and peanut oil. The term "alternative fuels" usually refers to a source of which energy is renewable. Renewable energy is the energy from renewable sources like wind power, solar power, tidal power, geothermal power, hydro power or thermal depolymerization (Lin, C.Y., et al., 2006; Naik, M., et al., 2008). There is growing social interest, and an economic and political need for the development of option energy sources. This is due to general concerns of sustainability, environmental, economic, and geopolitical reasons. Two major concerns are that of rising cost of fossil derived fuels caused by an era of growing energy consumption and of global warming crisis (Khan, M.Y. et al., 2006; Altan, R., et al., 2001; Ghormade, T. K., et al., 2002).

The major advantage of option energy fuels is that it burns cleaner than the traditional petroleum fuels. It also helps to reduce such emissions as carbon monoxide, organic compounds, nitrogen oxide, sulfur and particulate matter (Naik, M., et al., 2008). Other advantages of option fuels are that these fuel costs less, maintenance is cheaper and engines last longer. Most of the option energy fuels have greater conductivity and will increase the lubrication of engine parts depending on its performance (Kumar, et al., 2000; Huzayyin, A. S., et al., 2004).

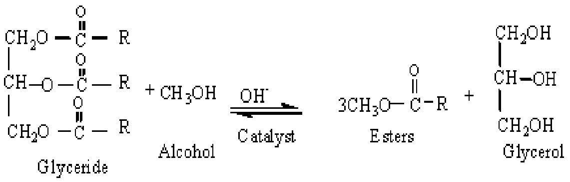
One of disadvantages of option fuel is that it might be expensive to incorporate this technology into our already set up infrastructure. Compatibility is one of the major concerns of option fuels. The production of option fuels can have widespread effects. As an example, the production of corn-based ethanol has created an increased demand for the feed stock, causing rising prices in almost everything made from corn. Whatever may be its advantages and disadvantages, due to the emerging needs of fuel, these renewable energy sources are better hope for us to solve the fuel crisis of the present and future (Narayan, C.M., 2002).

The use of vegetable oils as an alternative fuel for diesel engines dates back to around a century. Due to rapid decline of crude oil reserve and increase in price, the use of vegetable oils is again prompted in many countries. Depending upon soil condition and climate, different nations are looking for different vegetable oils-for example, soybean oil in U.S.A., rapeseed and sunflower oil in Europe, palm oil in Malaysia and Indonesia, coconut oils in Philippines are being considered to substitute of diesel fuel. The potential of bio-diesel production from mustard oil have been found to be a promising fuel for diesel engine in a number of studies. Mustard (Brassica juncea) is a widely growing seed in Bangladesh. Many countries consider mustard oil as unsuitable for human consumption as it has a high content of a substance known as erucic acid which is harmful to the body. Mustard plant is characterized by yellowish green leaves and round stems with long inter-nodes. The grayish brown seeds are tiny and round in shape and on reacting with water emit a strong smell. It is generally used in cooking. Every year the production of mustard seed surpluses our demand for it. So our endeavor was to use the surplus mustard oil as an alternative to diesel fuel. This paper shows the prospect of mustard oil as a renewable and alternative source to diesel fuel (Srivasata, A., et al., 2000; Yosimoto, Y., et al., 2001).

Trans-Esterification Reaction

The Vegetable oils are extracted from crude oil. There crude oil usually contains free fatty acids (FFA), water, sterols, phospholipids, odorants and impurities. Its can cause numerous problems in diesel engines. It also increased viscosity, low volatility and poor cold flow properties. They lead to severe engine deposits, injector coking, piston ring sticking etc. Bio-diesel may be produced by following four ways: Pyrolysis, Micro emulsification, Dilution and Transesterification.

In this work Transesterification process is used to prepare bio-diesel from mustard oil. It is the process of using an alcohol (e.g. methanol, ethanol or butanol), in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to break the molecule of the raw renewable oil chemically into methyl or ethyl esters of the renewable oil, with glycerol as a byproduct. Trans-esterification reaction for vegetable oil:



Trans-esterification, also called as alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis except that an alcohol is used instead of water. This has been widely used to reduce the viscosity of the triglycerides.

Experimantal Procedure

For the transesterification of mustard oil, Dr. Peeper's style has been followed in our work. First 250 ml (90% pure) methanol was mixed with 150 ml (1 N) NaOH. This mixture was swirled in a glass container until NaOH is fully dissolved in methanol. As this is an exothermic reaction, so the mixture would get hot. This solution is known as methoxide, which is a powerful corrosive base and is harmful for human skin. So, safety precautions should be taken to avoid skin contamination during methoxide producing.

The upper more transparent layer is 100% bio-diesel and the lower concentrated layer is glycerol. The heavier layer is then removed either by gravity separation or with a centrifuge. In some cases if the mustard oil contains impurities, then a thin white layer is formed in between the two layers. This thin layer composes soap and other impurities.

Bio-diesel produced in the above process contains moisture (vaporization temperature 100 degree Celsius) and methanol (vaporization temperature 60 degree celsius.) and usually some soap. If the soap level is low enough (300-500 ppm), the methanol can be removed by vaporization and the methanol will usually be dry enough to directly recycle back to the reaction. Methanol trend to act as a co-solvent for soap in biodiesel; so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed. Anyway, heating the biodiesel at temp. above 100 degree Celsius would cause the removal of both the moisture and methanol as well. Another process is to add directly mustard oil to the diesel fule without trans-esterafication process and blends of different proportion named B20, B30, B40, B50 and B100.

Test Of Fuel Properties

Biodiesel produced from mustard oil has comparable fuel properties with the conventional fossil diesel. A comparative study of fuel properties for fossil diesel, neat biodiesel and their blends with and without chemocal reaction have been carried out in this work.

Density: Density of fuel at different temperatures was measured by a standard 25 ml marked flask. Weight of the fixed volume of fuel (25 ml) was measured at different temperatures by an electronic balance which measures up to 0.0001 gm. The density values are reported in kg/m^3.

Viscosity: Viscosity of fuels has been measured as per ASTM standard D88-56 using saybolt viscometer and accessories. Time of falling of 60 ml sample under controlled conditions through a standard oil tube was measured. This time is reported as Saybolt Universal Second (SUS). Corresponding kinematic viscosity was obtained from ASTM standard conversion chart ASTM D2161-79 and the value was checked by computing the same as per empirical formula over a wide range of SUS. Measured values of kinematic viscosities are presented on ASTM standard D341-8 Viscosity- Temperature charts. Volatility: Volatility characteristics of fuels were determined by distillation as per ASTM standard D86-78. A 100 ml sample was distilled at atmospheric pressure. Temperatures were recorded after every 10 ml of condensate collection, and the results are presented with a Temperature vs. Percentage recovered graph. Carbon Residue: ASTM standard D189-81 method was followed to determine carbon residue of the test fuels. A weighed quantity of sample was placed in the apparatus subjected to destructive distillation. At the end of specified heating period, the final weight of remaining material in the crucible was taken. The weight of the residue was calculated as the percentage of original sample and the result is reported as Conradson carbon residue.

Ash Content: Ash content of the test fuels were measured by ASTM standard D482-87. Carbonaceous residue obtained after conradson method was subjected to destructive heating in a muffle furnace at 700-800 °C for 10 minutes. Crucible was then cooled and weighed. The residue at this stage was the ash content of the test fuel and it was reported as percentage weight of original sample.

Heating Value: Heating values of fuels used in this research has been measured experimentally following ASTM standard D240-87 using an oxygen bomb calorimeter. One gm of previously weighed sample was burnt at constant volume. Heat of combustion was computed from temperature observations using a Beckman thermometer before, during and after combustion with necessary temperature corrections. Flash Point: Flash points of test fuels were measured as per ASTM standard D93-85 using Pensky-Martens closed tester. The sample taken into the closed-cup tester was heated slowly with continuous stirring. A flame was inserted into the oil cup at every 2°C temperature rise of the oil. Flash point of the fuel was noted as the lowest temperature at which application of the test flame causes the fuel vapor to give flash of fire and then disappear.

The properties of the pure mustered oil has shown in the below Table – 1. During the test following ASTM standards were maintain and findout the properties of different bio-fuel blends. The below table shows the properties at room temperature. The properties of different bio-diesel blens have been tested at different temperature which has discussed later.

In the above Figure – 2, shown the color of different bio-diesel blends from left to right B20, B30, B40, B50, B100 pure bio-diesel from mustard oil, and at last pure diesel respectively. The properties of these bio-fuel blends have been tested in the fuel tasting laboratories. The test results have been shown in belowTable–1. The properties and color of the bio-fuel blends without

Table 1. Properties of bio-fuel blends, mustard oil (with Transesterification) and pure diesel.

Properties and Standards	Unit	Value for different bio-fuel blends					
		B20	B30	B40	B50	B100	Diesel
Density 35°C (ASTM D4052-11)	kg/m^3	838.8	841.21	851.4	859.3	881.1	825.9
Specific Gravity (ASTM D5453-09)	-	0.901	0.907	0.911	0.916	0.938	0.899
Kinematic Viscosity 35°C (ASTM D2161-79)	mm^2/sec	5.5922	11.531	10.89	11.95	25.13	3.96
Dynamic Viscosity @ 35°C (ASTM D7042-11a)	cP	4.691	9.699	9.262	10.26	22.16	3.27
Calorific Value (ASTM 2382)	MJ/Kg	42.65	42.21	42.18	41.97	39.51	44.00
Flash Point (ASTM D93-85)	°C	79	82	97	112	297	72
Fire Point (ASTM D92-11)	°C	96	105	116	129	343	210

Figure 1. (a) Pure mustard oil, (b) Seperation of biodiesel at 3 hours, (c) Seperation of biodiesel after 24 hours, (d) Produced biodiesel is heated to remove methanol and water, (e) Blending and (f) Pure bio-diesel.

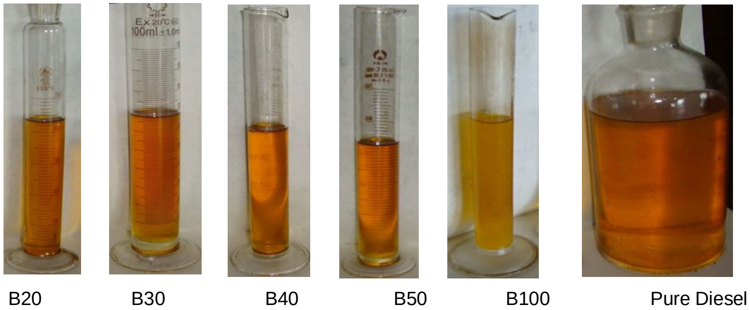


Figure 2. Color of different bio-diesel blends, mustard oil (with transesterification) and diesel

trans-esterification reaction has shown in below Table – 3 and Figure – 3. The bio-dieselblends color has shown from left to right B20, B30, B40, B50 and B10.

During the test of the bio-fuel, following ASTM standards were maintained and the properties shown the fuels at room temperature, which has shown in below Table – 2. The variation of fuel properties at different temperature has been discussed later.

The calorific value or heat value is the more important properties of a fuel. Heating value indicates the energy density of the fuel. In the study, ASTM 2382 method has been applied to measure the heating value of biodiesel

Table 2. Properties of different bio-fuel blends (without Transestarefication reaction), and pure mustard oil.

Properties and Standards	Unit	Value for different bio-fuel blends				
		B20	B30	B40	B50	B100
Density 31°C (ASTM D4052-11)	kg/m^3	840.96	847.96	855.6	863.8	925.24
Specific Gravity (ASTM D5453-09)	-	0.904	0.910	0.915	0.920	0.941
Kinematic Viscosity 31°C (ASTM D2161-79)	mm^2/sec	8.113	11.01	14.1	18.51	63.40
Dynamic Viscosity @ 31°C (ASTM D7042-11a)	cP	6.822	9.33	12.06	15.98	58.66
Calorific Value (ASTM 2382)	MJ/Kg	34.56	36.71	39.10	41.30	32.43
Flash Point (ASTM D93-85)	°C	85	85	100	130	310
Fire Point (ASTM D92-11)	°C	100	110	120	110	350

Table 3. Test Engine specifications.

Items	Engine Data
Model	S195G
Method of starting	Hand starting
Engine Type	Single cylinder, 4-stroke,
Cylinder Bore	95 mm
Piston stroke/ Stroke	115 mm
Swept Volume	85 cc
Nominal speed	2000 rpm, Anti-clockwise
Nominal power	9 KW
Compression ratio	1:20
Sp. fuel consumption	Less or equal 258.4 gm/kw-
Cooling system	Water cooled condenser
Fuel and Lube oil filter	Present

B20 B30 B40 B50 B100

Figure 3. Color of different bio-diesel blends (without Transestarefication), and pure mustard oil.

and their blends. Figure – 4, shows the comparison of the heating value of bio-diesel blends, neat biodiesel with pure diesel fuel in MJ/Kg.

In the below Figure – 4, it has been shown that the calorific value or heating value of diesel is 44.0 MJ/kg, bio-diesel (39.51 MJ/kg) and pure mustard oil (32.39 MJ/kg). The heating value decreases with the increased of bio-diesel blends by trans-esterification reaction. For B20 CV is 42.65 MJ/kg and for B50, it becomes 41.9 MJ/kg. In another case,

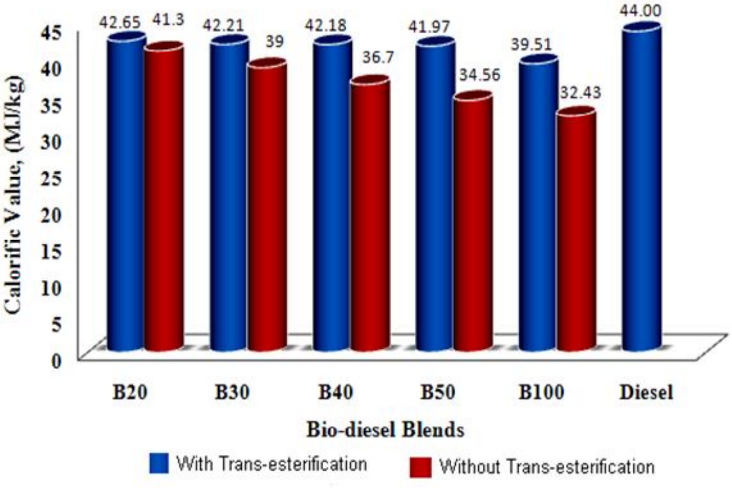


Figure 4. Comparison of the calorific value or heating value in MJ/kg between with trans-esterification and without trans-esterification reaction

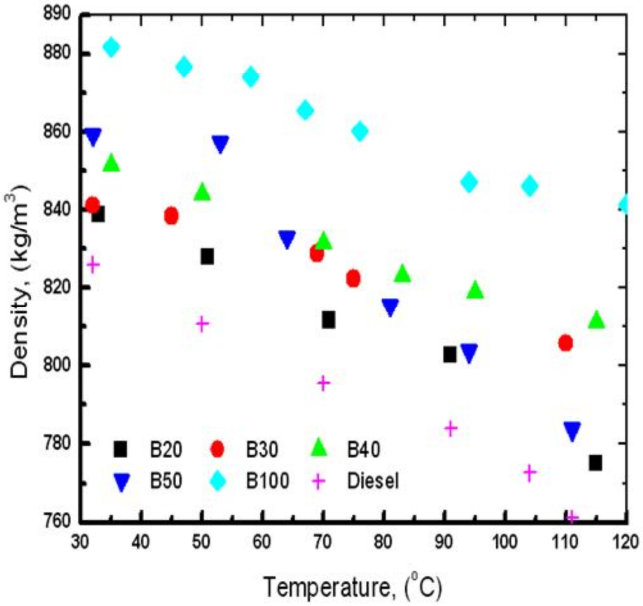


Figure 5. Variation of density of the bio-diesel blends with temperature(by Trans-esterification reaction).

without chemical process the heating value gradually decreases with the increased of bio-fuel blends. The CV at B20 is 41.3 MJ/kg which becomes 34.56 MJ/kg for B50. This is because, as biodiesel has lower energy density than diesel fuel, so higher amount of biodiesel is required for producing same amount of energy as compared to diesel fuel.

The above Figure – 5, has shown the density of different bio-fuel blends at different temperature after chemical reaction. The fossil diesel has lower density and the pure bio-diesel has higher density. The density increases with the increase of bio-fuel blends. Density of the fuel is an important property for IC engine. Higher density fuel required preheating for ignition and would

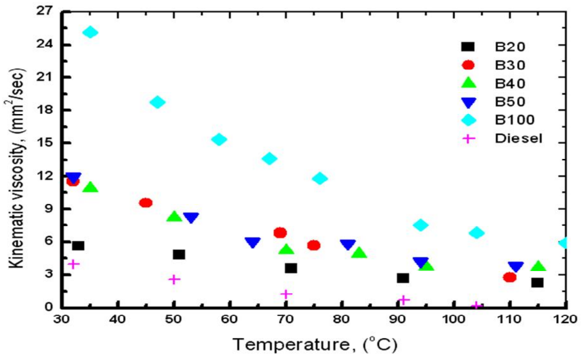


Figure 6. Variation of kinematic viscosity with temperature (by Trans-esterification reaction).

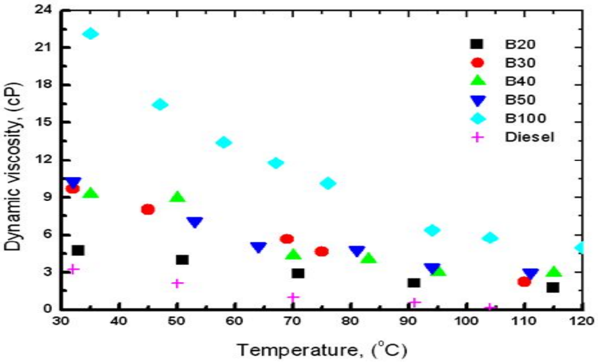


Figure 7. Variation of dynamic viscosity with temperature (by Trans-esterification reaction).

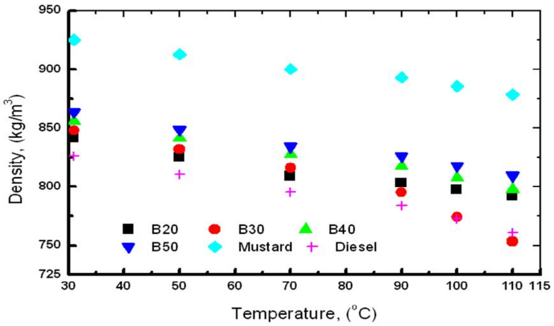


Figure 8. Variation of density of the bio-diesel blends with temperature (without Trans-esterification reaction).

causes low atomization, which will create higher unburned hydro-carbon and pollute the environment. So, the engine intake manifold should be redesigned so that preheating can be done utilizing the exhaust of the engine.

The Figure – 6 and 7 represents the variation of kinematic viscosity and dynamic viscosity of the fuel blends with different temperature. It has been shown that viscosity (both kinematic viscosity and dynamic viscosity) increases with the increase of bio-diesel blends. But at higher temperature the viscosity of B20 to B50 becomes closer to each other than lower temperature and it is about 2.5 times higher than the fossil diesel at room temperature.

On the other hand B100 is a much viscous fuel, and its viscosity is about 6 times higher than that of diesel fuel. So, using B100 fuel in the existing diesel engine would require modification of the fuel supply system so that the fuel supply system exerts high spray pressure to achieve the desired spray pattern inside the engine cylinder. Because, the higher viscous fuel causes low atomization (large-droplet size) and high penetration of the spray jet. The below figure – 8 has shown the variation of fuel Density at different temperature without trans-esterification reaction for different bio-diesel blends.

The density increases with the increase of bio-fuel

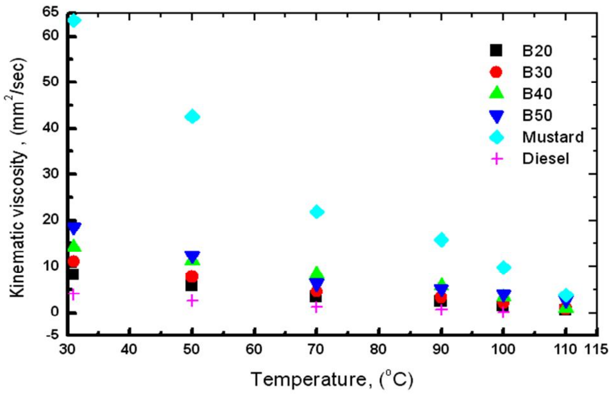


Figure 9. Variation of kinematic viscosity with temperature (without Trans-esterification reaction)

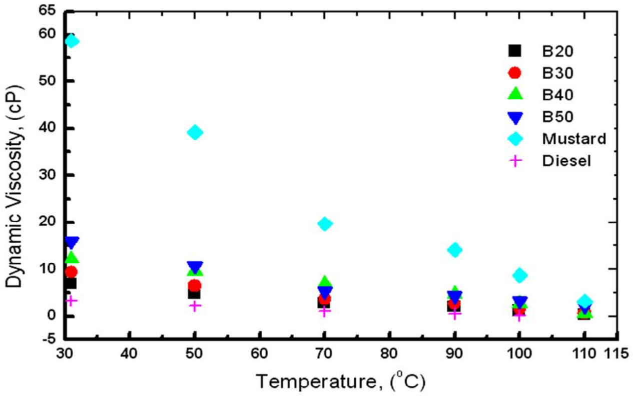


Figure 10. Variation of dynamic viscosity with temperature (without Trans-esterification reaction).

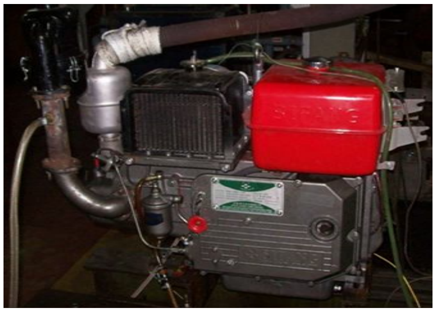


Figure 11. Experimental setup engine.

blends and decreases with increase of temperature. With compare of Figure – 5 and Figure – 8, it has been clearly shown that without chemical reaction fuel density is higher and effect of temperature on it is lower. Because it contains free fatty acids (FFA), phospholipids, odorants. The same effect occurs in the diesel engine have discussed above.

The above Figures – 9 and 10, shown the variation of kinematic viscosity and dynamic viscosity for different fuel blends without trans-esterification reaction. In the case of B20 to B50 variation of viscosity is lower to each other. But pure mustard is higher viscous fuel compare with chemical reaction. At 100 °C temperature viscosity of the bio-fuel blends have closeness with the diesel fuel. The effect of viscosity on engine have discussed above.

Performance Test Setup

In this experiment a single cylinder, water-cooled, 4-stroke, and DI diesel engine (specification Table-3) has been used for performance testing. The fuel injection timing was set at 24°BTDC.

The bio-fuel blends have been tested in a four stroke

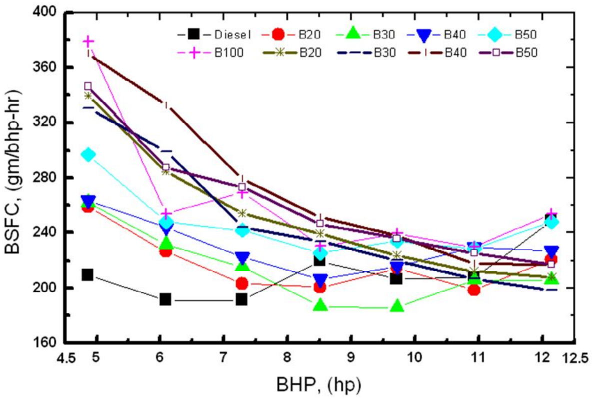


Figure 12. Variation of BSFC with BHP for different bio-fuel blends. Here, thick lines are with trans-esterification reaction and thin lines are without trans-esterification reaction.

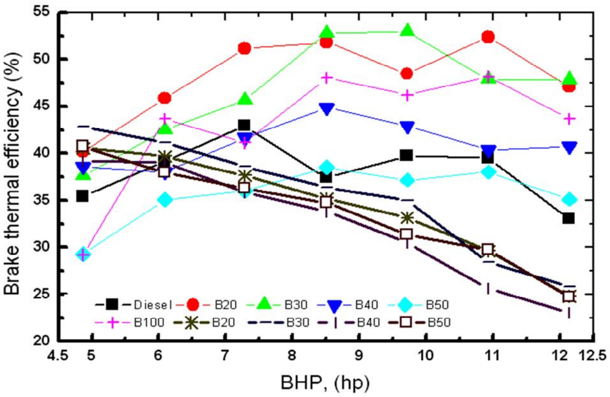


Figure 13. Variation of break thermal efficiency with BHP for different bio-fuel blends. Here, thick lines are with trans-esterification reaction and thin lines are without trans-esterification reaction.

single cylinder DI diesel engine. The engine performance has been shortly discussed in this article. The Figure – 12, has shown the variation of BSFC with BHP both bio-diesel blends with trans-esterification and without trans-esterification reaction. For each fuel blends, BSFC decreases with the increases of engine load but its also increases with the increase of bio-fuel blends. It has been clear from the above figure that without trans-esterification bio-fuel blends have lower BSFC than with trans-esterification reaction. Thermal efficiency has just reversed of BSFC. So, lower BSFC means higher thermal efficiency of the bio-fuel.

The above Figure – 13, has shown the variation of break thermal efficiency with BHP. The break thermal efficiency of the engine was observed to increase with increase in the load and decrease with the increase of bio-fuel blends in both case. The better result has been found overall thermal efficiency for M20. But the maximum was found for M30. At higher load condition, the bio-diesel blends from trans-esterification reaction gradually more decreases with respect to without trans-esterification reaction. So, from this discussion, it can be said that the bio-diesel blends B20 and B30 without trans-esterification reaction has given better performance than other blends.

CONCLUSIONS

In regard to the present experimental work of diffenernt bio-diesel blends the following conclusions are drawn:

The study was made on the properties of bio-fuel with trans-esterification reaction and without trans-esterification reaction.

The heating value of the bio-fuel has been decreases with the increase of bio-fuel blends in both cases.

The effect of temperature on fuel density and viscosity has been carried out and it has been shown that the variation of fuel properties changes with bio-fuel blends with diesel fuel.

At starting condition or low load condition the bio-fuel blends have higher bsfc than diesel. But for B30, after 10.0 kg load bsfc becomes lower than any other fuel in the experiment.

At higher load condition the bio-fuel prepared by chemical process has better performance than direct process because at high load BSFC becomes lower than other blends.

Through the experiment B20 and B30 have better performance than other bio-diesel blends.

Finally, it can be possible to run diesel engine with bio-diesel blends.

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