Non-edible Vegetable Oils for Alternative Fuel in Compression Ignition Engines

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Abstract

Non-edible vegetable oils instead of edible vegetable oils as a substitute for diesel fuel are getting a renewed attention because of global reduction of green house gases and concerns for long-term food and energy security. Out of various non-edible vegetable oils, karanja, mahua, linseed, rubber seed and cotton seed oils are selected in this study. A brief review of recent works related to the application of the above five vegetable oils and its derivatives in CI engines is presented. The production technologies of biodiesel based on non-edible vegetable oils are introduced. Problems in vegetable oil or biodiesel fuelled CI engine are included. In addition, future works related to spray characteristics of non-edible vegetable oil or biodiesel from it are discussed. The biodiesel fuel, irrespective of the feedstock used, results in a decrease in the emission of hydrocardon (HC), carbon monoxide (CO), particulate matter (PM) and sulphur dioxide (SO_2). It is also said to be carbon neutral as it contributes no net carbon dioxide to the atmosphere. Only oxides of nitrogen (NOx) are reported to increase which is due to oxygen content in the biodiesel fuel. The systematic assessment of spray characteristics of neat vegetable oils and its blends, neat biodiesel and its blends for use as diesel engine fuels is required.

1. Introduction

Due to shortage of petroleum diesel fuel and its increasing cost, an alternate source of fuel for diesel is very much required. In addition, solutions condisered in the pre-treatment of CI engine for the problems of NOx and PM include high pressure injection, multiple injection, micro- or mini hole nozzle injection, homogeneous charge compression ignition, dual fuel stratified injection and the introduction of reformulated or renewable fuel such as oxygeneted fuel. Several oxygenated fuels are known to have the potential for use as the alternative diesel fuel. Those oxygenates can be classified as alcohol, ether, ester, carbonate and acetate compounds. The biodiesel fuel belongs to ester compound in the above classification. The term biodiesel commonly refers to fatty acid methyl or ethyl ester made from vegetable oils or animal fats[1].

Vegetable oils can be divided into edible and non-edible oils. Vegetable oils are widely available from a variety of sources and they are renewable. Unlike hydrocarbon-based fuels, the sulphur content of vegetable oils is close to zero and hence, the enironmental damage caused by sulphuric acid is reduced. Moreover, vegetable oils take away carbon dioxide from the atmosphere during their production than is added to it by their later combustion. Therefore, it alleviates the increasing carbon dioxide content of the atmosphere.

In addition, Zabetta et al.[2] reported that inorganic makeup of bio-derived oils may work as an inherent additive for diesel particulate trap regeneration. In such scenario, bio-derived fuels could become a fuel of choice to ease the regeneration of particulate traps.

The use of edible vegetable oil or biodiesel from it as a substitute to diesel fuel may lead to a problem of self-sufficiency in vegetable production. Attempt to

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use esters of non-edible vegetable oils as a substitute for diesel fuel will be acceptable. The edible vegetable oils include rapeseed, soybean, sunflower, safflower, peanut, palm, corn, coconut, etc[1, 3].

The use of non-edible vegetable oils is of significance because of the great need for edible oil as food. In addition the selection of non-edible vegetable oil can reduce the production cost of biodiesel due to the relatively high cost of edible vegetable oils Therefore, the discussion in this paper will be limited to non-edible vegetable oil only.

The review about the combustion of fat and vegetable oil derived fuels in CI engines was published by Garboski and McCormick in 1998[3]. The development up to 2003 on the use of vegetable oils and its blends, biodiesel and its blends in CI engines were reviewed by Babu and Bevaradjane[4]. Recently, diesel engine emissions from biodiesel and diesel fuels were compared and reviewed by Lapuerta et al.[1], paying special attention to the most concerning emissions: nitric oxide and particulate matter. The effect of biodiesel fuel on engine power, fuel consumption and thermal efficiency is included. They cocluded that the highest consensus was in the sharp reduction in particulate emission and in an increase in fuel consumption in approximate proportion to the loss of heating value, when using biodiesel fuels as opposed to conventional diesel fuels.

The article based on a literature review of use of biodiesel fuel for CI engines between 1900 and 2005 was reported recently by Shahid and Jamal[5]. They concluded that neat vegetable oils can be used only for small engines for a short-term period. For long-term use and for heavy/big engines, blend of diesel and vegetable oils is recommeded. However, it should be noted that their conclusion came from the review of only six vegetable oils.

The advantages of non-edible vegetable oil as a diesel fuel are liquid nature portability, ready availability, renewability, higher heat content, lower sulphur content lower aromatic content, and biodegradability. On the other hand, the disadvantage of non-edible vegetable oil as a diesel fuel are higher viscosity, lower volatility, the reactivity of unsaturated hydrocarbon chains, and higher percentage of carbon residue[6].

Some of non-edible vegetable oil that could be used in CI engines are listed below.

1) Jatropha(Jatropha curcas) oil
2) Karanja(Pongamia pinnata) oil(Honge oil)
3) Mahua(Madhuca indica) oil
4) Linseed oil
5) Rubber seed oil
6) Cotton seed oil
7) Tobacco(Nicoina tabacum) seed oil
8) Pumpkin(cucurbita pepo L.) seed oil
9) Deccan hemp oil
10) Polanga(Calophyllum inophyllum L.) seed oil
11) Neem oil
12) Salvadora oleoides(Pilu)
13) Calophyluum inophyllum(Nagehapa)
14) Putranjiva(Putranjiva roxburghii) oil
15) Simarouba oil
16) Nagchampa(Calophyllum inophyllum) oil

Out of the above vegetable oils, jatropha oil is already widely known and is a leading candidate for the commercialization of non-edible vegetable oils. Therefore, jatropha oil is not included in this review and will be reviewed seperately in the continued paper. In addition, vegetable oils such as tobacco seed, pumpkin seed, deccan hemp, polanga seed, neem and putranjiva oils have only a few pubulished papers as an initial stage of research. Accordingly, karanja, mahua, linseed, rubber seed, and cotton seed oils are incldued in this review.

It has been found that four different types of alternative fuels from vegetable oil such as neat vegetable oil, vegetable oil blends with diesel or other fuel, neat biodiesel (methyl ester or ethyl ester), and biodiesel blends with diesel or other fuel were extensively examined in the diesel engine.Therefore, researches in the literature will be classified with two different groups as neat vegetable oil and its blends and neat biodiesel and its blends.

The review paper related to the performance characteristics and exhuast emissions of only non-edible vegetable oil as a substitute for diesel fuel could not be found. The purpose of this study is to review the application of non-edible vegetable oils in CI engine and to suggest the future works related to spray characteristics of those oils.

2. Production of biodiesel

Srivastava and Prasad[7] reviewed the methods to develop vegetable oil derivatives that approximate the properties and performance of the hydrocarbon-based diesel fuels. Latest aspects of development of biodiesel production had been discussed by Sharma et al.[8]

Biodiesel can be produced from renewable feedstocks through simple refining processes such as transesterification, microemulsification, dilution and pyrolysis. The precise process for these techniques can be found in the work of Srivastava and Prasad[7]. These techniques reduce the viscosity of vegetable oil. It is well known that out of the above four methods, transesterification is simple and cost effective.

Recently, degumming process which is easy, simple and less expensive process than transesterification is introduced by Haldar et al.[9]. Degumming is an economical process of acid treatment by which the gum of the vegetable oil is removed to improve the viscosity and cetane number of vegetable oil up to certain limit. Therefore, the evaluation and comparison between transesterification and degumming is required.

At present, biodiesel is commercially produced from the refined edible vegetable oils such as sunflower oil, palm oil and soybean oil, etc by alkaline-catalyzed esterification process. However, Ramadhas et al.[10] pointed out that this process is not suitable for production of biodiesel from many unrefined non-edible vegetable oils because of their high acid value. Hence, two-step[10, 11] and three stage[12] esterification methods for the production of biodiesel from rubber seed oil were introduced.

In the last few years, the study of the enzymatic synthesis of biodiesel, as an environmentally friendly process, have shown significant progress due to pollution and product separation problems of the chemical catalyzed process[13].

For the designation of derivatives produced from vegetable oil (for example, karanja oil), karanja oil biodiesel, karanja biodiesel, karanja based biodiesel, karanja oil methyl ester, biodiesel from karanja oil, and esterified karanja oil are using as synonym. In this study, karanja oil (KO) biodiesel is selected and will be used to the other non-edible vegetable oil as the same manner.

Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend. It can be used in CI engine with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics.

3. Problems in vegetable oil or biodiesel fuelled ci engine

Because of the high molecular weights (about 880), vegetable oil have low volatility[4]. In any case, the viscosity of neat vegetable oil and neat biodiesels is higher than that of typical diesel fuel.

High viscosity of vegetable oils and biodiesel leads to poor atomization of fuel spray, in turn large droplet size and thus high spray jet penetration. The jet tends to be a solid stream instead of a spray of small droplets. As a results, the fuel is not distributed or mixed with the air required for burning in the combustion chamber. This results in poor combustion accompanied by loss of power and economy.

The physical properties of biodiesel fuel depended upon the structure and type of the fatty acid esters present[12]. The properties of biodiesel also depend on the type of the vegetable oil used for the trans-esterification process[11]. Biodiesel is completely miscible with diesel and can be blended in any proportion to diesel fuel. From this point of view, systematic assessment of spray characteristics of neat vegetable oils and its blends, neat biodiesel and its blends for use as diesel engine fuels is required.

3.1 Karanja oil

It should be noted that karanja oil (botanical name

Pongamia pinnata), honge oil[14, 15], and pongamia oil[16] are using as synonym. In this study, the term, karanja oil (KO) will be used for the vegetable oil and KO biodiesel will be used for the biodiesel produced from karanja oil.

3.1.1 Neat karanja oil and its blends

A diesel engine was tested by Nazar et al.[17] with karanja oil, KO biodesel and diesel as pilot fuels while LPG was used as primary fuel. They concluded that LPG can be inducted along with air in order to reduce smoke levels and improve thermal efficiency of vegetable oil and biodiesel fuelled diesel engine.

1) Neat karanja biodiesel and its blends

Srivastava and Verma[18] tested different blends with karanja oil biodiesel in two cylinder diesel engine. They concluded that the thermal efficiency is lower with biodiesel of karanja oil as compared to diesel, whereas thermal efficiency of blending is higher than that of biodiesel.

At maximum load, the brake-specific fuel consumption of biodiesel was higher as compare to that of diesel. The BSFC of diesel at peak load was 0.276 kg/kWh, and that of biodiesel was 0.401 kg/kWh. It is known from the review by Lapuerta et al.[1] that the specific fuel consumption when using a biodiesel fuel is expected to increase by around 14% in relation to the consumption with diesel fuel, corresponding to the increase in heating value in mass basis. However, the brake-specific fuel consumption in this case is increased by 45.3%, showing the remarkable difference with the expected value. Correct the sentence, they reported that HC, CO and NO emissions are higher of methyl ester of karanja oil as compared to diesel.

Srivastava and Verma[18] have reported the HC, CO and NO emissions from karanja oil methyl ester to be slightly higher as compared with conventional diesel fuel. HC emission of diesel at maximum load was 85 ppm, while that of biodiesel was 120 ppm due to poor mixing with air. CO emission of diesel at maximum load was reported to be 0.18% as compared to 0.21% of biodiesel. However, emissions are lower for blends as compared to biodiesel. The emissions are 0.15%, 0.16%, 0.15% and 0.18% with blends of 5%, 10%, 15% and 20%, respectively, at miximum load. NO emission in the case of biodiesel fuel was higher than that of blends of karanja biodiesel. It was also reported that NO emission in the case of biodiesel fuel is approximately 12% higher than that of diesel fuel, which may be due to the higher temperature of biodiesel combustion chamber.

Raheman and Phadatare[19] tested karanja oil biodiesel and blends with diesel from 20% to 80% by volume in a single cylinder, four-stroke direct injection diesel engine having a rated output of 7.5 kW at 3000 rpm and a compression ratio of 16:1. The maximum brake thermal efficiencies were obtained to be 26.79 and 26.19% for B20 and B40 respectively, which were higher than that of diesel (24.62%). The lower brake thermal efficiency obtained for B60-B100 could be due to a reduction in the calorific value and an increase in fuel consumption as compared to B20.

It is clear that the yield of karajan oil biodiesel depends on the production method. Srivastava and Verma[18] reported that the yield of biodiesel was 84%, whereas Raheman and Phadatare[19] obtained 75% biodiesel from karajan oil in their experiment.

According to the results from the experimental work by Raheman and Phadatare[19], Kapilan et al[20] had selected B20 blend of karajan oil methyl ester in order to study the effect of injection pressure on the performance and emission of diesel engine. They found that in the range of 16 to 22 MPa, the injection pressure of 20 MPa results in higher brake thermal efficiency. The concluded that this may be due to better atomization and mixing of fuel with air, which results in better combustion of fuel.

In the work by Suryawanshi and Deshpande[21], neat pongamia oil methyl ester (PME) as well as the blends of different proportions of pongamia oil methyl ester and diesel were used to run a CI engine with standard injection timing and retarded injection timing. They found that the brake thermal efficiency is similar for all blends of PME as compared to diesel at standard injection timing. However, the brake thermal efficiency is higher at part load and similar at full load for all blends of PME with retarded injection timing as compared to all blends of PME with standard injection timing.

Suryawanshi and Deshpande[16], Kumar et al.[22], and Sureshkumar et al.[23] investigated the performance and combustion characteristics of KO biodiesel and its blend with diesel from 20% to 80% by volume in a single cylinder, direct injection diesel engine and compared the results with conventional diesel fuel. Kumar et al.[22] concluded that brake thermal efficiency improved when diesel engine was fuelled with 20% and 40% KO biodiesel blends. However, Suryawanshi and Deshpande[16] reported that the use of KO biodiesel and its blends with diesel results in a similar brake thermal efficiency as compared to diesel operation. Both studies found that the addition of KO biodiesel to diesel fuel has remarkably reduced HC, CO and smoke emissions but it increases the NOx emission slightly (10-20% in Kumar et al). However, Sureshkumar et al[23] reported the notable reduction in NOx emission for all the blends as compared to diesel fuel, particularly 40% and 60% of KO biodiesel blends.

Kumar et al.[22], and Sureshkumar et al.[23] concluded that the blends of KO biodiesel with diesel fuel up to 40% by volume could replace diesel fuel for running the diesel engine for getting less emissions and better performance.

Investigation was conducted to study the performance and smoke emission of different proportions of KO biodiesel blends with diesel fuel (5, 10, and 15%) in DI diesel engine under different operating conditions[24]. They conclude that KO biodiesel of 10% blend with diesel fuel is an ideal alternative fuel for diesel engine.

3.2 Mahua oil

In this paper, the term, mahual oil (MO) and MO biodiesel will be used for non-edible vegetable oil and for biodiesel produced from mahua oil, respectively.

3.2.1 Neat mahua oil and its blends

Agarwal et al.[25] performed the work to investigate the performance and exhuast emission of mahual oil blends in a four-stroke diesel engine and compare it with diesel fuel. It was obsered by them that all manua oil blends (10, 20 and 30%) have almost similar thermal efficiency and are very close to the thermal efficiency of diesel fuel. It should be pointed out that 30% mahua oil blend is found to be most thermally efficient from their work.

It was also found that smoke density is higher for mahua oil blends compared to diesel at lower loads. Smoke density increased with proportion of mahual oil in diesel.

3.2.2 Neat mahua biodiesel and its blends

Puhan et al.[26] performed a test of MO biodiesel (mahua oil methyl ester: MOME) with diesel fuel in a simple cylinder direct injection compression ignition engine and showed decreases (13%) in thermal efficiency. In the continuing work, Puhan et al.[27] tested MO biodiesel(mahua oil ethyl ester:MOEE) with diesel fuel in a same engine with the previous study and showed the comparable thermal efficiency with diesel fuel. They pointed out that this is due to the chemical composition of MOEE, which promotes the combustion process. It should be pointed out that the viscosity of MOEE (6.2 mm^2/s at 40°C) is slightly higher than that of MOME (5.2 mm^2/s at 40°C).

According to the works of Puhans et al.[26, 27], exhaust emissions of CO, HC, NOx and smoke number were reduced around 58, 63, 12 and 70% respectively in case of MOEE and 30, 35, 4 and 11% respectively in case of MOME, compared to diesel.

The amount of NOx produced for neat biodiesel of mahua oil was 50 ppm as compared to 44 ppm for diesel. This could be attributed to the increased gas temperature due to the oxygen content within biodiesel.

The mahua biodiesel (B100), diesel fuel and their blends (B20, B40, B60, and B80) were used by Raheman and Ghadge[28] to test a single cylinder four stroke diesel engine at a compression ratio of 18:1 and injection timing of 40°C before TDC with a rated output of 9 kW at 1500 rpm. In the continuing study[29], they conducted the experiment on the performance and exhaust emissions of same fuels in the same engine with the previous work, but at varing compression ratio (18:1-20:1), injection timing (35~45°C bTDC). They found that biodiesel could be blended with diesel fuel up to 20% at any of the compression ratio and injection timing tested for getting nearly same performance as that with diesel.

Raheman and Ghadge(29) found that the differences of brake thermal efficiencies between diesel fuel and neat mahua oil biodiesel were not significant at engine settings of compression ratio of 20:1 and injection timing of 40°C btdc.

At full load conditions, the mean brake thermal efficiency of neat biodiesel of mahua oil was about 10.1% lower than that of diesel fuel while at lower loads, the variation was as high as 17.1% which could be attributed to the significantly lower efficiencies of neat biodiesel, especially at lower loads(28).

3.3. Linseed oil

In this paper, the term, linseed oil (LSO) will be used for non-edible vegetable oil and LSO biodiesel will be used for the biodiesel produced from linseed oil.

3.3.1 Neat linseed oil and its blends

The study on the performance characteristics and exhust emissions of neat linseed oil in diesel engine could not be found.

Beg et al.(30) reported that brake thermal efficiency decreases as the proportion of diesel fuel decreases in the diesel fuel-linseed oil blends. They also reported the results of exhaust gas temperature, NOx emission level, CO emission level, smoke density in the semi-adiabatic type of engine by using diesel fuel-linseed oil blends according to the variation of piston coating thickness and compression ratio. Exhaust gas temperature, CO emission and smoke density are increased but NOx level are decreased in diesel fuel-linseed oil blends and biodiesel compared to diesel fuel operation.

Agawal et al.(31) found that 50% LSO blend showed maximum thermal efficiency and lowest brake specific energy consumption (BSEC), but higher smoke density, compared to all other LSO blends (10, 20, 30% v/v),

In the theoretical study for the comparison of three vegetable oils for diesel alternative, linseed oil has the highest NOx emission while cotten seed oil and peanut oil have lower NOx emission than diesel fuel(32). They pointed out that vegetable oils combustion behaves similarly to diesel fuel with higher injection pressure of 300 MPa.

3.3.2 Neat linseed oil biodiesel and its blends

In the test of LSO biodiesel, Beg et al.(30) found that brake specific fuel consumption of LSO biodiesel is higher than LSO blends and diesel fuel in both compression ratios. In addition, LSO biodiesel shows slightly higher brake thermal efficiency than diesel fuel with higher coating thikness. NOx emission is relatively lower in LSO biodiesel operation than LSO blends and diesel fuel operation. NOx emission lever decreases 38.96% in compression ratio of 19 and 29.41% in compression ratio of 20 for LSO biodiesel compared to diesel fuel operation. Neat diesel fuel has the lowest smoke density than LSO blends and LSO biodiesel.

Agarwal et al.(31) reported that 20% LSO biodiesel blend showed maximum thermal efficiency, maximum BSEC, and lowest smoke density compared to all other LSO biodiesel blends (10, 30, 50 and 100% v/v). An important observation is that all LSO biodiesel blends have higher thermal efficiency than diesel fuel.

The effect of injection pressure and injection timing on the performance and exhaust emission characteristics of a direct injection diesel engine operating diesel-biodiesel blends was investigated by Bhusnoor et al.(33). They recommended that engine operation with LSO biodiesel blends at advanced injection timing was better than operation at increased injection pressure in terms of engine performance and exhaust emissions.

Use of macro-emulsion of linseed oil in CI engine was carried out by Kumar and Khare(34). They found that the macro-emulsion of linseed oil with concentration up to 10% of alcohol gave satisfactory performance and engine ran smoothly without noise. The highest thermal efficiency higher than that of neat diesel could be obtained the operation with 60% of diesel, 30% of linseed oil and 10% of methanol.

The study on exhaust emission characteristics of neat linseed oil in diesel engine could not be found.

It is required to conduct the research about the exhaust emission characteristics of linseed oil biodiesel blends in diesel engine.

3.4. Rubber seed oil

In this paper, the term, rubber seed oil (RSO) and RSO biodiesel will be used for non-edible vegetable oil and for biodiesel produced from rubber seed oil, repectively.

3.4.1 Neat rubber seed oil and its blend

Geo et al.[35] had studied the performance and emission characteristics of a single cylinder diesel engine using preheated rubber seed oil by exhaust gas and rubber seed oil (RSO) without preheating and compared the results with those of diesel fuel. Their results show that the brake thermal efficiency increases from 26.56% to 27.89% when the fuel is preheated to a temperature of 155°C. However, lower thermal efficiency is found in neat RSO and preheated RSO compared to diesel fuel (29.93%). Specific fuel consumption of neat RSO is more than that of diesel fuel. However, fuel preheating leads to the improvement in specific fuel consumption.

NOx emission for neat RSO operation is 6.9 g/kWh and 10.69 g/kWh with diesel at full load. However, NOx emission increased with increase in fuel inlet tempreature, but the preheated RSO is still 20% lower than that of diesel operation.

Smoke emission for neat RSO operation is much higher than that of diesel fuel. This may be due to larger SMD of vegetable oil which will increase the evaporation time and poor fuel air mixing rate. Fuel preheating can remarkably reduce the smoke level. However, smoke level for preheated RSO operation was still higher than that of diesel fuel.

For the application of neat RSO in the electric power generation, dual fuel mode operation in diesel engines using RSO and coir-pith producer gas was introduced by Radmadas et al.[36] They found the decrease of engine performance and the increase of fuel consumption in addition to the higher CO emission under all load conditions.

The various blends of RSO and diesel were subjected to engine performance and eimssion tests and compared with that for diesel by Ramadhas et al.[37] In this study, the physical properties such as viscosity and specific gravity of the various blends of RSO were also evaluated and compare with that of diesel. They recommended that RSO-diesel blend fuel is more suitable for rural power generation because of higher carbon deposits inside combustion chamber and requirement of frequent cleaning of fuel filter and pump.

3.4.2 Neat rubber seed oil biodiesel and its blend

Neat RSO, diesel and RSO biodiesel were used as fuels in the CI engine and the performance and emission characteristics of the engine were compared and analyzed[10]. They found that the lower blends of biodiesel increase the brake thermal efficiency and reduce the fuel consumption. The exhaust gas emissions are reduced with increase in biodiesel concentration.

The investigation to analyze the engine performance and exhust emissions of CI engine fuelled with neat RSO, RSO biodiesel was carried out by Geo et al.[38]. The brake thermal efficiency is 26.53% with neat RSO, 27.89% with RSO biodiesel and 29.93% with diesel at full load. Smoke levels are higher with neat RSO and RSO biodiesel as compared to diesel. However, smoke emission is lower with RSO biodiesel than neat RSO due to the lower viscosity of RSO biodiesel. NOx emissions for neat RSO operation is 6.9 g/kWh and 9.6 g/kWh with RSO biodiesel and 10.7 g/kWh with diesel at full load.

A theoretical thermodynamic model was developed to analyze the performance characteristics of the CI engine fueled by biodiesel produced using unrefined RSO and its blends[11].

Baiju et al.[12] reported the experimenatal results using diesel, several blends of biodiesel with diesel and neat biodiesel. It should be noted that biodiesel was produced from the RSO in a three stage transesterification processes such as two acid catalyzed transesterification processes and one base catalyzed transesterification in sequence. The brake thermal efficiency was lowest with neat biodiesel in all loads. At higher loads, B10 and B20 were more efficient than diesel fuel. NOx emissions of biodiesel blends and neat biodiesel are higher than diesel at all loads. This is the opposite tendency with the results reported by Geo et al.(38) Smoke emissions decreased with increase in biodiesel concentration in the biodiesel blends with diesel.

3.5. Cotton seed oil

In this study, the term, cotton seed oil (CSO) and CSO biodiesel will be used for non-edible vegetable oil and biodiesel produced from cotton seed oil, respectively.

3.5.1 Neat cotton seed oil and its blends

For the application of neat cotton seed oil (CSO) directly in diesel engine, the effect of superchaging is investigated on the performance of direct injecion CI engine with the use of neat CSO under varying injection pressures. It is concluded in this paper that CSO can best be utilized if supercharging is employed at the recommended injection pressure of the engine(39). The computational examination of the combustion process of both neat CSO and diesel fuel in a heavy duty direct injection diesel engine was reported by Ruan et al.(40) They found that neat CSO have lower NOx emissions and longer ignition delay than diesel fuel.

The studies related to neat CSO and diesel fuel blends were conducted by two research groups. He and Bao(41) concluded in their paper that 30% CSO and 70% diesel blends was practically optimal in ensuring relatively high thermal efficiency of engine, as well as homogeneity and stability of the blends. However, Fontaras et al.(42) reported that 10% CSO and 90% diesel blends can be applied in common rail diesel engine without impacts on operation and emissions even though proper idle engine management is required.

3.5.2 Neat cotton seed oil biodiesel and its blends

The effects of neat CSO and CSO biodiesel on a single cylinder diesel engine performance and exhaust emissions were investigated by Altm et al.(43) The relations between three fuels such as diesel, neat CSO and CSO biodiesel on the specific fuel consumption, NOx and smoke emissions show the similar tendency with those of diesel, neat RSO and RSO biodiesel.

Diesel engine tests fuelled wth CSO biodiesel were carried out at full load-different speed range(44). It is found in this study that the engine torque and power of CSO biodiesel was lower than that of diesel fuel in the range of 3-9% and specific fuel consumption was higher than that of diesel fuel by approximately 8-10%. In addition, NOx emission of CSO biodiesel was lower than that of diesel fuel. These are the consistent results with those of Altm et al.(43)

An experimental study was conducted to evaluate and compare the use of CSO and CSO biodiesel blended with diesel fuel at blend ratios of 10/90 and 20/80 resepectively in a direct injection diesel engine(45). It was observed that the soot emitted by CSO biodiesel blends is significantly lower than that by the corresponding neat diesel fuel, with the reduction being higher the higher the percentage of the CSO and CSO biodiesel in the blend. NO emission from CSO and CSO biodiesel blends are slightly lower than that from the corresponding diesel fuel case, with the reduction being higher the higher the concentration of the CSO and CSO biodiesel in the blend. The specific fuel consumption for CSO and CSO biodiesel blends was a little higher than that for the corresponding diesel fuel case.

4. Summary

Considerable efforts such as pyrolysis,emulsification dilution or blending, transesterification, and degumming have been made to produce vegetable oils derivatives that approximate the properties and performance of the hydrocarbon based diesel fuels. The research on the comparison of non-edible vegetable oil derivatives from the above different techniques is required.

Recently, researchers related to performance and exhaust emission from diesel engine are on a consensus that biodiesel fuel, irrespective of the feedstock used, results in a decrease in the emission of hydrocardon (HC), carbon monoxide (CO), particulate matter (PM) and sulphur dioxide (SO_2). It is also said to be carbon neutral as it contributes no net carbon dioxide to the atmosphere, Only oxides of nitrogen (NOx) are reported to increase which is due to oxygen content in the biodiesel fuel.

It was reported that a diesel engine without any modification would run successfully on a blend of 20% vegetable oil and 80% diesel fuel without damage to engine parts. This trend can be applied to the biodesel blends even though particular biodiesel shows 40% blend.

Engine performance with vegetable oil or biodiesel pilot injection in a natural gas or LPG dual fuelled engine was satisfactory and comparable with the diesel fuel pilot operation.

The systematic assessment of spray characteristics of neat vegetable oils and its blends, neat biodiesel and its blends for use as diesel engine fuels is required.

References

(1) M. Lapuerta, O. Armas, J. Rodriguez-Fernandez, Progr. Energy Combustion Sci., 34, 2008, 198~223.
(2) E. C. Zabetta, M. Hupa and S. Neimi, Fuel 85, 2006, 2666~2670.
(3) M. S. Graboski and R. L. McCormick, Progr. Energy Combust. Sci. 24, 1998, 125~164.
(4) A. K. Babu and G. Devaradjane, SAE paper 2003-01-0767, 2003.
(5) E. M. Shahid and Y. Jamal, A review of biodiesel as vehicular fuel, Renewable and Sustainable Energy Reviews, article in press. P. K. Srivastava, Fuel, Vol. 87, 2008, 2846.
(6) A. Srivastava and R. Prasad, Renewable and Sustaianble energy Reviews, 4, 2000, 111~133.
(7) Y. C. Sharma, B. Shigh and S. N. Upadhyay, Fuel, 87, 2008, 2355~2373.
(8) S. K. Haldar, B. B. Ghosh and A. Nag, Biomass and Bioenergy, 2008 in press.
(9) A. S. Ramadhas, C. Muraleedharan and S. Jayaraj, Renewable Energy, Vol. 30, 2005, 1789~1800.
(10) A. S. Ramadhas, S. Jayaraj and C.Muraleedharan, Renewable Energy, Vol. 31, 2006, 1813~1816.
(11) B. Baiju, L. M. Das, and M. K. Gajendrababu, SAE paper 2008-28-0073, 2008.
(12) D. Royon, M. Daz, G. Ellenrieder and S. Locatelli, Bioresource Technology, 98, 2007, 648~653.
(13) N. R. Banapurmath, P. G. Tewari and R. S. Hosmath, Renewable Energy 33, 2008, 1982~1988.
(14) N. R. Banapurmath, P. G. Tewari and R. S. Hosmath, Renewable Energy 33, 2008, 2007~2018.
(15) J. G. Suryawanshi and N. V. Deshpande, SAE paper 2004-28-0018, 2004.
(16) J. Nazar, A. Ramesh and B. Nagalingam, SAE paper 2006-01-0237, 2006.
(17) P. K. Srivastava and M. Verma, Fuel, 87, 2008, 1673~1677.
(18) H. Raheman and A. G. Phadatare, Biomass and Bioenergy, 27, 2004, 393~397.
(19) N. Kapilan, R. P. Reddyand and T. Basavaraj, SAE paper 2006-32-0025, 2006.
(20) J. G. Suryawanshi and N. V. Deshpande, SAE paper 2005-01-3677, 2005.
(21) C. Kumar, M. K. Gajendra Babu and L. M. Das, SAE paper 2006-01-0238, 2006.
(22) K. Sureshkumar, R.Velraj and R. Ganesan, Renewable energy, 33, 2008, 2294~2302.
(23) M. Muralidharan et al., SAE paper 2004-28-0030, 2004.
(24) D. Agarwal, L. Kumar and A. K. Renewable Energy, Vol. 33, 2008, 1147~1156.
(25) S. Puhan, N. Vedaraman, B. V. B. Ram, G. Sankaranarayanan, and K.Jeychandran, Biomass and Bioenergy, Vol. 28, 2005, 87~93.
(26) S. Puhan, N. Vedaraman, G. Sankaranarayanan, B. V. B. Ram, Renewable Energy, Vol. 30, 2005, 1269~1278.
(27) H. Raheman and S. V. Ghadge, Fuel, Vol. 86, 2007, 2568~2573.
(28) H. Raheman and S. V. Ghade, Fuel, Vol. 87, 2008,

2659~2666.
(29) R. A. Beg, M. S. Rahman, P. K. Bose and B. B. Ghosh, SAE paper 2002-01-2692. 2002.
(30) D. Agarwal, L. Kumar, A. K. Agarwal, Renewable Energy, Vol. 33, 2008, 1147~1156.
(31) D. Ruan, W. L. Cheng and C-F Lee, SAE paper 2008-01-1639, 2008.
(32) S. S. Bhusnoor, M. K. G. Babu and J. P. Subrahmanyam, SAE paper 2007-01-0613, 2007.
(33) N. Kumar and U. Khare, SAE paper 2004-28-0040, 2004.
(34) V. E. Geo, G. Nagarajan and B. Nagalingam, SAE paper 2008-28-0049, 2008.
(35) A. S. Ramadhas, S. Jayaraj and C. Muraleedharan, Renewable Energy, Vol. 33, 2008, 2077~2083.
(36) A. S. Ramadhas, S. Jayaraj and C. Muraleedharan, Renewable Energy, Vol. 30, 2005, 795~803.
(37) V. E. Geo, G. Nagarajan and B. Nagalingam, SAE paper 2008-01-1386, 2008.
(38) G. A. P. Rao and P. R. Mohan, Energy Conversion and Management, 44, 2003, 937~944.
(39) D. Ruan, W. L. Cheng and C-F Lee, SAE paper 2008-01-1639, 2008.
(40) Y. He and Y. D. Bao, Renewable Energy, Vol. 30, 2005, 805~813.
(41) G. Fontaras, Z. Samaras, and G. Miltsios, SAE paper 2007-24-0126, 2007.
(42) R. Altın, S. Cetinkaya and H. S. Yucesu, Energy Conversion and Management, Vol. 42, 2001, 529~538.
(43) H. S. Yucesu and C. Ilkilic, Energy Sources Part A, Vol. 28, 2006, 389~398.
(44) C. D. Rakopoulos, K. A. Antonopoulos, D. C. Rakopoulos, D. T. Hountalas and E. G. Giakoumis, Energy Conservation and Management, 47, 2006, 3272~3287.