EFFECT OF C-5 AND C-10 FUEL BLENDS OF EUPHORBIA CADUCIFOLIA HAINES ON IC DIESEL ENGINE EMISSIONS

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ABSTRACT

The future severe emission regulations and demand to reduce dependence on fossil fuels have led to the development of alternate fuel sources. The present experimental study was conducted to introduce Euphorbia caducifolia plant biocrude blends as new, renewable and alternative liquid fuel. The research method described the formulation of C-5 and C-10 fuel blends, physical, chemical and emission characteristics of fuel blends. The effect of C-5 and C-10 blends on internal combustion (IC) diesel engine emissions was assessed by taking diesel as control. The parameters like engine performance (thermal efficiency and fuel consumption) and emissions (NOx, CO, HC and Smoke) characteristics designed with C-5 and C-10 blends were also studied. The engine was operated at constant speed (1500 rpm) and varying loads. Results were revealed that the physico-chemical properties of the fuel blends show good resemblance with that of diesel. The performance results were shown that C-10 fuel blend has maximum brake thermal efficiency and minimum brake specific fuel consumption (BSFC) at higher loads. Similarly, the overall emission characteristics are found to be best for C-10 except NOx emission. Those following results will conclude that the C-10 E. caducifolia fuel blend can be used as alternative fuel without any modification of IC engine.

KEYWORDS: Biofuel, C-5, C-10, *Euphorbia*, emissions, IC diesel engines, Load.

I. INTRODUCTION

Renewable energy has huge potential to provide solution to increase energy crisis. It is considered as the key factor to the economic security as well as global warming (Pehan 2009). India being growing economy, its requirement for energy is also growing. Further the gap between current energy production and consumption is huge. With depleting fossil fuel reserves and concerns about its negative environmental impact, production and d use of renewable energy is the only long-term solution. India is a net energy importer and almost 80% of the country’s export earnings are directly spent for purchase of petroleum products (Sahoo et al., 2005). Further, day by day energy demand increasing due to increase in population, vehicles and industries.

Diesel engines are preferred for transportation vehicles due to their inherent advantages of better fuel economy and high part load efficiency. In addition, Internal Combustion of Diesel engine exhaust is a mixture of thousands of different gases and tiny particles. They include polycyclic aromatic hydrocarbons and metals such as nickel and arsenic (these are known causes for human cancer). Most diesel particles are small enough to be inhaled deep into the lungs, where they pose the greatest hazard. Some of the main toxic gases in diesel exhaust are nitrogen oxides, and carbon monoxide. A major research aspect in engine development is to reduce engine emissions and with the increasing concern over environmental protection and the stringent exhaust gas regulation (Rosca et al., 1997; Lapuerta et al., 2008). Several studies have already shown that diesel and biodiesel blends reduce smoke opacity, particulates, un-burnt hydrocarbons, carbon dioxide and carbon monoxide emissions, but nitrous monoxide emissions have slightly increased (Agarwal and Das 2000,Valentino et al 2010).This has forced the countries to search for alternative renewable fuel for running diesel engines.

Agarwal et al (2001) have suggested that directly biofuel can be used in diesel engines, but these have certain disadvantages of gumming, sticking of piston and cylinder due to heavier hydrocarbon chain. The viscosity of these biofuel is also more compared to that of diesel which leads to atomization and combustion problems. One way of using straight biofuel is to preheat the oil to reduce the viscosity (Agarwal et al., 2009). In this connection, the present work was focused to develop *Euphorbia caducifolia* liquid biofuel blends (C-5 and C-10) from biocrude and it introduced as new renewable and alternative fuel similar like diesel with low emission and high BTE. This work also investigates the physico chemical properties, performance and emission characteristics of C-5, C-10 blends in a single cylinder direct injection diesel engine at various loads. The measured values are analyzed and compared with diesel fuel as base fuel. *E. caducifolia* biodiesel is biodegradable, non-toxic and environmentally less contaminant, being compatible with conventional diesel fuel, has received broad attention as a replacement for diesel fuel. Also, it can be blended in any proportion with fossil-based diesel fuel to create a stable biodiesel blend (Pinzi et al., 2009).

II. RELATED WORK

A wide-range of research work has been taking part on conversion of plant biocrude in to liquid biofuel and to control emissions in IC engines. Bhatia et al 1983, 1984; Kalita and Sakia 2004; Kalita 2008 has conducted extensive screening work for the suitability of plant families such as Euphorbiaceae, Asclepiadaceae, Apocyanaceae, Urticaceae as petro crops. Plant species of the genus *Euphorbia* (family *Euphorbiaceae*) are screened as a promising, potential, and contain higher percentages of hydrocarbons and total extractables than other petro crop families on a dry weight basis (Calvin 1977, 1979; Nielsen et al 1979; Magal 1980; Bhatia et al 1988). The biocrude of Euphorbiaceae species is a mixture of hydrocarbons and hydrocarbon-like chemical fraction extracted from plants by organic solvents and upgraded to either liquid fuels or other useful chemical feedstocks (Mc Laughlin and Hoffman, 1982) and it can be converted as liquid biofuels (Bhatia et al 1983).

III. MATERIALS AND METHODS

3.1 Collection and processing of plant material

Euphorbia caducifolia Haines plant (of approximately 5-6 m height) growing in the forest areas of Nandimandalam of Kadapa district of Rayalaseema region, Andhra Pradesh, India was selected for the present study. The clumps of phylloclades were separated from the plants. Separated phylloclades were kept in paper bags and shade dried at room temperature for more than 20 days until constant mass was obtained. Dried phylloclades were milled to a sieve mesh of 2 mm size. Further the dried powder was again desiccated in incubator at 35 ^{0}C for 24 h till constant mass was obtained and stored at ambient temperature in sealed polythene bags.

3.2 Extraction of biocrude

100g of milled dry powder was individually extracted in soxahlet apparatus with 250 ml of cyclohexane separately at 35 ^{0}C for 48 h (de Lucas et al., 1999). The subsequent cyclohexane extracts were concentrated by Rota-evaporator at 35 ^{0}C under reduced pressure where the solvent extracts and residues were separated carefully and the extracts were dried at room temperature, weighed for yield per gram of dry sample. The percentage of extracts and residues of these solvents were calculated.

3.3 Conversion of biocrude to liquid fuels and formulation of C-5 and C-10 biodiesel blends

Cyclohexane biocrude was blended with diesel at 140 ^{0}C to 150 ^{0}C in chilled water circulating vortex for 5 h and the resultant was filtered through Whatmann No. 1 filter paper to remove undisclosed particles in biodiesel blends. The C-5 (5% cyclohexane biocrude and 95% diesel) and C-10 (10% cyclohexane biocrude and 90% diesel) biodiesel blends were used to study the engine performance, emissions and fuel properties in comparison with commercial diesel.

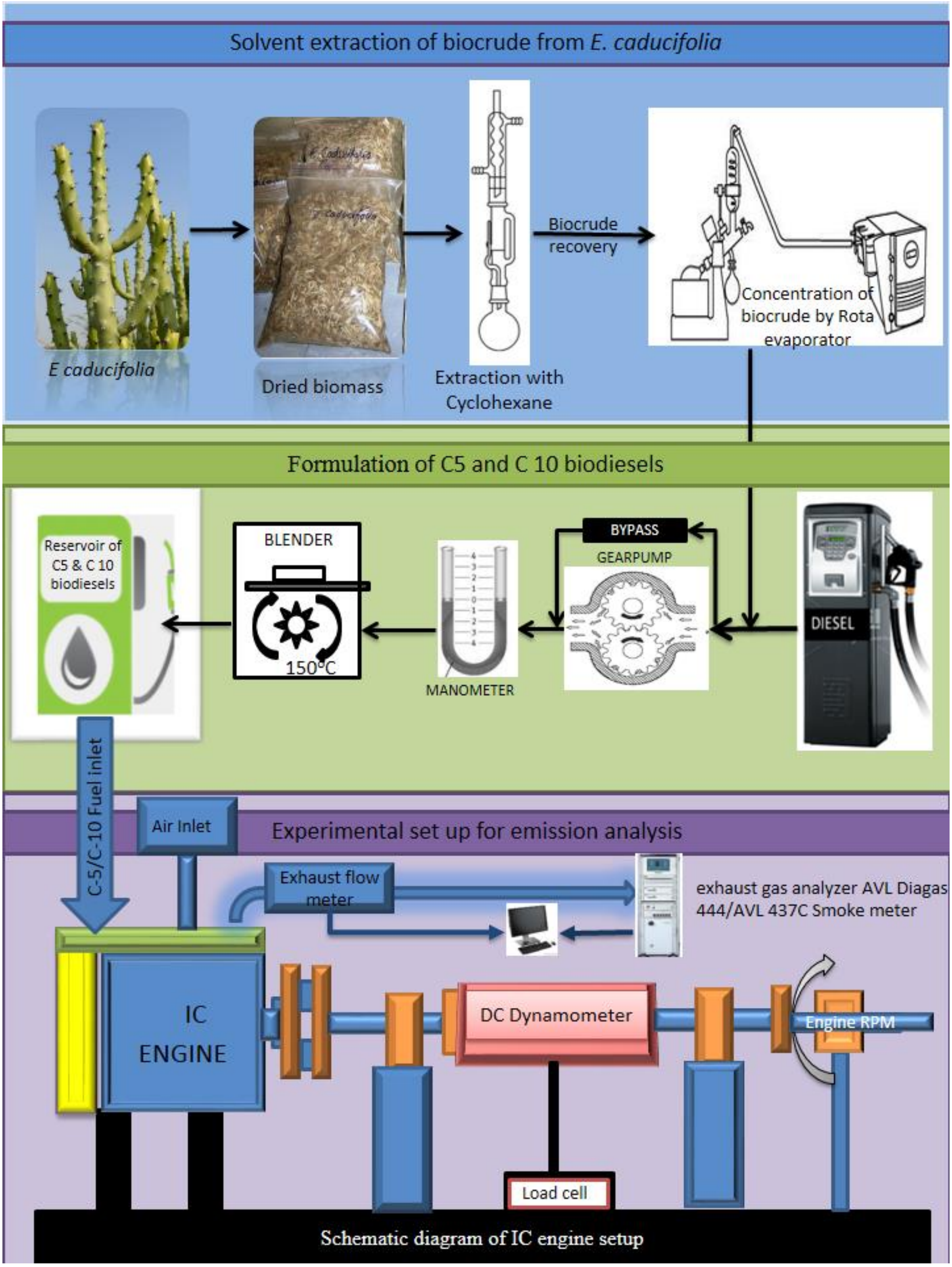


Figure 1. Schematic diagram of the biofuel extraction from E. caducifolia, formulation of C5 and C-10 fuel blends and test equipment.

3.4 Experimental set up

C-5, C-10 biodiesel blends and commercial diesel were used to test computerized single cylinder diesel engine Test Rig Legion brothers at a compression ratio of 16.7:1 and injection timing of 40^0 before TDC with a rated output of 9 kW at 1470 rpm. The performance of the engine and emissions were studied at 0%, 20%, 40%, 60%, 80% and 100% of the load corresponding to load at the maximum power at an average speed of 1500 rpm (Lapuerta et al., 2000). After engine reached the stabilizing working condition, fuel consumption, torque applied and exhaust temperature were measured from which brake specific fuel consumption (BSFC), brake thermal efficiency (BTE) were computed. The emissions such as $NO_{X,}$ CO, HC and smoke were measured using exhaust gas analyzer AVL Diagas 444 attached with AVL 437C Smoke meter (Table 2). Each reading was obtained thrice to obtain a reasonable value. The schematic experimental set up was shown in Figure1.

Table 1. Single cylinder engine (Test Rig legion Brothers) and dynometer specifications.

Engine specification	
BHP	5HP
SPEED	1500
Cylinder number	1
Compression ration	16.7:1
BORE	80 mm
Stroke	110 mm
Orifice Dia	20 mm
Type of ignition	Compression ignition
Method of Loading	Eddy current dynometer
Method of starting	Manual cracking
Method of cooling	Air
Specification of the dynometer	
Type	Eddy current
Cooling	Air
Load measurement method	Spring Balance
Max Speed	1500 rpm
Dynometer Horse Power	5 HP
Coupling type	Tyre coupling

3.5 Fuel properties of C5 and C10 biodiesel blends

The important chemical and physical properties of these blends were determined by standard methods and compared with diesel. Viscosity and density were measured by Fungilab EXPERT series Viscometer and density meter DM-300 (Lemis instrument) respectively. The calorific value of these blends was calculated by TECHED Model bomb-calorimeter. The flash point was determined by using Pensky markins flash point apparatus.

IV. RESULTS AND DISCUSSION

Euro diesel fuel (Euro) was used as a base fuel for biocrude-diesel blends in this study. The blends containing 5% and 10% biocrude by volume were called C-5 and C-10, respectively. The solubility of biocrude in diesel is mainly mediated by temperature and hydrocarbon composition of diesel (Ecklund et al., 1984). With the increase of biocrude concentration from 5% to 10 %, soluble temperature also increases and reaches the maximum of 120 ^{o}C, when biocrude content is about 10% by volume. The physico-chemical properties of C-5 and C-10 fuels were shown in Table 2.

Table2. Physico-chemical analysis of fuels

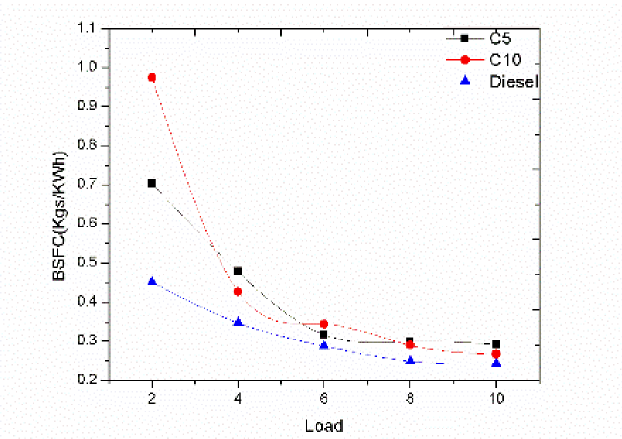
Fuel Properties	**Diesel**	**C5**	**C10**
Cetane Number	52	55.5	54
Viscosity a 40 ^{0}C [mm2/s]	3.2	3.19	3.22
Density @ 15 ^{0}C [g/cm^{3}]	0.84	0.86	0.88

Calorific value (Kj/kg)	42,500.13	42,791.40	41,463.10
Flash point	40	39	39
Fire point	72	69	65
Pour point	-120	-98	-109

Cetane number of the blends slightly decreases with increasing biocrude content in comparison with euro diesel fuel standards. Besides, the stability of the two blends is dependent on the composition of diesel and temperature. Diesel blends of C-5 and C-10, keeps stable for about 17 days in the range of temperature about 16 ^{0}C to 40 ^{0}C. As the proportion of biocrude in the blends were increases, oxygen content increases and aromatics fractions decreases, but slightly increases viscosity of C-5 and C-10 were 3.10 mm^2/s and 3.22 mm^2/s whereas density 0.86 g/cm^3 and 3.22 g/cm^3 respectively. The gross calorific value of C-5 and C-10 were ranged between 42,791.40 Kj/Kg to 41,463.10 Kj/Kg, respectively. Compared to the other Euro diesel (42,500.13), the GCV of blends from this study was slightly higher. The quality of fuel known by the amount of heat produced from a unit mass of fuel (Kj/Kg). The calorific value is also considered as an important parameter for comparing fuel with the other fuels. The amount of heat generated by fuel is dependent on the quantitative conversion of carbon and hydrogen present in the fuel, to water and carbon dioxide and is a function-chemical-elemental composition of fuel. It is also seen that biocrude improves flash and fire point and increases pour point, which can ensure good cold starting, reduced noise and long durability for diesel engines. But all these parameters are influencing to intensify the fire point of C-5 and C-10 fuel blends. However, all the blends satisfy the specifications as regards the Euro diesel.

3.6 Engine performance

The effect of C-5 and C-10 fuel blends of *E. caducifolia* on the brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) are illustrated in Figures 2 and 3, respectively.



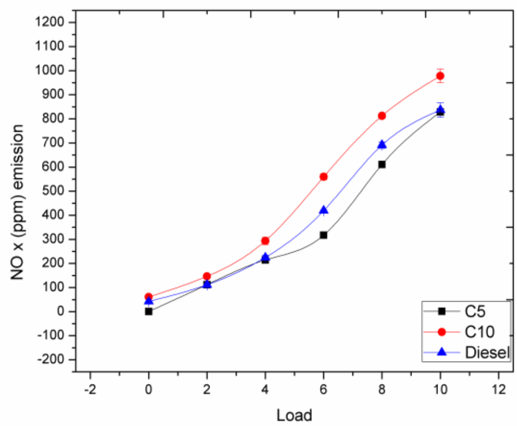


Figure 2. Variation of BSFC with load

Figure 3. Variation of BTE with load

It was observed that BSFC and BTE were slightly increased for C5 and C10 fuel blends. BSFC of C-5 and C-10 fuel blends increases by 0.252 Kgs/KWh and 0.051 Kgs/KWh respectively at initial loads of engine (2 kg) and at higher engine loads (10 Kg) for C-5 and C-10 fuel blends, it increased by 0.052 and 0.051 respectively. It represents upon increment of engine load, BSFC was reduced and engine consumes more fuel blend (C-10 and C-5) at 2 kg and 4 kg loads than reference diesel fuel. In spite of the fact that higher BSFC of fuel blends, BTE of fuel blends was found to be higher The maximum BTE of 36.4% for C-10 and. 35.75 for C-5 fuel blend, whereas the corresponding value with reference diesel fuel was found to be 33.93% at the engine load of 10 kg. The oxygen content of the fuel blends contributes higher BTE. The improvement in BTE can be referred to the enhanced oxygen content, which aids improvement in combustion, especially during the different combustion phase. Another factor that affects the BTE is cetane number. Lower cetane number of the fuel blend causes to longer ignition delay (Ying et al., 2006), thereupon a wider range fraction of fuel burned in the premixed mode, which elevates the BTE.

3.7 Effect of fuel blends/load on NOx emissions analysis

Nitric oxide (NO) and nitrogen dioxide (NO_2) are the oxides of nitrogen found in exhaust emissions. NOx emission is the hazardous part of pollutants emitted from the IC engines. The NOx formation majorly depends upon the in-cylinder temperature, the oxygen concentration and residence time for the reaction to take place (Ajav et al., 1998). The NOx emissions for diesel fuel starts at 42.6 ppm and raises up to 837 ppm at 10 kg load. But in case of C-5 and C-10 emissions starts at 62 ppm and 61 ppm at 0 kg load and raises to 828.6 ppm and 978 .33 ppm at 10 kg load respectively showed in Figure 4.

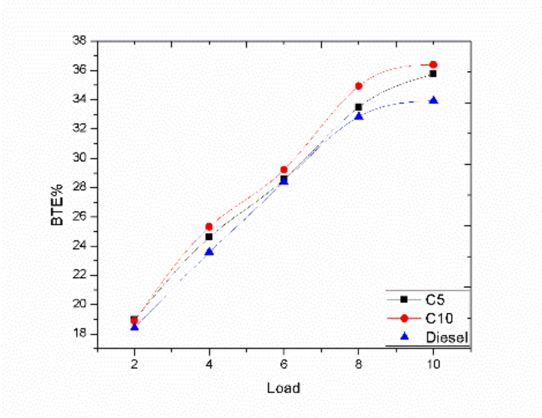


Figure 4. Variation of NOx emissions

The test results of NOx emission explores that the raising of engine loads for both diesel and fuel blends increases the NOx emission but C-5 fuel blend NOx emissions are lesser than diesel fuel, this might be due to nitrogen content in biocrude. It is also a good evidence for the presence of oxygenated components in the fuel blends has a controlled influence on the NOx emission level. But in case of C-10 NOx emission was higher than the diesel, due to high density and viscosity of fuel blend (Desantes et al., 2002), combustion was not up to the mark. The increases in NOx emissions obtained were in proportion to the concentration in biodiesel. An 8% increase was reached in the case of pure biodiesel. Schumacher et al. (1994) tested a 200kW 6-cylinder at 1200 and 2100 rpm and 50% and 100% load with 10%, 20%, 30% and 40% soybean-oil biodiesel blends. The NOx emissions increased up to 15% in the case of the 40% blend. Marshall et al. (1995) tested a Cummins L10E engine under transient conditions with diesel fuel and 20% and 30% biodiesel blends.

3.8 Effect of fuel blends/load on CO emissions

Carbon monoxide (CO) is a colorless, odorless, and tasteless gas. It is toxic to humans and animals, when encountered in higher concentrations. It reduces the blood's ability to carry oxygen.

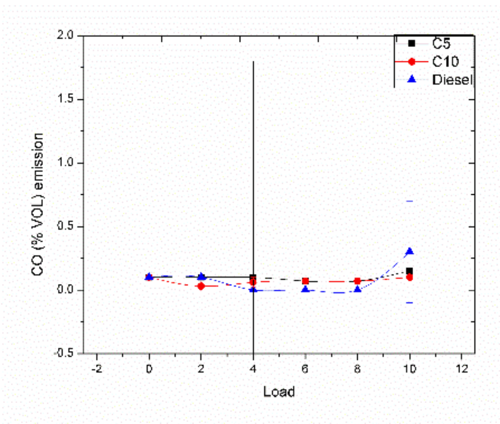


Figure 5. Variation of CO emissions with load

In contrast of environmental pollution it is having a role in the formation of ground-level ozone. CO produced from the IC engine due to partial oxidation of carbon from fuel, due to presence of less oxygen content. CO emission greatly dependent on the air-fuel ratio relative to the stoichiometric properties. The experimental results of CO emission were shown in Figure 5. It is observed that, except at higher loads (10 kg) diesel fuel emissions were maximum in comparosion with C-5 and C-10 fuel blends and the lowest emissions were given by C-10, due to presence of high oxygen content in biocrude.

3.9 Effect of fuel blends/load on HC emission analysis

The HC emission variation with varied engine loads for the fuels blends was shown in Figure 6. HC emissions showed negative trends with load, all the blends and pure diesel HC emission decreases with increase in loads. It can be noticed that the HC emission for C-10 is showed a drop in the range of 20.6 ppm to 11.6 ppm at 4 kg load, but frequently rises to 21 ppm at 10 kgs load. Also, for C-5 it drops by 22.3 to 20.oppm at 4 kg load, but instantly raised to 14.3 at 6 kg load and finally it dropped to21 kg at 10 kg load. In comparison to base fuel diesel initiated at 28ppm at 0 kg load but raised to 35 ppm at 6 kh load, finally saturated at 10 kg load by 22 ppm. Overall test result given an impression that, C-10 blend has performed good combustion which can be expected reduced smoke.

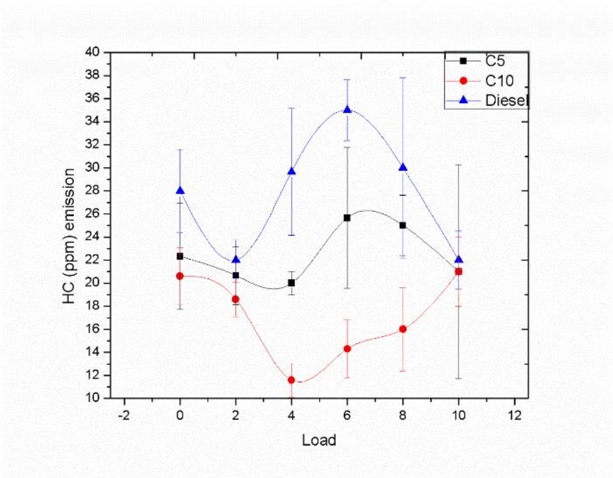


Figure 6. Variation of HC emissions with load

3.10 Effect of fuel blends/load on Smoke opacity

The Figure 7 shows variation of smoke for diesel at various loads. From the Figure 7, it can be concluded that smoke opacity increases with rise in load. It is observed that smoke emissions are slightly higher for C-5 and diesel fuel in comparison with C-10 fuel blends, but not up to acceptable range of variation from diesel fuel. Generally vegetable oils display higher smoke opacity, this may be due to heavier molecular structure, double bonds in vegetable oil chemical structure and higher viscosity and their esters. These factors are accountable for higher smoke emissions resulting in incomplete combustion. The number of double bonds present in the fatty acid is strongly related to emissions. Although the increased maximum temperature during combustion reduces the formation of soot (Ying et al 2006), the relative portion of SOM tends to increase because of the lower volatility of biodiesel (Tree et al., 2007, Krahl et al., 2003, Schröder et al., 1999). However, smoke opacity of C-10 is slightly lower than diesel oil. This is because viscosity and other fuel properties of C-10 (Table 2) were brought nearer to diesel. But at initial loads C-5 and C-10 emitted little higher smoke opacity than diesel but keep on increasing the loads, C-10 had maintained study state of reduced opacity and C-5 slightly raised its smoke opacity than diesel.

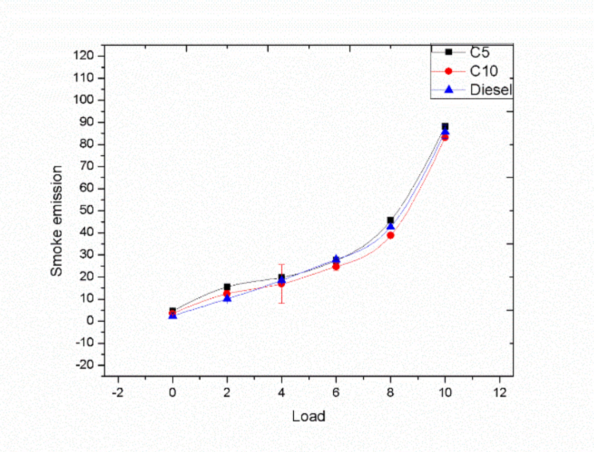


Figure7. Variation of smoke emissions with load

V. CONCLUSION

The experimental study was conducted to introduce *E. caducifolia* plant biocrude as a new renewable source for liquid biofuel. The research method explained to extract biocrude from dried plant biomass, preparation of C-5 and C-10 diesel blends and the effects of these fuel blends on the engine performance and emissions in comparison with diesel. The tests blends were designed with 5% and 10 % hydrocarbon extract, biodiesel by volume. The engine was operated on constant speed at 1500 rev/min and varying loads. From the experimental results following conclusions were drawn

- The C-5 and C-10 fuel blend were stable in
- The physico-chemical analysis of the blends shown similar properties like diesel.
- Minimum BSFC and higher BTE was observed for C-10
- CO HC and smoke emissions of C-10 blends were found less than that of diesel.

VI. FUTURE SCOPE

From the above experimental procedures it is clear that biocrude produced from biomass of *E. caducifolia* can be used as alternative fuel to run diesel engines. The residue of the plant biomass can be used for fermentable sugars and bioethanol production by standardizing the protocols for chemical, microbial and biological hydrolysis to utilize 100% plant biomass source. The efficiency of fuel blend can be increased and hydrocarbon chain length can be standardized by subjecting the hydrocarbon fraction to pyrolysis.

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