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Biodiesel Production From Animal Fats And Its Impact On The Diesel Engine With Ethanol-Diesel Blends: A Review

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***Abstract*— Mainly animal fats and vegetable oils are used for the production of biodiesel. Several types of fuels can be derived from triacylglycerol-containing feedstock. Biodiesel which is defined as the mono-alkyl esters of vegetable oils or animal fats. Biodiesel is produced by transesterifying the oil or fat with an alcohol (methanol/ethanol) under mild conditions in the presence of a base catalyst. This paper discuses fuel production, fuel properties, environmental effects including exhaust emissions and co-products. This also describes the use of glycerol which is the by-product in esterification process along with biodiesel. The impact of blending of biodiesel with ethanol and diesel on the diesel engine has described.**

***Keywords*— biodiesel, animal fats, transesterification, ethanol, biodiesel, petro diesel, blends**

I. INTRODUCTION

Continuing depletion of the reserves of non-renewable petroleum, price volatility, feedstock availability concerns have caused an intensified search for alternative sources of energy. Biodiesel derived from biological sources, among them lipid materials such as fats and oils have received increasing attention.

Different processes for biodiesel production using fats and oils as a feedstock yields fuels with different composition and properties [1, 2]. Biodiesel which is defined as the mono-alkyl esters of vegetable oils or animal fats, obtained by transesterifying oil or fat with an alcohol. The major reason for not using a neat vegetable oil as fuel is its high viscosity (28-40mm^2/s), which leads to operational problems in diesel engine including formation of deposits into the injector choking due to poorer atomization upon injection into the combustion chamber [1]. Transesterification of the oil reduces the viscosity of the oil to a range (4-5mm^2/s) closer to that of petro diesel.

The combustion of petroleum based fuels causes environmental problems, which threaten wild and human life, impacts on the environment and human health. Further global warming is caused of emission of CO, SO_2, NO_X etc as the combustion products. Its part in global warming potential has increased from year by year and now bigger than those of the domestic and industrial sector (17).

It was stated by Lloyd and Cackete (3) that diesel emission contributes to the development of cancer, cardiovascular and respiratory health effects; pollution of air, water and soil; soiling; reductions in visibility and global climate change. There are many works on reliable researching and implementation and useful results come to exist. The alternative fuels must be technically acceptable, economically competitive, environmentally acceptable and easily available. Research on biodiesel derived from vegetable oils and animal fats are being maintained to alternate this kind of fuels to petroleum based diesel fuel. It has been concluded by many studied that as an alternative engine biodiesel reduce the emissions of carbon monoxide (CO), hydrocarbons (HC), sulphur dioxide (SO_2), Polycyclic Aromatic Hydrocarbons (PAH), nitric Polycyclic Aromatic Hydrocarbons (nPAH) and particulate matter (PM) by NO_x to increase in the exhaust as compared with diesel fuel (4,5,6). Though biodiesel has some attractive properties like higher cetane number, no aromatics, almost no sulphur, high oxygen(by weight), non-toxic, bio-degradable, high lubricant ability (7,8,9) it has many properties need to improve such as Lower Calorific Value(LCV), Lower Effective Engine Power(LEEP), NO_x emission, greater sensitivity to low temperature (9).

II. PRODUCTION OF BIODIESEL

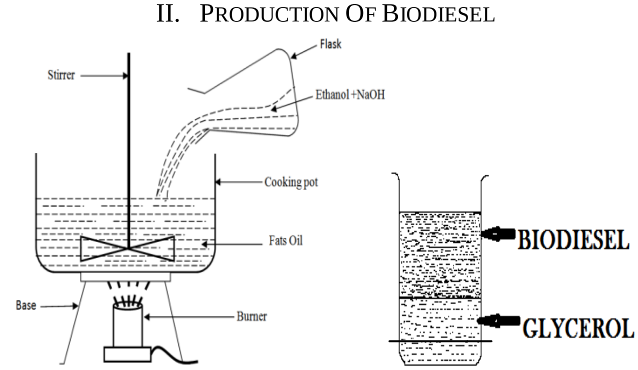

Figure 1: Production of Biodiesel

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Biodiesel is produced from the triacylglycerol-containing material by means of a transesterification reaction. In this process, alcohol (methanol/ethanol) and animal fats are mixed in the molar ratio of 6:1, heated at 60-65^{0}C for 1hr and the ambient pressure in the presence of catalyst such as NaOH/KOH. Before that, animal fat gets heated up to 105-110^{0}C so that it will be converted into fat oil then in the separate flat bottom flask, alcohol and NaOH/KOH (2% of fat)are mixed exothermic reaction take place. This mixer is then added to heated fat and keep it at 60-65^{0}C for 1hr. After this, it is poured into a bottle so that biodiesel and glycerol get separated as shown.

This biodiesel is used in diesel engine as a solvent in ethanol-diesel mixer for avoiding a phase separation. The increasing % of biodiesel in ethanol-diesel blends results in the increase of emissions NOx but it reduces the emissions of CO, HC, sulphur and particulate matter (PM) considerably.

The preparation of biodiesel by transesterification process can be shown as:

animal fat/ vegetable oil + alcohol ⇨ tryglycerol + biodiesel

Biodiesel is being produced from many of vegetable oils and animal fats. If it is produced from high quality edible oil and fats, it will resulted in high prices of raw material and biodiesel is more expensive than petroleum diesel fuel also shortage of edible oil for food purpose. Biodiesel may also be produced from less expensive animal fats including inedible tallow, pork lard and yellow grease. Animal fats are highly viscous and mostly in solid form at ambient temperature because of their high content of saturated fatty acids. The high viscous fuel leads to poor atomization of the fuel and result in incomplete combustion. Transesterification and emulsification are two main solutions that have appeared as effective methods for using animal fats in diesel engine. Animal tallow generated biodiesel offers a wide range of energy, environmental and economic advantage as stated by Nelon and Schrock (10).

Glycerol, which is a co-product in the biodiesel production, refining and unrefined, can be used in the manufacture of a variety of products as shown in figure given below. Glycerol obtain from biodiesel production does not require any further processing except purification.

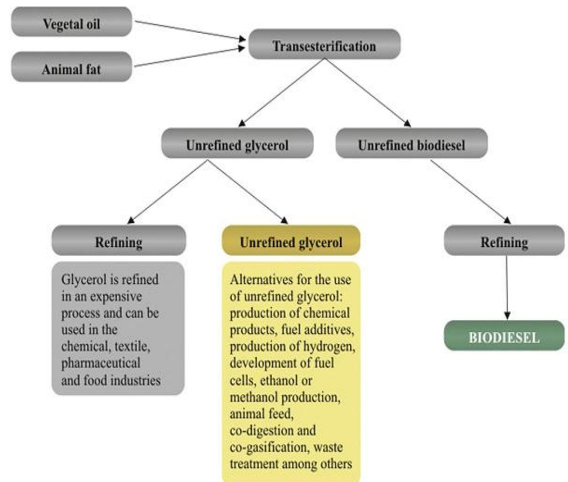

Figure2: Schematic summary of the generation of glycerol and its alternative routes (25)

Experimental set-up for the use of biodiesel in diesel engine can be shown in the figure given below:

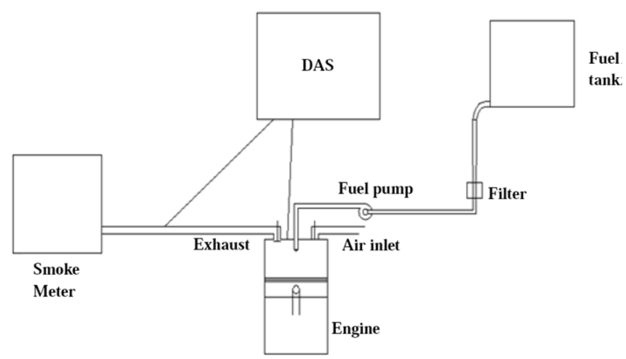

Figure3: experimental set-up

As shown in the experimental set-up, blended fuel is supplied to the engine through filter and fuel pump. Data acquisition system (DAS) is used to take readings of speed, inlet pressure, temperature, etc. and show output on the computer monitor. Smoke meter gives smoke reading per minute. Emissions such as NOx, CO, HC, and SO_2 can be measured with the help of exhaust gas analyzer (not shown here).

The composition of various biodiesel feed stocks in order of increasing saturated fatty acid content can be shown as (27):

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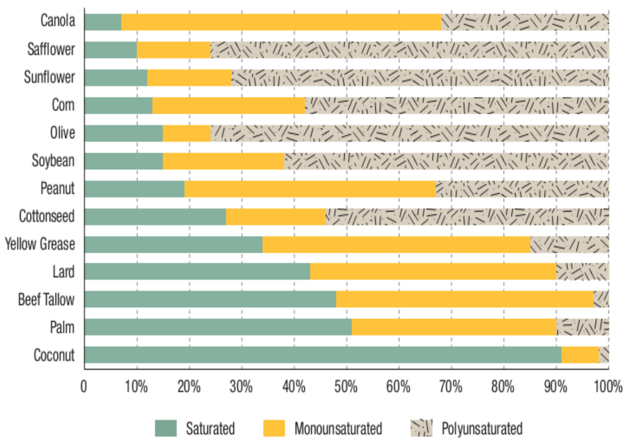

Figure4: composition of various biodiesel feed stocks in order of increasing saturated fatty acid content (27)

In this paper, an overview on the method of biodiesel production and its usability on a diesel engine as solvent in ethanol-diesel blends have studied.

III. Literature Survey

Many investigations were carried out in order to use biodiesel, ethanol and diesel in diesel engine individually as well as in different blends. These investigations can be categorised into mainly five approaches.

A. Use of Biodiesel (B100):

Turning to first sort of investigation, researchers studied 100% biodiesel as diesel engine fuel as follows [1, 11, 12 and 13]:

The term ''biodiesel'' defines a ''fuel comprised of mono-alkyl esters of long-chain fatty acids derived from vegetable oils or animal fats, designated ''B100'' as formulated in the biodiesel standard ASTM D6751 with the European biodiesel standard EN 14214 referring to fatty acid methyl esters (FAME) as fuel [1]. This fuel is obtained from an oil or fat by a transesterification reaction with glycerol as co-product. It may be argued that, when produced with methanol as alcohol component, the carbon atoms in biodiesel are only approximately 95% ''bio''. The reason is that methanol, although it can be obtained from renewable resources, is most commonly derived from non-renewable natural gas. In the case of ethyl esters, biodiesel is completely ''bio'' as ethanol is commonly derived from renewable resources such as corn and sugarcane.

In the paper [11], describes the preparation of biodiesel from mutton fat. The use of MgO impregnated with KOH as heterogeneous catalyst for the esterification of mutton fat with methanol has been evaluated.

In this process >98% conversion of fats into biodiesel in 20 minutes is become possible. At 0.02% weight of moisture and free fatty acid 0.002% with methanol completely converted into biodiesel but additional 1% weight of moisture result in soap formation. MgO-KOH-20 (MgO with 20% KOH) catalyst found to tolerate additional 1% of water in the fat.

In this study [12], chicken fat biodiesel with synthetic Mg additive was studied in a single-cylinder, direct injection (DI) diesel engine and its effects on engine performance and exhaust emissions were studied. A two-step catalytic process was chosen for the synthesis of the biodiesel. Methanol, sulphuric acid and sodium hydroxide catalyst were used in the reaction. To determine their effects on viscosity and flash point of the biodiesel, reaction temperature, methanol ratio, type and amount of catalyst were varied as independent parameters. Engine tests were run with diesel fuel (EN 590) and a blend of 10% chicken fat biodiesel and diesel fuel (B10) at full load operating conditions and different engine speeds from 1800 to 3000 rpm. The results showed that, the engine torque was not changed significantly with the addition of 10% chicken fat biodiesel, while the specific fuel consumption increased by 5.2% due to the lower heating value of biodiesel. In-cylinder peak pressure slightly rose and the start of combustion was earlier. CO and smoke emissions decreased by 13% and 9% respectively, but NOx emission increased by 5%.

Paper described [13]; efficient biodiesel production from beef tallow was achieved with radio frequency (RF) heating. A conversion rate of 96.3±0.5% was obtained with a NaOH concentration of 0.6% (based on tallow), an RF heating for 5 min, and a methanol/tallow molar ratio of 9:1. Response surface methodology was employed to evaluate the influence of NaOH dose, RF heating time, and methanol/tallow ratio. A viscosity of biodiesel products from beef tallow was 5.23±0.01 $mm^2\ s^{-1}$, meeting the specification in ASTM D6751. RF heating has a higher energy dissipating rate than conventional heating. In conventional heating, the energy is transferred through the interface of the reactants and the container. The heat can then spread through the reactants by conduction and convection. The molecule/ion kinetic energy distribution of the reactants achieved using RF heating may benefit the transesterification reaction. A chemical reaction happens when reactant molecules/ions with high enough energy collide. There are several obstacles, e.g. high viscosity, incomplete combustion and carbon build up, preventing vegetable oil and animal fat to be directly used in modern diesel engine.

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Among them, high viscosity may be the most important one. The viscosity will remarkably decrease after the conversion from oil/fat into biodiesel.

B) Use of ethanol+diesel:

As an alternative fuel, biodegradable and renewable fuel, ethanol has received increasing attention. In the paper [14], influence of injection timing on the exhaust emission of a single cylinder, four stroke, direct injection, naturally aspirated diesel engine has been experimentally investigated using ethanol blended diesel fuel from 0% to 15% with an increment of 5%. The engine has its original injection timing 27^0 CA BTDC but the tests were performed at injection timings 21^0,24^0,27^0,30^0,33^0 CA BTDC by changing the thickness of advanced shim. The experiment results in increased NOx and CO_2 emissions as CO and HC emissions decreased with increasing amount of ethanol in the fuel mixture. When compared to the results of original injection timing, at the retarded injection timings (21^0 and 24^0 CA BTDC), NOx and CO_2 emissions increased, and unburned HC and CO emissions decreased for all test conditions. On the other hand, with the advanced injection timings (30^0 and 33^0 CA BTDC), HC and CO emissions diminished, and NOx and CO2 emissions boosted for all test conditions.

C) Use of biodiesel+diesel:

Paper [15], describes biodiesel production from inedible animal tallow and its usability was investigated as pure biodiesel and its blends with petro diesel fuel in a diesel engine. Tallow methyl ester as biodiesel fuel was prepared by base catalyzed transesterification of the fat with methanol in the presence of NaOH as catalyst. Fuel properties of methyl ester, diesel fuel and their blends were determined. Viscosity and density of fatty acid methyl ester is found to be very close to that of diesel where as the calorific value of biodiesel is found to be slightly lower than that of diesel. Due to lower heating value of biodiesel, the addition of biodiesel to diesel fuel decreases the thermal efficiency of engine and increase specific fuel consumption. However, the effective engine power was comparable to diesel fuel. B100 were reduced emissions of CO, NOx, SO_2 and smoke opacity around 15%, 38.5%, 72.7% and 56.8%, respectively. For B20, lowest CO, NOx emissions and the highest exhaust temperature were obtained among all other fuels.

The reduction in exhaust emission made tallow methyl ester and its blends, especially B20 a suitable alternative fuel for diesel engine and thus could help in controlling air pollution.

In this paper [16], biodiesel was purchased from EKO biodiesel, a commercial supplier, used to run a four stroke, naturally aspirated, single cylinder DI diesel engine. Biodiesel blends (B100, B5, B20 and B50) were used for testing. Tests were carried out using three different CRs (17, 18, 19/1), ITs (15^0,20^0,25^0 CA BTDC) and IPs (18, 20, 22 MPa) at 20 Nm engine load and 2200rpm. The results showed that BSFC, BSEC and NOx emission increased while BTE, smoke opacity (OP), CO and HC decreased with the increase in the amount of biodiesel in the fuel mixture. Here a mixer was used between biodiesel-diesel tanks for avoiding the phase separation.

In paper [17], rice bran oil was used as diesel fuel. Blends of rice bran oil with diesel fuel from 0% to 50% were used with increment of 10% rice bran oil in diesel. Experimental tests were conducted on a DI diesel engine for increasing loads 0 to 100%. From the results it was showed that BSFC and emission parameters such as OP, CO, HC, NOx up to of RB20 were close to that of diesel fuel. Thereafter increased as compared to diesel fuel.

D) Use of biodiesel+alcohol:

In the paper [18], biodiesel prepared from cooking waste oil. In this study, carbon dioxide cylinder is used to dilute the charge in order to minimize NOx emissions. The blends of biodiesel and methanol/ethanol were used for testing the effects of charge dilution. The increase in ignition delay is enhanced for the blended fuels which decreased the peak pressure slightly and the peak heat release rate increases at higher engine load. With the increase of intake CO_2 concentration, CO and HC emissions increased for all tested fuels and reduced for the blended fuels while NO_X emission reduced (with increased in PM emission) for both the cases. Therefore, if the biodiesel fuel is replaced with biodiesel-alcohol fuels, the adverse effects can be reduced while the NOx reduction can be enhanced.

E) Use of Diesel-biodiesel-ethanol:

Prommes Kwanchareon et al **[**19**]** studied the phase diagram of diesel–biodiesel–ethanol blends at different properties of ethanol and different temperatures .It can be observed that the density of the blends decreased with an increasing of the percentage of ethanol in the blends. This is attributed to the fact that ethanol has lower density and as such will lower the density of the mixture.

But, when the percentage of biodiesel was increased, the density increased, which is due to the fact that the palm oil biodiesel has a higher density than the other two components. Normally, it is recognized that higher density leads to higher flow resistance of fuel oil, resulting in higher viscosity.

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This finding suggests that the higher viscosity can lead to inferior fuel injection. However, all the blends had density values that were acceptable for the standard limit for high-speed diesel.

The cetane index is also in proportion to density value. It was observed that the cetane index of the diesohol (diesel-alcohol) mixture decreased, when increasing amounts of ethanol because ethanol itself has very low cetane, approximately 5–8. As the cetane index is lower, the ignition property will be reduced. Cetane index also has an effect on the engine start up, combustion control, and engine performance. However, biodiesel, due to its high cetane value, could improve this property. Some of the fuel blends had a cetane index higher than base diesel. In this result, a blend of 80% diesel, 15% biodiesel and 5% ethanol was the most suitable ratio for diesohol production because of the acceptable fuel properties and the reduction of emissions.

*Hadi Rahimi***,** et al **[20]** performed experiment on the diesel oil, sunflower methyl ester and ethanol. The results of this paper found that: Adding bioethanol to diesel fuel can significantly reduce fuel blend cetane number. The cetane number of the die sterol (diesel-methyl ester-alcohol) is acceptable cetane number because biodiesel can increase bioethanol– diesel fuel cetane number. Bioethanol and sunflower methyl ester can improve low temperature flow properties due to very low freezing point of bioethanol and low pour point of sunflower methyl ester, consequently diesterol is more suitable for cold climate compared with diesel fuel. It was found that the diesterol viscosity is in the standard range and hence can be considered as acceptable. Adding only 3% bioethanol to diesel and sunflower methyl ester reduces the flash point of the fuel blend very much lower than ASTM standard limits which cause a problem in storage and transportation of diesterol. This problem can be solved by using biodiesel. Sulfur content of diesterol was found to be decreased when oxygenated compounds are increased. The power and torque produced by the engine using diesterol and conventional fuel was found to be very comparable. The CO and HC emission concentration of diesterol decrease compared to the conventional diesel fuel and even diesel– biodiesel blend.

*Pranil J. Singh [21]***,** in this paper hybrid fuels consisting of coconut oil, aqueous ethanol and a surfactant (butanol) were prepared and tested for DI diesel engine. The engine performance and exhaust emissions were investigated and compared with that of diesel. As similar to the other biodiesel coconut oil has high viscosity so it is better to use in blends with diesel.

The hybrid fuel investigated in this study is a micro emulsion consisting of vegetable oil, water, alcohol and surfactant mixture. Here emissions of CO was observed to be increasing because of the fuel rich region was observed and incomplete combustion takes place due to availability of insufficient oxygen. NO, SO_2 and CO_2 emissions of the hybrid fuels are lower compared to diesel. It showed that this hybrid fuel can be used successively for diesel engine.

The papers **[22 and 23],** observed the performance and characteristics of biodiesel produced from soybean oil added in the alcohol (ethanol and methanol) blended diesel fuels. In paper 22, blends are prepared by considering increasing trend of biodiesel where as in paper 23, increasing trend of methanol has considered. Both the papers showed that HC, CO and smoke emissions are lower compared to diesel but it required advanced NO_x reduction technique for the commercialization of blends.

In this paper **[24],** Jatropha derived biodiesel (methyl ester) addition, in adequate quantity, in the blends of diesel and ethanol, drastically improved the solubility of ethanol in diesel fuel. The blends tested are D70/E20/B10 (blend A), D50/E30/B20 (blend B), D50/E40/B10 (blend C) and diesel (D100). Oxygen content increased up to 14.53% by weight keeping the cetane index within limit for blend C. It was required to advance injection timing up to 21^0 from 13^0 CA BTDC (original injection timing), to run the engine on blend C. However, advancing the injection timing almost doubled NO emissions and increased peak cylinder pressure for blends as well as diesel fuel. BSFC was increased for blends as a consequence of reduced energy content, however, the thermal efficiency improved slightly. Smoke opacity reduced remarkably for blends especially for medium and high loads of both speed and all injection timings. Increased in NO emissions with load indicated that latent heat of vaporization is more effective than cetane index and oxygen content at these operating conditions. The injection timing is required to be advanced for use of high % ethanol blends, therefore, suitable NO reducing methods such as EGR, catalytic converters, SCR (selective catalytic reduction) shall be adopted to permit use of these blends. With increase of loads CO emissions decreased. The use of Cetane enhancer and advancing the injection timing would probably lead to better performance at high speeds and acceleration running modes.

IV. Properties Of Diesel, Ethanol And Biodiesel

From the literature survey it is observed that following properties are to be studied in order to use it efficiently.

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TABLE I
DIFFERENT PROPERTIES OF DIESEL, ETHANOL AND BIODIESEL

Properties	Diesel	Ethanol	Biodiesel
Density(kg/m^3)	850	789	883
Specific gravity	0.85	0.789	0.88
Kinematic viscosity at 40^{o}c	3.05	0.795	4.0-6.0
Calorific value (kj/kg)	42,800	29700	36000 to 38000
Cetane number	47	5-7	56
Flash point, ^{0}C	85	14	170
Pour point, ^{0}C	-4	___	-5 to10
Surface tension, N/m at 20^{0}C	0.023	0.02239 at 25°C	31.1 at 15ºC
Latent heat of Evaporation, kJ/kg	250	922	300
Molecular weight	170	46.07	294
Stoichiometric13 air to fuel ratio, Wt/wt	15	9	12.67
Cloud point, ^{0}C	-15 to -5	___	-3 to15
Carbon residue%	0.17	__	0.27
Ash content	0.156	___	0.04
Acid value mg KOH/g	0.03	___	0.15
Auto ignition temperature ^{0}C	316	422	363
Boiling point ^{0}C	188-344	78	315-350
Carbon content % weight	84-87	52.2	74-77
Hydrogen content % weight	33-16	13.1	30-12
Oxygen content % weight	0	34.7	11

V. CONCLUSION

Researchers have done the various experiments on the use of biodiesel, ethanol and diesel in order to minimize the use of petro diesel and search of renewable, alternative fuel on diesel engine. The following results are observed.

- The production of biodiesel from animal fats is a new option for vegetable oil biodiesel and can be efficiently use in diesel engine.
- Animal fats biodiesel can be used as solvent or properties improver in alcohol and diesel blends.
- In India, its better option to use biodiesel produced from waste animal fats in order to overcome the problems related to diesel price increment.

Advancement areas:

- We can use animal fats biodiesel in diesel engine with turbo charging.
- Also CFD modelling and analysis on the combustion phenomenon of biodiesel in alcohol-diesel blends can be done.

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