

3. Properties of Biodiesel

Table 1: Properties of diesel and biodiesel

Sl no	Fuel	Relative density(kg/m ³)	Kinematic viscosity (cSt)	Calorific value (KJ/kg)	Flash point (°C)	Reference
01	Diesel	840	04	42390	65	[1]
02	Karanja oil	905	8.9 (at 40 ⁰ c)	36120.3	150	[1]
03	Pongamia oil	880	5.82 (at 40 ⁰ c)	--	160	[4]
04		874	19 (at 30 ⁰ c)	29442	156	[5]
05	Waste Cooking oil	886	4.36 (at 40 ⁰ c)	36340	210	[7]
06	Neem oil	920	38 (at 40 ⁰ c)	39000	245	[8]
07	Jatropha oil	879	4.84 (at 40 ⁰ c)	38500	191	[10]
08	Mahua oil	849	6.8 (at 40 ⁰ c)	47400	74	[11]
09	Surahonne oil	850	11.84 (at 40 ⁰ c)	39912	220	[12]
10		880	6 (at 40 ⁰ c)	34200	165	[13]

Table 1 indicates that the kinematic viscosity of biodiesel oil varies in the range of 4.36- 38 at 40⁰c. The high viscosity of these oils is because of their molecular mass in the range of 849-920 kg/m³. The flash point of above oils is very high (74-245⁰C). The heating values are in the range of 29442-47400 KJ/Kg compared to 45000 KJ/Kg for diesel fuel.

4. Review of Experimental Investigations

A large number of experimental studies have been carried out on diesel engines fuelled with biodiesel using, single cylinder, water cooled diesel engine, the engine speed 1500 rpm with compression ratio 17.5 [1, 5,7,10 and 13] engine speed 1800 rpm with compression ratio 16.5:1 [8] engine speed 1500 rpm with Compression Ratio 16.7 [12]. A typical engine system widely used in the agricultural sector has been selected for investigation. A single cylinder, four strokes, constant speed, water cooled, direct injection diesel engine [3]. Single cylinder, four strokes, direct injection, water cooled [4]. CR (Compression Ratio) 17.5, modified to VCR (Variable Compression Ratio) engine CR 12 to 18 [6] single cylinder, four stroke, air cooled engine [9], two cylinder, four stroke, direct injected, water cooled and 7.4KW power at 1500 rpm with injector pressure of 17640kPa diesel engine [11].

5. Effect of Biodiesel on Engine Performance

5.1 Brake Thermal Efficiency (BTE)

Thermal efficiency is the true indication of the efficiency with which the chemical energy input in the form of fuel is converted into useful work [15]. Most of the work has been carried out at many research institutes to examine the potential of biodiesel engines for achieving high thermal efficiency. Researchers such as Naik et.al [1] reported that B20 (blend 20%) and B30 shows BTE comparable to diesel fuel. There was a reduction in BTE with the increase in biodiesel proportion in the fuel blends. The possible reason for low efficiency may be due to low calorific value, higher viscosity and higher density of the bio diesel of Karanja oil.

Stalin et.al [2] was observed that as the load increases BTE increases up to 70% load and then decreases for all the fuel samples tested. The low BTE for B60 (Karanja biodiesel), B80 and B100 may be due to the lower HHV and the

increase in fuel consumption. Further it is noticed that the BTE for B40 is more or less equal to that of diesel.

Kamal et.al [3] reported that Karanja diesel blend [K40] injection timing of 19⁰ BTDC (Before top dead center) is found to be the optimum injection timing, as highest BTE, lowest BSFC and lowest smoke density are observed over the entire load range at this injection timing. Pugazhivadiv et.al [4] reported that, the BTE has a tendency to increase with increase in load for all the fuels. This is due to the reduction in heat loss and increase in power developed with increase in load. It is seen that the BTE of the engine with B100 (Pongamia diesel blend) B50 is lower than diesel at all loads. The lower heat content and higher density of biodiesel fuels resulted in lower thermal efficiency.

Gaurav Dwivedi et. al [5] reported that the BTE of Pongamia biodiesel is about 24% almost similar to that of diesel at full load condition. Balajee et.al [6] reported that the BTE of Jatropha B10 and B20 is greater than the diesel whereas the BTE of Jatropha B30 is similar to diesel. Similarly in Pongamia oil, the BTE is maximum for B10 blend and the BTE of blend B10 and B20 is similar to diesel. This may due to lower heating or calorific value of the Pongamia oil than diesel.

Lovekush Prasad et.al [8] reported that the BTE for B10 (Neem biodiesel) is reduced by 21.10% as compared to diesel at maximum load and BTE for B20 is reduced by 10.52% as compared to B10 at minimum load and 7.62% at maximum load. This reduction in BTE with biodiesel blends was due to higher viscosity, poor spray characteristics and lower calorific value. Nishant tyagi et.al [9] was observed that BTE of B10 (Neem biodiesel) is very close to BTE of diesel. BTE of B20 is better than B10 due to the more oxygen content. It is found that slight drop in efficiency of B30 because of improper combustion which may be attributed to higher viscosity than B10 and B20. Because of higher viscosity which may lead to poor mixture formation.

Anand Kulkarni et.al [12] observed that BTE with biodiesel mixtures was little lower than that of neat diesel fuel. The slight reduction of BTE with biodiesel mixture was attributed to poor spray characteristics, poor air fuel mixing, higher viscosity, higher volatility and lower calorific value. BTE of B10 (Calophyllum Innophyllum- Cotton Seed Oil blend) was found very close to diesel for all applied loads.

Ravi et.al [13] reported that BTE is increasing with increasing brake power for all multi-blends of biodiesel and diesel. It may be due to reduction in heat loss and increase in power with increase in load. The decrease in BTE for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption. BTE of 100% biodiesel is very close to diesel for entire range of operation. Maximum BTE of 100% blend is 32.89% against, 35.60% of diesel oil. The maximum BTE 10% and 20% blends (Surahonne blend) are 29.69% and 28.56% against 35.60% of diesel. BTE for B20 (Surahonne biodiesel) fuel is very close to that of diesel. At full load, the maximum BTE for diesel is 0.31 kg/kWh for B20 the value is 0.33 kg/kWh, B10 is 0.35 kg/kWh and B100 is 0.391 kg/kWh.

5.2 Brake Specific Fuel Consumption (BSFC)

Brake specific fuel consumption is the ratio between mass of fuel consumption and brake effective power, and for a given fuel, it is inversely proportional to thermal efficiency [15]. Researchers such as Naik et.al [1] have reported that the BSFC for B10 (Karanja biodiesel) is nearer to that of diesel fuel. The possible reason may be that at higher load, the cylinder wall temperature is increased which reduces ignition delay leading to the improvement in combustion and reduction in fuel consumption.

Stalin et.al [2] reported that, the SFC (Specific fuel consumption for (Karanja biodiesel) B5, B10, B15 and B20 are more or less equal to that of diesel. The SFC for B40, B60, B80 and B100 are continuously increasing and they are less than the SFC for diesel. This may be due to the lower calorific value of biodiesel than diesel.

Kamal kishore et.al [3] was observed that BSFC decreases with increase in power output and then starts increasing after a point for the given injection pressure under study. The point at which it becomes minimum, is referred to as the "best economical load" which occurs at around 80-85% load for Karanja -diesel blend. When we retard the injection timing at first the BSEC decreases and then it increases. Lowest BSFC is observed at an injection timing 19° BTDC. The value of lowest BSFC is 0.269 kg/kWh.

Gaurav Dwivedi et.al [5] have reported, the highest BSFC for B100 (759g/kWh) at full load is about 30% higher than diesel (582 g/kWh). The reason for this is lower calorific value of Pongamia than the diesel. The BSFC depends on fuel specific gravity, viscosity and calorific value. The specific gravity increases and calorific value decreases and more amount of fuel is needed to produce the same amount of energy. The Pongamia biodiesel proportion in blend is increased, BSFC also increase. As it is clear from the results BSFC of B10 (580g/kWh) is same as that of diesel. (601g/kWh) for B20, (642g/kWh) for B30, (661 g/kWh) for B40, (669g/kWh) for B50 is respectively. The BSFC for B10 is same as that of diesel. The reason may be due to high viscosity higher volumetric fuel delivery of fuel per stroke of the engine. Another reason may be due to presence of inherent oxygen is dominating over lower calorific value for better combustion.

Balajee et.al [6] reported that the BSFC decreases with increase in load and compression ratio. Jatropha B10 and Pongamia B10 have the brake specific fuel consumption almost equal to diesel. For rest of the biodiesel BSFC is very much higher than the standard diesel. This is due to high density and high viscosity properties of the biodiesel.

Lovekush Prasad et.al.[8] have reported that BSFC decreases with increase in load; BSFC for B10 (Neem biodiesel) is increased by 23.38% as compared to diesel at maximum load and BSFC for B20 increased by 12.12% at minimum load and 9.53% at maximum load as compared to B10. This is caused due to effect of delay in ignition pressure, higher viscosity and lower calorific value of the fuel.

Nishant Tyagi et.al [9] reported that, SFC at different loads with all percentage of blending was found slightly decreased because of extra oxygen present in the blend is taking part in combustion process. Due to which extra amount of fuel is burning inside cylinder which improves the efficiency which results decreased SFC. In B30 (Neem biodiesel) blend specific fuel consumption just start increasing because of viscosity comes into the picture at this moment. In B10 and B20, viscosity is not predominant. It is found that B20 is having lower specific fuel

Hanumantha Rao et.al [10] reported that specific fuel consumption is lower than the diesel for various proportions of Jatropha oil with diesel at constant operated conditions. This is due to complete combustion, as addition oxygen is available from fuel itself. Similarly for various blends of esterified Jatropha oil with diesel at constant operating condition specific fuel consumption is lower when compared to diesel.

Ghosal et.al [11] reported that, the increase in the fuel temperatures and injection pressure, engine SFC decreased in all the blends of fuel. But engine SFC showed an increasing trend from B20 (Mahua biodiesel) to B100 at a particular temperature and pressure. The minimum engine SFC at 70°C and 24010 kPa was found to be 0.23 kg/kWh in pure diesel and followed by 0.25 kg/kWh for B20, 0.26 kg/kWh for B40 and maximum 0.27 kg/kWh for B100. The engine SFC increase may be due to the lower heat content of the Mahua methyl ester oil than diesel fuel. Increasing in injection pressure decreases the engine SFC and it might be due to the improved burning quality of finer injection sprays. By increasing the fuel temperatures, viscosity decreases and enhances flow ability and finer atomization of blends, which results in decreased engine SFC.

Anand Kulkarni et.al [12] observed that BSFC decreases with the increase in engine load and in case of biodiesel mixture, the BSFC values were found higher than those of diesel fuel. This is due to the fact that biodiesel mixtures have a lower heating value than the neat diesel fuel, and thus more quantity of biodiesel mixture was required to generate constant power output. BSFC for B10 (Calophyllum Innophyllum - Cotton seed bio diesel) found little higher than the diesel but very close to diesel.

Ravi et.al [13] observed that the power developed increases the SFC decreases for all the tested fuels. The SFC of blends (Surahonne biodiesel) is more than that of diesel, this is due to lower calorific value of the fuel, and engine consumes more amount of the fuel in order to produce the same output power.

5.4 Effect of Biodiesel on Emissions

Biodiesel mainly emits unburned Hydrocarbons (HC), Carbon monoxide (CO), nitrogen oxides (NO_x), Sulphur oxides. A brief review has made of these pollutants emitted from biodiesel-fuelled engines [15].

Naik et.al [1] reported that the exhaust gas temperature is found to increase with concentration of Karanja methyl ester blend due to coarse fuel spray formation and delayed combustion. NO_x was found to increase with increase in blend proportion. Nitrogen content of the fuel affects the NO_x emissions by formation of fuel NO_x. CO and HC emission decreases with increase in blend proportion.

Kamal Kishore et.al [3] reported that smoke density for Karanj-diesel blend was greater than that of diesel. This is possibly a result of poor spray atomization and non uniform mixture formation with Karanj oil. Smoke density increases with the increase in load in all the cases of fuels. The smoke density for the K40 at the optimum timing is lower than the smoke density for K40 at standard timing but it is greater than the diesel.

Pugazhvadivu [4] compared to B100 (Pongamia biodiesel) and B50, the NO_x emission decreased at low and medium power outputs significantly. At rated power output the NO_x emission decreased marginally. At rated power output, the NO_x emission decreased marginally. The smoke emission was lower for B100 (Pongamia biodiesel) and B50 fuels. The addition of ethanol to B100 and B50 resulted in significant decrease in smoke emission compared to diesel.

Gaurav Dwivedi et.al [5] reported that, the CO and HC emissions are drastically reduced by increasing the percentage of biodiesel (CO emission for B10- 0.37% and for B100% -0.10% ,for diesel it is 0.40% and HC emission (ppm) for B10-10.1 and for B100% -5.6 for diesel it is 11.2. NO_x emission (ppm) for B10 it is 3.81, for 100 it is 4 and for diesel it is 3) NO_x emission for the case of Pongamia biodiesel were lower at 100% load. These lower NO_x emissions could be due to lower temperatures in the combustion chamber using Pongamia blends.

Suwendu Mohanty et.al [7] was observed that (Waste cooking oil) CO emissions are increased with increase in engine load. Further it can be seen that volume of CO initially decrease but increase at full load indicating better burning conditions at higher temperature assisted by improved spraying qualities with uniform charge preparations of biodiesel. The emissions of unburnt hydrocarbon for biodiesel exhaust due to lower than that of diesel fuel the increased gas temperature and higher cetane number of biodiesel could be responsible for this decrease. Higher temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon reducing

unburnt HC and it can be seen that the fueling biodiesel or its blends NO_x emission increase.

Nishant Tyagi et.al [9] reported that,for B10 (Neem biodiesel) and B20 percentage of hydrocarbons decreases because of better combustion which may be attributed to extra oxygen present in the blend, but for B30 the percentage of hydrocarbons increases slightly due to insufficient combustion because of higher viscosity which may lead to poor mixture formation due to poor atomization. When percentage of blend of biodiesel increases, carbon monoxide decreases because of extra oxygen present in the blend which may lead to better combustion. But we found slight increases in carbon monoxide in B30 because of insufficient combustion. This may be attributed to higher viscosity which may lead to poor mixture formation. When percentage of blend of biodiesel increases, NO_x increases, because oxygen present in the blend perhaps also helped in complete combustion of fuel. But it is found that slight decreases in NO_x in B30 because of incomplete combustion. This may be attributed to higher viscosity which may lead to poor mixture formation.

Hanumantha et.al [10] reported that, the exhaust gas temperature is decreased with the methyl ester of Jatropha oil as compared to diesel, CO₂ emission is low with jatropha bio diesel, CO emission is low at higher loads and NO_x emission is slightly increased with methyl ester of Jatropha oil compared to diesel.

Anand Kulkarni et.al [12] reported that, the NO_x emission increases with an increase in load for biodiesel B100, B10 and diesel as expected. NO_x emission for B100 (Calophyllum Innophyllum-Cotton seed oil methyl ester) and its blend B10 are higher compared to that of diesel. Higher NO_x emission for pure biodiesel and its diesel blends may be associated with higher combustion temperatures. The CO₂ emission for all the blends and diesel goes on increases as load increases. B100 shows the lower CO₂ emission compared to neat diesel at all loads. CO₂ emission of B10 has found less but close to diesel. A reason for the reduction of CO₂ emission with biodiesel is the oxygen content in the fuel, which enhances a complete combustion of fuel thus reducing CO₂ emission. It is observed that biodiesel and its blend gives relatively lower HC compared to diesel. This is because of better combustion of the biodiesel inside the combustion chamber due to the availability of excess content of oxygen in the biodiesel blends as compared to clean diesel. Physical properties of fuels such as density and viscosity influence the hydrocarbon emission.

Ravi et.al [13] observed that the CO emission initially decreases at lower loads sharply increases for all tested fuels (Surahonne biodiesel). This is due to incomplete combustion at very high loads which results in higher CO emission. CO emission is found higher for B20 if we compare with diesel. Lowest for pure biodiesel B100 at all loads. The emission of HC is decreasing with increase of loads. HC of pure biodiesel (B100) has lower emission compared with all other blends followed by 20% blend. The minimum value of HC at pure biodiesel is 16 ppm against 18 ppm of diesel. For B10 HC value is 20 ppm it is higher than

the diesel fuel that is 18 ppm from the above observation it is clear that the engine operates at lower performance and higher smoke, CO and unburnt HC emission compared with diesel. This could be due to low volatility, which affects the spray formation in combustion chamber and thus leads to slow formation. NO_x emission increases with engine load for all test fuels. It is found highest for pure biodiesel and lowest for diesel at all loads. Higher NO_x emission in case of biodiesel is due to the fact that it contains higher oxygen which results in higher combustion temperature.

6. Properties Amoora Oil

Aphanamixis polystachya (Wall) R Parker (Amoora rohataka) commonly known as Amoora, a member of the family Meliaceae, is native to tropical Asia. It is distributed in Indian subcontinent, Bhutan, Sri Lanka, Indo China, Myanmar, Thailand, Malaysia, Indonesia, New Guinea and Philippines. In South India, it is commonly found in the lower Ghats and occasional in upper Western Ghats. This evergreen tree attains a height of 20-25 m. The tree starts yielding seeds at an age of 6 to 8 years with an average yield of 20 to 25 kg seeds/tree. Average seed weight is approximately 0.7-0.9 g. The rich seed oil content has made the tree a potential source for biodiesel. The biochemical properties of the oil extracted from Amoora have listed in table 2 [14].

Table 2: Biochemical properties of the oil from Amoora

Properties	Values
Oil percentage	40-44%
Acid Value	9.24 mgKOH/g
Iodine value	107gI ₂ /100g
Colour	Yellowish brown
Viscosity	44.9mm ² /s
Density	919 kg/m ³
Calorific Value	35.8MJ/kg

The biodiesel (Amoora) properties were measured as per American society for testing and materials (ASTM) methods. The properties of Amoora biodiesel were on par with biodiesel from Pongamia, Mahua, Jatropha and Petroleum diesel (table 3). The amoora biodiesel was found to be within the American (ASTM) and Bureau of Indian Standards (BIS) (ISO15607) specification [14].

Table 3: Comparison of properties of biodiesel from amoora with pongamia, jatropha and mahua[14]

Properties	Values					
	Amoora	Pongamia	Mahua	Jatropha	BIS (ISO15607)	Diesel
Density (kg/m ³)	866	876	880	880.3	860-900	840
Viscosity (mm ² /s) at 40°C	4.67	9.6	3.98	4.328	2.5-6.0	3.12
Flash point (°C)	150	187	208	130	120 Min	79
Calorific value (MJ/kg)	38.3	36.12	37	39.6	---	44.96

The data was collected on some of the nontraditional tree borne oils such as Surahonne and Amoora. Surahonne was

documented in its natural habitat ie, coastal belt of Karnataka and Amoora was documented along the roads in and around GKVK (Gandhi Krishi Vigyan Kendra) Bangalore campus. The oil percentage in Surahonne range from 55-60% and that of Amoora is between 40-45%. The yield varies between 10-30kg per tree and in case of Surahonne it is little higher [16].

7. Conclusions

The combustion and emission characteristics of single cylinder four stroke diesel engines fueled with Karanja, biodiesel and its blends with diesel were analyzed and compared to standard diesel fuel. The fuel properties like density, flash point, viscosity and calorific value of B10 and B20 are very similar to diesel fuel thus biodiesel B20 and less can be used as an alternative fuel without modification of diesel engine and found improved performance and emission characteristics of diesel engine with diesel fuel [1].

The dual fuel combination of B40 (Karanja biodiesel) can be recommended for use in the diesel engines without making any engine modification. Also the cost of dual fuel (B40) can be considerably reduced than pure diesel [2].

Information available about the inedible oils in the literature, Mahua, Neem, Karanj and Jatropha are the front runners in India in terms of the production and availability. Mahua is most abundantly available oil but the calorific value of Mahua is very low (30349 KJ/kg). Jatropha has also emerged as a major oil source but it is carcinogenic in nature. Neem oil can be a very good substitute but it should be spared for its well established use and practices in herbal and medical field. So by analyzing and comparing the properties of these oils, Karanj is chosen as straight vegetable oil for the research [3].

The fuel properties like density, flash point, viscosity and calorific value of B10 (Pongamia biodiesel) B20 are very similar to diesel and therefore diesel may be well replaced by biodiesel in near future [5]. The Pongamia and Jatropha are safe to use as an alternative fuel in VCR engine in which Jatropha B10 and Pongamia B10 shows the optimum performance and emission characteristics [6].

The result of all blends show that blends up to 20% straight Neem oil have value of viscosity and density equivalent to specified range for CI engine fuel, therefore it can be concluded that up to 20% blend can be used to run the CI engine at short term basis [8]. Methyl esters of neem can give better performance when blended with diesel and blend B20 shows better performance characteristics as compared with diesel and better emission characteristic as compared to other blend [9].

The performance of the engine with B20 (Mahua biodiesel) blend fuel was found to be at par with the diesel fuel for short term engine test. The Mahua methyl ester can be used as a substitute for diesel fuel in compression ignition engine with lower percentage of emission and engine wear compared to diesel [11].

It can be observed that in case of biodiesel mixture, the BSFC values were found higher than those of neat diesel fuel. BSFC for B10 (Calophyllum Innophyllum-cotton seed oil) found little higher than the diesel but very close to diesel. This is due to the fact that biodiesel mixtures have a lower heating value than the neat diesel fuel, and thus more quantity of biodiesel mixture was required to generate constant power output [12].

Performance, combustion and emission characteristics of 20% blend (Surahonne) are better than other blends, followed by B100 and efficiency of B100 is well compare with the diesel. The maximum BTE of B100, B10 and B20 are respectively 32.89%, 29.69% and 28.56% against 35.66%. The maximum BTE of Surahonne biodiesel is 32.89% against 35.66% of diesel. The minimum BSFC of Surahonne biodiesel (B100) is 0.037 kg/kWh higher compared with diesel. After comparison of Surahonne biodiesel with Karanja and Mahua oil it is concluded that, the BTE of Surahonne biodiesel is lesser than that of Karanja oil and higher than the Mahua oil [13].

Amoora was investigated as non edible source of biodiesel. The study showed that Amoora oil has great potential to be used as one of the feed stocks for biodiesel production, mainly owing to its higher oil content and yield potential. The quality of the biodiesel was found to be comparable with the ASTM (American society for testing and materials) and Indian standards [14].

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