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Experimental Investigation of Performance, Combustion and Emission in Diesel Engine by Using Biodiesel Blends of Cottonseed Oil and Eucalyptus Oil

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ABSTRACT

In a modern days world alternative source of energy are given importance due to gradual depletion of fossil fuels reverse vegetable oil can be used as an alternative to diesel in CI engines. the use of vegetable oils in CI engine result in low CO and HC emission compared to conventional diesel fuel.The aim of this report is to study various edible and non-edible oils used as a biodiesel. Also study of their fuel properties, fuel economy, and fuel production techniques. Through the literature review study of various biodiesel and their effect on engine parameters so that best use of biodiesel obtain which give good performance, combustion and emission characteristics. The report is focused towards cotton seed oil and eucalyptus oil. Which are easily available and some chemical compound obtain by transesterification process having equivalent properties as a diesel fuel. The oil used in the form of blends. various proportion of cotton seed oil and eucalyptus oil are prepared on the volume basis and used as a fuel in single cylinder four stoke diesel engine, to observe performance and emission characteristic of this fuel.

keywards:- **Diesel engine; cotton seed oil; eucalyptus oil; combustion; emission; performance; blend**

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I. INTRODUCTION

The term compressed-ignition (CI) is used all over the world to denote diesel oil engines. This includes two or four stroke engines with airless fuel injection. The combustion is initiated by injection of fuel to the highly compressed air. The concept of compressed-ignition (CI) Engines is credited to great German Engineer Rudolf Diesel. Great inventor of diesel engines Rudolf Diesel was born in Paris (1858-1913). In 1892, he proposed "compression of air alone until a sufficiently high temperature was attained to ignite the fuel which was to be injected at end of compression stroke". In his first experiment, he tried to inject coal dust into a cylinder containing air that has been already highly compressed. He was successful only to some extent. Later on he turned to liquid and achieved success after four years of extreme hard work. The invention of diesel engine was financed by M.A.N of Augsburg. Later by end of journey of this great inventor, engine he invented and fuel used are known by his name called "Diesel Engine" for CI Engines [1].One prominent key on liquid fuel was given by Rudolf Diesel. He used peanut oil as fuel for demonstration on CI Engine, and suggested it as an alternative fuel option. However, he quoted very true predicting fact as, ''the use of vegetable oil for engine fuels may seem insignificant today. But such oils may become, in course of time, as important as petroleum and the coal tar products of the present time''- Rudolf Diesel, 1912. After eight decades, the awareness about environment rose among the people to search for an alternative fuel that could burn with less pollution. Rudolf

Diesel's prediction is becoming true today with more and more bio-diesel being used all over the world [2].The rapidly increasing interest of people towards automobile, moving machinery and off-road appliances have put front some serious (burning) issues. The continuous hike in fuel prices, demand for high power, economy, efficiency and year after year tightening emissions norms are some major issues. Further, over recent past year's stringent emissions legislations are imposed word wide on NOx, smoke and particulate emitted from diesel engine [5]. CI Engines are also typically characterized for low carbon mono-oxides (CO) emissions, where as oxides of nitrogen (NOx) emissions still remains high [3].CI Engines are well known as better power source due to high thermal efficiency, fuel economy, higher compression ratio, lean air-fuel mixture operation, good reliability, higher performance, and fuel economy compared to Spark Ignition (SI) Engine. Due to these merits, CI Engines are predominantly used to drive tractors, heavy Lorries, trucks, buses, moving machinery etc. Also, CI Engines are quality governed engines. Owing to low fuel consumption, CI Engines have become increasingly attractive for small Lorries, various agriculture machines and passenger cars [1, 3, 4]. Besides, CI Engines run on diesel, dual fuel such as LPG, CNG, bio-gas, producer gas, with diesel as pilot fuel, and alternative fuels like bio-diesel, its blend with diesel. Diesel is abundantly used as fuel for CI Engines. Also, diesel, bio-diesel fuels are non volatile, more viscous and self lubricating [3]. However, biodiesel is emerging efficient and economical alternative fuel for diesel in CI Engines without any considerable modifications in existing engine [4].

1.2 Biodiesel- an alternative to diesel

1.2.1Indian petroleum products scenario:

At present, India is producing only 30% of the total petroleum fuels required. The remaining 70% is being imported, which costs about Rs. 80,000 crore every year. It is an astonishing fact that mixing of 5% bio-diesel fuel to the present diesel fuel is made available in our country, which can save about Rs. 4000 crore every year. It is estimated that India will be able to produce 288 metric tons of bio-diesel by the end of 2012, which will supplement 41.14% of the total demand of diesel fuel consumption in India. The planning commission of India has launched a bio-fuel project in 200 districts from 18 states in India. It has recommended two plant species, viz. jatropha (Jatropha curcas) and karanja (Pungamia pinnata) for bio-diesel production. The recent auto fuel policy document states that bio-fuels are efficient, eco-friendly and 100% natural energy alternative to petroleum fuels [5].

1.2.2 International petroleum products scenario:

Use of bio-diesel is catching up all over the world especially in developed countries. In Malaysia, the tropical climate encourages production of bio-diesel from palm oil [1]. The US is contributing 25% of the world green house gases: i.e., oil and coal. We also need to reorganize its 70% of oil consumption is in transportation. The cost of bio-diesel is $3.00 a gallon (~ 4.5 l).With the tax subsidy available in the law now, it could be sold for about $1.80. It is clearly known that the future depends on bio-fuels as replacement for fossil fuels. At present, USA uses 50 million gallons and European countries use 350 million gallons of bio-diesel annually. It is mixed with 20% of bio-diesel in fossil diesel. France is the country which uses 50% of bio-diesel mixed with diesel fuel. In Zimbabwe, 4 million jatropha has been planted in 2000 ha by the end of 1997. In Nicaragua, one million Jatropha curcas has been planted in 1000 ha. The harvest of pods reached 3, 33,000 tones in the 5th year with a seed of 5000 tones and the oil extracted was approximately 1600 tones per annum. [6] The increasing price factor coupled with increased awareness about environmental degradation has prompted governments and scientific community the world over to look for suitable alternative fuels. During the last decade the use of alternative fuels for diesel engines has received renewed serious attention. It is important to explore the feasibility of substitution of diesel with an alternative fuel, which can be produced within the country on a massive scale for commercial utilization. As far as our country is concerned, the need to search for alternative fuels is more urgent as India is heavily dependent upon the import of petroleum products to meet its demands for automotive, agricultural and power sectors [7]. In this context, a few fuels that are gaining prominence are as follows [3];

1. Alcohol fuels (Methanol and Ethanol) 2. Compressed Natural gas (CNG)
3. Biogas 4. Producer gas
5. Liquefied Petroleum Gas (LPG) 6. Hydrogen, and
7. Biodiesels.
8. Methanol

Biodiesel is a clean burning alternative fuel, produced from domestic, renewable resources. It can be used in CI Engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics. Biodiesel is made through
a chemical process called "transesterification" whereby the glycerin is separated from the shown in Fig. 1 below [7].

Methanol+Catalystic→transterfication→Refining →biodiesel
↑ ↓
Methanol recovery Crude glyserin

Fig1.1 Basic Transesterification process [7]

ASTM D6751 definition of biodiesel states that biodiesel is composed of mono-alkyl esters of long chain fatty acids, oxygenated fuel derived from plant oils or animal fats. The term mono-alkyl ester indicates that biodiesel contains only one esters linkage in each molecule. However, plants oil contains three ester linkages and is therefore not legally biodiesel. Also, biodiesel can be made from methyl, ethyl, isopropyl and other alcohols. But most biodiesel research focuses on methyl esters. Biodiesel prepared from ethyl esters (eg. ethanol) are known as ethyl ester biodiesel. However, high prices of ethanol, government's legislations on ethanol, and low ethyl esters conversions had restricted use of ethyl esters [7].

Biodiesel is a clean burning alternative fuel, produced from domestic, renewable resources. It can be used in CI Engines with little or no modifications. Biodiesel is simple to use,

biodegradable, nontoxic, and essentially free of sulfur and aromatics. Biodiesel is made through a chemical process called "transesterification" whereby the glycerin is separated from the fat or vegetable oil as shown in Fig. 1 below [7].

- **Merits of bio-diesel:**

1. It is renewable and energy efficient fuel.
2. It can be used as a 20% blend in most diesel equipped with no or only minor modifications.
3. It can reduce global warming gas emissions because the balance between the amount of CO2 emissions and the amount of CO_2 absorbed by the plants producing vegetable oil is equal.
4. It can reduce tail pipe emissions, including air toxics, as bio-diesel is an oxygenated fuel.
5. It is non toxic, biodegradable (bio-diesel degrades four times faster than diesel), and suitable for sensitive environments.
6. The higher flash point makes the storage safer

- **Demerits of bio-diesel:**

1 Slight decrease in fuel economy on energy basics (about 10% for pure bio-diesel).
2 Density, viscosity is more than diesel fuel.
3 More expensive due to less production of vegetable oil.
4 Long term operations and storage of respective biodiesel should be checked.
5 NOx and PM emissions are increased to serious level.
6 Emissions from diesel engine are CO_2, CO, HC, PM and NO_x. [7-10]

However, biodiesel minimizes CO, HC, and CO_2 to large extent but increases NOx and PM because of presence of more O_2 molecules. Use of biodiesel can extend life of CI Engine because it is more lubricating and energy secure source than petroleum diesel fuel. Owing to this, bio-diesel with NO_x emission reduction techniques in CI Engine will not only solve energy crises but also bring vital revolution in CI Engine development [2, 4, 7 - 8].

Detailed specification of bio-diesel as per ASTM D6751 standard is given in Table 1.3 [8]

Table: 1.1 ASTM standards specification for properties of diesel and biodiesel fuel [8]

Property	Diesel	Biodiesel D6751
Fuel Standard (ASTM)	ASTM D975	ASTM D6751
Fuel composition	C10-C21 HC	C12-C22 FAME
Lower Heating Value (Btu/gal)	131,295	117,093
Kin. Viscosity, @ 40 8C	1.3–4.1	1.9–6.0
Specific Gravity @ 60 8F	0.85	0.88
Density, @ 158C	7.079	7.328
Water(ppm by wt	161	0.05% max
Carbon(wt.%)	87	77
Hydrogen (wt.%)	13	12
Boiling Point (^{0}C)	188-343	182-338
Cetane Number	40-55	48-65

1.3 Aim and Objectives:-

The main aim of this report is to study of various biodiesel fuels and there fuel efficient properties used as alternative fuel at today. Biomass derived fuel are preferred alternative fuel for I.C. Engine due to its availability and renewable nature. In this work complete replacement of diesel fuel with bio-fuel is studied, where bio-fuel, Namely, cotton seed oil and eucalyptus oil were chosen and used as fuel in the form of blends. various proportion of cotton seed oil and eucalyptus oil are prepared on the volume basis and used as a fuel in single cylinder four stoke diesel engine ,to observe performance and emission characteristic of this fuel.

In this present work biodiesel studied was cotton seed oil methyl ester and Eucalyptus oil

- Potential characteristics of cotton seed oil and eucalyptus oil.
- Various methods used for biodiesel production.
- Property analysis of COME AND Eu.
- Thorough review of related literature on Cotton Oil and eucalyptus oil.

1.5 Potential characteristics of cotton seed oil and eucalyptus oil.

1.5.1 Cotton seed Oil :

India is the fifth largest cotton producing country in the world today, the first-four being the U.S, china, Russia and Brazil. Our country produces about 8% of the world cotton. Cotton is a tropical plant. Cottonseed oil is a vegetable oil extracted from the seeds of the cotton. After being freed from the linters, the seeds are shelled and then crushed and pressed or treated with solvents to obtain the crude cotton seed oil. Cotton seed oil is one of the most widely available oils and it is relatively inexpensive. most of researchers have reported that cotton oil methyl ester blend is good supplement for diesel fuel in CI Engine(10).

1.5.2 Eucalyptus oil:

The eucalyptus tree is nonedible species capable of growing in nearly all climate conditions. Its tall evergreen trees and attend height of 100m.the adult leaves are 15 to 30 cm long and 2 to 5cm broad. Its production is perennial and not seasonal. Its colorless liquid over the temp. range 0^oC to 177 0^oC with vapour pressure of 69 mmHg at 20 ^oC and strong characteristics of Odour. Eucalyptus oil can be extracted from eucalyptus leaves, abundantly available throughout the year. Currently, the eucalyptus oil uses are limited just for few traditional applications such as medicine or traditional pharmacopoeia. But there is not a comprehensive investigation on applying eucalyptus oil in diesel engines yet except an experimental investigation related to performance and emissions of diesel engine running with paradise biodiesel-eucalyptus oil blend[11]

- **Fuel Properties:**

1) It has low viscosity and high volatility.
2) It act as ignition improver in biodiesel.
3) These oils are composed of mixture of volatile organic compounds including hydrocarbons, alcohols,

aldehydes, key tones, acids, ethers and esters. 1-8 cineole or simply cineole is active component of eucalyptus oil. Cineole is a cyclic ether with empirical formula $C_{10}H_{18}O$ and systematic name1,3,3-trimethyl-2-oxabicyclo octane.

4) Commercially it is called as eucalyptol.

1.6 Various methods used for biodiesel production.

The alternative diesel fuels must be technically and environmentally acceptable and economically competitive. From the view point s of requirements, triglycerides (vegetable oils or animal fats) and their derivatives may be considered as viable alternative for diesel fuels [5]. The problems with substituting triglycerides for diesel fuels are mostly associated with high viscosity, low volatility and poly un-saturated character. The problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance and make them compatible with the hydro carbon based diesel fuels by following methods: Dilution (blending), Pyrolysis (cracking), Micro-emulsification [10] and Transesterification.

1.6.1 Biodiesel Preparation and Its Characterization:

To remedy the problem of eucalyptus oil high viscosity (30 cSt at 40◦C) [18], ethyl transesterification is tested in this study. Biodiesel was prepared using 97mL (92 g) of eucalyptus oil and 42mL (33 g) of ethanol with 1 g of sodium hydroxide (NaOH) as catalyst (1% of oil by weight). After dissolving NaOH catalyst in ethanol, the eucalyptus oil was added to the reaction tank to start the transesterification reaction. The mixture was agitated thoroughly for 1 hr at 45◦C. The stirring process is characterized by the mixture color conversion from clear yellow to reddish yellow. Once the separation is operated, the glycerol is removed as a dark brown- colored liquid from the bottom of the flask. Then, the eucalyptus biodiesel is washed to remove the remaining alcohol and catalyst in the biodiesel phase. The previous parameters affecting the transesterification yield such as the reaction time and the ratios oil : alcohol : catalyst have been fixed after adjustments, which give the optimal yield estimated at 95%. The important chemical and physical properties of the biodiesel and its blends were then determined by standard methods and compared with diesel . It can be seen that the main eucalyptus biodiesel properties are comparable to those of diesel fuel. These results show that eucalyptus oil holds good potential as biodiesel no edible feedstock.[11]

1.6.2 . Transesterification process:

Biodiesel is made through a chemical process called "transesterification" whereby the glycerin is separated from the fat or vegetable oil as shown in Fig. 1 & 2 below[8].Transesterification is the reaction of vegetable oil or animal fat with an alcohol, in most cases methanol, to form esters and glycerol. The transesterification reaction is affected by alcohol type, molar ratio of glycerides to alcohol, type and amount of catalyst, reaction temperature, reaction time and free fatty acids and water content of vegetable oils or animal fats. The transesterification reaction proceeds with or without a catalyst by using primary or secondary monohydric aliphatic alcohols having 1–8 carbon atoms as follows:

Triglycerides + Alcohol Glycerin + Mono-alkyl esters.

Generally, the reaction temperature near the boiling point of the alcohol is recommended. Nevertheless, the reaction may be carried out at room temperature. The reactions take place at low temperatures (~65°C) and at modest pressures (2 atm, 1 atm = 101.325 kPa). Bio-diesel is further purified by washing and evaporation to remove any remaining methanol. The oil (87%), alcohol (9%), and catalyst (1%) are the inputs in the production of bio-diesel (86%), the main output . Pre-treatment is not required if the reaction is carried out under high pressure (9000 kPa) and high temperature (~240°C), where simultaneous esterification and transesterification take place with maximum yield obtained at temperatures ranging from 60 to 80°C at a molar ratio of 6:1. The alcohols employed in the transesterification are generally short chain alcohols such as methanol, ethanol, propanol, and butanol. It was reported that when transesterification of soybean oil using methanol, ethanol and butanol was performed, 96–98% of ester could be obtained after 1 h of reaction.[10]

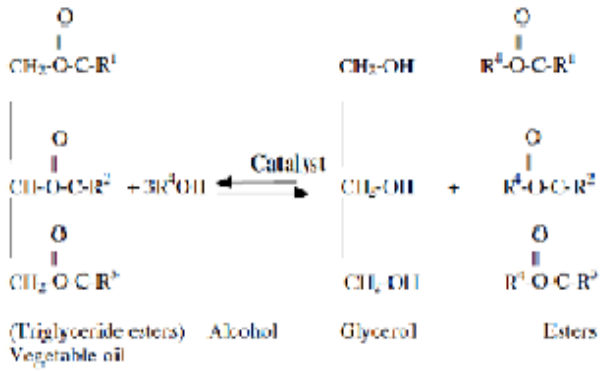

Figure 1.4 Chemical Equation of transterification process

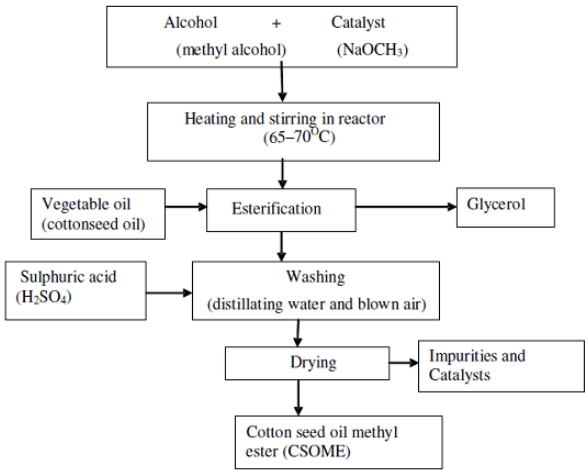

Figure 1.5 The flow chart of the Cottonseed Oil Methyl Ester(CSOME) Production Process

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term mono-alkyl ester indicates that biodiesel contains only one esters linkage in each molecule. However, plants oil contains three ester linkages and is therefore not legally biodiesel. Also, biodiesel can be made from methyl, ethyl, isopropyl and other alcohols. But most biodiesel research focuses on methyl esters. Biodiesel prepared from ethyl esters (eg. ethanol) are known as ethyl ester biodiesel. However, high prices of ethanol, government's legislations on ethanol, and low ethyl esters conversions had restricted use of ethyl esters [8].

Blending of Biodiesel

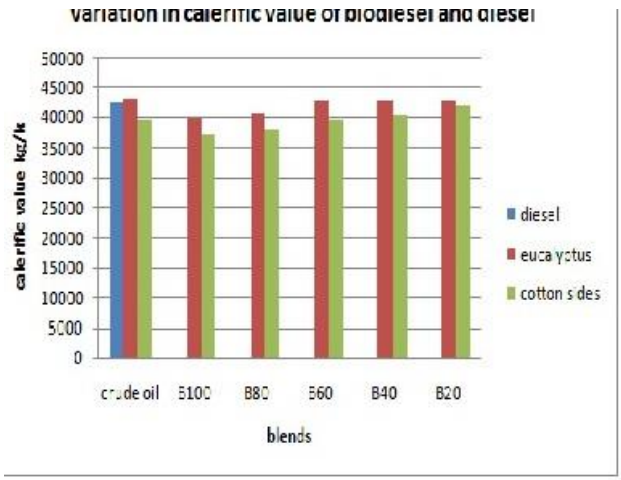
In these five different blends containing 10,20,30,40 & 50% of eucalyptus oil with COME were prepared in volume basis. Tested to observe fuel property. So that it can be compare with standard diesel. As shown in Table No.1.6

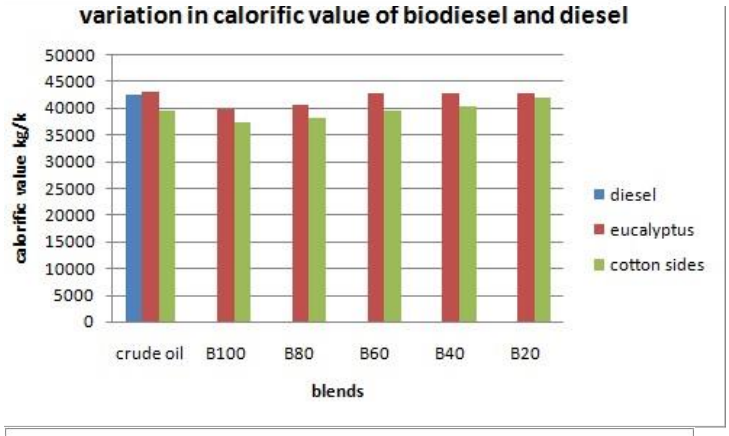
1.8 Property Analysis :-

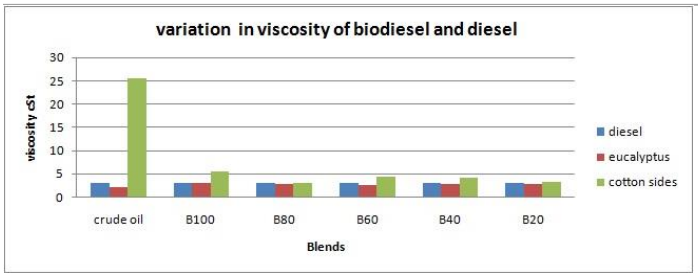
The properties of COME and eucalyptus oil are compared with diesel and given in table 1.5.It is observed that both the oils have important properties comparable with those of diesel fuel. Viscosity, calorific value and density of blends of COME and eucalyptus oils are given in table 2. When eucalyptus oil which has high volatility and low viscosity, blended with COME it resulted in a fuel with reduced viscosity and increased volatility. The reduction in viscosity and increase in heating value would result in better engine performance. The volatility of the blend also increased which results in fine atomization and better spray formation. The properties of blend like lower calorific value, flash point and viscosity are comparable with those of diesel oil, Eucalyptus oil.

COME and EOF is having good biodiesel.[10,12]

Sr. No	Properties	Standard Diesel	Cottonseed Oil	Eucalyptus Oil
1	Density at 15 ^{0}C Kg/mm^3	0.835	0.850	0.913
2	Kinematic iscosity 40 ^{0}C Cst	2.78	2.52	2
3	Calorific Value kJ/kg	43,000	39,648	43270
4	Flash oint ^{0}C	440	234	53
5	Fire Point ^{0}C	490	192	-5
6	Cloud oint ^{0}C	-2	1	1.9
7	Pour oint ^{0}C	-5	-2	-5
8	Cetane mber ^{0}C	40-55		40-55
9	Carbon lues% mass	0.01	0.42	1.9







CONCLUSIONS

Even though many oil-bearing crops are identified, only few are potential biodiesel like cotton seed oil ,eucalyptus oil ,sunflower, palm and jatropha. It is observed that biodiesel has similar combustion characteristics as diesel and also found that the base catalyst performs better than acid catalyst and enzymes. It is also inferred that the engine performance was inferior when using vegetable oil/ diesel blend as the high viscous oil caused injector coking and contaminated the lubricating oil. The tests with refined oil blends indicated considerable improvement in performance. The emission of un burnt hydrocarbon from the engine was found to be more on the all the fuel blends as compared to diesel. The emission of oxides of nitrogen from the engine found to be higher on the all fuel blends as compared to diesel.

1) Use of blends of eucalyptus oil as biodiesel the BSFC increases and BTE decreases with addition of biodiesel

content in the blends. Also CO,HC, and PM in the exhaust emission decreases, where NOx increases with increasing percentage of biodiesel in the blends. However level of emission increases with increase in engine load for al fuel tested.

2) The eucalyptus oil is that, it can be blended with any oil without any modification.
3) The blends of COSME are optimum blends which can produce better value with pure diesel for diesel engine as far as performance and emission were consider.
4) There was increasing BTE OF COME –C20 as Compare to pure diesel because of complete combustion. it was observe that smoke and emission for the blends of CSOME and NOME are less as compare to pure diesel. The properties of the 20% blend of CSOME are nearer to diesel fuel.

References

1. Mathur M. L., Sharma R. P., "A course in internal combustion engines" Dhanpat-Rai publications, ND, 15th ed., (2005), pg. 3-9, 252-254.

2. Babu A. K, Devaradjane D. "Vegetable oils and their derivates as fuels for CI engines, An overview" SAE (2003) - 01-0767.

3. Ganesan V., Engine emission and their control, "Internal combustion engines", McGraw Hill, ND, 3rd ed., (2008), pg. 471-500

4. Heywood J. B. "Fundamental of Internal Combustion Engines" McGraw Hill International Editions, Automotive Technology series, (1988) 87-1525.

5. Murugesan A., Umarani C., Subramanian R., Nedunchezhian N., "Bio-diesel as an alternative fuel for diesel engines—A review", Renewable and Sustainable Energy Review 13 (2009) pg. 653–662

6. Banapurmath N. R., Tiwari P. G., Hosmath R. S., "Experimental investigations of a four stroke single cylinder DI diesel engine operated on duel fuel mode with producer gas as inducted fuel and honge oil and its methyl ester (HOME) as injected fuel", Renewable Energy, 33 (2008) pg. 2007-2018.

7. Biodiesel handling and user guide, 4th edition, National Renewable Energy Laboratory, NREL/TP-540-43672.

8. Singh S. P., Singh D., "Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: A review", Renewable and Sustainable Energy Reviews 14 (2010) pg. 200–216

9. Atadashi I. M., Aroua M. K., Aziz A. A. "High quality biodiesel and its diesel engine application: A review", Renewable and Sustainable Energy Reviews 14 (2010) 1999–2008.

10. K.Dilip Kumar, P.Ravindra Kumar " Experimental Investigation of Cotton Seed Oil and Neem Methyl Esters as Biodiesel On Ci Engine".IJMER Vol.2 Issue4,july-Aug2012 pp-1741-1746.

11. Lyes Tarabet,Khaled Loubar, Mohand Said Lounici,Samir Hanchi,1andMohand Tazerout "Eucalyptus Biodiesel as an Alternative to Diesel Fuel: Preparation and Tests on DI Diesel Engine". journal of Biomedicine and Biotechnology Vol.2012 article ID235485.

12. D. Tamilvendhan,V. Ilangovan "Aperformance, Emission and Combustion Investigation on Hot Air Assisted Eucalyptus oil Direct Injected Compression Ignition Engine. "modern applied science Vol.,No4;Aug.2011.

13. Janlin Xue,Tony E.Grift,et al "Effect of Biodiesel on engine performance and emission" Renewable and Sustainable Energy Review 15(2011) 1098- 1116.

14. A Murugesan C.Umarani et a. "Bio-diesel as an alternative fuel for diesel engines—A review" Renewable and Sustainable Energy Reviews 13 (2009) 653–662.

15. K. Anandavelu,, N. Alagumurthi, and C.G. Saravannan ' Experimental Investigation of Using Eucalyptus Oil and Diesel Fuel Blends in Kirloskar TV1 Direct Injection Diesel Engine"- journal of sustainable energy and environment (2011)93- 97.

16. S. Naga Sarada., M. Shailaja., A.V. Sita Rama Raju., K.Kalyani Radha., et al. "Optimization of injection pressure for a compression ignition engine with cotton seed oil as an alternative fuel." International Journal of Engineering, Science and TechnologyVol. 2, No. 6, 2010, pp. 142-149.

17. Tamilvendhan D., Ilangovan V. and Karthikeyan R. "Optimisation of engine operating parameters for eucalyptus oil mixed diesel fueled DI Diesel engine using Toguchi method"ARPN Journal of engineering and applied science Vol.No. 6.June 2011.

18. M. Liaquat, H.H. Masjuki et al. "Effect of coconut biodiesel blends on engine performance and emission characteristics." 5th BSME International Conference on Thermal Engineering Procedia Engineering 56 (2013) 583 – 590.

19. A.S. Ramadhas., S. Jayaraj., C. Muraleedharan., et al "Use of vegetable oils as I.C. Engine fuel-a review" Renewable Energy 29 (2004) 727–742.

20. Ekrem Buyukkaya "Effects of biodiesel on a DI diesel engine performance, emission and combustion characteristics" Fuel 89 (2010) 3099–3105

