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Extraction and Use of Non-Edible Oils in Bio-Diesel Preparation with Performance and Emission Analysis on C.I. Engine

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Abstract:- The present study covers the various aspects of bio-diesel fuel derived from jatropha curcas and pongamia pinnata. Different methods of oil extraction techniques, processing and standardization have been described. Finally results on engine performance and emission have been presented to justify the potentiality of the straight vegetable oil as well as the biodiesel blends as alternative compression ignition engine fuel.

Keywords:- Oil extraction engines, Bio –diesel production method, CI engine**.**

I. INTRODUTION

Bio diesel is an alternative to conventional diesel fuel mode from renewable sources, such as non-edible oil. The oil from seeds such as Jatropha and Pongamia can be converted to a fuel commonly referred as Biodiesel. It can be mixed with Petroleum – based diesel in any proportion. Diesel fuel has an essential function in the industrial economy of a developing country and used for transport of industrial and agricultural goods and operation of diesel tractors and pump sets in agricultural sector. The requirement of petrol diesel in India is expected to grow from 39.815 MMT in 2001-02 to 90 MMT in 2014-15. The domestic supply of crude oil will satisfy only about 22% of the demand and the rest will have to be met from imported crude [1]. This has stimulated recent interest in alternative sources to replace petroleum-based fuels. Of the alternative fuels, bio-diesel obtained from vegetable oils holds good promises as an eco friendly alternative to diesel fuel [2].

Vegetable oil is a promising alternative fuel for CI engine because it is renewable, environment friendly and can be produced in rural areas. The use of non-edible vegetable oils compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and they are too expensive to be used as fuel at present.

The term, bio-diesel, was first introduced in the United States during 1992 by the National Soy Development Board (presently National Biodiesel Board), which has pioneered the commercialization of biodiesel in the USA [3].Bio-Diesel is essentially sulfur free and engines fueled with biodiesel emit significantly fewer particulates, hydrocarbons, and less carbon monoxide than those operating on conventional diesel fuel. Emissions of No, however are slightly higher than those of diesel engines operating on conventional diesel fuels [4].The use of non-edible vegetable oils as, compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and they are too expensive to be used as fuel at present. Many researchers are working on non edible oils of jatropha curcus, pongamia pinnata and mesua ferrea seeds for the production of biodiesel.

II. OIL EXTRACTION TECHNIQUES

There are so many investigations on oil extraction techniques for non-conventional feed stocks of oils have done in last few years. Foidl et.al [11] used one screw press to extract the oil from jatropha seeds. Kpikpi [12] has reported that solvent extraction with n-hexane could produce about 41% yields by weight of oil per kg of the jatropha seed. Shah et.al [13] used combination of ultrasonication and aqueous enzymatic method to extract oil from jatropha curcus seed kernels.

A. Mechanical Presses

The technique of oil extraction by using mechanical presses is most conventional one. But oil extracted by mechanical presses needed further treatment of factorization and degumming. One more problems associated with conventional mechanical presses is that their design is suited for some particular seeds, and yield affected for other seeds.

B. Solvent Extraction Technique

It is the technique of removing one constituent from a solid by means of a liquid solvent also called leaching. The process may be employed either for the production of a concentrated solution of a valuable solid material or in order to free an insoluble solid, such as pigment from a soluble material with which it is contaminated. In this process, a chemical solvent such as n-hexane is used to saturate the crushed seed and pull out the oils. After completion of the extraction process the solvent is condensed and reclaimed.

C. Hot Water Extraction

In this method water bath used for extraction of the oil. The crushed seeds are mixed with the solvent and taken in a beaker, which has incubated in the water bath at a fixed temperature for fixed period of time. Agitation provided externally for same period of time. After completion of the desired time interval, the beaker has allowed to stand at room temperature. The heavier crushed seeds settle down in the beaker and clear mixture of oil and hexane has separated by filtration process.

The mixture of solvent and oil, taken in a round-bottomed flask has kept on the hot plate/heating mantle. The flask has been fitted to the distillation apparatus. Because the solvent has a lower boiling point then the oil, it gets evaporated leaving behind oil in the flask. The solvent gets condensed back and has thus reclaimed. The advantage of this process is that, it has taken leaser time than soxhlet apparatus. The disadvange of this process is that, it requires filtration and recovery of solvent lesser than the soxhlet apparatus.

D. Soxhlet Extraction

In comparison to water bath, improved oil yields were obtained using an ingenious device called a soxhlet apparatus. This apparatus allows extraction of oil from the seed samples using the distillation extraction method. In the Soxhlet apparatus (also called extractor, or chamber), the sample soaks in hot solvent that is periodically siphoned off, distilled and returned to the sample. The process continues until the siphoned-off solvent becomes clear. The advantage of soxhlet apparatus over hot water extraction is that, there is no filtration necessary and oil yield is better then hot water extraction process. Hexane is the solvent most commonly used in the solvent extraction technique because of its relatively low cost and low toxicity.

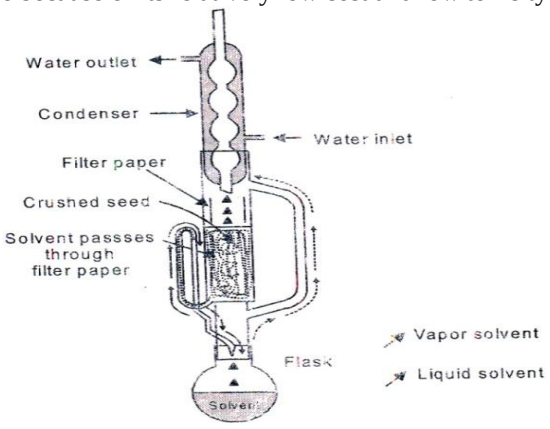

Fig. 1. Soxhlet Apparatus

E. Ultrasonication Technique

In this process an ultrasonic water bath has used. A flask or a test tube containing the crushed seeds and solvent has partially immersed in the bath. This has then subjected to ultrasonic vibrations. Ice may be added to prevent the apparatus from overheating. Colloid formation has an indication of extraction of oil from the seeds in the solvent. This method depends upon the surfactant solution, operating temperature and degassing of the solution.

F. Enzymatic Oil Extraction Technique

Enzymatic oil extraction technique has emerged as a promising technique for extraction of oil. In this process suitable enzymes are used to liberate oil from crushed seeds. Its main advantages are that it is environment friendly and does not produce volatile organic compounds as atmospheric pollutants. One disadvantage associated with this technique is the long process time which is necessary for enzymes to liberate oil bodies.

III. METHOD OF BIO-DIESEL PRODUCTION

There are so many investigations on bio-diesel production of non-conventional feedstocks of oils done in last few years. Ramadhas et.al. [3] Described various methods by which vegetable oils can be used in CI

engines. Overview of transesterification process to produce biodiesel is given for introductory purpose. It is reported that enzymes, alkalis, or acids can catalyze process and alkalis result in fast process.

Barnwal and Sharma [14] give theoretical knowledge of catalyzed and supercritical method of transesterification process to produce biodiesel. It is mentioned that catalyzed process is easy but supercritical method given better result. Usta et al. [15] produced a methylester bio-diesel from a hazelnut soap-stock (45-50% free fatty acids) and waste sunflower oil mixture using methanol, sulphuric acid and sodium hydroxide in a two stage process and found satisfactory results.

Adaptation of the vegetable oil as a CI engine fuel can be done by four methods [1, 14]; pyrolysis, Micro emulsification, Dilution, and Transesterification.

A.Pyrolysis

The pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. The liquid fractions of the thermally decomposed vegetable oils are likely to approach diesel fuels. The pyrolzate had lower viscosity, flash point, and pour point then diesel fuel and equivalent calorific values. The cetin number of the pyrolyzad vegetable oils contain acceptable amounts of sulfur, water and sediments and give acceptable copper corrosion values but unacceptable ash, carbon residual and pour point. Depending on the operating conditions, the pyrolysis process can be divided in to three subclasses: conventional pyrolysis, fast pyrolysis and flash pyrolysis. The mechanism of pyrolysis of triglycerides was given by Schwab et al. [16].

B.Micro-emulsification

The formation of micro emulsion is one of the potential solutions for solving the problems of vegetable oil viscosity. Micro emulsions are defined as transparent, thermodynamically stable colloidal dispersion. The droplet diameters in micro emulsions ranges from 100 to 1000 A. Micro emulsion can be made of vegetable oils with an ester and dispersant (co solvent), or of vegetable oil, and alcohol and a surfactant and a cetane improver, with or without diesel fuels. All micro emulsions with butanol, hexanol and octanol met the maximum viscosity requirement for diesel fuel. The 2-octanol was found to be an effective amphiphile in the micellar solubilization of methanol in triolein and soybean oil [17].

C. Dilution

The dilution of vegetable oils can be accomplished with such material as diesel fuels, solvent or ethanol. Dilution results in reduction of viscosity and density of vegetable oils. The addition of 4% ethanol to diesel fuel increases the brake thermal efficiency, brake torque and brake power, while decreasing the brake specific fuel consumption. Since the boiling point of ethanol is less than that of diesel fuel, it could assist the development of the combustion process through an unburned blend spray [18].

D.Transesterification

The transesterification is the method of biodiesel production from oils and fats and can be carried
a.Catalytic Transeserifiation.
b.Suptercritical Methanol transeserificaiton.

E.Catalytic Transesterification

The “Catalytic Transesterification” process is the reaction of a triglyceride (fat/oil) with an alcohol in the presence of some catalyst to form esters and glycerol. A triglyceride has a glycerin molecule as its base with three long chain fatty acids attached. The characteristics of the oil/fat are determined by the nature of the fatty acids attached to the glycerin. The nature of the fatty acids can in turn affect the characteristics of the bio-diesel.

F.Super Critical Transesterification

The simple transesterification processes discussed above are confronted with two problems. i.e. the processes are relatively time consuming and needs separation of the catalyst and saponified impurities from the biodiesel. The first problem is due to the phase separation of the vegetable oil/alcohol mixture, which may be dealt with by vigorous stirring. These problems are not faced in the supercritical method of transesterificaiton. This is perhaps due to the fact that the tendency of two-phase formation of vegetable oil/alcohol mixture is not encountered and a single phase is found due to decrease in the dielectric constant of alcohol in the supercritical state (at 340 C and 43 MPa). As a result, the reaction was found to be complete in a very short time within 2-4 min. Further, since no catalyst is used, the purification on biodiesel is much easier, trouble free environment friendly.

IV. EXPERIMENTAL INVESTIGATION

The use of non-edible vegetable oils as compared to edible oils is very significant in developing countries because of the tremendous demand for edible oils as food and they are far too expensive to be used as fuel at present. In the present investigation, oil of pongamia pinnata has extracted by solvent extraction technique and the diluted and transesterified non-edible oils of pongamia pinnata and jatropha curcus have been considered as a potential alternative fuels for CI engines. Based on various experimental results a comparative study of both the oil varieties has been presented.

To compare the fuel potential of non-edible oils of pongamia pinnata and jatropha curcus as a substitute of petrodiesel various experiment were performed by standard methods. The details of all experiments performed in this study are described in the following subsections.

A.Solvent Extraction Technique

Soxhlet extraction gives the total oil content of the non-edible seeds [19]. With this aim, extractions were carried out for different seeds to solvent ratio. Seeds were seprated from stems and kernel manually and dried for 48 hours at 105^0C. Then they were milled, sieved by particle size $\left(d < 0.4mm\right)$ and kept in a deciccator until use.

The required amount of seeds sample are loaded into a thimble and placed into the extractor and subjected to heating. The vapors rise through the vapor arm and into the reflux condenser. Hot solvent condenses and drops on to the seed thereby soaking the oil from the seeds. Eventually a siphon arrangement draws the saturated solution away so that a fresh batch of solvent can further extract the oil from the seeds. In this way the maximum amount of soluble material can be extracted. Each time the process is repeated, the color of the solvent become smore concentrated because more oil is being extracted from the solid mass. Completion of the process is indicated by the decrease in the intensity of color of the recirculated solvent in the siphon.

B.Dilution and Catalytic Transesterification

Dilution or blending of vegetable oils with alcohol or petrodiesel brings their viscosity close to the petrodiesel specifications [20]. Therefore, the pongamia pinnata and jatropha curcus oil were diluted with petrodiesel in different proportions to reduce their viscosity close to that of the diesel fuel. Simple mixing gives homogeneous and stable mixture for all blends of SVO and petrodiesel.

The “catalytic transesterificaiton” process is the reaction triglyceride (fat/oil) with an alcohol in the presence of acidic, alkaline or lipase as catalyst to form mono alkyl ester (i.e. biodiesel) and glycerol.

It is reported [21] that alkaline catalyzed transesterificaiton is fastest and require simple setup therefore, in current study the SVO of pongamia pinnata and jatropha curcus were transesterified with methyl alcohol in the presence of strong alkaline sodium hydroxide catalyst in a batch type transesterification reactor (shown in Fig.2).

To prepare biodiesel from SVO of pongamia and jatropha, first the sodium hydroxide was added in to the methyl alcohol to form sodium-methoxide, simultaneously oil was heated in a separate vessel to remove moisture. Moisture free oil was kept in to the inner vessel of transesterificaiton reactor, and subjected to heating and stirring. When kept temperature of the oil reached at 60` C then Sodium methoxide was mixed into the oil and reaction mixture was stirred for more than one hour until separate of glycerol is not started. Separation of glycerol was checked by taking a small sample of reactant in test tube. When separation of glycerol started than stirring was stopped and reaction mixture was transferred to a separate container. After 8 hours reaction mixture was separated into the methyl esters as upper layer and the glycerol as lower layer. The methyl esters were decanted and were washed three times will warm distilled water to remove traces of soap and other impurities. The final product was good quality biodiesel. The values of various variables of transesterification reaction of pongamia and jatropha are given in Table 1.

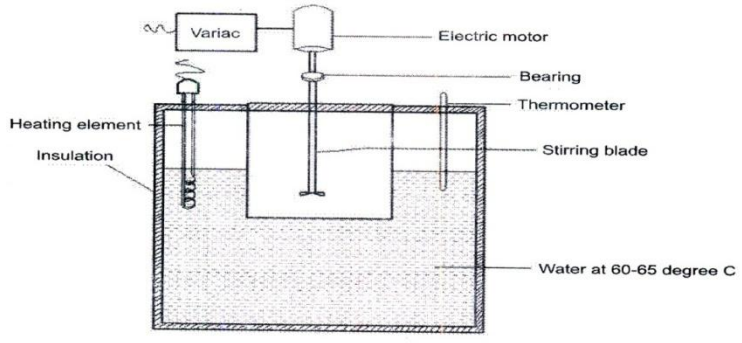

Fig. 2. Transesterification Reactor

Table 1: Variables of transeterificaiton reaction

Reaction Variable	Pongamia Pinnata Oil	Jatropha Curcus Oil
Amount of Na OH catalyst (g/litre oil)	7.3	8.1
Ratio of Methyl alcohol /oil (v/v%)	20	25
Reaction Temperature (C)	60	60
Stirring speed (Range in RPM)	350-500	350-500

C.Physical and Chemical Properties

The important fuel properties of SVO of both the verities and of their methyl ester were studies by performing various tests using standard methods. Most of the fuel properties were tested in the laboratories.

D. Engine performance and Emission Tests

The schematic of experimental setup used for the present work is shown in Fig. 3. The set up consists of a 5 HP water-cooled, direct-injection, four-stroke diesel engine coupled to a water dynamometer. The specifications of engine are given in Table 2. The fuel supply system is modified. To allow rapid switching between the petro diesel oil used as a standard and the test fuels, an additional two-way control value was used in the test rig. At each loading, the speed of the shaft was measured using a handheld tachometer. The fuel was fed to the injector pump under gravity and the volumetric flow rate was measured by noting the time taken for 50ml of fuel to flow through a graduated measuring device. The petro diesel/SVO of pongamia pinnata, petro diesel / SVO of jatropha curcus, petro diesel/pongemia pinnata methylester blends and petro diesel / jatropha curcus methylester blends were tested successfully in this set up. Test runs were also carried on certified petro diesel fuel in order to make comparative assessments. In all the cases, the engine speed was almost constant at 1500 RPM while power output was varying by external loading through hydraulic dynamometer. An infrared exhaust gas analyzer was used for the measurement of CO and HC % in exhaust gases for Petro diesel, B15, and B20 fuel of Pongamia Pinnata and Jatropha curcus methylesters.

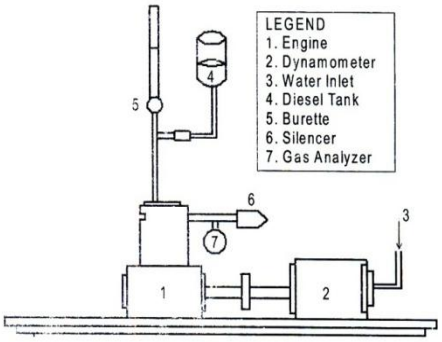

Fig. 3. Engine Set-up

Table 2: Specifications of engine

Manufacturer	Kirloskar
Number of cylinder	1
Power 5 HP	5HP
Stroke	110 mm
Volume displaced	553 cc
Compression Ratio	16:1
Loading device	Hydraulic Dynamometer
Cooling system	Water cooled

V. RESULTS AND DISCUSSION

Oil Extraction by Solvent Extraction Technique

Non-edible vegetable oils of Pongamia Pinnata, were extracted by solvent extraction technique in the laboratory. Effect of contact time, temperature, ultrasonication time, ultrasonic frequency, and seed to hexane ratio, particle size and oil recovery was studied and is discussed below.

A Effect of Contact Time of the oil Yield

On immersing the seeds in solvent at fixed temperatures for different contact time effect resulted in different oil yields. It has ranged from 17-19% (ml/w) (Table 3). The best result (19% ml/w) was obtained at 120 min. after 120 min equilibrium stage has reached and no more oil extraction takes place.

Table 3. Effect of contact time on the oil yield

Seeds s	Solvent	Seed solvent	Temperature of water bath (C)	Contact time (min)	Oil yield (ml)	Oil yield (% ml/w)
50	300	1.6	75	30	8.50	17.0%
50	300	1.6	75	60	9.00	18.0%
50	300	1.6	75	90	9.25	18.5%
50	300	1.6	75	120	9.50	19.0%
50	300	1.6	75	150	9.50	19.0%

B. Effect of Temperature of Water Bath on the oil yield

On immersing the seeds in solvent at various temperatures of water bath for fixed time period resulted in different oil yields. It ranged from 13-19% (ml/w) (Table 4). The best results (19% ml/w) was obtained at 75` C. Result show that low temperature of water bath gives less amount of oil yield and extraction rate continuously increases with temperature. After 75` C extraction the rate is not increasing because of the boiling point of solvent is 65` C and recovery of solvent reduced.

Table4. Effect of temperature of water bath on the oil yield

Seeds s	Solvent	Seed solvent	Temperature of water bath (C)	Contact time (min)	Oil yield (ml)	Oil yield (% ml/w)
50	300	1.6	35	120	6.50	13.0%
50	300	1.6	45	120	7.75	15.5%
50	300	1.6	55	120	8.50	17.0%
50	300	1.6	65	120	9.25	18.5%
50	300	1.6	75	120	9.50	19.0%

C. Effect of Seeds to Solvent on the Experimental Time

Seed to hexane ratio has been found to be a critical parameter when using the Soxhlet apparatus for solvent extraction technique. Keeping temperature constant, the seed to hexane ratio was varied and the oil yield ranged from 30-31% (ml/w) (table 5). This is somewhat higher than the yield obtained by simple solvent extraction technique like hot water extraction and ultrasonication. The best result (31% ml/w) oil yield was obtained at 1:6 (seed: hexance). Additional solvent (say 1:8) does not improve the oil yield but it can reduce the time duration of the process and also improve the color ness of oil. More amount of solvent gives light color of oil. [22]

Table 5. Effect of seeds to solvent on the experimental time

Seeds s	Solvent	Seed solvent	Temperature of water bath (C)	Oil yield (ml)	Oil yield (% ml/w)
50	200	1.4	72	15.0	30.0%
50	250	1.5	67	15.0	30.0%
50	300	1.6	60	15.5	31.0%
50	350	1.7	54	15.5	31.0%
50	400	1.8	51	15.5	31.0%

F.Physical and Chemical Test Results

The results of tests for various physical and chemical properties of different fuels are presented in Tables 6 to 9. The fatty acid composition of vegetable oils can affect fuel properties of biodiesel therefore fatty acid compositions of pongamia and jotropha oil were studied and results are shown in. It can be observed from that vegetable oil of pongamia and jotropha have high percentage of unsaturated fatty acid. Unsaturated character of fatty acid will result in gum formation when vegetable oil will come in contact to atmospheric oxygen. Saturated fatty acid methyl estaers increases the cloud point, cetane number and improve stability whereas more poly-unsaturated fatty acid ester reduces the cloud point. Cetane number and stability.

Table 6. Fatty acid distribution of pongamia pinnata and Jotropha curcus SVO [23,24]

Fatty acid	Structure and molecular wt.of fatty acid	Fatty acid % by weight for pongamia pinnata oil	Fatty acid % by weight for jatropha curcus oil
Capric	C10:0	--- (172)	0.1

Myristic	C14:0	--- (228)	0.1
Palmitic	C16:0	3.7-7.9 (256)	15.1
Stearic	C18:0	3.7-7.9 (284)	7.1
Arachidic	C20:0	--- (326)	0.2
Behenic	C22:0	--- (354)	0.2
Lignoceric	C24:0	1.1-3.5 (368)	---
Palmitoleic	C16:1	--- (254)	0.9
Oleic	C18:1	44.5-71.3 (282)	44.7
Linoleic	C18:2	10.8-18.3 (280)	31.4
Lenolenic	C18:3	--- (278)	0.2

It is noticed from Table 7 that petrodiesel is having low viscosity (2-5 cSt) whereas viscosity of SVO of pongamia pinnata and jatropha is 15.2 cSt and 52.76 cSt respectively (very high for a CI engine fuel). The value of viscosity of pongamia pinnata methylester is 5.75 cts and for jatropha curcus ethylester the value is 6.7 cSt. It shows that viscosities of methylesters of pongamia pinnata and jatropha curcus oil are comparable to petrodiesel specification. The specific gravity and calorific values of pongamia pinnata oil and its methyl ester are compatible with petrodiesel but jatropha curcus oil and its methylester have higher specific gravity as compare to petrodiesel. One can also observed that pongamia pinnata oil, jatropha curcus oil and their mathylesters have higher flash point than petrodiesel which makes sure that SVO and of their methylesters blend with petrodiesel will improve flash point of petrodiesel and can be transported with less hazard.

Table 7. Physical and chemical properties of different SVO, methylesters and certified diesel

Properties	Pongamia pinnata oil	Methyl ester of pongamia pinnata oil	Jatropha curcus oil	Methyl ester of jatropha curcus oil	Petrodiesel
Viscosity (cSt) at 30^0 C	15.2	5-75	52.76	6.7	2-5
Flash pint, ^0C	205	110	240	126	35-50
Specific gravity at 30^0C	0.870	0.865	0.932	0.890	0.830-0.850 42,000,46,000
Calorific value, (kj/kg)	37.225	36.540	39.774	38.584	

The effects of dilution of vegetable oils with petrodiesel were studied and results are shown in (Table 8). It can be observed that blends up to 10% SVO are having viscosity comparable to petrodiesel. Even 30% SVO blend shows almost 50% reductions in viscosity. Thus blends up to 30% can be considered for thermo-mechanical study. Variation in density for up to 30% blend is very less and comparable to petrodiesel. One can also observe that calorific value of blends decreases with increase in percentage of SVO. However, these variations are low compared to petrodiesel up to 30% blend.

Table 8 Physical and Chemical properties of SVO-Petro diesel blends

SVO Petrodiesel	**Properties of blend of SVO of Pongamia pinnata and Petrodiesel**			**Properties of blends of SVO of Jatropha surcus and Petrodiesel**		
	Viscosity (cSt)	**Specific gravity**	**Calorific value (kj/kg)**	**Viscosity (cSt)**	**Specific gravity**	**Calorific value (kj/kg)**

5	3.23	0.832	41256	4.21	0.851	41624
15	4.83	0.840	41180	5.41	0.861	41415
20	5.41	0.843	41063	6.23	0.867	43289
25	6.15	0.846	40904	8.21	0.873	42731
30	7.42	0.851	70577	9.15	0.881	42413
50	12.3	0.872	39745	15.20	0.890	41162

The fuel properties of pongamia and jatropha biodiesel blends with petrodiesel were determined and results are shown in (Table 9). It can be observed from these results that 15% and 20% blends of pongamia pinnata and jatropha curcus methylester. (i.e.B15 and B20) have density, viscosity, and pour pont and Cu strip corrosion within specified limits for petrodiesel. The improvement in cetane index and flash point can also be observed. The most valuable results is reduction in percentage of total sulphur that will results in reduction of SO_x is exhaust gases which is one of the reasons of acid rain.

Table 9.comparison of physical and chemical properties of B-15 and B-20 with diesel

Sl.No	Properties	Petrodiesel	Jatropha curcus		Pongamia pinnata	
			B15	B20	B15	B20
1.	Density (g/cc at 15^0 C)	0.820-0.870	0.862	0.868	0.849	0.857
2.	Kinematic viscosity (cSt at 40^0 C)	2.0-5.0	3.67	3.68	3.29	3.73
3.	Total sulphur (% Wt.)	0.25 max /0.20 (defense)	0.034	0.023	0.036	0.036
4.	Pour point (^0C)	+6 max (Nov-Jan.)	+4	+4	+6max (Nov.-Jan)	+6max (Nov.-jan)
5.	Cetene Index	43 min	45	46	46	48
6.	Copper strip Corrosion (3 hrs. at 100^0C)	Not worse Than one	2-A	2-A	1-A	1-A
7.	Flash point (^0C)	35 min	61	66	59	65
8.	Calorific value (kj/kg)	42000-46000	42,134	40,893	42201	41868
9	ASTM Distillation (%v/v) Recovered @ 350^0C	85 min	84	85	85	84
	Recovered @ 370^0C	95 min	90	91	94	93

G.Engine performance

One 5 HP single cylinder water-cooled CI engine at rated speed of 1500 RPM was tested to check its performance under variable load condition with different blending ratio of pongamia pinnata, jatropha curcus oil, and of their methylesters with petrodiesel. The plots of performance results are shown in fig. 4 and fig. 5.

The results of variation in the specific Fuel consumption (SFC) with brake power for 5-30% blends of SVO of pongamia pinnata and jatropha curcus and for B15 and B 20 fuel of their methylesters are plotted in Fig. 4. For comparison, results with petrodiesel as standard fuel are also plotted. Results show that fuel consumption increases with increase in percentage of SVO of pongamia pinnata and jatropha curcus in blends. This is mainly due to the combined effects of the relative fuel density, viscosity and hearting value of the blends. However, at higher load fuel consumption is comparable to petrodiesel for up to 30% SVO blend. Blends of SVO of jatropha curcus and petrodiesel results in higher fuel consumption as compare to corresponding blends of SVO of pongamia pinnata. It can also be observed that B15 and B20 results in slight reduction in fuel consumption as compared to petrodiesel and SVO blend. Throughout the entire load range, minimum fuel consumption is obtained with B20[25].

The variation of brake thermal efficiency of the engine with brake power was evaluated for various blends of pongamia pinaa oil/petrodiesel and for B15 and B20 of both oils and results are plotted in Fig.5. it can be observed that the brake thermal efficiencies increase with brake power for all fuels. The brake thermal efficiencies of the pongamia pinnata SVO, jatropha curcus SVO blends were lower than that with petrodiesel

fuel, B15 fuel, and B20 fuel for entire range of loading. It can be noticed that B15 and B20 show increase in efficiency as compared to petrodiesel; highest efficiency is obtained with B20. The drop in thermal efficiency with increase in proportion of SVO of pongamia pinnata and jatropha curcus must be attributed to the poor combustion characteristics of the SVO's due to their high viscosity and poor volatility with subsequent higher SFC.

The increase in thermal efficiency with B15 and B20 can be attributed to 10% built-in oxygen that is present in all methylester of vegetable oils (i.e.biodiesel). extra oxygen causes better combustion inside the combustion chamber.

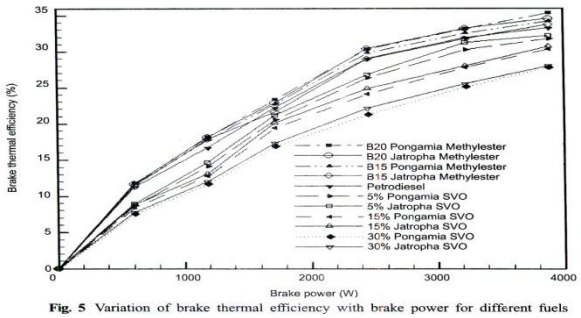

Fig. 5 Variation of brake thermal efficiency with brake power for different fuels

H. Engine Emission

The emission characteristic of the engine was studied by using an infrared exhaust for measurement of CO and HC% in exhaust gases of the engine running with petrodiesel, B15, and B20 fuel of pongamia pinnata and jatropha curcus methylesters. The emission results are pplotted in Figs. 6-7.

Emission of CO (% volume) is shown in Fig.6. it can be noticed that for petrodiesel, B15 and B20 fuels of pongamia pinnata and jatropha curcus; CO emission first decreases with increase in load and after reaching some minimum values it starts to increase in load and after reaching some minimum value it starts to increase. This behavior can be explained by the fact that at lower output, engine gets lean mixture and at a higher output, rich mixture is supplied to the engine that results in incomplete combustion and, therefore, higher % of CO. one can also notice that at low power output, CO emission is less with petrodiesel as compare to B15 and B20 fuels. However, at higher power output, Co emission reduces drastically with increasing amount of methylester. This phenomenon can be explained from the fact that at higher temperature, part of methyl esters in B15 and B20 plays significant role for better combustion of fuel due to presence of bilt-in oxygen. Results show that B15 B20 fuels of pongamia pinnata methylester gives better to higher viscosity and specific gravity of jatropha curcus methylester as compare to pongamia pinnata methylester.

The emission of Hydrocarbon (HC) in ppm is shown in Fig 7. It can be noticed that the HC emission has almost the same behavior as that of CO emission. This can be explained with the same reasoning including an additional fact of the absence of aromatic compound in methyl ester of pongamia pinnata oil. The absence of aromatic compound results in better combustion and therefore, less emission of HC. For most of the loading range the hydrocarbon emission with B15 and B20 fuels of jotropha curcus methylester is slightly higher as compare to B15 and B20 fuels of pongamia pinnata methylester [25-26].

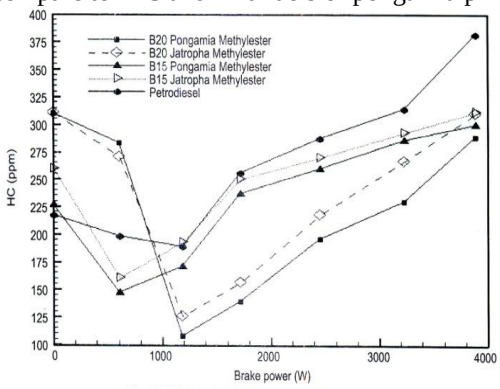

Fig. 7. Variation in HC emission with brake power

VI. CONCLUSIONS

An experimental investigation was conducted to found the suitability of pongamia pinnata and jatropha curcus oil as petrodiesel substitute. From the experimental results following conclusions were made:In case of hot water extraction, maximum amount of oil yield was obtained at the boiling point of the solvent. Operating temperature above the boiling point temperature reduces the solvent recovery.

1. Soxhlet apparatus gives better amount of oil yield and quality oil yield. The time consumption and dependence on solvent is the major drawback of this process.
2. The straight vegetable oils of pongamia pinnata and jotropha curcus have higher specific gravity; higher viscosity and low volatility as compared to petrodiesel therefore straight vegetable oil can not be used directly in CI engine.
3. Significant reduction in viscosity was achieved by dilution of straight vegetable oils of pongamia pinnata and jotropha curcus with petrodiesel in varying proportions, which can be further reduced by heating the blending.
4. The blends of both pongamia pinnat oil and jatropha curcus oil with petrodiesel were compatible with diesel oil at higher load from the perspective of engine performance.
5. Physical and chemical prosperities test revealed that the pongamia pinnata methlester and jatropha curcus methylester (B15 and B20) have almost similar or better physical and chemical properties than the diesel oil, except the viscosity which is slightly higher than that of specified range for petrodiesel fuel. Both the blends are suitable as fuel for CI engines without any engine modification.
6. Brake thermal efficiency and SFC results show improvement for B15 and B20. Thermal efficiency was found to be highest with B20.
7. Emission test shows reduction in % of CO and HC in exhaust gases for B15 and B20 fuels with respect to petrodiesel at medium and higher power output.

From all of the results it can be concluded that both pongamia pinnata and jatropha curcus oils have substantial prospects as a long-term substitutes for petrodiesel fuels. The 95% petrodiesel and 5% SVO of pongamia pinnata or jatropha curcus blend competed favorably with petrodiesel fuel and offer a reasonable substitute alotheough blend of 85% diesel and 15% SVO of pongamia pinnata or jatropha curcus can also be used without any significant loss in engine output and without any major operational difficulties.

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