AN EXPERIMENTAL INVESTIGATION ON CHARACTERISTICS OF UPPAGE OIL METHYL ESTER FUELLED DICI ENGINE

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Abstract— In the present study, Uppage (Garcinia Cambogia) biodiesel and blended with high speed-diesel (HD) fuel in different proportions used as test fuels. This study evaluates the characteristics of a direct injection compression ignition (DICI) engine fuelled with Uppage oil methyl ester (UOME) blends (B20U-B100U) and HD under different loads (0%-100%) and fuel injection pressures (FIP) of 200-240 bar at rated speed of 1500 rpm. B20U is observed to be an approximate best fuel among the test fuels. B20U showed improved performance within acceptable emission level such as HC, CO, NOx and smoke opacity at 240bar FIP and 80% load.

Keywords— DICI, FIP, SIP, Smoke Opacity, UOME.

I. INTRODUCTION

Fuel energy is an essential input for human being to develop in economical, social, and improving the quality of life. Since its exploration, the petroleum-derived fuels continued as the major conventional energy source. With increasing trend of modernization and industrialization, the world energy demand is also growing at a faster rate and turned to focus on alternative fuels. Moreover, to curb the air pollution there is an effective means of study on conventional diesel engine with the use of alternative fuels. For the past few decades, efforts have been made to commercialize various alternative fuels such as vegetable oil(soya bean oil , rapeseed oil, palm oil, sunflower oil, karanja, jatropha, polanga, rice bran, Moringa oleifera ,Uppage etc.), animal fat(beef tallow etc.),alcohol(Methanol, Ethanol), compressed natural gas, biogas, liquid petroleum gas, hydrogen.

Vegetable oils are edible and non- edible type. Vegetable oils using in diesel engines is not a fundamentally new concept as the inventor of diesel engine 'Rudolf Diesel' demonstrated his first diesel engine at the World Exhibition at Paris in 1900 by using peanut oil as fuel. However, due to abundant supply of petro-diesel, research activities on vegetable oil were not seriously pursued. It received attention recently when it was conclusively realized that petroleum products are deteriorating fast and environment-friendly renewable substitutes must be identified [1]. Vegetable oils decrease power output and thermal efficiency while leaving carbon deposits inside the cylinder are the problems due to its high viscosity, resulting incomplete combustion. To avoid these problems, vegetable oils have been converted as vegetable oil methyl esters or ethyl esters through transesterification process with methanol or ethanol to ensure the standards of ASTM protocol as fuel in diesel engine. Biodiesel fuel is an alternative, renewable, biodegradable, nonflammable, non toxic green fuel. The most common edible oils of biodiesel includes palm oil, rapeseed oil, coconut oil, sunflower oil, and peanut oil etc., where as Neem, Jatropha , Karanja, Rubber, Rice bran, Mahua, Moringa oleifera Polanga, Uppage etc. are the non-edible oil sources of biodiesel . Biodiesel offers as a renewable feed stock and as for as environmental concern it is clean burning free sulfur less pollutant fuel. Approximately 60-70% of biodiesel cost is attributed to raw material cost. However, use of cheap and non-edible oil as substrate and utilization of by product may result in substantial reduction in its production cost.

Since last three decades many of the researchers have conducted experiments to examine the performance and emissions of biodiesels. Interestingly, some of the researchers have reported that thermal efficiency improved with biodiesel fuelled engine[2].The biodiesel could effectively reduce harmful emissions viz., carbon monoxide (CO), unburned hydrocarbons(HC) and smoke but with little increment in nitric oxides (NOx) emissions relative to mineral petro diesel [3]. The biodiesel blends and neat biodiesel in diesel engine reduces carbon monoxide by about 3-15% [4] unburnt hydrocarbons by about 6-40% [5,6] and smoke emission by up to 45% [7,8] compared to ULSD (ultra low sulfur diesel). However, increased in NOx emission levels by up to 26% [9,10], increased in BSFC by about 6-15% [11,12] decreases in brake thermal efficiency by up to 9% [13,14].Tsolakis et al. [15] investigated the effects of rapeseed methyl ester on emissions from a single-cylinder diesel engine. Using rapeseed methyl ester reduced smoke, CO and HC by 65–81%, 34–50%, 58% respectively, while NOx increased by 47–70% relative to diesel fuel. Fujia Wu et al.[16] examined the effects of five biodiesels such as cottonseed, soybean, rapeseed, palm and waste cooking oil methyl ester on emissions of six cylinder turbo charged diesel engine. It reports that the least NOx, in descending order are: CME, PME, SME, WME, and RME and PM emissions reduction varies from 53% to 69%, in descending order are: WME, PME, CME, RME, and SME. Different biodiesels increase NOx emission by 10–23% on average. All biodiesels produce less HC and CO than diesel fuel.

Sahoo et al. [17] concluded that 50% jatropha biodiesel blend showed maximum power with less smoke amongst all the biodiesels and their blends when compared with diesel. Agarwal et al. [18] concluded in his investigations rice bran biodiesel fuelled engines produce less carbon monoxide, unburned hydrocarbon, and particulate emissions compared to mineral diesel fuel but higher NOx emissions. Palash et al. [19] concluded that biodiesel and blends have strong beneficial impacts on HC, CO and PM emissions but adverse effects on NOx emissions. Similar trends have also been reported by other researchers [20, 21]. Jindal et al. [22] carried out experimentation for three different injection pressures (15, 20 and 25 MPa) at various loads on diesel engine. It was found to be BTE increases and BSFC reduces with increase in injection pressure.

It has been found that a very few studies only on Uppage biodiesel. In the present study mainly analyzed on important performance parameters such as BTE, BSEC and emissions such as CO, HC, NOx, and smoke opacity, and also while UOME blends as fuel in DICI engine.

II. MATERIALS AND METHODS

A. Test Fuels

The test fuel samples in the present study have chosen as UME and its blends with HD. The blend percentages and abbreviations of test fuels shown in table1. The most common method for production of biodiesel from crude uppage seed oil is through transesterification process of vegetable oil. Uppage is one of the most suitable feedstock among the non edible feed stocks in Indian continent which being grown abundantly in saline and alkaline soils which located in southern region of India and also is grown in region of high rainfall. It is very interestingly; the trees grow up in forest which helps in controlling soil erosion and binding soil to roots because of their crowded network of lateral roots. The seeds are hugely exploited in the forest for oil extraction and also for its medicinal properties. So far there is no systematic approach to collection of seeds from these trees. The crude oil appears in brown to creamy color. It has a bitter taste and unpleasant odor [22].Some of the important properties of uppage oil methyl ester (UOME) and diesel fuel given in Table 2.

B. Experimental Test Setup and Method

The Test setup consists of single cylinder, 4-stroke diesel engine and equipped with eddy current type dynamometer for loading and the specifications of test engine is shown in table 3. Experimental set up is shown in Fig. 1. The setup equipped with the necessary arrangements to measure in cylinder pressure and crank-angle etc. The performance parameters like BP, BTE and specific energy consumption can be evaluated by measuring the observations viz., speed and load on the engine, rate of fuel consumption, and airflow rate, with suitable instruments provided on the engine setup. The emissions such as HC, CO, NOx, and Smoke were directly measured with exhaust gas analyzer and Hartridge Smoke Meter, respectively. All tests conducted after the engine attaining steady condition only. Initially the engine runs on diesel before conducting each test.

Table 1: The blend percentage of test fuels

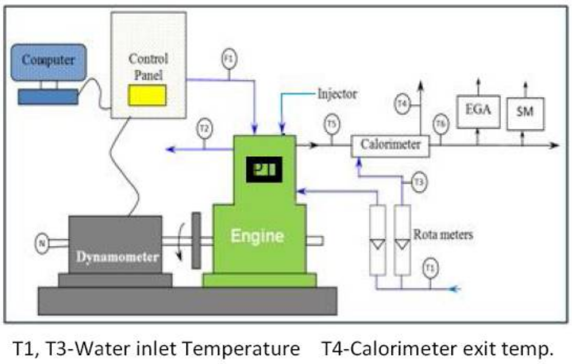
Abbreviation	% of test fuel
B20U	20% UOME +80% HD(volumetric)
B40U	40% UOME +60% HD(volumetric)
B60U	60% UOME +40% HD(volumetric)
B100U	100% UOME
HD	High Speed-Diesel
UOME	Uppage Oil Methyl Ester

Table 2: Properties of Fuels

Property	HD	UOME
Density@15° C - kg/m^3	840	860
Lower Heating Value - kJ/kg	43000	36970
Kinematic Viscosity@40°C – cSt	2.5	5.2
Flash point (°C)	50	178
Stoichiometric air–fuel ratio	14.7	-
Cetane Number	48	55

Table 3

Specifications of Test Engine	
Type	Kirloskar, TV1,1 cylinder, 4-s, DI diesel engine
Injector opening pressure	200 bar
Rated power	5.2 KW (7 HP) @1500 RPM
Cylinder Bore	87.5 mm
Stroke length	110 mm
Compression ratio	17.5 : 1
Standard Injection Timing	23° bTDC



T1, T3-Water inlet Temperature   T4-Calorimeter exit temp.
T2-Engine water jacket outlet   T6- EGT after Calorimeter
PT- Pressure transducer   EGA-Exhaust gas analyzer
N-RPM encoder

Fig. 1 Schematic view of Engine Test Setup

III. RESULTS AND DISCUSSION

Based on the fundamental definitions, calculations, the diesel engine performance parameters such as BTE, BSEC for the test fuels high speed Diesel, B20U, B40U,B60U, and B100U (neat uppage biodiesel fuel) are recorded and represented graphically in Figs. 2a and 3a. The emission parameters like carbon monoxide, unburnt hydro carbons, nitrogen oxides and smoke opacity are measured directly and represented graphically in Figs. 4a -7a.

The influence of fuel injection pressure on BSEC, BTE and emissions CO, HC, NOx and smoke opacity of the same diesel engine fuelled with uppage oil methyl ester (UOME) best blend as test fuel and compared the results with baseline data of HD fuel which shown in Figs.2b-7b. The tests conditions can be selected as follows: loads 80% and, 100%, rated speed 500rpm and five different FIPs 200-240bar.

A. BTE and BSEC

Fig. 2a shows the brake thermal efficiency increased with load while decreased with biodiesel proportion in the blend. The average efficiency for B20U,B40U,B60U,B80U,B100U and diesel fuels are found to be 17.58%, 17.08%, 16.24%, 17.37%, 16.79% and 21.35%, respectively. Fig.2b shows the maximum BTE at 240bar FIP as 26.44 % and 25.86% at 80% and 100% load whereas HD has 30.25 % and 29.04 at the respective loads. This could be reason of fine fuel spray and optimized droplet size of biodiesel blend at 240bar FIP. The smaller fuel droplets of B20U mixing well with air throughout the combustion chamber and forming more combustible homogenous mixture, as a result better combustion at 240bar. These results trend are inline agreement with the reports published [25]. Fig.3a shows BSEC decreased with load and higher values observed for all blends as compared to diesel fuel. Reduction in thermal efficiency as well as increased BSEC values for all blends attributed to lower heating value (about13%) of biodiesel. The same trend has been conformity with literature published [26, 27].

Fig.3b showed that lower BSEC value obtained at 240bar. This results trend is similar with the reports published [28].

B. CO, HC, NOx and Smoke Emissions

Fig. 4a represents carbon monoxide (CO) versus load for different UOME blends. It reveals that CO emissions initially decreased then increased with load while decreased with increasing biodiesel concentration. The CO emissions for B20U-B100U are reduced in range of 12.5%-26.97% (mean) respectively. Since, CO emissions mainly depend upon the cylinder temperature and availability of oxygen. The trend of CO emission results in-line with literature [29]. Fig. 4b demonstrates that the increased injection pressure lessened CO emissions. The lowest CO values obtained at 240bar which reduced by 22.7% and 21.53% at 80% and 100% load when compared to HD fuel, respectively. Higher FIP improves the mixing rate of fuel and air in a short time. These effects tend to better combustion thus reduce CO emissions [30]. The higher amount of CO emissions released at 240bar due to the partial and longer combustion duration, which results in lower peak heat release rate and lower peak pressure [31]. The trend of CO emissions followed the literature published [28].

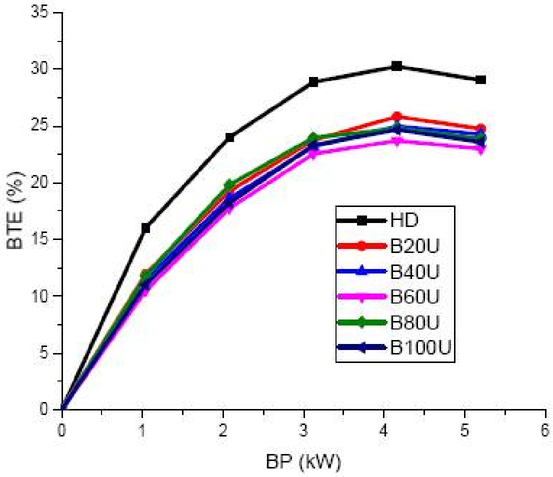


Fig.2a BTE vs. BP for different UOME blends

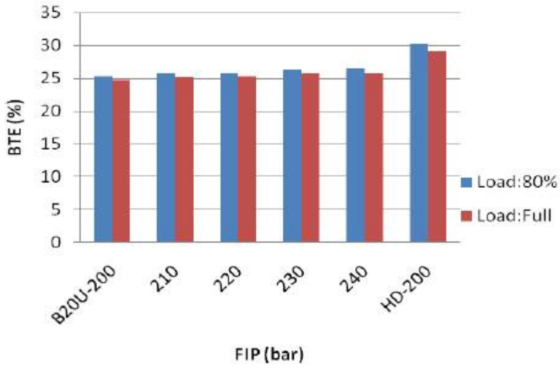


Fig.2b BTE vs. FIP for B20U blend

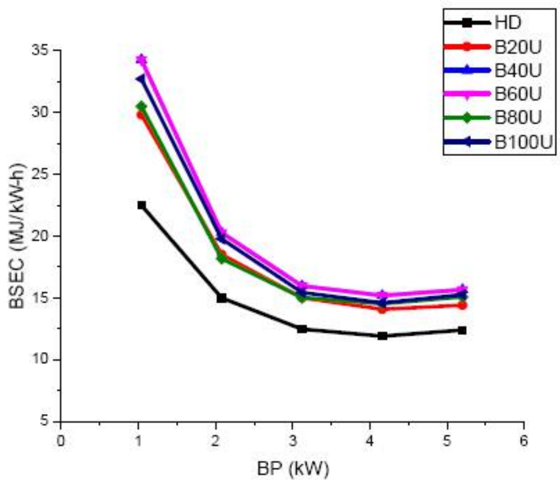


Fig.3a BSEC vs. BP for different UOME blends

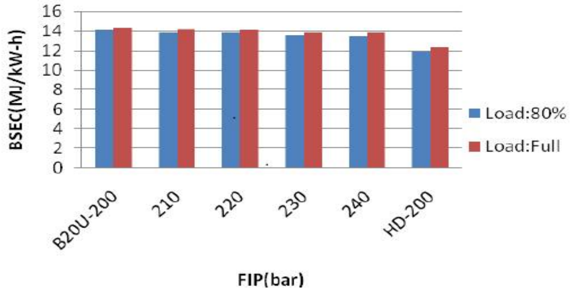


Fig.3b BSEC vs. FIP for B20U blend

Fig.5a demonstrates that HC emissions for uppage oil methyl ester (UOME) blends initially decreased up to medium loads and then increased but the mean values were less than those of high speed diesel fuel. The HC emissions decreased with blend percentage. Fig.5b shows the variation of HC emission with different FIPs (200-240bar) for B20U blend fuel. The lowest HC emissions for B20U noted at 240bar as lowered by 38.89% and 41.37% than diesel at 80% and full load, respectively. Higher FIP improves the fuel spray pattern which leads to better fuel-air mixing in the combustion chamber; consequently lower HC emissions. Normally, oxygenated fuels give lower emission of HC and CO [31]. These variations are comparable and agreement with literature published [28].

Fig. 6a-b shows the variation of NOx emission results for different blended fuels with respect to different loads and injection pressures, respectively. Fig.6a shows that the NOx emissions increased with concentration of UOME blend

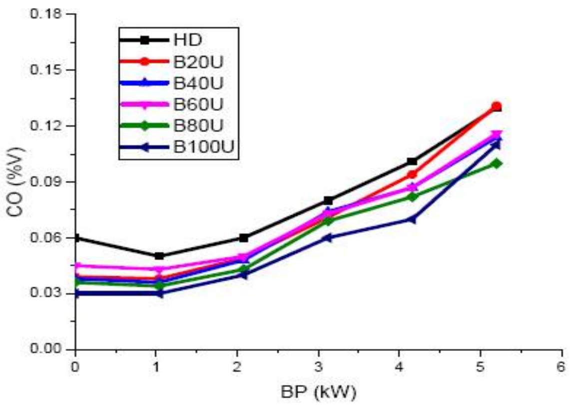


Fig.4a CO vs. BP for different UOME blends

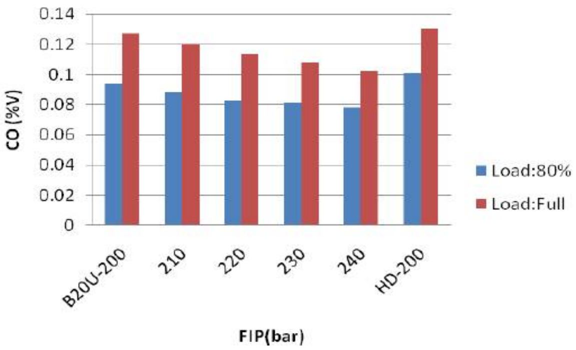


Fig.4b CO vs. FIP for B20U blend

as well as with load. NOx emissions increased in the range of 4.5%–13.4% by an average for B20U-B100U than HD. The results are in agreement with literature published [28]. Fig.6b demonstrated that the injection pressure boosted the NOx emission levels. The NOx emissions increased in the ascending order of injection pressures 200-210-220-240-230bar for B20U due to better burning, but higher than diesel fuel.

Fig.7a-b shows the smoke emissions verses engine load and injection pressures, respectively. Fig.7a reveals that the smoke emissions lower for all uppage biodiesel blends than diesel fuel. The average smoke reductions for the blends B20U-B100U are in the range of 2.5% - 22.7% than those of diesel at full load. The reason for the reduced smoke is the availability of premixed and homogeneous charge inside the engine cylinder well before the initiation of combustion.

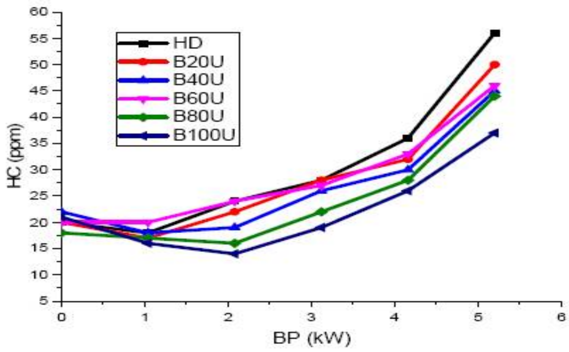


Fig.5a HC vs. BP for different UOME blends

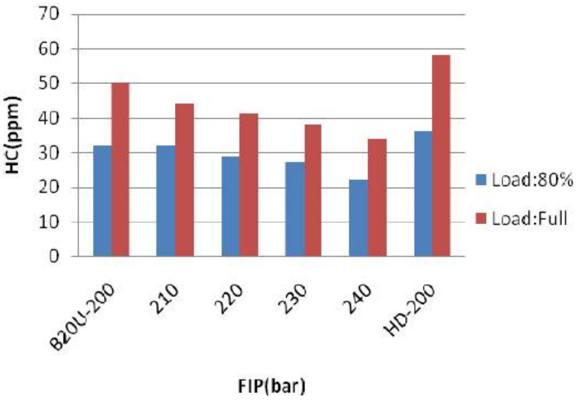


Fig.5b HC vs. FIP for B20U blend

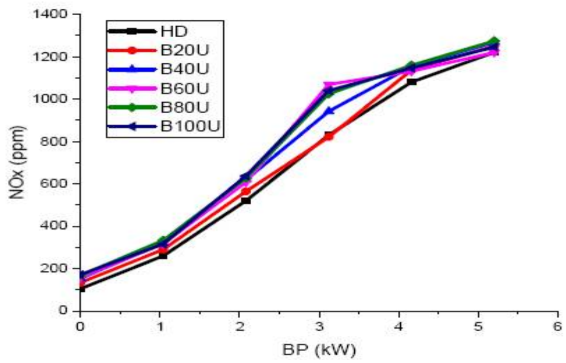


Fig.6a NOx vs. BP for different UOME blends

Higher temperature of combustion, extended duration of combustion and rapid flame propagation are the other reasons for reduced smoke. These results are in similar with literature published [32]. Fig.7b demonstrates the Smoke opacity of B20U decreases with FIP. The maximum reductions of Smoke opacity are 41.3% and 33.33% at 80% and full load for B20U at 240 bar fuel injection pressures, when compared to HD, respectively. This is may be attributed to reduced drop size of the injected fuel as injection pressure increased. Since mixing of fuel with air becomes better during injection period, smoke opacity will be less [33]. This trend is in similar with literature published [24].

CONCLUSIONS

In this study, a single cylinder DI diesel engine is successfully operated with uppage oil methyl ester (UOME) and its diesel blends B20U- B100U at different loading conditions and also further investigations carried out with best blend B20U at two different loads (80% and Full load) at different fuel injection pressures (200-240bar). The following conclusions have been drawn based on the experimental results.

- B20U is observed to be best blend with regard to mean values of BTE, BSEC with acceptable emission levels when compared to base line data of HD. The higher BTE noted at 240bar FIP for B20U amongst blends, but lower than HD at 80% load. The BSEC decreased with load and B20U has followed closely to the lowest curve HD.
- The lowest CO and HC emissions obtained at B20U at 240 bar FIP when compared to those of HD fuel. The NOx emission decreased with blend concentration while increased with load and FIP but at the240bar slightly decreased. The Smoke emission reduced with blending concentration. However, a significant reduction noted at 240bar FIP for B20U compared to those of HD fuel.

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