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A Review of the Effects of Biodiesel from Different Feedstock on Engine Performance and Emissions

Dr. J. H. Bhangale[1], Mr. A. B. Kulkarni[2]

[1]Head of Department, Dept. of Mechanical Engineering, MCERC, Nasik, Maharashtra, India
[2]UG Student, Dept. of Mechanical Engineering, MCERC, Nasik, Maharashtra, India

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Abstract - *The world is focusing on the impending energy crisis and each country needs to concentrate on energy security as well as growing pollution and environmental concerns. Due to the increasing demand fossil fuel reserves are depleting rapidly. Also due to the rapid rise in petroleum prices and uncertainty in their supply, it has become necessary to search for other alternatives fuels. The biodiesel can be considered as alternative to fossil fuels. In this review the focus is to identify the performance and emission of various biodiesels along with cottonseed and thumba biodiesel.*

Key Words: **energy crisis; pollution; alternative fuels; biodiesel; cottonseed and thumba, etc**.

1. INTRODUCTION

Availability of energy is the main aspect for economic growth and is important for sustenance of modern economy. The economic growth in future depends mainly on the long-term availability of energy from affordable, accessible and environmental friendly sources. Increasing industrialization, growing energy demands, limited reserves of fossil fuel and increasing environmental pollution have joined necessitated exploring some alternative of conventional petroleum fuels. Biofuels are strongly emerging as partial substitutes for fossil fuel from the economic as well as environmental angle. Among the biofuels, vegetable oils like mahua oil, jatropha oil, thumba oil, karanja oil, sunflower oil, castor oil, soybean oil, jojoba oil, cotton seed oil, palm oil, neem oil etc. are expected to be promising alternative to petroleum fuels to full fill energy needs in the future. Vegetable oils are non-toxic, biodegradable and they can reduce pollution significantly, hence, can be used as alternative fuels. Vegetable oils are able to significantly reduce the emissions like carbon monoxide, smoke and particulate emissions. Vegetable oils have approximately 90% heating value of mineral diesel due to higher oxygen content. High viscosity of vegetable oil than petroleum diesel is the main problem of use in diesel engines due to which problems like carbon deposits on the piston, cylinder head and ring grooves, ring sticking, problems in pumping and atomization, etc. occurs. The problem of high viscosity of vegetable oils can be resolved in several ways, such as blending or dilution with other fuels, preheating the oils, thermal cracking or pyrolysis and transesterification. One of the possible methods to overcome the problem of high viscosity is blending of vegetable oil in proper proportions with diesel. It is a fact that biodiesel is a safer, more economical and infinitely more environmentally friendly than the diesel.

2. BIODIESELS

2.1 Different feedstock for biodiesel

The primary aspect of production of biodiesel is feedstock selection. There are four main categories of the feedstock for production of biodiesel: vegetable oils (edible and non-edible), used cooking oil, animal fats, and algae. [1, 2].

- Vegetable oil
  a. Edible vegetable oil: sunflower, olive, rapeseed, palm, rice bran, corn, soybean, peanut, coconut, pistachio, sesame seed, opium poppy, sunflower oil, etc.
  b. Non-edible vegetable oil: jatropha, karanja or pongamia, neem, jojoba, cottonseed, linseed, mahua, deccan hemp, kusum, orange, rubber seed, sea mango, algae, halophytes, etc.
- Animal fats: yellow grease, chicken fat, tallow, and byproducts from fish oil etc.
- Waste or recycled cooking oil.
- Algae.

2.2 Fuel properties of various biodiesel

- Density: Regardless of feedstock type all biodiesel fuels are less compressible and denser than the diesel fuel [3]. Molecular weight of biodiesel is one of the factors that contribute to the increase in biodiesel density [4]. Density of a fuel directly effects the engine performance characteristics.
- Viscosity: One of the most important properties of an engine fuel is the viscosity since it plays a significant role in the combustion process, mixture formation and fuel spray. Similar to density, viscosity also affects the penetration, the size of fuel drop, and the atomization quality. Therefore, it influences the quality of combustion [5]
- Flashpoint: The flash point is the temperature at which when the fuel comes in contact with fire, it will start to burn it [6]. At this temperature, if the source of ignition is removed, vapor stops burning. Although combustion is not affected directly by flashpoint, it plays a significant

role in fuel handling, storage, and transportation. The flash point of biodiesel is always be far higher than diesel fuel irrespective of the quality and cost of biodiesel. Flash point reflects the nonvolatile nature of the fuel [7].

- Cetane number: The Cetane number is the major indicator for fuel ignition quality. It is shortly defined as the measure of knock tendency of a diesel fuel. If Cetane number is lower ignition delay will be longer. Long ignition delay causes diesel knocking which is not acceptable. Low Cetane number will lead to incomplete combustion which will increase particulate exhaust emissions (PM) and gaseous exhaust emissions [8]. Due to the presence of saturation in molecules and its longer fatty acid carbon chains and the biodiesel has higher Cetane number than that of pure diesel [9, 10, and 11]. Generally, the higher chain length will imply higher Cetane number value [12].

- Cloud and pour point: Pour points can be defined as the lowest temperature before fuel turns in to a cloud of wax crystals when cooled and the fuel can still flow and can be pumped [6, 13, and 14]. Generally, the biodiesel from fats and greases has higher cloud and pour point than that of vegetable oil based biodiesel [3].

- Calorific value: Calorific value indicates the available energy in fuel and represents the amount of heat transferred into the chamber by burning the fuel [15, 16]. If the calorific value is higher, the yield of the fuel is higher. It is desired to have high calorific value because it releases higher heat during combustion and improves engine performance [17].

3. LITERATURE REVIEW

K. Sureshkumar, et al. carried out emission analysis on single cylinder 4 stroke Kirloskar diesel engine having brake power 3.68kW at 1500 rpm and 16.5 compression ratio. They used Pongamia Pinnata Methyl Ester (PPME) in proportion of 20, 40, 60, and 80% by volume mixed with petrodiesel and 100% biodiesel. The findings of their experiment was that the BSFC was equal to that of diesel for the blends B40 and lower than that of diesel for B20. The CO concentration is totally absent for the blends of B40 and B60 for all loading conditions. Also, very low amount of CO_2 was emitted B40 and B60. For B20 at no load and full load some traces of HC are seen. However, HC emission is almost nil for all other PPME blend. The exhaust temperatures for the different blends reduced as concentration of PPME in the blends increased [18].

M. Mofijur, et al. carried out trial on engine using Moringa oleifera biodiesel mixed with diesel in proportions of 10 and 20% by volume and compared the results with that of 100% diesel at various speeds. The engine used for trial was a Mitsubishi Pajero 4 Cylinder with compression ratio 21:1, having maximum power 78 kW at 4200rpm. B10 and B20 fuels increased brake specific fuel consumption by 5.13% and 8.39%, respectively, compared with diesel fuel over the entire range of speeds. B10 and B20 reduced CO emission by 10.60% and 22.93% and HC emission reduced by 9.21% and 23.68%. For B10 and B20 Nitric oxide emission raised by 8.46% and 18.56%, respectively, compared with diesel. The BP reduced by 4.22% and 8.03% respectively, compared with diesel fuel. For Moringa biodiesel blends brake thermal efficiency was lower than that of pure diesel [19].

R. M. Rathod, and S. V. Channapatana tested karanja biodiesel with and without EGR on Single Cylinder Diesel 4 Stroke Kirloskar engine having Cubic Capacity 1.323 Liter and compression ratio 17.5. B.S.F.C. value on 9% EGR was observed to be 0.5417 kg/kWhr. Highest exhaust gas temperature of 174°C was recorded for the karanja oil, whereas with EGR the corresponding value was 135°C only. Brake thermal efficiency value was higher at lower EGR rate and lower at higher EGR rate [20].

In another study, A.M. Liaquat et al. carried out an experiment using blends of coconut oil with diesel in the proportion of 5% and 15% by volume. CB5 blend (5% coconut oil and 95% Diesel), and CB15 (15% Coconut oil and 85% Diesel) were tested on a 4 stroke, single cylinder, 7.7 kW CI engine having compression ratio 17.7 and the outcomes were compared with that of pure diesel. Compared to petrodiesel the torque reduced by 2.58% and 0.69% and the brake power is reduced by 2.61% and 0.66% for CB15 and CB5, respectively. BSFC increased by 0.53% for CB5 and for CB15 by 2.11% compared to diesel fuel. Average reduction in CO at 2200 rpm was 13.38% for CB5 and 21.51% for CB15, at 100% throttle. At 2200 rpm and 100% throttle HC for CB5 reduced by 13.89% and by 22.88% for CB15 respectively. Whereas, HC reduced by 16.58% for CB5 and for CB15, it is 27.19% respectively, at 80% throttle position. Compared to diesel fuel increase in NO_X for CB5 was observed as 1.42% and for CB15 it was 3.19% at 2200 rpm and at 100% throttle, whereas, for CB5, increase was found as 2.44 and for CB15 it was 4.64% respectively, at 80% throttle position [21].

M.M. Rashed et al. compared the performances of Moringa biodiesel, Palm biodiesel, Jatropha biodiesel, and diesel fuel. Each biodiesel was blended with diesel fuel separately forming 20% blend of each biodiesel i.e., MB20, PB20, and JB20. The trials were conducted on a 4 cylinder Mitsubishi Pajero engine having maximum engine speed 4200 rpm compression ratio 21, and Maximum power 55 kW. According to the observations, diesel fuel showed the highest brake power, followed by PB20, MB20, and JB20; compared with diesel the brake power was reduced by 6.92%, 8.03%, and 8.75% for PB20, MB20, and JB20, respectively. At all speeds, the fuel samples of PB20, JB20, and MB20 and increase the BSFC by 5.42%, 7.15%, and 8.39%, respectively, than diesel i.e, highest BSFC was observed in MB20 fuel.

Lower CO emissions were found in the biodiesel blended fuel than diesel fuel. The fuel samples PB20, JB20, and MB20 reduce CO emission by 32.65%, 27.23%, and 22.93%, respectively, compared with diesel. Compared to diesel, MB20, JB20, and PB20 reduce HC emission by 11.84%, 19.73%, and 30.26% respectively; and increased NO emission by 6.91%, 14.22%, and 18.56%, respectively. Considering overall performance, it was concluded that superior performance was showed by palm biodiesel blend among the biodiesel fuel blends [22].

K. Srithar et al. blended two different biofuels with diesel and tested it on single cylinder 4.5 BHp Kirloskar engine having speed 3000 rpm and Compression ratio 18:1. In this study, pongamia pinnata oil ethyl ester (PPEE) and mustard oilethyl ester (MEE) were mixed in various proportions with diesel. The blends thus formed were: Blend A (Diesel 90%+PPEE 5%+MEE 5%), Blend B (Diesel 80%+PPEE 10%+MEE 10%); Blend C(Diesel 60%+PPEE 20%+MEE 20%); Blend D(Diesel 40%+PPEE 30%+MEE 30%); Blend E(Diesel 20%+PPEE 40%+MEE 40%); Blend F(Diesel 0%+PPEE 50%+MEE 50%) by volume basis. At maximum load, the values of SFC were observed to be is 0.32 kg/kW h, 0.35 kg/kW h, 0.37 kg/kW h and 0.31 kg/kW h for blends A, B, C and diesel fuel respectively. For all dual biodiesel blends Brake specific energy consumption (BSEC) is highest compared with mineral diesel. The maximum mechanical efficiency observed for Blend A 79.3% for the maximum brake power, whereas the diesel gives 78.2% at the same brake power. For the other blends, mechanical efficiency is lower than diesel. The diesel shows higher exhaust temperature than all other blends. The smoke for diesel, blend A and blend B was 60%, 64% and 68% respectively, with the same maximum load. Blend A and Blend B gave lower CO and CO_2 than diesel. NO_X emission was 166 ppm, 180 ppm and 190 ppm for blends A, B and C respectively, whereas diesel gives 150 ppm. Blend A gives lesser HC than other blends. At lower engine loads the dual biodiesels and blends generally exhibit lower HC emission [23].

Aman Mamualiya and Harvinder Lal blended Pongamia pinnata (Karanja) oil in the proportion of 10%, 20% and 30% by volume with petrodiesel. The blends were tested in single cylinder 5 BHP Engine with speed 1500 rpm and compression ratio 17.5. The best and effective blend was B20 which improved the brake thermal efficiency (BTH) and reduced brake specific fuel consumption (BSFC) and also reduced emissions like CO_2, CO, smoke, and HC, but there was increase in smoke density and NO_X as compared with pure diesel. In case of B20 the BTH was 28% and for petrodiesel it was 27.2%. At low load, the more BSFC is required for biodiesel as compared to petrodiesel due to poor atomization. At full load the BSFC is almost same in all fuels. The EGT increases as the load on the engine increases. At higher load, EGT for karanja B30 was 370 °C as compared to neat diesel 330°C. In case of B30 the carbon dioxide was 3.05% as compared neat diesel was 3.5%. In case of B30 the NO_X level was 575ppm and for petrodiesel it was 500ppm. The NO_X level was higher in all blends as compared to neat diesel. At full load in case of B30 the smoke density was 38% as compared to neat diesel was 50%. The smoke density was low in all blends than that of neat diesel at all loads [24].

S V Channapattana et al. aimed their study on Calophyllum Inophyllum linn oil (Honne oil Methyl Ester) mixed by 20%, 40%, 60%, 80% by volume with diesel and 100% biodiesel at various compression ratios. The test was carried out in 4 stroke single cylinder VCR Kirloskar engine with1500 rpm and rated power 3.5 kW and the performances of biodiesel blends were compared with pure diesel fuel. As CR raised from 15 to 18, the BTE increased up to 7% approximately for all blends. At CR18 the BTE using Honne biodiesel is 8.9% lower than Diesel. BSFC increases as the amount of biodiesel increases in the blends. For all fuels, as CR increases, BSFC decreases. The fuel consumption of pure Honne biodiesel is about 11% and 27% more at CR of 18 and 15, respectively. BMEP is not affected considerably with CR and use of different blends. At CR of 18, they observed that values of EGT for biodiesel blends B80, B60, B40, B20 and Diesel are 343.77°C, 346.99°C, 347.25°C, 345.67°C, 347.96°C and 350.75°C respectively. It indicates that at higher CRs EGT for all blends are closer to Diesel. It was found that blends showed lesser CO emissions than Diesel. CO emissions for pure Honne biodiesel are 64% less as compared to Diesel at CR 18. As blend proportion increases HC decreases. With Honne biodiesel the HC emission decreased by 58% as compared to Diesel. NO_X emissions decreases for Diesel and increases for blends with increasing CR. At a CR of 15 the Diesel showed 70.4% higher NO_X emissions and they are lower by 24.6% at CR 18 as compared to Honne biodiesel. CO_2 emission is higher for biodiesel compared to Diesel at all CRs. With increase in CR the CO_2 emissions decreased by 22% over the range of CR [25].

R. Kumar et al. used Jatropha ethyl ester blends B10, B20, B30, and B40 with diesel and compared the performance with that of diesel. The engine used was single cylinder 3.67 KW VCR (5 to 20) engine. The findings from the tests are that SFC for diesel was lower than all blends of biodiesel. Break thermal efficiency for B10, B20, B30 and B40 fuel varied from 16.45 to 31.72%, 16.6 to 31.92%, 16.65 to 33.00%, and 17.98 to 33.91% and was higher than that of diesel fuel (16.42 to 30.87%) at 25 to 75% of rated load, respectively. Mechanical efficiency for B10, B20, B30 and B40 fuel was observed to be 64.09%, 65.99%, 67.39% and 68.34% at 75% of rated load respectively which was 62.14% higher than diesel fuel. With increase in load and proportion of ester in blends the exhaust gas temperature increased. NO_X concentration were higher for Jatropha blends than that of diesel. As compared to diesel the emission of CO was reduced [26].

De-Xing Peng tested emission characteristics of Petrodiesel, soybean oil, palm oil, and waste edible oil in a 4 stroke, water cooled, 4 cylinder, 1991 cc HYUNDAI, TRAJET

2.0 engine with compression ratio 17.7. The engine was equipped with emission control systems like DOC: diesel oxidation catalyst; Positive Crankcase Ventilation (PCV) and Exhaust Gas Recirculation (EGR). According to emission tests, on average, CO emission was reduced by 33.9%, 32.0%, and 25.2%, for soybean oil, palm oil, and WEO, respectively. It was found that the lowest level of HC was produced from soybean oil fuel, followed by WEO and palm oil. The HC emission observed for pure petrodiesel, palm oil, soybean oil, and WEO was 28.0, 26.2, 22.8, and 25.1 ppm, respectively. The CO_2 emission for all types of fuel was found at 3000 r/min: 2.51%, 2.72%, 2.64%, and 2.87% for pure petrodiesel, palm oil, soybean oil, and WEO, respectively. Soybean oil increases NO_X emissions by 10.34%, palm oil reduces them by 22.4%, and WEO increases them by 31.0% when compared with pure petrodiesel. The WEO oil and soybean oil fuels showed 18.5% and 20.3% less smoke opacity than pure petrodiesel fuel. Petrodiesel showed the lowest level of exhaust gas temperature followed by WEO, palm oil, and soybean oil. The fuel consumption was lowest in petrodiesel, followed by soybean oil, WEO, and palm oil. Overall, the rsults can be summarized as that for the biodiesel case the fuel consumption is increased by 7.38%, the engine combustion temperature can be increased by 7.17%, the O2 emission can be increased by 14.14%, CO emissions can be reduced up to 25.24%, HC emissions can be reduced up to 18.57%, and smoke emissions can be reduced up to 19.6%. Thus, the biodiesel can be applied in the diesel fuel to upgrade the engine performance. For biodiesel the exhaust emissions are also lower than those of pure petrodiesel [27].

Vandana Kaushik et al. concentrated their study on engine performance using Thumba methyl ester mixed with diesel in the proportion of 10, 20 and 30% by volume and the results were compared with that of pure diesel. The engine used was Legion Brothers Single Cylinder VCR (Compression Ratio 5:1 to 20:1) engine with Eddy Current Dynamometer and power from 3 to 5 HP. For diesel fuel higher brake thermal efficiency was observed for entire load range compared to all thumba methyl ester diesel blends. Among all thumba methyl ester diesel blends the maximum brake thermal efficiency was observed for 20% TME blend. The BSFC of engine fuelled with 20% TME diesel blend was found minimum at maximum load among all the tested blends of TME in diesel. EGT (Exhaust Gas Temperature) was higher for all TME blends compared to diesel fuel. Among all the TME blends the lowest exhaust temperature was observed for the blend of 20%. When engine is fueled with blends of TME the volumetric efficiency obtained is highest for TME20CR19 than TME10 CR18 and TME30 CR19 and then that of pure diesel. The TME fuel has lower Mechanical Efficiency than diesel fuel. At full load the highest efficiency is achieved for TME20 CR19 than TME10 CR18 and TME30CR20. It was observed that the Engine Performance is better or optimized with TME20 and the compression ratio CR19 [28].

Ratnam Ramesh Gujar et al. compared the performance of B00% (i.e. diesel fuel) with Citrullus methyl ester (thumba) blends with proportions like TB10%, TB20%, TB30%, TB40% and TB50% using a 5 HP 1500 rpm engine setup. It was found that the maximum brake thermal efficiencies at load 8 for diesel, TB10%, TB20%, TB30% were 17.86%, 18.9%, 19.1%, 19.11% etc. HC decreases as Thumba biodiesel percentage in bio-diesel blends increases. It is also observed that with thumba biodiesel HC emission are much lower compared to base line diesel at full load condition. The variation in CO emissions for all biodiesel blends and diesel is fairly small. It is also identified that CO_2 and CO concentration of Thumba biodiesel emission is lower while Nitrogen Oxides (NO_X) emission is higher than conventional diesel at rated load. Result showed that among all methyl ester blends of citrullus, CB20% blend shows lower emissions as well as performance as assimilated with running diesel fuel at all load[29].

B. Murali Krishna and J. M. Mallikarjuna carried out testing of cottonseed biodiesel blended with diesel in proportions CSO10D90, CSO30D70, CSO50D50, CSO70D30 and CSO100 and compared it with that of diesel (D100). The performance testing was done on a 4-stroke, Single cylinder, Compression ratio 16.5:1, direct injection, CI engine with rated speed of 1500 rpm and rated power 3.7 kW. Out of all the tested blends the CSO10D90 blend fuel showed best results when compared to that of other blends and pure biodiesel. 3.7% reduction was shown in BSFC by CSO10D90 blend, BTE was increased by 1.7%, ME increased by 6.7%, and smoke emissions reduced by 21.7% compared to diesel fuel [30].

Hüseyin Serdar Yücesu and Cumali İlkiliç tested Diesel and Cottonseed Oil Methyl Ester in a 395cc 6.25kW Lombardini 6LD400 diesel engine with compression ratio of 18:1. Performance test was done at various speeds and at rated load. The engine torque of cottonseed oil methyl ester was found to be lower than that of diesel fuel in the range of 3–9% over the speed range. SFC was approximately 8–10% higher than diesel fuel. Compared to diesel fuel, CO, CO_2, and NOx emissions of COME (cottonseed methyl ester) were lower. The combustion efficiencies at the maximum engine speed are 93.3% and 89.9 for diesel and COME, respectively. 3% combustion loss is observed between the two fuels. The maximum engine power was obtained at 3100 rpm. At this speed the engine powers obtained were 5.51 kW and 5.19 kW with diesel and COME, respectively. 6% drop in engine powers was observed between these two kinds of fuels. The specific fuel consumptions were 289 g/kWh for diesel and 298 g/kWh for COME. The difference between diesel and COME is 3%. At the maximum torque speed CO_2 amount is higher for both fuels. The CO_2 emission is 9.85% for Diesel and 7.70% for COME at 3100 rpm, the maximum power speed. COME's CO and NO_X emissions level is lower than that of diesel at all the test speeds [31].

4. SUMMERY OF LITERATURE REVIEW

Table -1: Performance and emission characteristics of various biodiesels

Sr. No.	Author	Test Fuel	Concluding Remarks
1	K. Sureshkumar, R. Velraj, R. Ganesan	Pongamia pinnata methyl ester And diesel blends B20, 40, 60, 80, 100	1. The BSFC for the blends B20 and B40 is lower than and equal to that of diesel, respectively. 2. For the blends of B40 and B60, CO concentration is nil. 3. PPME blends emits less CO_2 than diesel. B40 and B60 showed lowest emissions. 4. For all PPME blends emission of HC is absent except for B20. 5. Diesel has the highest exhaust temperature also the temperatures for different blends decreased with increasing concentration of PPME in the blends.
2	M. Mofijur, H.H. Masjuki, M.A. Kalam, A.E. Atabani, M.I. Arbab, S.F. Cheng, S.W. Gouk	Diesel fuel (B0) and Moringa oleifera biodiesel B10 and B20	1. B10 and B20 fuels have decreased brake power and brake specific fuel consumption is increased as compared to B0. 2. CO emissions from B10 and B20 fuels have reduced by 10.60% and 22.93% respectively, as compared to B0. 3. Moringa biodiesel blends have shown lower brake thermal efficiency than that of diesel fuel. 4. NO emission from B10 and B20 is 8.46% and 18.56% higher than diesel fuel over the entire speed range. 5. Compared to that of pure diesel fuel, over the entire range of speed, B10 and B20 reduced HC emission by 9.21% and 23.68%, respectively.
3	R. M. Rathod, S. V. Channapatana	Karanja Biodiesel tested on CI engine with and without EGR	1. B.S.F.C.value on 9% EGR was 0.5417 kg/kWhr. 2. The highest value of exhaust gas temperature reuced cosiderably with EGR. 3. Brake thermal efficiency value was higher at lower EGR rate and lower at higher EGR rate.
4	A.M. Liaquat, H.H. Masjuki, M.A. Kalam, I.M.Rizwanul Fattah, M.A. Hazrat, M. Varman, M. Mofijur, M. Shahabuddin	Diesel Fuel (DF) and Coconut oil CB5 and CB15	1. For CB15 the average brake power reduced by 2.61% and 0.66% for CB5. 2. Compared to diesel fuel, the average increase in bsfc is found as 0.53% for CB5 and 2.11% for CB15 respectively. 3. The temperature of exhaust gas is increased compared to diesel fuel 4. CO emission is reduced compared to diesel fuel. 5. CO_2 emission for biodiesel blends is increased compared to diesel fuel. 6. Reduction in HC emissions were reduced by 16.58% CB5 and 27.19% for CB15, ompared to diesel fuel. 7. The NOx incresed as amount of biodiesel in blend incresed compared to diesel fuel.
5	M.M. Rashed, M.A. Kalam, H.H. Masjuki, M. Mofijur, M.G. Rasul, N.W.M. Zulkifli	Moringa biodiesel, Palm biodiesel, Jatropha biodiesel, and diesel fuel. MB20, PB20, and JB20,	1. Diesel fuel showed highest brake power, followed by PB20, MB20, and JB20. 2. MB20 fuel showed the highest BSFC, followed by JB20, PB20, and B0. 3. The biodiesel fuel has average brake power slightly lower than diesel fuel. 4. Due to lower calorific value BSFC for biodiesel is higher than pyre diesel. 5. The CO emission (22.93–32.65%) and HC (11.84–30.26%) emissions are reduced to a large extent by All the biodiesel blended fuels but there is a increase in NO emission slightly (6.91–18.56%) than diesel fuel. 8. Palm biodiesel blend showed superior performance than moringa and jatropha biodiesel blend.,among the biodiesel fuel blends,
6	K. Srithar, K.Arun Balasubramanian, V. Pavendan, B. Ashok Kumar	Pongamia pinnata ethyl ester (P), Mustard ethyl ester (M) and diesel (D) Blend A- (D90+P5+M5%) Blend B- (D80+P10+M10%) Blend C- (D60+P20+M20%) Blend D- (D40+P30+M30%) Blend E-(D20+P40+M40%) Blend F-(D0+P50+M50%)	1. Brake specific energy consumption (BSEC) is the highest for all dual biodiesel blends compared with mineral diesel. 3. Blend A gives the maximum mechanical efficiency i.e., higher than diesel for the maximum brake power. , Mechanical efficiency for the other blends is lower than diesel. 4. All the blends are having less exhaust temperature than the diesel values for any brake power. 5. For the maximum load, blend A has a closer smoke value with diesel followed by blend B. 6. Blend A and Blend B give lower CO and CO_2 than diesel at maximum load. 7. From the results, NOx emission is higher for dual biodiesel blends than diesel and increses with increased amount of biodiesel in the blend. 8. Blend A gives lesser HC than other blends. The emission of HC is lower at the lower engine loads for the dual biodiesels and blends.
7	Aman Mamualiya and Harvinder Lal	Pongamia pinnata (Karanja) oil and petrodiesel B10 B20 B30	1. B20 blend was found to be the best and effective blend which improves the BTE. 2. Blend B20 also reduced all exhaust emissions like CO, CO_2, HC and smoke, but there was increase in smoke density and NOx as compared to neat petro-diesel. 3. In case of biodiesel at low load due to poor atomization, the more BSFC is required as compared to neat diesel. BSFC at full load the is almost same in all fuels. 4. As the load on the engine increases the EGT is also increases. It is found that at higher load karanja B30 EGT was comparable to neat diesel. 5. At higher load in case of karanja B30 showed lowest carbon dioxide emission. 6. At higher load in case of B30 the less concentration of CO as compared to all fuels. 7. It was found that HC is almost similar in case of B20 and neat diesel as compared to all fuels. 8. In all blends the smoke density was low as compared to neat diesel at all loads.
8	S. V. Channapattana, Kantharaj C., V. S. Shinde, Abhay A. Pawar, Prashant G Kamble	Honne oil Methyl Ester B20, B40, B60, B80 and 100% biodiesel and petrodiesel.	1. The BTE of the engine at 18 CR operated with Honne biodiesel is 8.9% lower than that of Diesel. 2. With the increase in percentage of biodiesel in the blend the BSFC increases. 3. The BMEP characteristic of Diesel and B20 blends are approximately the same. 4. EGT at higher CRs for blends are closer to Diesel. 5. CO emissions are lesser for blends compared to Diesel. 6. HC decreases with the increase in blend proportion. 7. As CR increases NOx emissions increases for blends while it decreases for Diesel. 8. CO_2 emission is higher for biodiesel compared to Diesel at all CRs.
9	R.Kumar, A.K.Dixit, R.K.Sharma	Diesel fuel and Jatropha ethyl ester B10 B20 B30 B40	1.SFC for all blends of biodiesel was higher than that of diesel 2. Break thermal efficiency was higher than that of diesel fuel at 25 to 75% of rated load for B10, B20, B30 and B40 fuel. 3. Mechanical efficiency for all the blends was higher than diesel fuel. 4. The exhaust gas temperature increased with increase in load and also increased with increase in proportion of ester in blends. 5. The concentration of oxides of nitrogen were higher for Jatropha ester blends during whole range of experiment than that of diesel. 6. Emission of CO was reduced as compared to diesel.
10	De-Xing Peng	Petrodiesel soybean oil, palm oil, and waste edible oil	1. On average, soybean oil, palm oil, and WEO reduced CO emission compared to diesel. Highest reductio was observed for soyabean oil, followed by palm oil and WEO. 2. WEO oil produced higher amounts of CO_2 than palm oil and soybean oil fuels. 4. Compared with pure petrodiesel, soybean oil and WEO increases NOx emissions while palm oil reduces them. 5. WEO oil showed the lowest smoke emission level compared with palm oil and soybean oil. The WEO oil and soybean oil fuels showed less smoke opacity than pure petrodiesel fuel. 6. The lowest level of exhaust gas temperature was found in pure petrodiesel followed by WEO, palm oil, and soybean oil. 7. The lowest level of fuel consumption was found in petrodiesel, followed by soybean oil, WEO, and palm oil.

Sr. No.	Author	Test Fuel	Concluding Remarks
			8. The biodiesel can be applied in the diesel fuel to upgrade the engine performance. The exhaust emissions of biodiesel are also lower than those of purepetrodiesel
11	Vandana Kaushik, Dr. O. P. Jakhar, Dr. Y. B. Mathur	Thumba methyl ester Blends (TME10, TME20, TME30) and diesel fuel	1. Higher brake thermal efficiency was observed for diesel fuel for entire load range compared to all thumba methyl ester diesel blends. The maximum BTE among all biodiesel blends was observed for TME20 blend. 2. Brake Specific Fuel Consumption for various blends of TME in diesel found marginally higher than diesel at all load conditions. At maximum load the BSFC of engine fuelled with 20% TME diesel blend was found minimum among all the tested blends of TME in diesel. 3. Exhaust Gas Temperature was observed higher for all TME blends compared to diesel fuel at high loads. The lowest exhaust temperature among all the TME blends was observed for the blend of 20% 4. When engine is fueled with blends of TME the volumetric efficiency obtained is highest for TME20. 5. The diesel fuel has the highest Mechanical Efficiency than TME fuel. The highest efficiency at full load is achieved for TME20. 6. The Engine Performance is better or optimized with TME20 and the compression ratio is at CR19.
12	Ratnam Ramesh Gujar, Rajesh Kale, Supriya Baburao Chavan	B00% i.e. diesel fuel and Thumba diesel blends TB10%, TB20%, TB30%, TB40%, TB50% TB100%	1. The BTE for all the thumba blends was higher than that of diesel fuel and increased with increasing amount of thumba in the diesel blend. 2. HC decreases with the influence of Thumba biodiesel percentage in bio-diesel blends. It is also confirmed that thumba biodiesel reduced HC emissions to much extent when compared to base line diesel at full load condition. 3. The variation in CO and CO_2 emissions for all biodiesel blends and diesel is fairly small. It is also identified that CO and CO_2 emission of Thumba biodiesel is lower than conventional diesel at rated load. 4.Nitrogen Oxides (NOx) emission is higher than that of diesel fuel. 5. TB20% blend shows lower emissions as well as performance as assimilated with running diesel fuel at all load.
13	B. Muali Krishna and J. M. Mallikarjuna	Diesel (D100) and Cottonseed oil CSO10D90 CSO30D70 CSO50D50 CSO70D30 CSO100	1. It was found that the average BSFC with CSO10D90 blend is about 3.7% less in comparison with neat diesel operation. 2. The BTE of CSO10D90 blend was very close and slightly higher about 1.7% as compared to that of conventional neat diesel operation. Thermal efficiency was found to be lower for higher blend concentrations compared to that of conventional diesel. 3. Mechanical efficiency was more for CSO10D90 blend in comparison with neat diesel fuel operation. 4. The air-fuel ratios for blended and neat CSO are slightly lower than that of neat diesel operation due to increased fuel consumption with increase of CSO concentration in the blends.
14	Hüseyin Serdar Yücesu & Cumali İlkiliç	Diesel and Cottonseed Oil Methyl Ester (COME)	1. The engine torque and power of cottonseed oil methyl ester was found to be lower than that of diesel fuel. 2. Specific fuel consumption of COME was higher than that of diesel fuel. CO_2, CO, and NO_X emissions of cottonseed methyl ester were lower than that of diesel fuel. 3. At the maximum engine speed, the combustion efficiencies are 93.3% and 89.9 for diesel and COME, respectively.

5. CONCLUSIONS

The performance and emission indicators such as brake torque, brake power, BTE, EGT, BSFC, NO_X, PM, CO, CO_2, HC and smoke density have been evaluated and compared with pure diesel by many researchers. The results of these studies showed that different sources of biodiesel feedstock give different results to engine performance and emissions. Surprisingly some of the research yielded favorable results towards the biodiesel as compared to pure diesel. A number of studies reported that biodiesel can improve the combustion in the engine. Most of the studies reported that the brake power for biodiesel blends is slightly lower than pure diesel. The cottonseed oil and Thumba oil showed favorable results for the engine performance at lower blends while higher blends reduced the emission. Most of the researchers used single biodiesel blended with that of diesel. Two or more biodiesels having different desirable properties can be blended with diesel fuel for better performance and emission results.

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BIOGRAPHIES

Dr. J. H. Bhangale,
H. O. D., Mechanical Department,
Matoshri College of Engg. & R. C.,
Eklahare,
Nasik.

Mr. A. B. Kulkarni,
Mechanical Department,
Matoshri College of Engg. & R. C.,
Eklahare,
Nasik.