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BIODIESEL: BENEFICIAL FOR ENVIRONMENT AND HUMAN HEALTH

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Abstract

Biodiesel production has received considerable attention in the recent past as a biodegradable and non polluting fuel. Alkyl esters of fatty acid (biodiesel) have several outstanding advantages among other non-renewable and clean engine fuel alternative and can be used in any diesel engine without any modification. Transesterification of edible and non- edible oils is mainly used to decrease the viscosity of edible and non-edible oil; however, other properties of the oil remain same and this new fuel has been called as biodiesel. It consists of edible and non-edible oil and belongs to ecological fuels because of the qualitative composition (carbon 77%, hydrogen 12% and oxygen 11%). Environmental benefits of its use include lower exhaust emission of particulate matter and green house gases, such as CO, CO_2 and SO_x. Biodiesel is an environment friendly biofuel since it provides a means to recycle of CO_2; biodiesel does not contribute global warming. Perhaps the next most critical pollutant from the perspectives of human health and environmental quality is NO_x; NO_x is the key to controlling ground level ozone and smog in urban areas. The review paper presents the results of biodiesel combustion emission on the environment.

Keywords: Biodiesel; emission; environment, renewable energy.

1. Introduction

Recent petroleum crisis [1], increasing cost and unavailability of petroleum diesel gave impetus to the scientists to work on alternative fuel, biodiesel. It reduces levels of global warming gases such as CO_2, CO, and So_x. As plants like jatropha carcus grow, they take CO_2 from the air during photosynthesis reaction. After the oil is extracted from jatropha carcus, it is refined into biodiesel and, when burned, produced CO_2 and other emissions, which are returned to the atmosphere. However, this cycle does not add to the CO_2 level in the air because the next jatropha carcus crop will reuse the CO_2 to grow [2]. The diesel engine is main prime mover compare to any other engine in transporation power generation and many miscellaneous applications i.e. in industries and agriculture [3]. The major pollutants from diesel engines are smoke, particulate matter (PM), carbon monoxide (CO), nitrogen oxide (No_x) and unburned hydrocarbon (UBHC) [4]. Incomplete combustion increases the pollution level as compared to proper combustion [5]. Due to reliance on transport consumption of fossil fuel has increase drastically and world witness long-term damage to the climate [6]. As transport is one of the few industrial sectors where emissions are still growing and this fact has made transport a major contributor of green house gases (GHGs) [7], Generally carbon dioxide (CO_2), methane (CH_4), nitrous oxide (No_x), ozone (O_3) etc are known as greenhouse gases. These gases interact with solar terrestrial radiation and causing imbalance on the Earth's climate system and increase earth surface temperature. The significant effect of global warming has been felt for last two decades. The rise in earth surface temperature is known as global warming.

Reducing the emission of gases will lead to the solution to the climate change problem. Different methods of reducing the climate change problem could be increasing the use of carbon capture and storage (CCS) technique, increasing energy efficiency and promoting the use of renewable energy and carbon free fuels. The main obstacle in using the edible and non-edible oil as fuel is its high viscosity. The transesterification of the edible and non-edible oils is mainly used to decrease the viscosity of edible and non-edible oils; to decrease the viscosity of the oil remain same and this new fuel was called biodiesel [8]. In fact biodiesel contains no petroleum, even though it can be used in pure form in the compression ignition engine with little or no engine modification, or it can be used in blend with petroleum diesel at any level [9]. These benefits occur because biodiesel contain 11% Oxygen (O_2) by weight. The presence of O_2 allows the fuel to burn more completely, resulting in fewer emissions from unburned fuel. This same principle also reduces air toxicity, which is associate with the unburned or partially burned hydrocarbon (HC) and particulate matter (PM) emissions. Testing has shown that PM, HC and CO reductions are independent of the edible and non-edible oil use to make biodiesel. This has been confirmed by (EPA), which reviewed 80 biodiesel emission tests and calculated that the benefits are real predictable over a wide range of biodiesel blend [10].

2. Material and Methods

2.1 Transesterification Reaction

Transesterification or alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except an alcohol is used instead of water [11], this process has been widely used to reduce the high viscosity of triglycerides. The triglycerides are reacted with a suitable alcohol (methanol or ethanol) in the presence of a catalyst under a controlled temperature for a given length of time. The final products are alkyl esters and glycerin. The alkyl ester, having favorable properties as fuels for use in CI engines, are the main product and glycerin is a byproduct. The chemical reaction of the triglyceride with methanol is shown in figure 1.With higher alcohols the chemical equation would change correspondingly [12, 13].

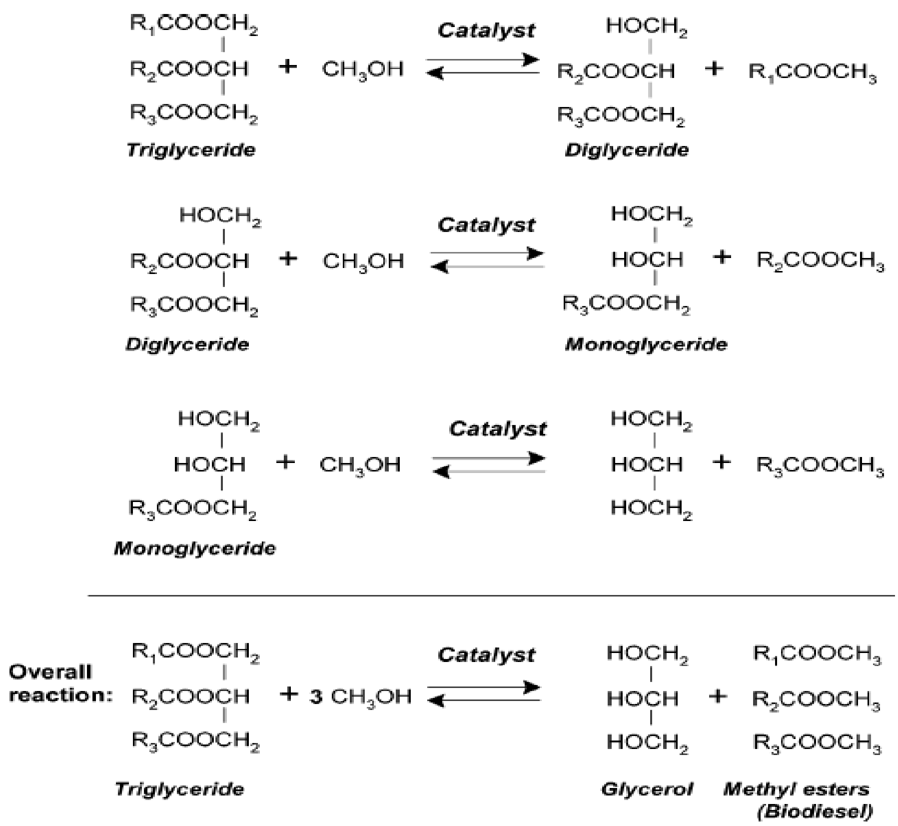

Fig. 1 Transesterification chemistry for methyl ester (biodiesel) production

It can be seen from the above reaction that one mole of the heavy tri-glycerides and three moles of methyl alcohol yield one mole of glycerol and three moles of fatty acid methyl esters. Without the use of a catalyst the reaction would be very slow and also incomplete. A temperature of 60°C to 70°C would be needed for the reaction to become effective [14]. Also a vigorous agitation of the reactants would be needed and so a mechanized stirrer in the reaction vessel becomes necessary. Various catalysts can be used. The most common are the acid catalyst like H_2SO_4 and alkaline like NaOH or KOH. For transesterification any alcohol can be used, as the ethyl alcohol or methyl alcohol. Once formed, the methoxide are strong nucleophiles and attack the carbonyl moiety in the glycerides molecule to produce the alkyl esters [15].

2.2 Effect of Biodiesel on Emissions

Biodiesel mainly emits unburned hydrocarbon, carbon monoxide, carbon dioxide, oxides of nitrogen, sulphur oxide and particulates. A brief review has made of these pollutant emitted from biodiesel fuelled engines.

2.2.1 Unburned Hydrocarbon (UBHC)

Hydrocarbon emission occurs due to incomplete combustion of fuel. Better atomization, mixing and proper ignition results in efficient combustion with depends upon the physical properties of fuel. The emission of hydrocarbon decrease as the diesel is substituted by biodiesel [16], the reported that the reduction of hydrocarbon in case of biodiesel is an around 63% [17], the result shows that a deduction in hydrocarbon emission level for all fuel blends at all injection timing and at all loading condition as compare to diesel as shown in figure 2. The hydrocarbon emission was decreased by 74% with pure rapeseed oil methyl ester and 53% rapeseed oil ethyl ester as compare to diesel as shown in figure-1. The hydrocarbon emission decrease as the ignition delay gets shorter. Cetane number of biodiesel is higher than petro-diesel, due to this exhibit a shorter delay period which contributes to better combustion of fuel resulting in low emission of hydrocarbon. Other reason can be the oxygen molecules present on the structure of biodiesel which helps in complete combustion of the fuel and hence decrease in hydrocarbon emission [18].

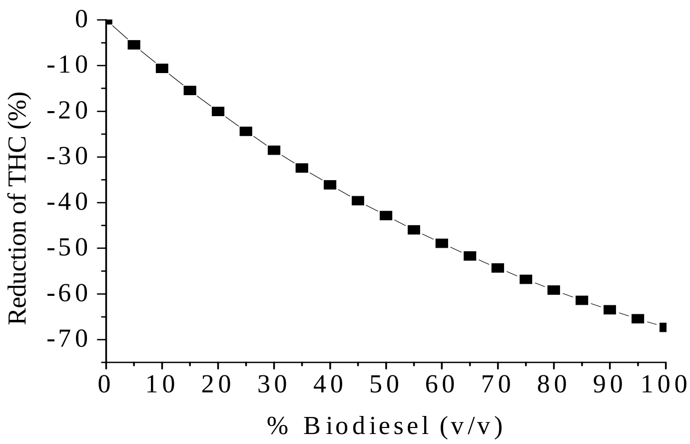

Fig.2 Reduction of total hydrocarbon (THC) emission by using biodiesel in diesel engine

2.2.2 Carbon monoxide (CO)

Carbon monoxide is a poisonous gas and it is perfect emission product assessor. More carbon monoxide emission indicates more loss of thermal energy. Generally carbon monoxide emission is caused, due to poor mixing of fuel and air, locally rich zone and incomplete combustion of fuel. However, with the air fuel ratio more than stoichiometric value, the carbon monoxide concentration in the emission increases [19], as shown in experiment that for biodiesel mixture carbon monoxide emission was lower than that of diesel fuel shown in figure 3. A detail investigation of the behavior of biodiesel reveals the carbon monoxide emission is lower for percentage of up to (40-60%) of the biodiesel and higher for higher biodiesel in the blends. At low concentration of the biodiesel in the blend, the inbuilt oxygen helps in complete combustion of the fuel. But high concentration of biodiesel increases the viscosity of the fuel and there is a slight increase in the specific gravity. This causes poor atomization of biodiesel which results in poor combustion of fuel. This suppresses the complete combustion process and as a result the emission of carbon monoxide increases [20].

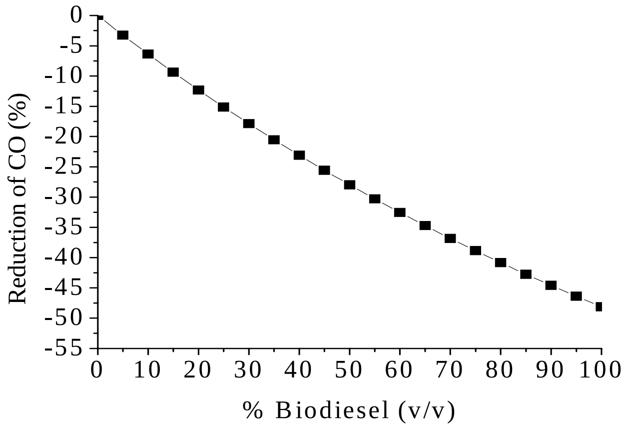

Fig. 3 Reduction of CO emission by using biodiesel in diesel engine

2.2.3 Nitrogen Oxides (NO_x)

Most of the researchers have shown in their work that emission of No_x increases with the use of biodiesel. No_x is formed by chain reaction involving nitrogen and oxygen in the air. These reactions are highly temperature dependent. Since diesel engines always operate with excess air, No_x emissions are mainly a function of gas temperature and residence time. Most of the earlier investigations show that NO_x emissions from biodiesel engines are generally higher than that in petro-diesel fueled engines. Also earlier investigation revealed that NO_x emissions increase with an increase in the biodiesel content of diesel as shown in figure 4. The oxygen contain in the biodiesel facilitate in the oxidation of the nitrogen present in the air resulting in the formation of the NO_x has found during test, that the NO_x formation is generally linearly co-related to the actual start of the combustion [21].

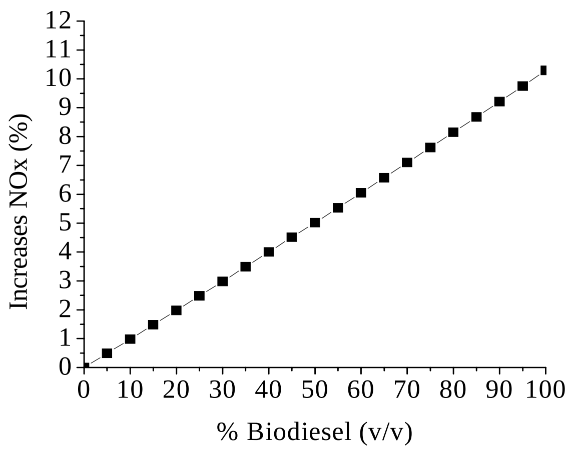

Fig. 4 Reduction in NOx emission by using biodiesel content increase in diesel engine

2.2.4 Smoke and Particulates

Smoke formation occurs primarily in the fuel rich zone of the cylinder, a high temperature and pressure. Smoke formation can be controlled by applying partially oxygenated fuel, which reduces locally over-rich regions [22]. For all tested engine condition, the smoke emission decreases consistently with the increasing amount of biodiesel in the blend. The smoke reduction with pure biodiesel was around 26.05 to 28.73% as compared to diesel. The maximum and minimum reduction in smoke level at different lad was found as 46% and 05% respectively [23] as shown in figure 5. The reduction in smoke and particulate matter (PM) level at higher load may be due to better combustion at higher load and more biodiesel is required. Other reason may be the difference in chemical structure and presence of oxygen in the biodiesel.

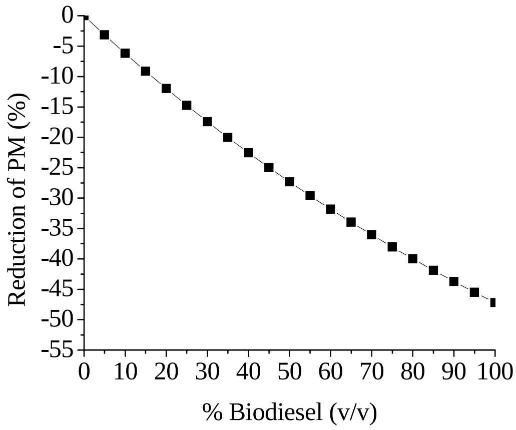

Fig. 5 Reduction of particulate matter (PM) emission by using biodiesel in diesel engine

2.2.5 Carbon dioxide (CO_2)

Generally the emission of carbon dioxide increase with increasing load for both biodiesel and diesel [24]. Increasing percentage of biodiesel in the blend, decrease the emission of carbon dioxide (CO_2). For B20 biodiesel the CO_2 emission is comparable with diesel and B40 and B60 biodiesel the emission is less than diesel. This may be because of the fact the biodiesel is a low carbon fuel and also biodiesel has low elemental ratio of carbon to hydrogen as compare to diesel. Every molecule of alkyl esters contains almost 100% carbon of biological nature. Thus all CO_2 released by the burning of biodiesel has no adverse effect on greenhouse gas formation. However, in case of biodiesel, all CO_2 releases are contributing to formation of greenhouse effect. The advantage of biodiesel lie in the fact that CO_2 level is kept in the balance as the crops of biodiesel are readily absorbing the CO_2, thus biodiesel are CO_2 neutral [25,21]. Biodiesel is a environment friendly biofuel, since it provides a means to recycle CO_2, biodiesel does not contribute to global warming as shown in figure 6.

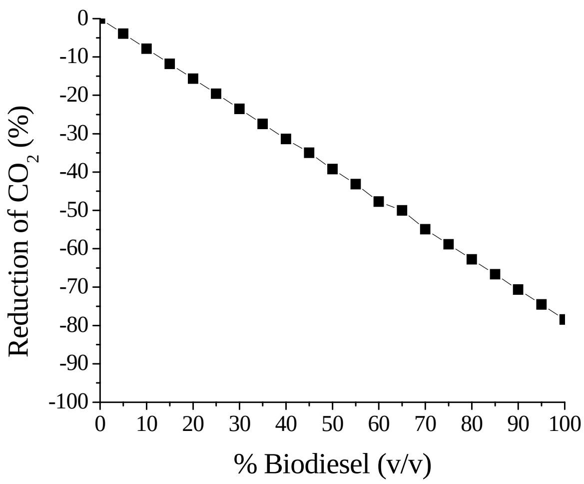

Fig.6 Reduction of CO_2 emission by using biodiesel in diesel engine

3. Result and Discussion

Biodiesel is an ester that is produced from the transesterification of edible and non-edible oils. This process involved reacting a edible and non-edible oil with alcohol (ethanol or methanol) in the presence of a catalyst to produce an ester (biodiesel) and glycerin. Biodiesel can be produced from various oilseeds by first extracting from the seeds, purifying it, adding methanol for the transesterification, and finally, separating and purifying the resulting methyl ester (biodiesel). By-product from biodiesel production are the meal produced during the stage of oil extraction that is used as animal feed and the glycerol produced during the transesterification stage which is used for pharmaceutical purposes. Other possible feedstocks except from oilseeds are animal fats and used frying oil. Besides the lower atmospheric emissions as compared to diesel, other properties of biodiesel which contribute to its positive environmental profile are.

3.1 High biodegradability

It is proved that over 98% of biodiesel degrades biologically in three weeks in comparison to 50% of diesel during the same period. When mixed, biodiesel can also promote and accelerate the biodegradation of diesel and therefore substantially reduce risks of pollution to ground and surface waters. Low oral and dermal toxicity and low evaporation reducing inhalation risk [26]. High flash point, reducing risk of fire for biodiesel it ranges from 100-180°C, compared to 55-60°C for petroleum diesel.

3.2 Similar to Petroleum diesel fuel

Biodiesel is similar to petroleum diesel fuel in many chemical and physical properties. Engine performance and the fuel consumption were favorable that make it better substitute to diesel fuel. The comparison of properties of edible and non-edible oil biodiesel and standard specification of diesel oil are given in table 1 [27].

Table 1 Properties of edible and non-edible oil biodiesel and diesel fuel

Edible & non edible Oils	Viscosity (mm^2/s)	Cetane Number (°C)	Flash Point (°C)	Lower Heating Value	Cloud Point (°C)	Pour Point (°C)	Density (Kg/I)
Peanut	4.9	564	176	33.6	5	-	0.883
Soybean	4.5	45	178	33.5	1	-7	0.885
Sunflower	3.6	63	127	31.8	4	-	0.875
Palm	5.7	62	164	33.5	13	-	0.880
Babassu	4.6	49	183	33.5	1	-	0.860
Tallow	-	-	96	-	12	9	-
Diesel	3.06	50	76	43.8	-	-16	0.855
20%Biodiesel	3.2	51	128	43.2	-	-16	0.859

3.3 Sustainability and non-toxicity

Biodiesel is 100% renewable. Being plant based it does not emit sulphur or carbon monoxide on burning and non polluting, biodegradable and environmentally safe [28].Studied the cytotoxic and mutagenic effect of diesel engine emission using biodiesel and petroleum diesel as fuel. In this study the particulates associated emission from DEP of biodiesel and mutagenic effects were compared and the results showed the lower mutagenic potency of biodiesel as compared to petroleum diesel.

3.3 Environmental and Health effect of biodiesel

In view of environmental consideration, biodiesel is considered 'carbon neutral' because all the carbon dioxide (CO_2) released during consumption had been sequestered from the atmosphere for growth of vegetable oil crops. Studies have shown that the combustion of 1 kg petroleum diesel fuel leads to the emission of about 2.6 kg of CO_2 against 1 kg of CO_2/ kg of biodiesel [29], so the use of biodiesel may directly displace this amount of CO_2 when used in diesel engines. The combustion of biodiesel has been reported to emit lesser pollutants as compared to diesel. The emission of SO_2, soot, CO, hydrocarbon (HC, polyaromatic hydrocarbon, PAH) and aromatics[30] is given in table 2, which indicates that the engine exhaust contains no SO_2, and shows decreasing emissions of PAH, soot, CO, HC and aromatics. The NO_x emissions are reported to be in the range between 2- 10% as compared to petroleum diesel depending on engines combustion characteristics.

Table 2 Average biodiesel emission compared to petroleum diesel according to EPA [31].

Emission type	B100	B20
Regulated		
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NO_x	+10%	+2% to -2%
Non-Regulated		
Sulphats	-100%	-20%
PAH (Polycyclic Aromatic Hydrocarbon	-80%	-13%
nPAH (nitrated PAH)	-90%	-50%
Ozone potential of speciated HC	-50%	-10%

A Harvard University study has come out with the dramatic figure of death per hour in Delhi (India) caused by air pollution. Increased greenhouse gases and resultant climatic change has dramatically increased the number of natural disasters release of greenhouse gases into atmosphere, mainly transport related pollutant emission causes air pollution. Biodiesel is nearly carbon-neutral, meaning it contributes almost zero emissions to global warming. For example the characteristics of jatropha oil biodiesel are comparable to European specifications. The analysis of exhaust gases suggests that jatropha oil biodiesel will be environmentally safer fuel. Tests conducted the United State Environmental Protection Agency (USEPA) have shown that the use of biodiesel almost completely eliminates life cycle of CO_2 emissions

4. Conclusions

The problems with substituting edible and non-edible oil for diesel fuels are mostly associated with their high viscosity, and low volatilities. The viscosity of vegetable oils can be reduced by transesterification. The transesterification is the most common method and leads to mono-alkyl esters of edible and non-edible oils and fats, known as biodiesel. Biodiesel is a better fuel than petroleum diesel and meets most of the physical and chemical standards of petroleum diesel. It is also observed that biodiesel has similar combustion characteristics as petroleum diesel. Biodiesel engines offer acceptable engine performance compared to petroleum diesel fueled engines. The environmental benefits of biodiesel can be significant in terms of reduction in the emission of greenhouse gases and reduction of pollutants e.g. acid rain, photochemical smog etc. Biodiesel is said to be carbon neutral as more CO_2 is absorbed by the biodiesel plants than what is added to atmosphere when used as fuel. Even though biodiesel engines emits more NO_x, these emissions can controlled by adopting certain strategies such as the addition of cetane improvers, retardation of injection timing, exhaust gas recirculation etc. Biodiesel can be considered as the best option and has the largest potential, which meets the requirements and could ensure fuel supply in the future.

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