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A Review of Research and Policy on Using Different Biodiesel oils as Fuel for C.I. Engine

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Abstract

The increasing demand of energy for rapid industrialization and domestic needs are putting an additional pressure on existing conventional energy sources. These are already producing more hazardous emissions into the environment than its prescribed limits. So we need some kind of energy source which must be easily available, cost effective and most importantly it must be environmental friendly. Many researches worked on this and found an alternate fuel i.e. biodiesel which can be produced from the various feed stocks. This may be the best substitute for the conventional energy and having almost negligible effect on environment and also a solution to one of the most challenging environmental issues. This paper analyses the various aspects such as performance and emission of biodiesel. The main focus area of this review is to discuss the reduction of major pollutants like carbon monoxide (CO), unburnt hydrocarbons (UHC), particulate matter (PM) and effect of fatty acid composition on performance and emission characteristics. Biodiesel can be used as fuel without modification in CI engine, it means biodiesel replaces the diesel fuel. The various results show that the different chemical composition of biodiesel lead to the variation in performance and emission characteristics based on their source of origin. The biodiesel obtained from saturated feedstock shows low emission of NOx and high resistance to oxidation, however to improve the atomization further research and policy issues is required to understand the complex relationship between biodiesel feedstock and its characteristics & use.

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Keywords: Edible and non edible oil ; Biodiesel ; transesterification; engine performance and emissions

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1. Introduction

The overwhelming demand for diesel and its scarcity due to exhaust use incites the researchers to look for an alternative fuel which can replace or supplement the fossil fuels. Moreover there is a huge uncertainty in diesel oil reserves. So it was required to have a more research on developing an alternate fuel source. The first time peanut oil was used by Rudolf Diesel on August 10, 1893 in the engine designed by him [1]. Since then vegetable oils were used as the substitute of diesel oil whenever needed as it was not having the good characteristic as diesel oil. Around a century later first time the primary concerns like cost, effect on performance of engine, durability and standardization of fuel production were discussed in International conference on plant and vegetable oils as fuels, held in Fargo, North Dakota in August 1982[2]. Vegetable oils have a great potential to fulfill the requirements of an alternative source of energy. Although it is in its primary phase of development of efficient fuel for the diesel engine [3,4]. The main concerns with the vegetable oils are low volatilities, inadequate cold flow properties and high viscosities. The various derivatives were produced from the vegetable oils using various methods in response to improve the characteristic of vegetable oils. Fatty acid methyl esters is one of the most important derivatives, also known as Biodiesel, obtained from triglycerides through the trans-esterification process [5,6]. The word biodiesel was used for Fatty acid methyl esters for the first time by national bio diesel board (earlier National Soy diesel Development Board) during 1992 in USA. Biodiesel is better than that of petroleum diesel in terms of renewable, biodegradable, non-toxic, exhaust emission, substantially free from sulfur and aromatics nature. Since biodiesel holds very similar characteristics to petroleum diesel, so it can be mixed homogenously in any proportion. The exhaust emission of petroleum diesel gets reduced when biodiesel is mixed with it, henceforth it can be considered as key to reduce the pollutants level and probable carcinogens in petroleum diesel [7]. According to Ma et al. [8] Biodiesel has turn into the centre of attraction due to its environmental and renewable benefits. The sunflower, rapeseed, coconut, soybean, linseed, jatropha, caster, neem, mahua etc are used as crude for the production of Biodiesel [9].

Nomenclature

NOx	nitrous oxides
CO	carbon monoxides
UHC	unburn hydrocarbons
HC	hydrocarbons
BSFC	brake specific fuel consumption
CN	cetane number
FAC	fatty acid composition
FAME	fatty acid methyl ester
IMEP	indicated mean effective pressure
PPM	parts per million
HRRmax	maximum heat release rate
B0	pure diesel
B10	10% biodiesel
B20	20% biodiesel
B30	30% biodiesel
B40	40% biodiesel
B50	50% biodiesel
B100	100% biodiesel
DDCL	diesel from direct coal liquefaction
TG	tri-glycerides
ME	methyl esters
EGT	exhaust gas temperature
BTE	brake thermal efficiency
RPO	rapeseed plant oil

CAD	crank angle degree
SOC	start of combustion
SVO	straight vegetable oil
FFA	free fatty acid
SOI	start of injection
THC	total hydrocarbons
Vol. %	percentages of volume

2. Production of biodiesel

The researchers have consistently trying to produce the vegetable oil derivatives which hold approximately similar characteristics as conventional diesel fuels. Methyl alcohol is most frequently used however sometimes ethyl alcohol is also used in the production of biodiesel. In general any primary secondary and tertiary alcohol can be used only the constrained is that higher alcohol leads to higher cost. The fatty-acid ethyl esters (FAME) produced from Methyl alcohol is more volatile than that of fatty-acid ethyl esters (FAEE). FAEE also shows higher viscosity, lower cloud and pour points in comparison to FAME [10].Methyl alcohol is cheaper and more reactive than ethyl alcohol. However in terms of toxic nature and renewable, ethyl alcohol shows good characteristics. Presently major source of production of Methyl alcohol are non renewable fossils. A catalyst is also required to speed up the production of biodiesel. Sodium hydroxide (NaOH) or potassium hydroxide (KOH) is used as a base catalyst in this reaction. The main issues with the use of triglycerides as substitute for conventional diesel fuel are higher viscosity, lower oxidation stability and lower volatility [11].These characteristics can be improved though mainly four methods namely direct use and blending, micro-emulsification pyrolysis/cracking and transesterification.

2.1 Direct use and blending

First method is very simple. In this biodiesel and diesel fuel is mixed in a specified proportion and it can be used directly in CI engine. The several experiments have been done successfully regarding the blending of vegetable oil with conventional diesel fuel. In 1980 Caterpiller Brazil Company mixed 10% vegetable oil with 80% diesel oil and tested it for pre-combustion chamber engines. It was found that this blended fuel retained it's total power without modification in the engine [12]. Subsequently 95% cooking oil and 5% diesel was tested in 1982. Later on it has been proved that the 100% vegetable oil can also be used in engine with little modifications. High viscosity was major problem with blended fuel while used in compression ignition engines. The high viscosity can be improved by Micro-emulsification, pyrolysis and transesterification.

2.2 Micro-emulsification

In micro-emulsion process methanol, ethanol and butanol are used as solvent to reduce the high viscosity problem of vegetable oil fuel. A micro emulsion is a colloidal equilibrium dispersion of optically isotropic fluid. According to Ramadhas et al. / Ramadhas et al. / Renewable Energy 29 (2004) 727–742 **,** microstructures in liquids have the dimensions ranges from 1 to150 nm. Both liquids are immiscible and at least one of them must be ionic or non-ionic amphiphiles. It helps in improving the spray characteristics through explosive vaporization of constituent in micelles.

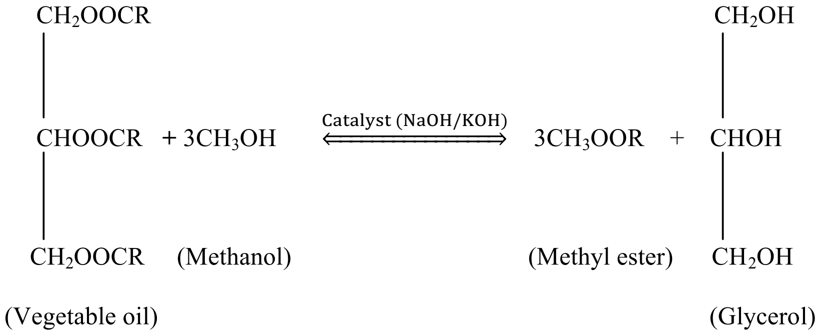
The micro emulsions show maximum viscosity limitation when butanol, hexanol and octanol are used as a solvent for CI engine. Czerwinski [13] produced an emulsions which consist 13.3% ethanol, 33.4% butonal and of 53% sunflower oil. It had cetane number of 25 and viscosity 6.3 centistokes at 40°C. It was also observed that increasing the butanol percentage leads to better spray patterns and lower viscosities.

2.3 Pyrolysis/cracking

Cracking can be defined as conversion of one substance into another by application of heat in presence of catalyst. In this process heating is done in absence of air which leads to smaller molecules. The methyl esters of fatty acids, vegetable oils, natural fatty acids and animal fats can be used as pyrolyzed substances. For more than 100 years ago pyrolysis of fats was done where there was scarcity of petroleum [14]. After the World War I various researchers have been trying to study the pyrolysis process to obtain the engine fuel from vegetable oil.

2.4 Trans-esterification

Transesterification can be defined as the reaction of vegetable oil and alcohol in presence of catalyst. The reaction rate and yield gets improved with the use of catalyst [15]. It is also known as alcoholysis. Due to low cost, physical and chemical advantages methanol and ethanol are used in the tranesterification process. These alcohols react quickly with tri-glycerides in presence of catalyst (NaOH). Generally 3:1 molar ratio of oils and alcohol is used in transesterification process. Acid (H_2SO_4) / Base (NaOH or KOH) / Enzymes (Lipase) are used as the catalyst.



$$\underset{\text{(Vegetable oil)}}{\begin{array}{l} CH_2OOCR \\ | \\ CHOOCR \\ | \\ CH_2OOCR \end{array}} + \underset{\text{(Methanol)}}{3CH_3OH} \overset{\text{Catalyst (NaOH/KOH)}}{\Longleftrightarrow} \underset{\text{(Methyl ester)}}{3CH_3OOR} + \underset{\text{(Glycerol)}}{\begin{array}{l} CH_2OH \\ | \\ CHOH \\ | \\ CH_2OH \end{array}}$$

Fig. 1 Transesterification Reaction

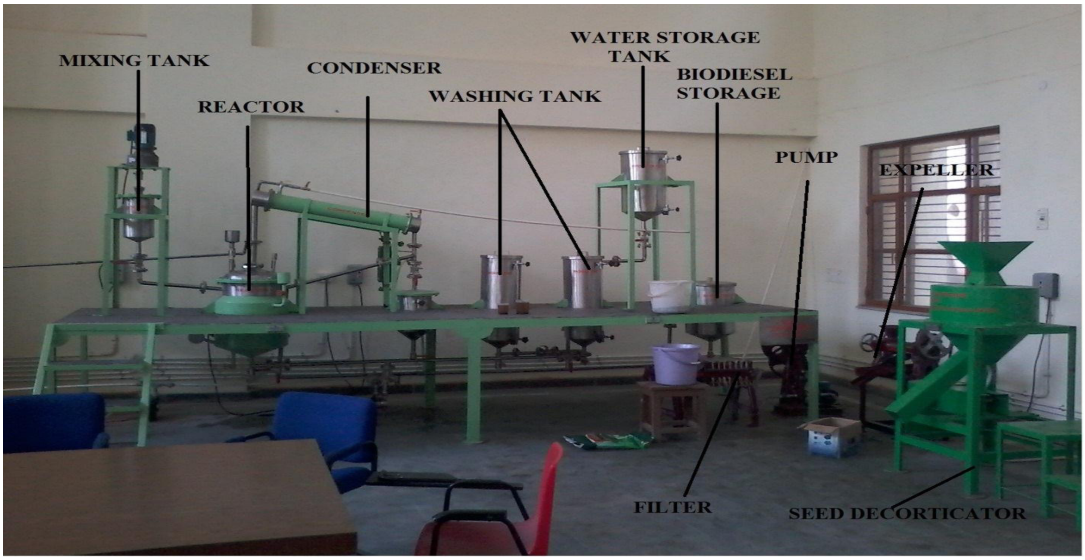


Fig. 2 Transesterification unit

Out of these base catalyst gives the faster transesterification and hence it used commercially as well. Firstly methanol (used as alcohal) and NaOH (used as catalyst) are mixed. After proper mixing it is transferred to reactor. In reactor mixture of vegetable oil, methanol and NaOH are heated and kept at 65 ^{o}C for 1-1.5 hour. At this temperature reaction takes place and alcohol starts vaporizing. This vaporized alcohol is separated through condenser in tank. After the separation of alcohol this mixture is transferred to washing tank where it is mixed by water. This mixture is kept for 24, 48, 72 hours depending upon the types of vegetable oil. After this specified period three layers are formed namely at top vegetable oil methyl ester (biodiesel), in middle glycerin and at bottom waste water. Finally this biodiesel (vegetable oil methyl ester) is transferred to storage tank.

3. Performance and emissions of biodiesel from various feedstock

3.1 Non Edible Oils

3.1.1 Jatropha curcas

Jincheng Huang et al. [16] have conducted the experimental work on diesel engine using jatropha biodiesel at two working condition at the engine speed of 1500 rpm (maximum torque point) and at engine speed of 2000 rpm (state of rated power). The thermal efficiency and engine performance for jatropha biodiesel, other biodiesel and diesel fuel are comparable to each other. The BSFC (brake specific fuel consumption) for diesel fuel is slightly lower than jatroha and other biodiesel. At engine high load the carbon monoxide (CO) and hydrocarbon (HC) emissions from jatropha and others biodiesels are lower than that of diesel fuel and at low loads comparable to each others. Mostly reduction in NOx emissions (specially at engine high loads) from jatropha biodiesel than diesel fuel. At all load smoke emission from jartopha and other biodiesels are lower than diesel.

T.Ganapathy et al.[17] studied the influence of injection timing on performance, emission and combustion characteristics of a single-cylinder, four stroke, air cooled, vertical, Greaves Cotton model GL 400 II A, diesel engine fuelled with jatropha biodiesel. For the advance injection timing BSFC, CO, HC and smoke levels reduces and increases the BTE, Pmax, HRRmax, NO emission with Jatropha biodiesel as a fuel. But opposite trends for retarded the injection timing .BSFC, peak pressure and NO are more with Jatropha biodiesel than that of diesel at any given injection timing, load torque and speed, but reduction in BTE,HC,CO and smoke levels. For the maximum BTE ,peak pressure, HRR max and minimum BSFC, CO, HC and smoke the best injection timing is found to be 340 CAD(crank angle degree). However for minimum NO emission 350 CAD is an optimum injection timing.

3.1.2 Castor oil

Osmano Souza Valente et al.[18] studied on fuel consumption and exhaust emissions of a diesel power generator fuelled with castor biodiesel. Under variable (9.6 to 35.7 kW) engine load with blending (5%,20%,35%) of castor oil and diesel oil tested on diesel power generator. With increasing the castor biodiesel contents in fuel SPC (specific fuel consumption) increases. High CO_2 emission at low load and low at high load with castor biodiesel fuel blends as compare to diesel oil .Generally for castor biodiesel blends shows higher HC emission .At any load higher CO emission for castor biodiesel as compare to diesel.

3.1.3 Mahua oil

H. Raheman et al.[19] studied the Performance and emission evaluation of a single cylinder, four stroke, water cooled Ricardo E6 engine fuelled with mahua biodiesel and its diesel blends. After conducted the test it has found that the increasing the proportion of biodiesel in the blends BSFC increases and BTE decreases. However for injection timing and compression ratio with increasing engine load a reverse trend was found.With increasing the proportion of mahua biodiesel in the blends it was found that the smoke level and CO in exhaust emissions reduced, whereas NOx increased.However for all tested fuels the emission levels increased with increasing in engine load.

Without noticeable affecting the engine performance (BSFC, BTE, EGT) and emissions (Smoke, CO and NOx) pure mahua biodiesel (B100) could be safely blended with diesel up to 20%.

Swarup Kumar Nayak et al.[20] demonstrated that the performance and the exhaust gas emissions on four stroke single cylinder vertical water cooled diesel engine fuel with mahua biodiesel and mahua biodiesel using additive. The brake thermal efficiency increased with increasing additive proportion in mahua biodiesel.For pure biodiesel it is lower. Because of high density, volatility and low heat content of biodiesel BSFC is higher, but with increases the proportion of additive BSFC deceases. Because of high oxygen content and due to high combustion temperatur ,highest EGT for biodiesel. It was founded that with increasing the percentage of additives in biodiesel EGT decreases. Because of its higher oxygen content in biodiesel CO and HC emission are lowest.It was concluded that CO and HC emission decreases with increasing the additive percentage in Mahua biodiesel. Because of high viscosity ,volatility and low heat content, Smoke and NOx emissions are higher as compare to pure diesel.It was founded that increasing the percentage of additives in mahua biodiesel both smoke and NOx emissions decreases.

3.1.4 Pongamia Pinaata / Karanja

S.Jaichandar et al. [21] studied the effect of varying the combustion chamber geometry (of four stroke water cooled single cylinder diesel engine) on the performance of a diesel engine using 20% Pongamia Oil Methyl Ester blends with pure diesel. Engine tests have been conducted with three types of combustion chambers namely Hemispherical combustion chamber (HCC),Toroidal combustion chamber(TCC) and Shallow depth combustion chamber (SCC) without changing the compression ratio.After conducted the experiment TCC shows higher brake thermal efficiency as compare to other two types of combustion chamber(CC). For TCC noticeable improvement in reduction of CO,UHC, and particulates as compare to the other two CC .Though slightly higher oxides of nitrogen for TCC.

Atul Dhar and Avinash Kumar Agrawal [22] studied the effect of 20% karanja biodiesel blends on engine wear in a Four stroke, in-line, naturally aspirated, water cooled, direct injection, compression ignition SUV engine. High carbon deposits on engine components (cylinder head, injector tip and piston top) biodiesel for fuelled engine. It was observed for biodiesel fuelled engine comparatively lower wear of pistons, piston rings, liners, valves and small end bearing of connecting rods. For main bearings, big end of connecting rods, bearings and crank pins was found to be higher wear. The endurance tests showed that the surface texture of cylinder liners in acceptable condition with Karanja biodiesel blends and diesel. In spite of the higher carbon deposits and increase the wear of vital engine components, any defect was not observed during the test of resistance in the long run the engine with biodiesel.

Atul Dhar and Avinash Kumar Agrawal [23] studied the performance ,emissions and combustion characteristics of a naturally aspirated, Four stroke in-line water cooled diesel engine fuelled with karanja biodiesel, blend of karanja biodiesel (BD50,BD20,BD10 &BD05) with pure diesel and diesel fuel at different speed and load. Lower blends have achieved higher maximum torque than diesel, while higher blends produced less torque. BSFC for diesel and lower blends comparable to each other. For higher biodiesel blends BSFC increased. At lower engine load for higher biodiesel blends have lower BTE and at higher engine loads BTE for all blends is comparable to pure diesel. The reduction in CO emissions was comparable for biodiesel blends and diesel at high speeds and loads. However higher CO for high biodiesel blends at lower loads.

HC emissions and Smoke opacity of biodiesel blends were lower as compare to pure diesel. At higher engine loads higher biodiesel blends produces high NOx emission than pure diesel. At lower engine speeds for higher blends low cylinder pressure observes. Due to higher bulk modulus of compressibility of biodiesel fuel-line pressure of higher blends was slightly higher than pure diesel. The Combustion started earlier for lower blends but slightly delayed for higher blends. Shorter combustion duration for low blends than pure diesel and higher blends shows longer combustion duration.

3.1.5 Cannola oil

D.H. Qi et al.[24] demonstrated that the Performance and combustion characteristics of two cylinder four stroke DI diesel engine fuelled with biodiesel-diesel methanol blend(BDM). The test results showed that the combustion starts almost identical at high engine load but at low engine load combustion starts later for BDM5 and BDM10 than for BD50.BDM5 and BDM10 have shown the similar peak cylinder pressure at low engine load of 1500 rpm and peak of pressure rise rate and peak of heat release rate higher than that of BD50. BDM5 and BDM10 showed the peak of pressure rise rate and peak cylinder pressure are lower than those of BD50 at low engine load of 1800 rpm, but similar heat release rate. The crank angles at which the peak values occur are earlier for BD50 than for BDM5 and BDM10. The peak of pressure rise rate, peak of heat release rate and the peak cylinder pressure at higher engine load for BDM5 and BDM10 are higher than those of BD50, and almost similar crank angle of peak value for all tested fuels.BDM5 and BDM10 have shown the slightly lower torque and power outputs than BD50.Smoke emission dramatically reduces for BDM5 and BDM10.At speed characteristic of full engine load NOx and HC are similar and CO emissions are slightly lower than those of BD50.

3.2 Edible oils

3.2.1 Coconut oils

H.G. How et al.[25] studied the performance, emissions and combustion characteristics of coconut biodiesel in a direct injection four stroke (turbocharged) high-pressure common-rail diesel engine, fuelled with coconut biodiesel and its blend at various load. The results have shown that the biodiesel blended fuels increase the BSFC and reduction in BSEC (brake specific energy consumption) at all engine loads. With increasing the proportion of biodiesel in blends and engine load BSCO (brake specific carbon monoxide) decreases. Smoke emission decreases regardless of load condition for increasing the blends ratio. Generally BSNOx (brake specific nitrogen nitrous oxide) emission increases with increasing in engine load and biodiesel blend ratio. Large reduction in smoke opacity at engine load of 0.86 MPa with B50.Under all loading conditions a longer combustion duration and slightly shorter ignition delay were found with biodiesel blends. Generally it was found lower peak heat released rate for biodiesel blends than that of diesel.

M. Habibullah et al. [26] studied biodiesel production and performance evaluation of coconut, palm and their combined blend with diesel in a single-cylinder diesel engine. The test results showed that the average engine brake power respectively lower 3.92%, 4.71%, and 4.10% for (palm biodiesel)PB30, (coconut biodiesel)CB30, and PB15CB15 and higher BSFC values (8.55–9.03%) than that of diesel fuel. Because of their lower HHV the BTE values are much lower compare to diesel.BTE for PB15CB15 showed slightly higher than PB30 and slightly lower BTE and BP compare to CB30 fuel. By contrast, BP slightly improved by 0.63% than that of CB30 and slightly reduced by 0.20% than that of PB30. For all the biodiesel blends average NOx emissions are higher than that of diesel. For CB30 and PB15CB15 the NOx emission slightly higher compare to PB30. PB15CB15 showed slightly lower emission compare to CB30. High reduction in CO and HC for CB30, PB30 and PB15CB15 as compare to diesel.

3.2.2 Rapeseed oils

L. Labecki et al.[27] studied the Combustion and emission of Multi-cylinder turbo-charged DI diesel engine, fuelled with Rapeseed plant oil, its blends and pure diesel oil.The tests showed that the soot emissions for (Rapeseed plant oil) RSO and its blends are higher, however the NOx emissions lower than that of diesel. By simultaneously retarded the injection timing up to 3^{o} bTDC and increased the injection pressures up to 1200 bar for blend of 30% RSO it was achieved equivalent levels of soot emission as diesel. Under the diesel equivalent soot operating levels for 30% blend of RSO it was found that the reduction in NOx emission again by 22%. With retarded injection timing and an increase in injection pressure for 30% RSO blend the exhaust soot particle number concentrations reduces. For 30% RSO blend the exhaust soot particle number concentration were still more as compare to diesel, even the equivalent level of soot emission was already achieved by diesel.

Hanbey Hazar et al. [28] studied the Performance and emission evaluation of a(Rainbow–186 diesel) single cylinder direct injection diesel engine fueled with preheated raw rapeseed oil (RRO)–diesel blends. Preheated raw rapeseed oil (RRO)–diesel blends have shown some positive effects on engine emissions and performance. Smoke density reduces, NOx emissions increases and CO emissions reduces for all fuels, BSFC remarkably reduces. The high viscosity of raw rapeseed oil (RRO)–diesel blends and vegetable oil can be reduced by preheating.

3.2.3 Palm oil

Pedro Benjumea et al. [29] demonstrated the Effect of altitude and palm oil biodiesel fuelling on the performance and combustion characteristics of a HSDI diesel engine. The results have shown that the increases the altitude from 500 to 2400 m fuel consumption also increased. From test results it was found an additive effect on the advance in injection and combustion timing for biodiesel fuelling and altitude as compare to diesel fuel. The duration of the premixed combustion stage depending upon altitude and biodiesel, increases with altitude and decreases with biodiesel. With increasing the height which leads to reduction in combustion duration, increasing the cylinder pressure and air-fuel equivalence ratios while operating with biodiesel. With increasing the altitude for both fuels Brake thermal efficiency decreased, but very high for B0. The increasing in altitude the exergy destruction decreased with biodiesel.

M.J. Abedin et al.[30] studied the Performance, emissions, and heat losses of a four-cylinder diesel engine at full load and in the speed range of 1000 to 4000 RPM, fuelled with palm, jatropha biodiesel blends and pure diesel oil. For 10% and 20% blends of palm and jatropha biodiesel the brake power was decreased on average 2.3% to 10.7% respectively. BSFC for PB20 and JB20 blends were increased by 26.4%. The carbon monoxide (CO) and hydrocarbon (HC) emissions were reduced by 30.7% and 25.8% respectively for B20. The NOx emission was increased by 3% while fuelled with JB10 and JB20 blends, whereas it reduced by 3.3% while fuelled with on PB10 and PB20 blends.

3.2.4 Soybean oil

Orkun Ozener et al.[31] studied the performance, emission and combustion characteristics of a single cylinder four stroke naturally aspirated air cooled direct injection diesel engine fuelled with soybean biodiesel and B10, B20, B50 blends diesel oil. The test results have shown that reduces the premixed peak and ignition delay while addition of biodiesel to diesel fuel .The biodiesel and its blends (up to B50) were comparable Combustion, performance and emission to diesel fuel. Due to the lower heating value of biodiesel increased (2-9%) in BSFC and decreased (1- 4%) in torque. Reductions in the CO emission and unburned THC. Slightly increased in NOx and CO_2.

D.H. Qi et al.[32] have studied the combustion characteristics and performance of a single cylinder four stroke direct injection diesel engine fueled with soybean biodiesel and diesel blends. Due to the lower heating value of biodiesel BSFC increases with increased in proportion of biodiesel in the blends. At low engine loads the BTE of biodiesel and its blends were slightly lower as compare to diesel, while at high engine loads keep almost same. Due to oxygen content in biodiesel better combustion and increased the combustion chamber temperature .Because of this higher NOx emissions, especially at high engine loads .There have little differences in HC emissions between biodiesel, diesel and its blends. At high engine loads noticeable reduction in CO and smoke emissions. For biodiesel and its blends combustion starts earlier as compare to diesel. Generally the peak cylinder pressure of diesel is lower as compare to biodiesel and its blend, while almost same at high engine loads. At low engine loads the peak heat release rate and peak pressure rise rate of biodiesel are higher as compare to diesel, but inversely at high engine loads.

3.2.5. Mustard oil

Sanjid Ahmed et al.[33] studied the of biodiesel production, characterization, engine performance, emission and noise of Brassica juncea methyl ester and its blends. The test results showed that the superior cloud point, oxidation stability and calorific value (40.40 MJ/kg) for MB (Mustard oil) as compare to others biodiesel. The blended (MB10 and MB20) mustard biodiesel have shown the lower (7-8%) brake power and higher (8-13%) BSFC as compare to diesel. During engine emissions and noise tests it was found that the lower (19-40%) CO, (24-42%) HC, (2-7%) noise and higher (9-12%) NO emissions for MB blends than that of diesel fuel. From above it was found that MB10 and MB20 can be used as a fuel for diesel engine without modifications.

3.2.6 Sunflower oil

G. Antolın et al.[34] studied the Optimization of biodiesel production by sunflower oil transesterification. The tests showed that the Methanol and catalyst quantity were gave the major influences. Due to large quantity of methanol conversion of the TG and ME was maximum but slowed down separation of two phases during production of biodiesel. The calorific value of biodiesel was lower (12%) than that of diesel fuel, but lesser (6%) loss of energy. As compare to diesel sunflower biodiesel showed similar CO, HC, NOx and CO_2 emissions.

Cumali Ilkılıç et al.[35] studied the production of biodiesel from sunflower and its application to diesel engine. Performance and emission tests were conducted on a single cylinder diesel engine to fuelled with biodiesel blends and diesel fuel. The test results showed that the reduction in performance for B5, B20 and B50 fuels were 2.2%, 6.3% and 11.2% respectively than that of diesel fuel. These low reduction can be neutralize by increase in BSFC. For biodiesel blends B5, B20 and B50 increased in BSFC by 2.8%, 3.9% and 7.8% respectively. Biodiesel showed that the slight reductions of PM and smoke emissions. NOx and HC emissions increased and CO emissions decreased for biodiesel blends. But increases in HC emissions can be ignored because it has very low amounts of all types of fuel test. It can be concluded that the use of biodiesel fuel safflower has beneficial effects in terms of reducing emissions and alternative diesel oil.

3.2.7 Rice bran oil

Lin Lin et al.[36] studied the Biodiesel production from crude rice bran oil and properties as fuel. The engine test showed slightly higher fuel consumption rate and similar power output for rice bran biodiesel as compare to diesel fuel. NOx emission slightly increased, while CO, HC and PM emissions reduced as compare to diesel fuel. The production of biodiesel from rice bran oil was more economical as compare to production from refined vegetable oil.

3.3 Waste cooking oils

Jinlin Xue [37] studies the Combustion characteristics, engine performances and emissions of waste edible oil biodiesel in diesel engine. With no or minor modification on diesel engine reduction in PM, HC and CO emissions accompanying with minor loss of power, increase in consumption of fuel and NOx emissions than that of diesel. And also the combustion characteristics such as heat release rate, peak pressure, rate of pressure rise, and ignition delay for the WEO biodiesels showed slight differences as compare to diesel. Despite what was taken from the conflicting conclusions on the CO_2 emission of WEO biological, it reduces to a large extent from the point of view of the trading life cycle CO_2. Although the WEO has similar engine performances, combustion characteristics and emissions as compare to various biodiesels and blends of WEO biodiesel could replace the standard diesel to help in controlling the air pollution. Also motivating the storage and reusing of waste edible oil for production of biodiesel and relieve pressure on scarce resources, largely without greatly sacrificing emissions, economy and the engine power.

G.R. Kannan et al.[38] studied the performance emission and combustion characteristics of single cylinder water cooled direct injection diesel engine operated at a constant speed of 1500 rpm at different operating conditions fuelled with biodiesel. For production of waste cooking palm oil biodiesel ferric chloride ($FeCl_3$) used as a fuel borne catalyst. 20 lmol/L dosage of metal based additive was added to biodiesel. Due to mixing of fuel borne catalyst with biodiesel it was observed that the slight increment of brake thermal efficiency, BSFC and BSEC at optimized operating condition. Also with addition of fuel borne catalyst slight increment in emission of NO and CO_2 at optimized operating conditions .It can also seen that the significant reduction in emission of CO,UHC and smoke emission. Due to addition of fuel borne catalyst with biodiesel showed the higher cylinder gas pressure, heat release rate and shorter ignition at optimized operating conditions.

4. Effect of free fatty acids on properties of biodiesel

The fatty acid methyl or ethyl ester known as biodiesel, made from vegetable oils or animal fats. Hence, we can say that the fatty acid ester contributing to the properties of the fuel. In this section, the discussion has been carried out in connection with the fatty acid composition of the bio-diesel fuel properties. The structure of its component fatty esters and the nature of its minor components are strongly affected the biodiesel properties like ignition quality, cold flow, viscosity, and lubricity oxidative stability. While biodiesel using as a fuel in diesel engine these properties are very critical. The cetane number ranges from 48 to 65 for different biodiesel derived from various feed stock. The chemical structure, oil processing technology and climate condition of the area where oil is collected are responsible for variation in cetane number [41]. Both composition of biodiesel and oxidative aging have been affecting the cetane number. Depending on condition of oxidation, with oxidation derived cetane number increases [42]. Cetane number of biodiesels increases with increasing chain length and decreases with increasing unsaturation. A high cetane number is obtained by one long straight chain. The cetane number affected by alcohol while it used in production of biodiesel. Methyl or other straight chain alkyl esters have competitive cetane number with branched esters [39,40,43]. Canakci et al. [44] have demonstrated that saturated compounds (stearic acid, palmitic acid, myristic acid etc.) having high cetane number. Further due to variation in temperature they tend to crystallize indefensibly. Due to the formation of low cetane number compounds during pre-combustion Some fatty compounds (especially more unsaturated esters) have shown lower cetane number [45]. The production of biodiesel from saturated oil (tallow and frying oil) having higher cetane number. According to degree of unsaturation, the carbon/hydrogen ratio will be slightly difference for biodiesel from different sources. Around 10–12% (by weight) oxygen contains in biodiesel which are responsible for lower heat of combustion and reduced particulate emission as compare to diesel. The important parameter of fuel is calorific value or heat of combustion which shows the amount of heat liberated by the fuel within engine. Moreover, the energy in the chemical signals. Calorific value, which determines the energy value of the fuel is important property [46].Generally with increases in chain length heat of combustion increases. The major problem during the use of biodiesel as a fuel for engine is cold flow properties such as cloud points and pour points. The variation in feed stock influences the cold flow properties of biodiesel and strongly affected by level of saturation of fat [47].Unsaturated esters act as solvents because of their very low melting point while saturated ester dissolved in it. Consequently, with decreasing temperature, unsaturated fatty compounds in a crystallize mixture at lower than saturated fatty compound [48].That is why, a noticeable amounts of saturated fatty compounds presents in biodiesels shows higher pour point and cloud point. Highly saturated oil such as coconut, palm and Animal fats have higher cetane number, higher cloud point. Viscosity, volatility, flow ability and filterability are affected by the presence of solid crystals in the biodiesel. Moreover, branched chain alcohol ester improves cold flow properties [49]. Viscosity and density of biodiesel and diesel fuel are the two main fuel quality standards. Pratas et al. [50] have measured the viscosities and densities at atmospheric pressure and temperatures (0oC to 90oC) for eight methyl esters and seven ethyl esters. The results indicate that the viscosity decreases with level of unsaturation and increases with ester chain length for all ester. For equivalent fatty acid composition methyl ester has shown the lower viscosity than ethyl esters. The nature and number of double bonds achingly affected kinematic viscosity of unsaturated fatty compounds, although effect of double bond is not much .Significantly higher viscosity of compounds with hydroxyl groups or free fatty acid [51]. Biodiesel have higher viscosity and spray penetration than that of diesel. The higher viscosity of biodiesel prevents the breaking of the spray jet, consequently the size of the spray droplets increases. Due to increasing the size of the spray droplets momentum increases and hence decreases resistance preventing penetration [52]. Injection system, the pump and the nozzles properly adjusted to provide the proper amount of fuel for combustion as fuel density is remarkable properties [53].In spite of higher density of biodiesel, the energy content is lower than that of diesel. As a result of that more fuel injected and hence increases in fuel consumption for biodiesel in order to gain the same power [42]. The level of unsaturation is measure by the iodine number of fuel [56].Due to increase in level of unsaturation increase in number of double bonds and therefore increase in iodine number [55].Biodiesel has oxidative stability problems due to the presence of polyunsaturated fatty esters [54]. CN of DDCL can be effectively improved with 1 vol% addition of fatty acids. Various ester like methyl myristate (C14:0M), methyl palmitate (C16:0M), methyl stearate (C18:0M),ethyl stearate (C18:0E), and methyl oleate (C18:1M) can increased the CN of DDCL from 44 to 45. And also various factor like chain length, unsaturation, and esters generated by different alcohols can improved the CN. In such a way that clearly visible improvement in cetane number when increases the length of carbon chain. On the contrary, increases the unsaturation of fatty acid esters less effect on cetane number [57]. At lower blend (below 5%) fatty acid profile did not affect the cold flow properties. The high percentage of long chain (C16 and above) saturated FAME can affect the cold flow properties [58]. D.H. Qi et. al.[59] have worked on soybean biodiesel and evaluated high percentage of biodiesel in the blends shows high cloud point, cold filter plugging point and acid value. And also with increases the content of biodiesel calculated cetane index decreases slightly. Due to complex nature of vegetable oils and fats very difficult to correlate the properties of biodiesel with fatty acid profile. Palm oil, animal fats, coconut oil etc. comprise insignificant unsaturated fatty acids, lower molecular weight fatty acids and high very degree of saturation .As a results of that the ester have higher viscosity, calorific value and high cloud point. Opposite of this, Rapeseed, safflower etc. have insignificant saturated fatty acid and lower cloud point, with very high percentage of unsaturated fatty acids.

5. Conclusion

Researchers in various countries carried out many experimental works using vegetable oils as I.C. engine fuel substitutes. These results showed that thermal efficiency was comparable to that of diesel with small amounts of power loss while using vegetable oils. The particulate emissions of vegetable oils are higher than that of diesel fuel with a reduction in NOx. Vegetable oil methyl esters gave performance and emission characteristics comparable to that of diesel. Hence, they may be considered as diesel fuel substitutes. Raw vegetable oil can be used as fuel in diesel engines with some minor modifications. The use of vegetable oils as I.C. engine fuels can play a vital role in helping the developed world to reduce the environmental impact of fossil fuels. Since biodiesel holds the most promising features like renewability, sustainability, and lesser impact on environment so it it can play a vital role in transport sectors in forthcoming years. It possesses the all properties of diesel with added advantages. The performance and emission characteristics of biodiesel obtained from different feedstock, affect the performance of CI engine. A relation established for nature of feedstock, performance and emission characteristics of biodiesel enable us to produce more efficient fuel. Apart from this other factor which influences the properties of biodiesel such as free fatty acid composition of vegetable oils and fats. Higher saturated esters have higher cetane number, lower density and lower iodine number in comparison to unsaturated esters. The low carbon chain compound has higher density and higher carbon chain compound has lower density. The viscosity and cold flow property of unsaturated biodiesel is better than saturated, however it shows low oxidation stability. Biodiesel obtained from saturated feedstock produces less NOx and also more resistive to oxidation. It is highly viscous in nature so exhibit poor atomization. Lower carbon saturated esters produces more NOx than higher carbon saturated esters. So slightly on compromising the performance characteristics of biodiesel the animal fat may be the better solution to reduce the NOx emission.

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