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Review of Biodiesel Production, Emissions and Performance characteristics of Mahua oil

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Abstract

This paper presents a brief review on the current status of biodiesel production from Mahua oil and its performance and emission characteristics as diesel engine fuel. This review is based on the reports on Mahua oil production process and its characteristics were published in the current literature by different researchers. Biodiesel was produced from raw Mahua oil by Transterification process. The main aim of the Transterification process was to reduce the amount of free fatty acid. Biodiesel of Mahua oil is also called methyl (MOME) or ethyl (MOEE) ester. It was completely miscible with diesel oil, thus allowing the use of blends of petro-diesel and biodiesel in any percentage. Presently, biodiesel is blended with mineral diesel and used as fuel. Biodiesel fueled CI engines perform more or less in the same way as that fueled with the mineral fuel. Exhaust emissions are significantly reduced due to the use of Mahua oil biodiesel or blends of biodiesel and mineral diesel.

***Keywords**: Review, Mahua oil, Biodiesel, CI engine.*

1..Introduction

The most harmful effect of our present day civilization is global warming and environmental pollution. With rapid industrialization and urbanization, we are making our planet unsafe for us and for the generations to come. We are now all well aware of the lethal effects of pollution. India is already the fifth largest greenhouse gas emitter of the world and is expected to become the third largest GHG emitter by the year 2015 with China topping the list. The vehicle population throughout the world is increasing rapidly; in India, the growth rate of automotive industry is one of the largest in the world. It is quite evident that the problem cannot be solved with the conventional fossil fuels, however stringent the emission control norms may be. This demands the search for a suitable alternative to conventional fossil fuels.

Many researches are going on to replace diesel fuel with a suitable alternative fuel like biodiesel. Non-edible sources like Mahua oil, Karanja oil, Neem oil, Jatropha oil, Simarouba oil etc. are being investigated for biodiesel production. Fatty acids like stearic, palmitic, oleic, linoleic and linolenic acid are commonly found in non-edible oils. Mahua oil (Madhuca Indica) is one of the forest based tree-borne non-edible oils with large production potential of about 60 million tons per annum in India. The Mahua tree belongs to the genus Madhuca. The tree, its seed and flowers had been very useful in Indian economy for a long time. The flowering season extends from February to April. It is rich in sugar (73 %) and next to cane molasses; it constitutes the most important raw material for alcohol fermentation. The yield of alcohol is 405 liters from one ton of dried flower. The kernel of the Mahua fruit contains about 50% oil. The expelled cake is relevant to recover the residual oil. Fresh oil is yellow in colour, while commercial oil is generally greenish. As this tree grows mainly in forest area and also in waste and fallow land, its cultivation would not produce any impact on food production but would in an attempt is made in this paper to study the feasibility of Mahua methyl ester and its blends with diesel fuel for a compression ignition engine. Sharanappa et al. (2009) had undergone the development of Mahua trees grown in draught prone areas and found abundantly over several parts of India. The seeds are collected and oil is extracted at village level expellers, million tons of oil will be available for lighting lamps in rural area. Mahua oil is considered for preparing ghee, but in India considered as non-edible oil. Mahua is substitute for kerosene. Due to increase in awareness and growth in research in this area the Mahua, an alternative source of fuel by replacing diesel. The properties like density, viscosity, flash and fire point of Mahua oil under test are higher, and calorific value is lower, and are in the range of 86% that of diesel.

1.2.Biodiesel Production

Researchers are trying to find several ways to make biodiesel from different feed stocks like edible and non-edible vegetable oils, waste cooking oil, animal tallow, algae etc. Most of the researchers prepared biodiesel by transesterification process from the raw feedstocks using a base catalyst. Shashikant and Hifjur (2006) reduced the high FFA (17%) level of crude Mahua oil to less than 1% for using Mahua oil as a biodiesel in diesel engine. They took the process parameters of methanol (0.32 v/v), H2SO4 as catalyst (1.24% w/v), 1.26 h reaction at 60^{o}C temperature. After pretreatment step, settling time of minimum one hour was required for removal of methanol–water mixture. This process gave yield of Mahua biodiesel as 98%. Properties of the biodiesel satisfy both American and European standards for biodiesel. Kian and Suhaimi (2012) produced biodiesel from low quality crude jatropha oil by Transterification process by using modified natural zeolite as a solid catalyst. The process parameters were 20:1 molar ratio of methanol to oil, of 5wt% catalyst and 70^{o}C reaction temperature. Finally they got the optimum yield in which the biodiesel content exceeded 96.5%.

Shakinaz et al. (2006) had undergone a study of production of biodiesel using microwave technique. Microwave irradiation was used for the production of biodiesel. Biodiesel from Jatropha oil was obtained using a methanol/oil molar ratio of 7.5:1, potassium hydroxide as catalyst. Radio frequency microwave energy helped for improving the separation process at reaction rate (2 min instead of 150 min). By using the microwave technique, no pretreatment is required. This technique paved way to increase the yield and time controlled process. Hasan et al. (2013) produced biodiesel from neem seeds, its properties was close to diesel. The methodology of esterification process were selected and carried out by 1000ml raw neem oil, 300ml methanol and sodium hydroxide on mass basis as a catalyst usually kept in oven to form methyl ester, and initially to reach equilibrium condition at temperature 55-66^{o}c. Next step to separate ester and glycerine by stimulating continuously and allow settling under gravity for 24 h. Thus the separated ester contains 3% to 6% methanol and soap agents. The methanol was removed by vaporization. The biodiesel had some catalyst; it was removed by warm water mix with ester. Kinematic viscosity lay between 1.9 to 6.0 according to the ASTM D6751 specification. Hence, 0.95 ltr biodiesel was production from 1 ltr neem oil.

Priya et al. (2013) described that the transesterification along with the alkaline catalysts was the well known process for the preparation of biodiesel. In Taguchi method ANOVA were used to analysis and optimize the experimental parameters which included catalyst concentration, catalyst type, reaction time and oil to alcohol molar ratio for the production of Mahua oil methyl ester. The results showed that the optimized experimental condition were oil to the

alcohol molar ratio as 1:15, catalyst used in the process is sodium hydroxide and 5 min of reaction time. In addition the analysis result concluded that the catalyst type was the major influencing parameter in number of experimental trials for the production of Mahua oil methyl ester. In future this work must be carried out for estimation of multiple parameters in production of Biodiesel.

Javidialesaadi and Raeissi (2013) focused on minimizing the production costs and searching a permanent oil source for green fuel. In this work, high free fatty acid oils were used for esterification reaction and the main parameters were analysed experimentally. The investigation showed that there was no change occurs in altering methanol-to-oil ratio, the amount of catalyst and time for the progress of the reaction compared to diesel fuel. Daming et al. (2012) recalled the history and some advance improvement in the production of biodiesel. This paper reviewed various types of biodiesel, processing, the characteristics and cost of biodiesel production. The application of biodiesel in automobile industry, the huddles of biodiesel industry development and the biodiesel policy were clearly explained.

Giovanilton et al. (2011) produced biodiesel from soybean oil by transesterification with ethanol. Optimum conditions for the production of ethyl esters were the following: mild temperature at 56.7 °C, reaction time in 80 min, molar ratio at 9:1 and catalyst concentration of 1.3 M. For esterification reaction, H_2SO_4 was added as a catalyst and for transesterification KOH was added as the catalyst with methanol. Widayat et al. (2013) produced biodiesel from the rubber seed by situ method. They focus on influence of reaction time, concentration of acid catalyst and ratio of raw material to methanol. This process took 120 minutes at 60^oC with maximum yield of FAME 91.05% at H_2SO_4 0.25% (v/v) and ratio of raw material to methanol (1:3). Based on the results, ratio of raw material to methanol was quite important to increase yield of FAME significantly.

Lieke et al. (2014) produced biodiesel by two step process. The first step process which was designed for 3 hours reaction time at 30^oC and 5.8% of ozone using either 1 or 1.5 weight % KOH at various percent weight of supporting catalyst had proved simultaneous reaction for both ozonolysis and transesterification. The short chain methyl esters (methyl hexanoate, methyl octanoate and methyl nonanoate) were effectively produced for the first step process using 5.8% mol ozone at 30^oC for 3 hours either for 1 or 1.5 weight % KOH at various percent weight of extracted supporting catalyst. From this reaction, the esters predicted by ozone reaction were sufficiently produced. The highest short chain methyl esters and long chain methyl esters produced in the first step process was 85.722 mg/liter and 655.286 mg/ltr respectively, which used 17.3 weight % ash and 1.5 weight % KOH. The presence of extracted ash in methanol as supporting catalyst enhanced the production of total methyl esters compared to that without the presence of ash in the first step process. Higher temperature (60^oC) in the second step process without the presence of ozone gave enough vibration of energy, to increase rate of transesterification and decrease the viscosity. However, longer time reaction at higher temperature would lead in the losses of total methyl esters.

Padhi and Singh (2010) produced biodiesel from Mahua oil through the Esterification. The conditions for produce biodiesel were 8% Sodium Methoxide, 0.33%v/v alcohol/oil ratio, 1 hr reaction time, 65^oC temperature and 150% v/v excess alcohol. They concluded this was the best condition for biodiesel production. Kapilan and Reddy (2008) produced biodiesel from Mahua oil methyl esters (MOME) were prepared by transesterification using potassium hydroxide (KOH) as catalyst and test the conversion of vegetable oil to biodiesel by nuclear magnetic resonance (NMR) testing method. They studied the performance characteristics fuelling with Mahua biodiesel in a diesel engine. They concluded B20 gave higher thermal efficiency and lower specific fuel consumption then diesel fuel.

Nanbanita et al. (2014) studied about the transesterification process and factors to be effected (oil to alcohol ratio, concentration of catalyst used, temperature, stirring rate and reaction time) in the biodiesel production process. The process parameters were optimized and a maximum biodiesel yield of 94% had been achieved. They tested the properties of the biodiesel like density, flash point, calorific value and viscosity are close to the diesel. The present analysis revealed that biodiesel from refined Mahua oil was quite suitable as an alternative to diesel. Edmilson et al. (2014) produced biodiesel from Residual oils and also check the viability and degradation level of production process. Residual bovine, chicken and soybean oils were used for biodiesel production process. They used four transesterification methods, using acidic and basic catalysis and, gas chromatography with flame ionization detector (GC–FID). They concluded use of acidic catalysis at a lower temperature were the most efficient in the biodiesel production process.

Dulari et al. (2013) revealed the possibility of utilizing bioethanol obtained from Madhuca Indicaflower as an alternative fuel in a direct injection (DI) diesel engine. The following conclusions were declared by authors, the nitric oxide (NO) and smoke emissions were found to be lesser by about 4% and 20% and also the bioethanol produced from Madhuca Indica flower can be used as a potential alternative fuel replacing 5% of petroleum diesel. In addition the BMDE5 emulsion gave a better performance and lower emissions. Vaibhav et al. (2006) had studied the epoxidation of Mahua oil by using hydrogen peroxide The effects of the following parameters, such as temperature, hydrogen peroxide-to-ethylenic unsaturation mole ratio, acetic acid-to-ethylenic unsaturation mole ratio, and stirring speed, on the epoxidation rate as well as on the oxirane ring stability and iodine value of the epoxidised Mahua oil (EMO) were studied and also the effects of these parameters on the conversion to the epoxidised oil were studied and the optimum conditions were established.

3.Performance and Emission Characteristics

Navindgi et al. (2012) developed an experimental study to evaluate the performance of CI engine with different blends of Mahua biodiesel under varying operating conditions. The brake specific fuel consumption and brake thermal efficiency of the engine and emissions are measured to evaluate and analyze the behavior of the diesel engine running on biodiesel at two injection pressures like 180 bar and 240 bar and temperatures of 30, 50 and 70° C. They concluded the comparison of diesel, Mahua methyl ester oil and its blends under varying operating conditions. Himangshu and Veeresh (2013) investigated on this paper is more concerned with an experimental investigation to study the diesel engine emission characteristics using Mahua oil methyl ester with the help of a three way catalytic converter with diesel exhaust fluid by running the engine in steady state conditions and also they concluded that the hydro carbon emission and nitrogen oxides emission also lower.

Sharanappa et al. (2009) investigated an engine performance such as brake specific fuel consumption, brake specific energy consumption and exhaust gas temperature and emissions (CO, HC and NO_x). Brake specific energy consumption decreased and thermal efficiency of engine increased when operating on 20% biodiesel than that operating on diesel. The amount of CO and HC in exhaust emission decreased, whereas NO_x increased with increase in percentage of Mahua biodiesel in the blends. Mahua biodiesel blended gave better result compare to diesel up to 20% without affecting the engine performance. Hifjur et al. (2013) investigated the Performance of a diesel engine with blends of biodiesel and high-speed diesel and the experiments were also conducted to assess soot deposits on engine components, such as cylinder head, piston crown, and fuel injector tip, and addition of wear metal in the lubricating oil of diesel engine when operated with the biodiesel blend (B10) for 100 h. Various fuel properties of MO, SRO, MSO, biodiesel obtained from this mixture of oils, and its blends with HSD (B10 and B20) were determined as per the ASTM standards.

Santhosh et al. (2013) discussed the Mahua oil and mixed with diesel from 15%, 25%, 35% & 45% of volume in running diesel engine. Biodiesel was extracted by transesterification process of Mahua oil with methyl ester in presence of magnesium phosphate as catalyst. Exhaust Gas Temperature emissions& emissions (CO, HC, NO_x & CO_2) were measured and to evaluate the power output, brake thermal efficiency and specific fuel consumption. The brake thermal efficiency for biodiesel in comparison to diesel engine is a better option for part load. The specific fuel consumption for the Mahua oil in the blend is more than 25% of diesel. Santhanakrishnan et al. (2013) conducted an experiment to measure specific fuel consumption, brake thermal efficiency and hydrocarbon emission. Biodiesel was extracted by transesterification process of Mahua oil with methanol in presence of sodium hydroxide as catalyst. Using biodiesel in diesel engine, it would decrease the engine's efficiency and increase the specific fuel consumption which could be overcome by using ceramic coatings in engine. Due to coating, the brake thermal efficiency of low heat rejection biodiesel engine was 13.41% higher at maximum load condition compared to conventional biodiesel engine. The specific fuel consumption of biodiesel blend in low heat rejection engine was 10.41% higher at maximum load condition. The unburned hydrocarbon emission of biodiesel blend in low heat rejection engine is 17.1% lower than the conventional engine at maximum load.

Shruthi and Rahul (2013) studied the combustion and performance characteristics fuelling with various blends of Mahua oil biodiesel (20%, 40% and 60%) in single cylinder DI engine at constant speed of 1500 rpm. The delays were consistently shorter for M100, varying between 9.9° and 6.2° crank angle lower than diesel with the difference increasing the load. However, further research and development on the additional fuel property measures, long-term run and wear analysis of biodiesel fueled engine was also necessary along with injection timing and duration for better combustion of biodiesel in diesel engines. Swarup and Bhabani (2014) concluded that the brake thermal efficiency and exhaust gas temperature increases and the specific fuel consumption was reduces with reduce the percentage of additive in all the test fuels. Emissions of CO, HC, smoke and NO_x decrease with increase in mixing percentage in the biodiesel fuel. Kapilan et al. (2009) prepared Mahua oil biodiesel from Mahua oil by transesterification using methanol and potassium hydroxide. They compared the fuel properties of MOB with the diesel and ASTM standards. It was close to the diesel and ASTM standards. They found the low CO, HC and smoke emissions from the MOB, B5 and B20 blends compared to diesel. The B5 and B20 blend results in higher efficiency as compared to diesel fuel. The B5 blend results in higher efficiency than the B20 blend. Sukumar Puhan et al. (2005) used Mahua oil methyl esters as biodiesel. They found Brake thermal efficiency of Mahua Oil Ethyl Ester (26.36%) was higher than diesel (26.42%). Emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and Bosch smoke number were reduced around 58, 63, 12 and 70%, respectively, in case of MOEE compared to diesel. Based on this study, MOEE can be used a substitute for diesel in diesel engine.

Lakshmikanth and Arunkumar (2013) conducted experiment with the help of Mahua oil biodiesel and its 50% blend with diesel in four strokes, direct injection compression ignition diesel engine. The performance tests are carried out in short term engine. The performance characteristics of different blends were predicted and compare with diesel. The performance test concluded the fuel consumption and exhaust gas temperature were maximum for Mahua oil biodiesel and its blends and also it showed the break thermal efficiency was lower than diesel. Hence, without any modification the engine operated well in Mahua biodiesel. Ratnakara et al. (2009) investigated experimentally on a single cylinder for variable compression ratio in C.I engine using Mahua oil as the fuel. The experiments were done at standard test conditions of about 70°c cooling water temperature and at a uniform speed of 1500rpm for 7 various compression ratios(13.2,13.9, 14.8, 15.7, 16.9, 18.1and 20.2). The performances as well as exhaust analysis were done to find the exact compression ratio. The results concluded that 15.7 compression ratio is the best for Mahua oil. It also shows the thermal efficiency is maximum and also fuel consumption and the exhaust gas temperatures were minimal at this compression ratio.

Sundheer Nandi (2013) studied the performance characteristics of transesterified Mahua oil diesel blends. The thermal efficiencies of transesterified Mahua oil were higher at 25% diesel blends. The cost of transesterified Mahua oil was low compared to the cost of diesel. They found Mahua oil blended with diesel was more economical and best alternate for diesel fuel. Sitaramaiah et al. (2013) produced Mahua oil biodiesel by considering various parameters for esterification and transesterification process at optimal experimental condition. The experiment were carried out in diesel engine, the Mahua methyl ester’s performance, emission and combustion characteristics were analyzed and the results were compared with diesel fuel. The result clearly showed that there was an increase in brake thermal efficiency and brake specific fuel consumption is minimized. CO, HC and NO_x emission were considerably reduced as compare to diesel. In addition the analysis concluded the blend B20 gives optimal performance than other blends. Eman and Cadence (2013) investigated characteristics of biodiesel produced from palm oil via base catalyst transesterification process. To find the optimum yield value of biodiesel ,three important parameters were selected such as reaction temperature 40, 50, and 60 °C, reaction time 40, 60 and 80 and methoxide ratio 4:1, 6:1 and 8:1.By conducting the experiments the optimum yield value 88% was achieved by the parameters such as reaction temperature 60^{0}c ,reaction time 40minutes and methoxide ratio 6:1.from the optimum yield value, the physical properties were calculated like, density is 876.0 kg/m3, kinematic viscosity of 4.76 mm2/s, cetane number of 62.8, flash point of 170 °C, cloud point of 13°C. The produced biodiesel had similar properties of ASTM D 6751, and EN 14214.

Narinder singh et al. (2013) investigated the characteristics and emission performance of Mahua oil with different blends of ethanol contains 5, 10 and 15 percent, its volume denoted in M5, M10 and M15 respectively. The experiment was conducted on single cylinder CI engine to study brake horse efficiency, brake specific fuel consumption and brake thermal efficiency under load condition. The experimental results of BHP increased with increase in % of ethanol and M5 it was maximum. The specific fuel consumption increased with increase on more Mahua oil blend. Emission of carbon monoxide is high in the Mahua oil biodiesel but it can be reduced by addition of ethanol. Emission of smoke quantity were high in full load, it was controlled by adding blends at high loads. Haiter Lenin et al. (2013) analyzed the performance, emission and combustion behavior of Mahua methyl esters and its blends with diesel as fuel in diesel engine. The performance tests were carried out for various ratios such as 25% and 50% of Mahua methyl ester fuel blends at different loading conditions. The test result showed that brake thermal efficiency, smoke density and NO_x were higher than that of diesel. There was no change in CO_2 emissions; HC and CO emissions were drastically reduced compared to the diesel engine. The carbon release from the engine was minimized which control the environmental pollution. The result also concluded that the B25 fuel was optimized alternative fuel for diesel engine.

Solaimuthu et al. (2012) compared the Mahua oil and its different blends with diesel to investigate the engine performance, combustion and emission characteristics in four stroke tangentially vertical single cylinder kirloskar 1500 rpm direct injection diesel engine. The experiment was performed at various static injection timings of 19°, 20°, 21°, 22° and 23° bTDC with nozzle opening pressure of $250x10^5 N/m^2$. This investigation showed that B25 fuel was best one to replace diesel at an injection timings of 20° which also save 25% of petro-diesel. Chandrakasan and Palanisamy (2011) explained the effect of injection timings on performance, combustion and emission characteristics in diesel engine. They conduct he test in uniform ignition pressure of 220 bar and various injection timings about 22°, 23° and 24° at optimal load conditions. The result concludes that the B25 at an injection timing of 22° gives high performance almost equal to pure diesel which also saved 25% of fuel consumption. In addition the emission of HC, CO and NO_x was reduced.

Sukumar puhan et al. (2005) analysed the performance and emission characteristics of Mahua oil methyl, ethyl and butyl ester in four stroke DI diesel engine. The experimental result showed that the methyl ester have high thermal efficiency compared to all other ester and diesel. NO_x emission was lower in ethyl ester than other ester. When compare to diesel fuel, CO and NO_x emission were lower for MOME, MOEE, MOBE but CO_2 emission was slightly high than diesel. This paper concluded that MOME was the best alternate fuel for diesel than other esters. Senthil and Thundil (2013) experimentally investigated the effect of fuel injection timing and in-take air temperature using pure ethanol blend biodiesel fuel which was done in four stroke, DI diesel engine. The tests were carried out at constant speed (1500 rpm) and load (2 kW) at 1.1 bar intake manifold pressure with various injection timing such as 12, 15, 18, 21 and 24 CA bTDC and inlet temperature 40 ºC and 60 ºC. The test concluded that when there was advancing in injection timing result in maximizing in-cylinder pressure, temperature, heat release rate and NO_x emission. It also showed that increase in inlet temperature reduce the CO and HC emission.

Lokanadha and Appa rao (2013) conducted experiments on DI diesel engine with neat diesel, Mahua oil methyl ester (MOME) and MOME with dimethyl carbonate and they concluded that the Mahua oil methyl ester (MOME) is blended with viscosity improver DMC to decrease the viscosity. In addition the heat release curves and the combustion pressure curves indicate smoother combustion in case of 6% DMC additive. Compared to diesel the emissions are considerably reduced the HC emission reduced by 11.6 % for 6 % DMC blend with Mahua oil methyl ester.

4.Conclusion

From the study of literature reviews, Mahua oil biodiesel was one of the better alternatives to mineral diesel as fuel in compression ignition engine. And also the review shows that transesterification process is the best and most popular way to produce the biodiesel. The efficiency and quality of biodiesel are significantly higher than the conventional fuels. The characteristic of emission like NO_x, CO and other toxic smokes can be reduced by Mahua oil biodiesel. Great demands, unstable price, non biodegradability are the major issues for the current conventional fuels. For such kind of problems, the people think about the alternative sources. Today, biodiesel is an non-toxic, increasingly attractive, biodegradable and shows the good replacement to fossil fuel.

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