Feasibility of Biofuels as a Substitute to Conventional Fuels in IC Engines for Mass Transport and Distributed Power Generation

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Abstract

Depletion of petroleum based fuels has been a lot of concern among the governments and researchers around the world. Usage of biofuels in place of the conventional fuels is showing rapid growth because of the favourable characteristics like better performance and time improved emission characteristics. Present paper discusses about different available biofuels and their effectiveness in replacing fossil fuels and also how they affect the technological growth. Different works are compared to bring out the actual scenario with respect to the performance, emission, availability, production and preparation methods. It is observed that much effort is made by the stake holders in order to see biofuels as a viable alternative and as a future fuel for internal combustion engines. Performance improves slightly with the usage of biofuels and reduced emission characteristics may be logical to observe. But it may not be appreciable, considering the series of production processes involved. It still requires lot of time to commercialize and produce biofuels in

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mass. Also, there have been constraints like the availability of raw materials for the same. It is concluded that biofuels do play significant role in the days to come provided there is much more effort from researchers to simplify the technology in making biofuel as sustainable and cost effective with at least comparable performance.

Keywords: biofuels, diesel engine, alternative fuels, emissions.

1 Introduction

Because of the depletion of fossil fuels, biofuels are gaining importance day by day. These are made from biomass and can be conveniently converted to energy containing substances by thermal, chemical and biochemical conversions. This may result in solid, liquid or gaseous fuels. Biofuels have gained importance because of increasing oil prices and rising need for energy security. Figure 1 presents the decreasing aspect of crude oil production and rising gas prices as per the US Energy Administration Information (USEAI) statistics. In India too, the consumption of gasoline and diesel is increasing as shown in Figure 2. Because of which, it is observed that the prices of these two are increasing. Same is the case with all the countries across the world. Hence, in the first decade of the 21st century, worldwide biofuel production reached more than 100 billion liters with a yearly increment estimated about 15–20% [1]. Issues rise whenever any government aimed at these kind of fuels [2]. Also, there is an issue of how these bio resources can be used, whether as food or fuel.

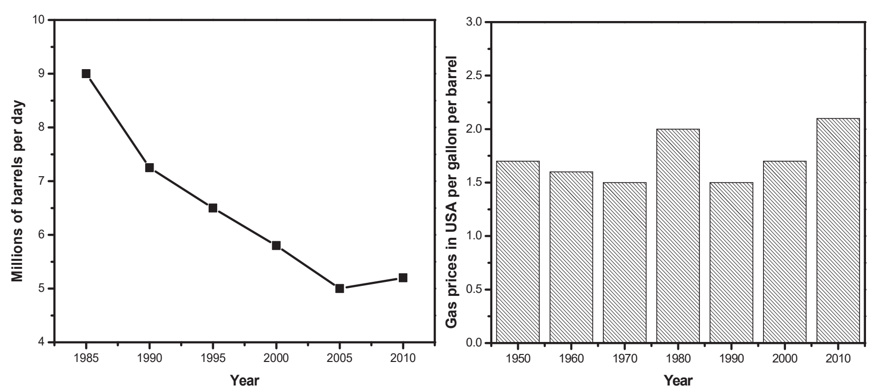

Figure 1 Crude oil production and gas price in USA.

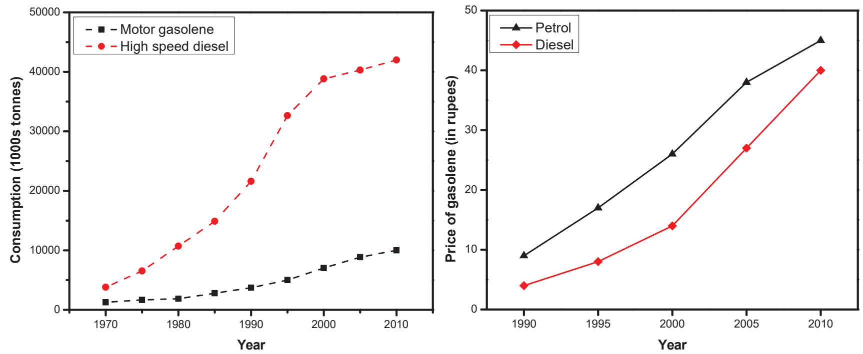

Figure 2 Consumption and prices of diesel and petrol in India for the last few decades.

1.1 Scope of Biofuels

Using biofuels in engines becomes a valuable method in order to get better performance as well as reduce unwanted emissions. In order to negotiate the environmental pollution issue, most of the researchers shifted their attention to alternative fuels. Biofuel is a renewable fuel, which is extracted from sources like vegetable oils and animal fat oils, unlike fossil fuels. Biodiesel extracted from vegetables and animal fat becomes a better alternative for conventional diesel fuel. In recent years, lot of studies are undertaken in the area of bio fuels, but they convey that the use of vegetable oils in well-ordered method is probable, but not desirable. Usage of petrol and diesel lead to increased environmental pollution. In order to reduce the effect of this, biofuel has been one of the promising and economically viable alternatives [3]. But, using biofuel in engines causes various problems due to high viscosities that are because of molecular mass and chemical structure [4]. The problems occurring due to high viscosity of biofuels are propelling, burning and atomization in the injector related to diesel engine. In spite of these effects, usage of biofuels leads to reduction in emission percentage of the internal combustion engine [5]. Biofuels play a predominant role in addressing emissions and will improve efficiencies and electrification [6]. Today, biofuels possess better ignition quality, high density, non-toxic and due to higher flash point, they are very safe [7, 8]. Some of the biofuels like jatropha and karanja plants can be grown in even in waste land so that these types of plants do not require much care [9]. Experimental studies show that biodiesel prepared from mango seed oil has similar characteristics to those of diesel [10]. It is clear from the literature that ethanol, methanol and hydrogen can be added to fossil fuels in proportion to obtain biofuel that has comparatively better performance and emission characteristics. This shows that there is definitely a lot of scope for the alternatives when compared to the conventional petroleum based fuels. In this context, present work aims at studying the production and usage of bio-fuels that may lead to present clear picture that decides whether it is a viable option or not. Also, this work attempts to find reality with respect to the technical abilities of biofuels and their potential to replace petroleum based fuels.

1.2 Scientific Issues

Few researchers reported that using of biofuel will lead to the extension of engine life as it has more lubricating ability than the petroleum based engine. Use of bioethanol in motorized engines is advantageous to the environment as it produces CO_2 that is absorbed by plants for photosynthesis. These plants deliver lignocelluloses, which is used for producing ethanol. Hence this biodiesel does not contribute to global warming as CO_2 emitted is once again absorbed by the plants grown for making vegetable oil. This is suggested by other researchers as well as here is no need to modify engine characteristics when biofuel is used. Biofuels were one time identified as economy rescuers and reply to the constantly rising energy demand. Although biofuels have many benefits over conventional fuels, their amalgamation with the fuel supply chain has to be done with great care to ensure that their probable shortcomings are either removed or diminished. Presently, other alternative fuel technologies have problems like portability and in transportation. Transportation losses are more with regard to electricity. Whereas, it is easy to transport biofuels, and they have decent energy densities with minor modifications to the existing engine. With such advantages added to the above mentioned in Section 1, biofuel finds suitability, but with limitations as discussed in the following sections. Disadvantages are regional suitability, food security, deforestation and biodiversity. Apart from this, global warming is the main concern. Recently, no works are reported because of the difficulties faced except few review works [11]. Limitations in case of bio fuel research scenario are discussed by few other researchers [12].

2 Processes Involved in the Preparation of Biofuels

There are lot of processes and methods involved in the preparation of biofuels. Few important processes are discussed and assessed in the present work.

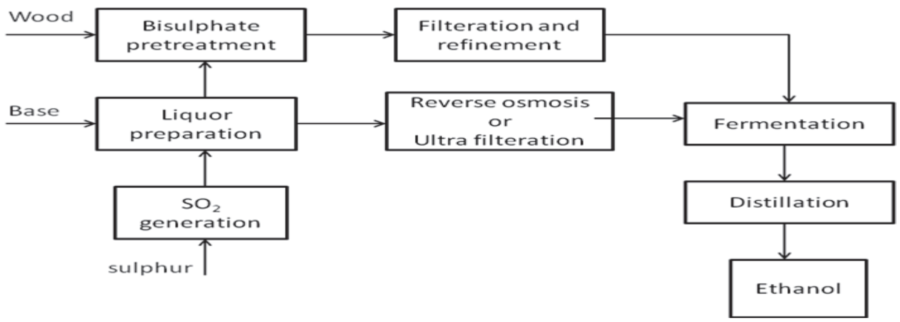

Figure 3 Preparation of ethanol.

2.1 Bioethanol

Bioethanol is an alcohol prepared through fermentation process. Mostly obtained from the carbohydrates formed in corn, sugarcane or sweet sorghum. Ethanol is also used as a fuel in its pure form. But, it is normally used as an additive to increase octane number for improvement in vehicular emissions. Preparation of sugar cane based ethanol is much more important in view of petroleum substitution or reduced carbon emissions. Most of the developed countries grow sugarcane and several of these produce ethanol like USA and Brazil. In general, emission characteristics reduce when ethanol is used as biofuel. But, there is scope of increased formaldehyde and acetaldehyde emissions. Application of ethanol in engines leads to reduced emission characteristics. Figure 3 shows the schematic layout for step wise process for preparation of ethanol that involves processes like pre-treatment, filteration, distillation and chemical recovery.

2.2 Biodiesel

Biodiesel is the mostly used biofuel. It is made by transesterification of oils or fats. It is similar to petroleum based diesel. It contains mainly fatty acid esters of methyl or ethyl base. Feedstocks for biodiesel comprise of vegetable oils, animal fats, mahua, karanja, jatropha, sunflower, palm oil, mustard and algae. Pure biodiesel is normally referred as B100 and can be used as a fuel for vehicles in its pure form. But, it is generally used as an additive to reduce levels of particulates and other emissions from diesel vehicles. Chemically complex esters of fatty acids are popularly known as vegetable oils. Oilseeds naturally contain fats known as tri-glycerides of fatty acids. These fatty acids contain higher molecular weights as they are highly viscous

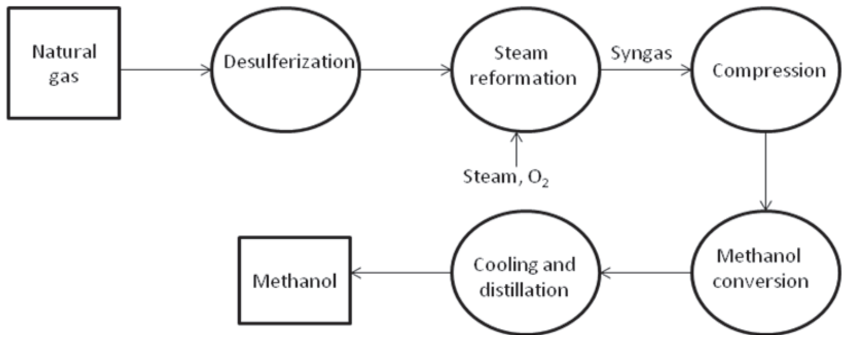

Figure 4 Schematic of biomethanol preparation.

in nature. This property causes major problems in their presence, when used in diesel engines. In order to reduce their viscous nature, these fatty acids or vegetable oils are modified. Properties of biodiesel are most like that of the conventional fuels and thus it may be a better alternative. The cost of biofuels is reduced if non-edible oils are considered above edible oils.

2.3 Methanol and Syngas

Methanol can be prepared from concentration carbon sources like natural gas, coal biomass and even carbon dioxide from fuel gases. Mostly the production of methanol is taken from coal in the locations where natural gas is not available and is expensive. But, in few countries, natural gas is available in cheap, because of the construction of new plants. Methanol is most frequently used due to its low cost and physical and chemical advantages. Moreover, it can react quickly with triglycerides and NaOH. Figure 4 shows the schematic layout of preparation of biomethanol that involves mainly desulphurization, steam reforming and methanol conversion. In the end, fuel is ready after the process of cooling and distillation. Syngas is a blend of CO, H_2 and other HCs, which is produced by partial combustion of biomass. Figure 4 shows the formation of syngas in the preparation of biomethanol. Syngas may be used directly in turbines, I.C engines or fuel cells of high operating temperature.

2.4 Jatropha

Another way is to use jatropha seeds in order to produce biofuel that is being adopted for the last few years. It can grow in varied environments and requires sufficient water and additional care. The life span for jatropha

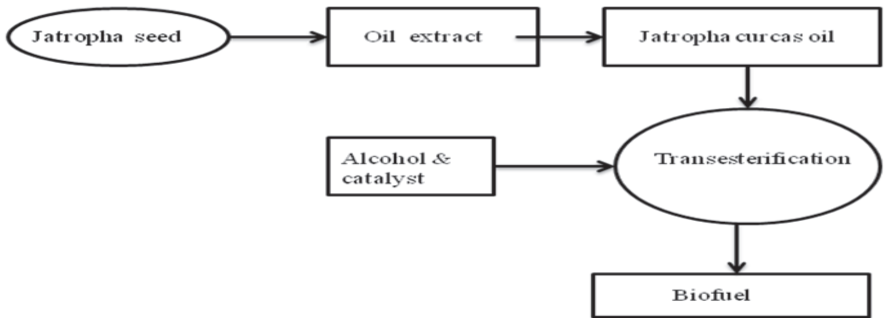

Figure 5 Schematic for the preparation of jatropha based biofuel.

is about 50 years and is prepared by the method of extraction. The main problem of jatropha when used as a biofuel is that it increases the emission characteristics due to poor performance in combustion. Figure 5 represents the schematic layout of preparation procedure for jatropha biofuel. Transesterification brings oil properties close to diesel. It involves the conversion of organ ester into another ester of the same acid by reacting with alcohol to produce alkyl ester. This is a batch process for production in low quantities and takes more time.

3 Engine Performance Characteristics

From several years, experimental studies have been carried in testing at different operating conditions in order to attain better performance characteristics. Most of them concluded that there could be only slightly improved or comparable efficiency, but, significant change was possible in emission characteristics than conventional petroleum based fuels. This section describes the effect of various biofuels with regard to their performance and emissions.

3.1 Effect of Biodiesel

Brake thermal efficiency relates the work output obtained with regard to heat input given by the fuel. It increases in proportion to load as presented in Figure 6. It is detected that there can be noteworthy change in efficiency when different types of biodiesel fuels are used. Nayak et al. [4] and Panner et al. [5] found slightly higher efficiency with diesel at all load conditions as shown in Figure 6(a) and 6(b). Whereas, Senthil et al. [6] found the beneficial nature of biodiesel blend over diesel as shown in Figure 6(c). This may

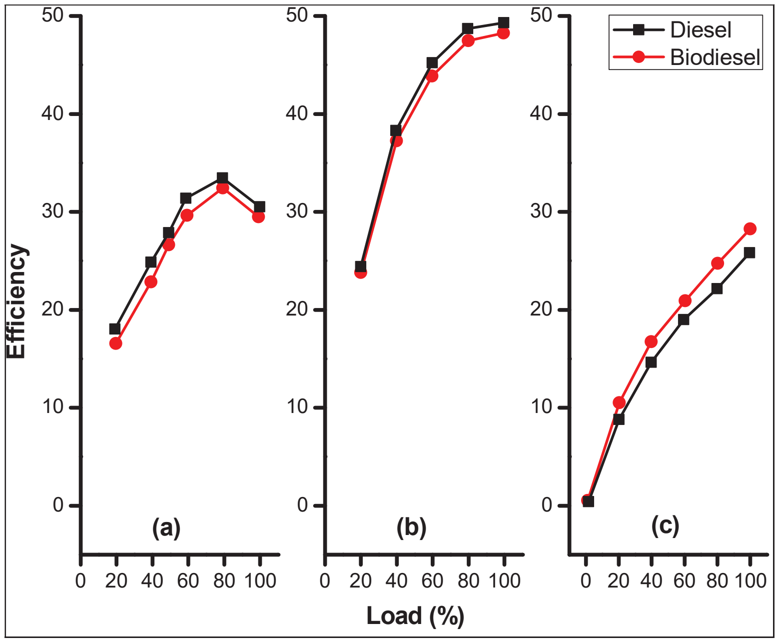

Figure 6 Brake thermal efficiency with load in case of biodiesel.

be due to better combustion and low friction with higher lubrication as a result of high viscosity and stability. It is also observed that the trends have been similar between diesel and biodiesel and comparable in most of loading conditions. Brake specific fuel consumption (bsfc) is the ratio of mass of fuel consumed and the brake power. But, bsfc is either more for biodiesel (or) similar to diesel as shown in Figures 7(a) and 7(b) for the same cases as seen in Figures 6(a) and 6(b). This is because of high viscosity, density and low volatility. It is interesting to see that Senthil et al. [6] could not report the fuel consumption details, where the biodiesel is showing higher performance. With increased fuel consumption and not so improved performance, biodiesel blends are not showing advantageous nature over diesel as described in earlier sections.

3.2 Effect of Jatropha Based Biofuels

Usage of jatropha oil (or) its blends as biofuel leads to increase in thermal efficiency than diesel fuel as shown in Figure 8. Elango et al. [7] reported that the increase in thermal efficiency is due to jatropha oil concentration

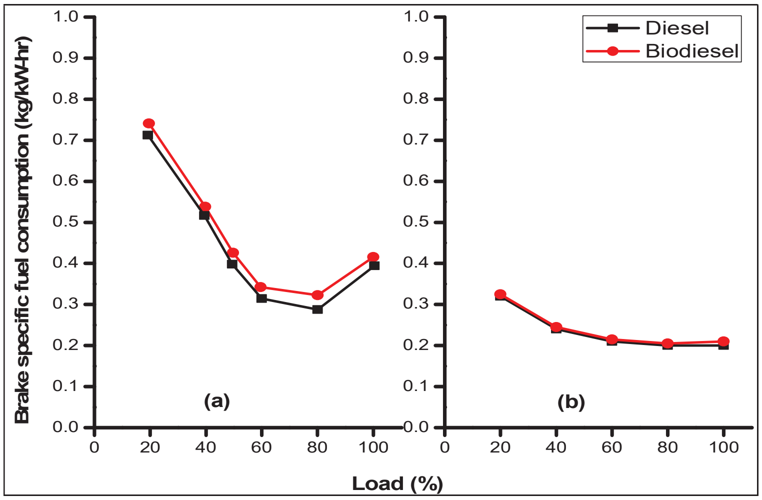

Figure 7 Variation of bsfc with load in case of biodiesel.

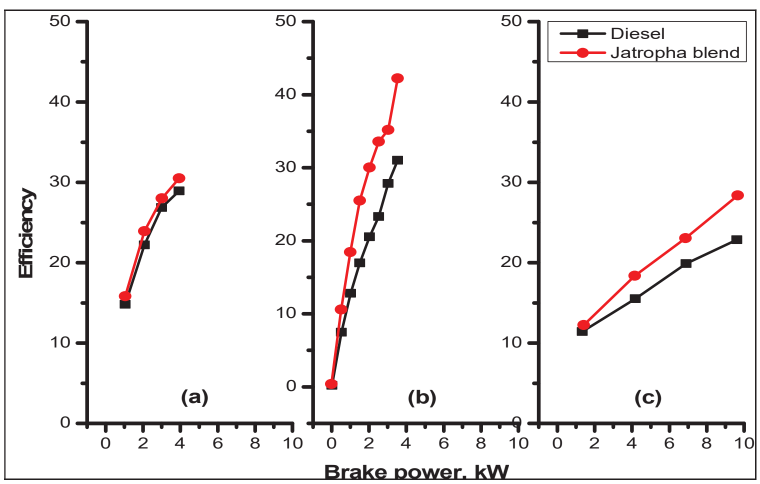

Figure 8 Variation of efficiency with jatropha oil blends.

and high viscosity as shown in Figure 8(a). Similar tendency is shown by Hanumantharao et al. [8] and Keyur et al. [9]. Using biofuel leads to higher fuel consumption, when the concentration of the blend is more than 30%, in comparison to diesel as shown in Figure 9(a). Similar aspect is reported by other researchers as well as observed in Figure 9(b). This is because

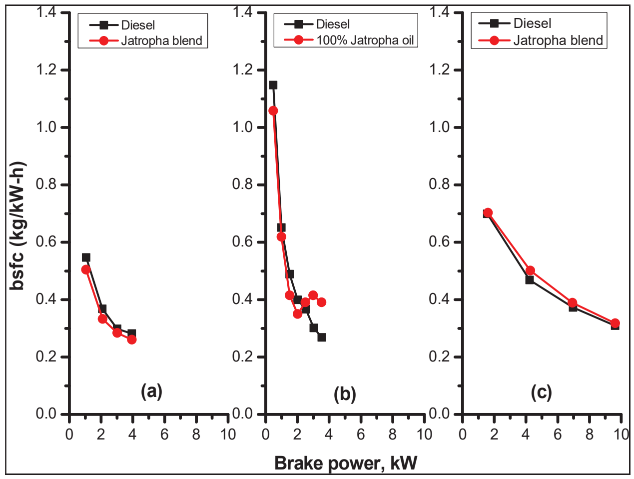

Figure 9 Variation of bsfc with jatropha oil blends.

of insufficient atomization of the fuel. Thus, it is clear that jatropha based fuel can be seen as an alternative, if not fully, to replace the conventional diesel with the limitations on fuel consumption and performance. Keyur et al. [9] also found slightly increased fuel consumption with jatropha as seen in Figure 9(c). Overall, it is certain that improved efficiency with less fuel consumption is found with jatropha oil blends when compared to diesel fuel.

3.3 Effect of Ethanol and Methanol

The effect of ethanol when used in biofuels does not make great change in the performance characteristics of the engine due to varied density and viscosity values. Decrement of thermal efficiency and increment in fuel consumption are observed as shown in Figure 10 with the use of ethanol blend. Performance is decreasing with reduction in the speed of the engine and fuel consumption is increasing with speed. Gvidonas et al. [10] identified that biofuels mostly emit unwanted HC, CO, NO_X, SO_X and particulate emissions. It is visible that methanol based blends are showing favourable aspect over ethanol ones, which are not suitable, considering lower efficiency and higher fuel consumption. Yasin et al. [13] found that methanol based blend gives improved performance than diesel as revealed in Figure 11(a). At the same time, fuel consumption is less or comparable to diesel. Thus, advantageous aspect is observed in such kind of biofuels.

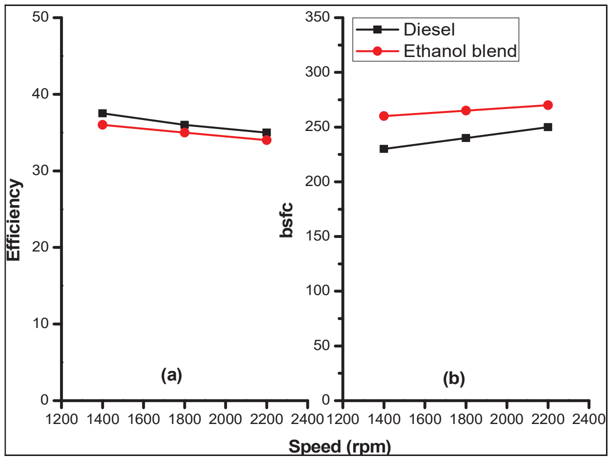

Figure 10 Efficiency and bsfc as a function speed with ethanol.

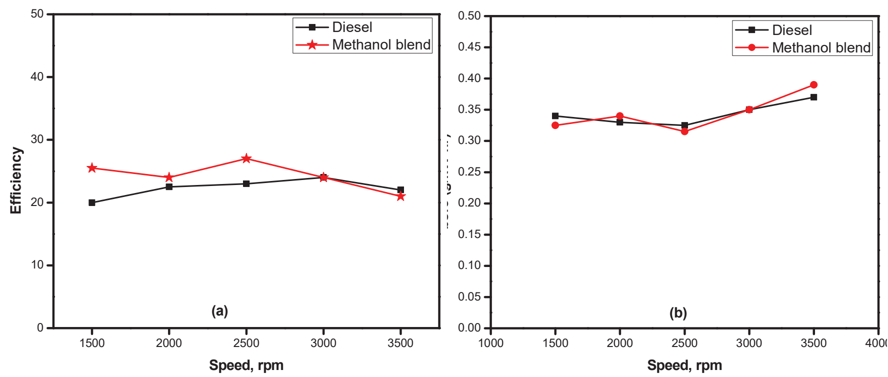

Figure 11 Efficiency and bsfc with Methanol blend.

3.4 Effect of Karanja

Effect of karanja based biofuel on the performance characteristics is shown in Figure 12. It is observed that there is no substantial variation between the conventional diesel and biofuel in case of Sanjay and Das [14]. In case of Avinashkumar and Rajamanoharan [15], the jatropha based fuel is showing improved performance. But, with karanja alone as fuel, Kiranteja et al. [16] found improved scenario. Fuel consumption in case of karanja based fuels is less (or) comparable in both the cases as shown in Figure 13. Sanjay and

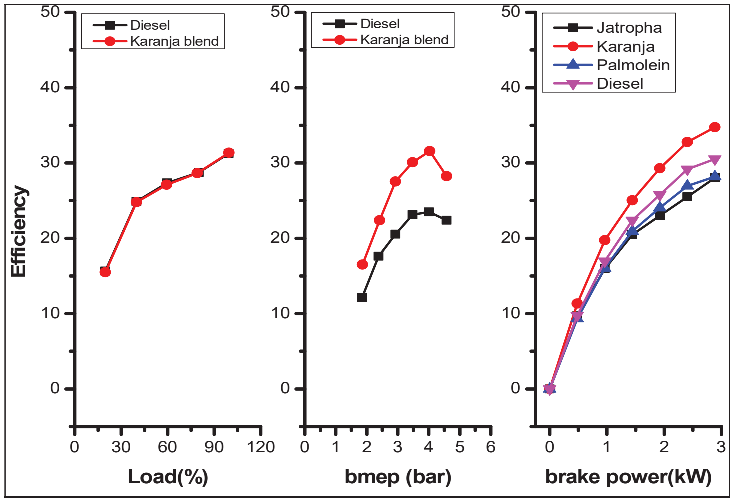

Figure 12 Efficiency with karanja and its blends.

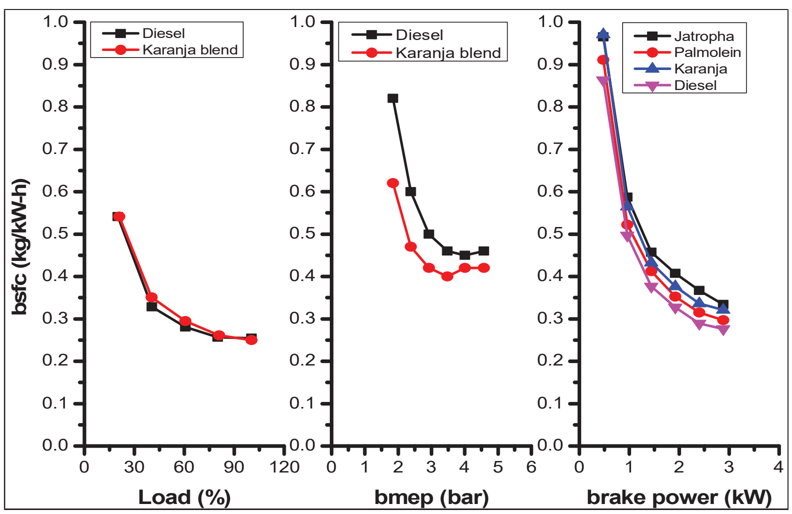

Figure 13 Fuel consumption with karanja based fuel.

Das [14] found efficiency levels similar with less fuel consumption. Whereas, Avinashkumar and Rajamanoharan [15] found higher efficiency with karanja blends with very less fuel consumption. It can be confirmed that karanja based fuels show advantageous nature over conventional diesel.

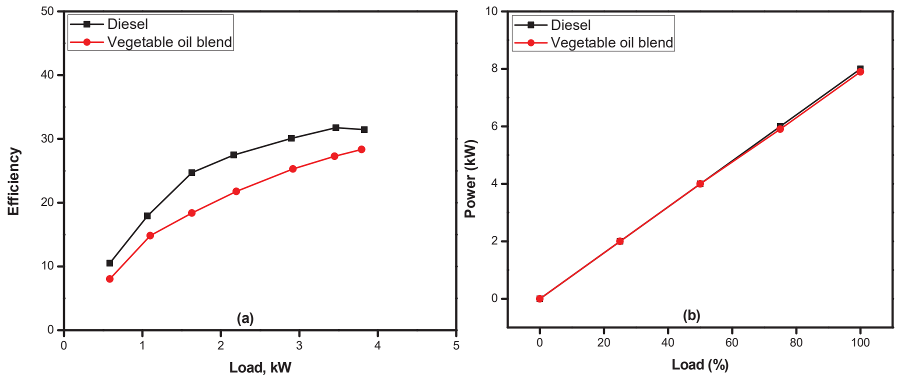

Figure 14 Efficiency and power output with vegetable oil.

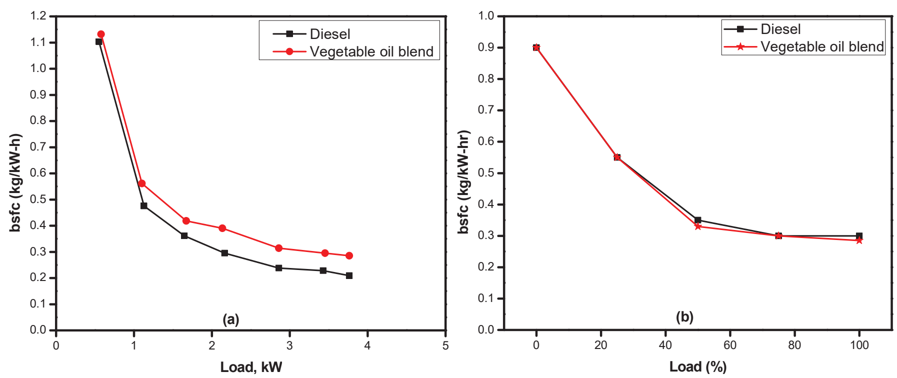

Figure 15 Fuel consumption with vegetable oil blends.

3.5 Effect of Vegetable Oil

Vegetable oils are also tested by various researchers. Nanthagopal and Subbarao [17] presented a work on waste vegetable oil blends that showed decreased performance as shown in Figure 14(a). But, Wang et al. [18] found that performance is better in unused vegetable oil and is as good as diesel as shown in Figure 14(b). Trends have been similar in both used and unused vegetable oil blends. Power output is increasing with increased load. Specific fuel consumption for used oil blend is more as shown in Figure 15(a). With vegetable oil, it is similar to diesel as shown in Figure 15(b). Considering the aspect of food security, vegetable oil is not advisable to use in engines even though it seems advantageous. But, used vegetable oil may replace a diesel, keeping in view, its further usage and applicability elsewhere.

4 Emission Characteristics

4.1 Effect of Biodiesel in HC Emissions

Different types of emissions are possible in I.C engines when biofuels are used. These emissions can be like NOx, CO or CO_2 depending on the fuel used. Researchers have reported that there is decrement of unburned hydrocarbons when conventional diesel is substituted with biofuel. This may be due to better combustion with the use of biodiesel fuelled engines. By substituting conventional diesel with biofuel, it is oxygenated and promotes complete combustion. As reported by Nayak et al. [4], there is reduction in unburned hydrocarbons when conventional diesel is replaced with biofuel as shown in Figure 16(a). Senthil et al. [6] found similar trend as shown in Figure 16(b), where emissions are proportionately increasing with load and are distinctly less than that of diesel fuel. Vinay et al. [19] established that there is slight increment in hydro carbon emissions when fuel is used in dual mode, which is due to incomplete combustion as shown in Figure 16(c). Increased HC emission up to 30% in dual mode is also reported by Avinashkumar and Sasikumar [20] recently. Running the engine in dual fuel mode is not always appreciable considering the emissions it gives. It is worth to note that hydrocarbon emissions are less with biodiesel fuel. Influence of hexanol as additive with Calophyllum Inophyllum biodiesel for CI engine applications was studied by Ramesh et al. [21].

4.2 Effect of Biodiesel in CO Emissions

CO emissions cause problems directly or indirectly to the mankind and are supposed to be as low as possible. Decrement in CO emissions was observed in earlier works, when biodiesel is used. CO is formed due to incomplete combustion, but biofuels are oxygenated fuels and hence there is complete

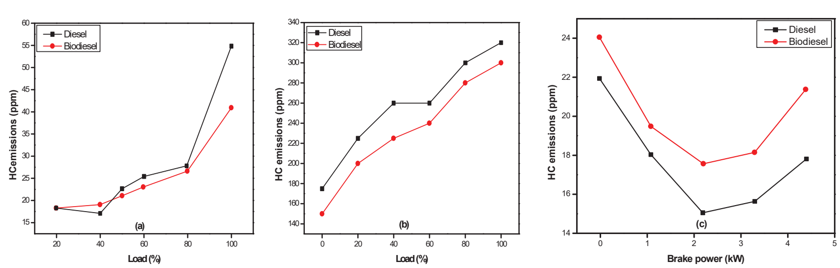

Figure 16 Variation of HC emissions with biodiesel fuel.

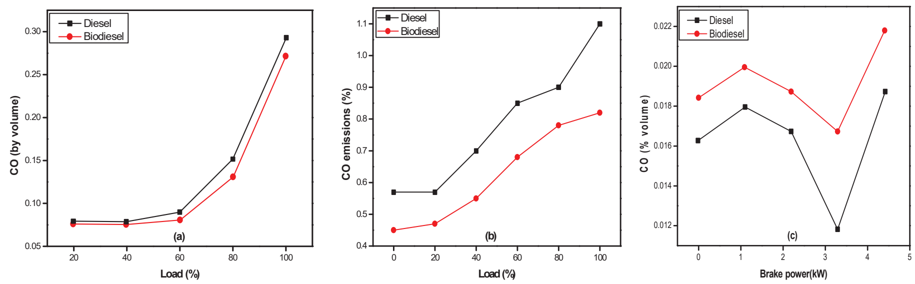

Figure 17 Variation of CO emissions with biodiesel fuel.

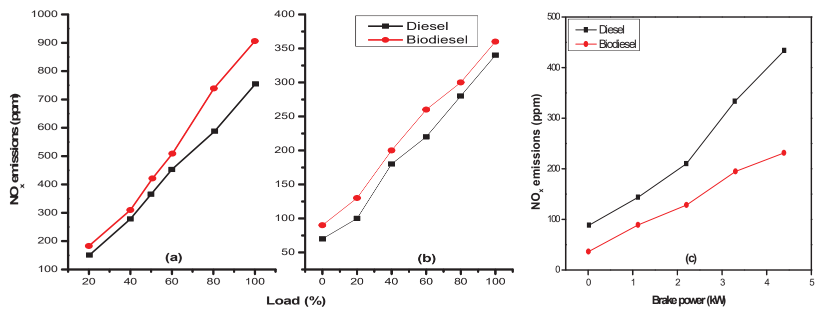

Figure 18 Variation of NO_x emissions in case of biodiesel.

combustion. Panner et al. [5] and Senthil et al. [6] reported that there is decrement of CO emissions in case of biofuels as shown in Figures 17(a) and 17(b). The formation of carbon monoxide is due to the fact that required amount of oxygen is not supplied and there is poor mixture formation. Carbon monoxide emissions are more in dual fuel mode as compared to conventional diesel as shown in Figure 17(c). With the brake power, emissions increase first and for an optimum value, they are minimum. As HC and CO emissions are more in dual fuel mode when compared to diesel, it is not a preferred process.

4.3 Effect of Diesel in NO_x Emissions

Chain reactions of Nitrogen and Oxygen lead to the formation of NOx and are highly temperature gradient. Previous studies proved that NOx emissions are more for biofuelled engines as compared to conventional diesel engines as observed in Figures 18(a) and 18(b). It is due to complete combustion in case of pure biofuel that leads to higher temperature and NOx emissions. By

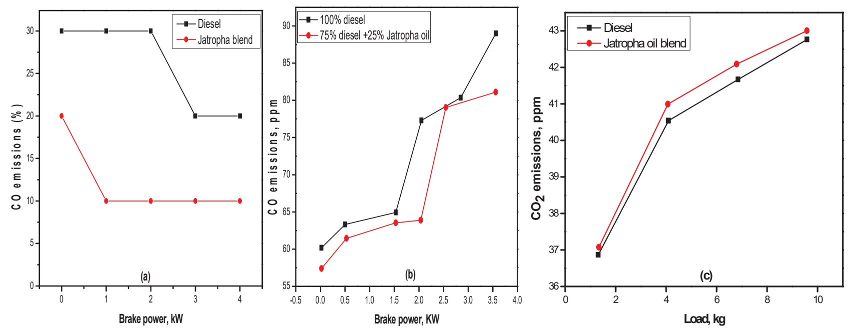

Figure 19 Variation of carbonic emissions with jatropha blends.

using additives, reduction in NOx is observed. But, it is found that there is decrement in formation of NOx when the fuel is used in dual mode as shown in Figure 18(c). Reduction of NOx emissions up to 60% is also reported by Britto et al. [22]. This is due to the fact that nitrogen does not react with oxygen at lower temperatures. On the other hand, conflicting observations are reported with respect to smoke and particulates when biodiesel replaces diesel. Yet, studies need to be done more meticulously, the aspect of these emissions and improved technology has to come handy in order to identify and confirm that such particulate emissions exist while using these alternatives.

4.4 Effect of Jatropha in CO Emissions

It is clearly observed that usage of jatropha oil would reduce CO emissions. Elango et al. [7] found that CO emissions are very less when jatropha is used as shown in Figure 19(a). Similarly, Hanumantharao et al. [8] observed that CO emissions are reducing with the blend of 75% diesel and 25% jatropha oil. But, Keyur et al. [9] found that jatropha blend has slightly higher emissions of CO_2 as shown in Figure 19(c) that may be due to reasons already discussed in the earlier sections.

4.5 Effect of Jatropha in NO_x and HC Emissions

Elango et al. [7] and Keyur et al. [9] found slightly increased emissions with the fuel blend as shown in Figures 20(a) and 20(c). But, favourable effect is observed by Hanumantharao et al. [8] as shown in Figure 20(b). Also, it is found that use of jatropha as biofuel leads to decreased HC emissions as

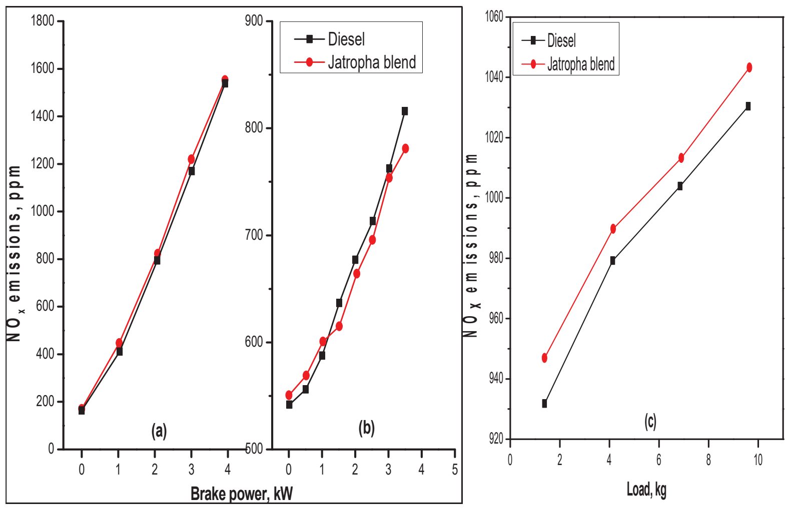

Figure 20 Variation of NO_x emissions with jatropha blends.

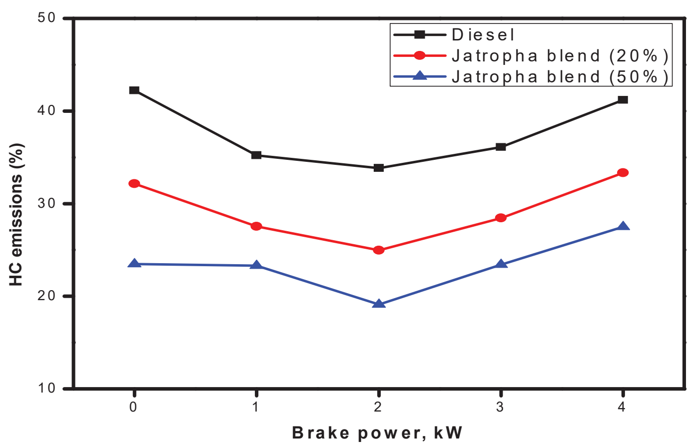

Figure 21 Variation of HC emissions with jatropha blends.

shown in Figure 21. Elango et al. [7] reported that HC emissions decrease with the blend of 20% itself and further increasing the jatropha content will have positive effect on emissions. A suitable and appropriate blend is possible, keeping view, the emission and performance characteristics. As observed in this section, since jatropha is showing beneficial aspects, nongovernmental organizations across the globe are trying to dedicate themselves to research

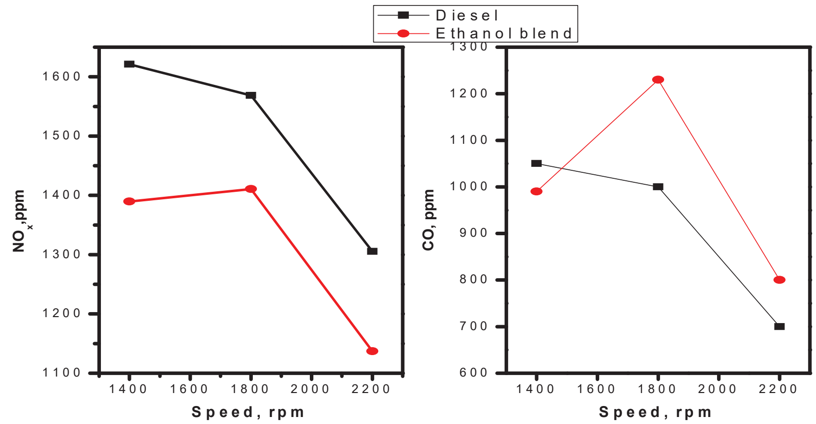

Figure 22 NO_X and CO emissions with ethanol blends.

on the planation of jatropha. Effective considerations in this area project increase in jatropha production by about 200–300% during the next decade. Also, Ashok et al. [23] could reduce the CO, HC and smoke emissions more effectively in diesel engine by the addition of nanoparticles.

4.6 Effect of Ethanol and Methanol

Usage of ethanol as biofuel reduces NOx emissions as shown in Figure 22, because of advanced fuel ignition timing and auto ignition delay. Gvidoneas et al. [10] reported decreased emission characteristics while using ethanol. Ethanol blend showed less NOx emissions as shown in Figure 22(a). Emissions decrease with increased speed. CO emissions are more for the ethanol blend as shown in Figure 22(b). In case of methanol also, Yasin et al. [13] obtained more NOx emissions, as shown in Figure 23(a). Qi et al. [24] found similar trends with speed in both methanol blend and diesel, as shown in Figure 23(b). But, emissions are comparable to diesel, which is not observed in other works. It is clear that ethanol and methanol blends give higher or comparable CO and NOx emissions.

4.7 Effect of Karanja

This section deals with the effect of karanja based blends on emissions. Similarities are observed with respect to jatropha based fuels. However, quantitative change in CO and NO_X emissions from karanja based biofuels are compared with conventional diesel as shown in Figures 24 and 25. Baiju

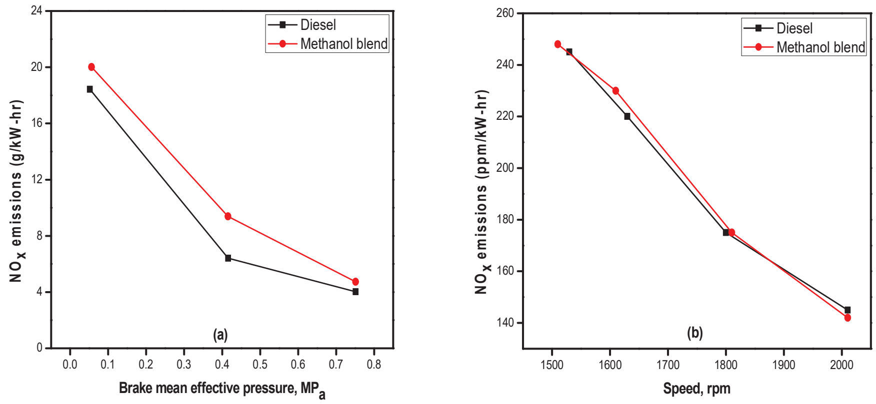

Figure 23 NOx emissions with methanol blends.

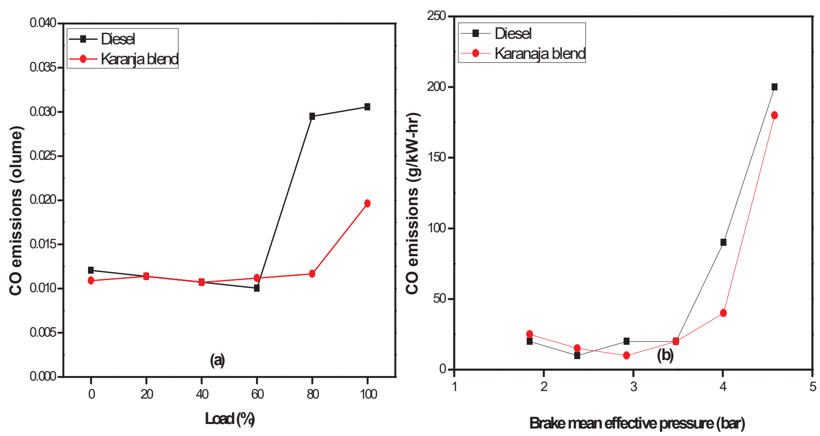

Figure 24 CO emissions from karanja based biofuels.

et al. [25] observed comparable CO emissions with diesel and karanja blends up to loads about 80%. Beyond this, emissions are less for the blend as shown in Figure 24(a). Avinashkumar and Rajamanoharan [15] found less emissions with karanja blend over the entire pressure region as shown in Figure 24(b). Similarly, it is found that NOx emissions are clearly less when compared to diesel as shown in Figure 25. With load, variation of emissions is not proportional, but fewer quantities are observed with karanja blend. In view of the three aspects of performance, heat losses and emissions, Kiranteja et al. [16] confirmed that better alternative like karanja can be effectively applied in diesel engines.

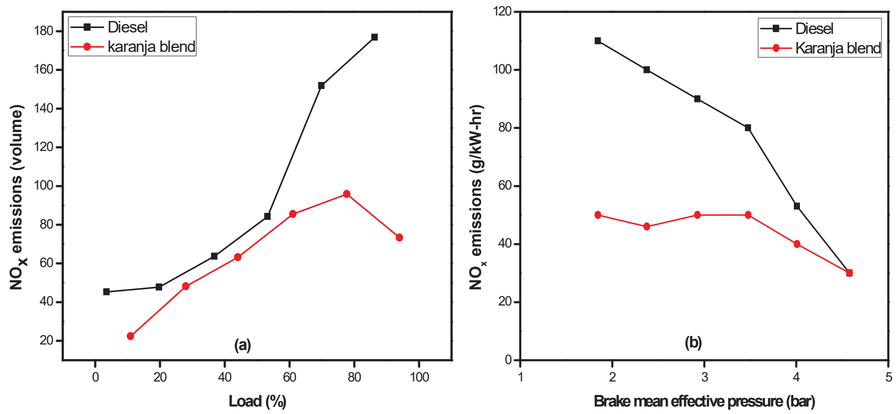

Figure 25 NO_x emissions from karanja based biofuels.

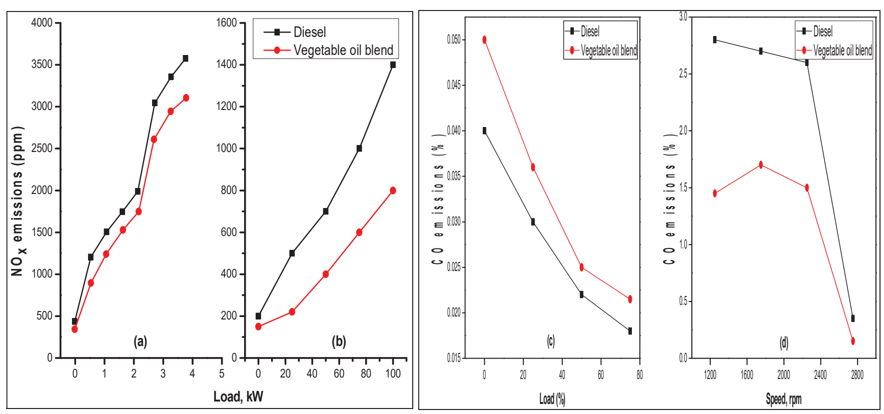

Figure 26 NO_x and CO emissions from vegetable oil blends.

4.8 Effect of Vegetable Oil

NOx emissions are less when vegetable oils are used in case of Wang et al.[18] as in Figure 26(b). But, in case of used vegetable oils, fewer emissions are observed by Nanthagopal and Subbarao [17] as in Figure 26(a). Similarly, in case of CO emissions, Aydin [26] found beneficial aspect with vegetable oil blends as shown in Figure 26(d). But, CO emissions are high with oil blends as shown in Figure 26(c). Overall, vegetable oil blends showed reduced emissions when compared to diesel.

5 Other Aspects

The engine life is extended by using of biofuel, as it is more lubricating when compared to petroleum diesel engine. For motor engines, bioethanol is useful to the environment, as bioethanol produces CO_2 from combustion engines and this CO_2 is absorbed by plants for photosynthesis. Lignocelluloses are provided by these plants and also used for ethanol production. Unlike conventional fuels, the usage of biofuels does not lead to global warming. Also, many researchers observe that there is no need to alter engine features when biofuel is used in an I.C engine. Biofuels are once treated as the protectors of the economy answering the energy requirements. Although biofuels have more benefits over fossil fuels, their incorporation to the fuel resource chain has to be done with much attention. Presently, portability and transportation are the problems of alternative fuel technologies. Usually, conveyance of huge amounts of electricity is very difficult. On the other hand, biofuels are more easily transportable and also have decent energy concentrations. These can be used with only slight modifications to the prevailing technology. The only advantage of biofuels is their suitability to different environments. Disadvantages are food safety, provincial appropriateness, deforestation and biodiversity. Table 1 gives the appraisal of biofuels with diesel with respect to performance and emissions. It is found that some of the biofuels or biodiesel blends are advisable. Beef tallow and diesel blends, jatropha oil and its blends, waste cooking oil diesel mixture are advisable. Biofuels like ethanol, mahua, ethanol etc. are not advisable. It is clear that mass production of the advisable oils is in question.

6 Distributed Generation

From efficiency and emissions aspect, it can be seen that they are not that suitable for conventional power generation when there is power from conventional source is available. Similar to the aspects of wind or solar, biofuels can play vital role for remote places and provide employment for the local youth. Biofuel cells for the energy supply of distributed systems was hinted by Kerzenmacher et al. [27]. Studies by Bailey et al. [28] revealed the same. It was assessed that biofuel like lingo cellulosic can be more suitable alternative. Production of biofuels from the residues of tequila industry gives the ray of hope in this direction, which suggest the installation of bio-refinery in the regions, where there is plenty of supply pf biofuel, making them

Table 1 Comparison of biofuels with diesel

	Biofuel	Efficiency	Emissions	Remarks
Nayak et al.	mahua biodiesel using additive	lesser	more	not advisable
Panner et al.	beef tallow and diesel blends	equal for few loads only	lesser	advisable
Senthil et al.	diesel-2 ethoxy ethyl acetate blends	more for all loads	more than diesel	not advisable
Elango et al.	jatropha biodiesel blends	lesser	more than diesel	not advisable
Hanumantharao et al.	jatropha oil and its blends	higher for all loads	lesser	advisable
Keyur et al.	jatropha biodiesel	higher for all loads	more	not advisable
Sanjay and Das	jatropha biodiesel	same as diesel	reduced emissions	advisable
Avinashkumar and Rajamanoharan	karanja oil blends	dominantly higher for all loads	more	Not advisable
Kiranteja and Subbarao	biofuels, not blends	dominantly higher for all loads	lesser	advisable
Nanthagopal and Subbarao	waste cooking oil diesel mixture	higher for all loads	lesser	advisable
Wang et al.	vegetable oils	lesser for all loads	lesser	not advisable
Gvidonas et al.	Ethanol based blends	lesser for all loads	lesser	not advisable
Yasin et al.	methanol based blends	dominantly higher for all loads	more	not advisable

independent of the main power grid [29]. Use of biogas for distributed power generation is theoretically studied by Mikielewicz et al. [30]. But, it seems to be a possibility in the days to come.

7 Conclusions

Aspects of various biofuels being the right source as fuel for running in an I.C. engine are studied. Conclusions are:

a. Production processes of biofuels involves processes, which cannot be applied for larger quantities. This itself becomes the main drawback to see biofuels as an alternative.

b. Fuels like ethanol and methanol are available in plenty in some areas/countries. In such cases, these may become viable option in case of saturation of fossil fuels.
c. Vegetable oils give better performance and emission characteristics. Even though, it is highly unlikely that such oils are preferred for transportation. Waste cooking oils or unused vegetable oils may be a viable option, but with compromise on performance and emission characteristics.
d. Beef tallow and diesel blends, jatropha oil and its blends, waste cooking oil diesel mixture are advisable. Biofuels like ethanol, mahua, ethanol etc. are not advisable.
e. The processes involved in the preparation and purification of biofuels are found to be fixing many limitations for their expansion and growth.
f. It is clear that mass production of the advisable oils is in question. At the same time, beneficial aspects are expected, if it could be used for remote areas with plenty of biomass source potential as distributed power generation, where the production can be self-sustainable as well.

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