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Research Article

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Analysis of engine test and emission test of seaweed biodiesel for sustainable energy

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ABSTRACT

Algal biodiesel is realized to be the most sustainable solution to meet future energy demands in comparison to its competitors. Marine seaweed was explored for the feasibility of biodiesel production. The present study deals with the production of biodiesel from the green seaweed Caulerpa pelata. Algal biodiesel was blended with various ratios of commercial diesel. Blends of B10, B20, B50, B100 and commercial diesel were compared for engine testing and emission analysis. Engine testing was performed for Caulerpa peltata algal biodiesel and it was found that properties like brake thermal efficiency, total fuel consumption and indicated thermal efficiency were comparable to commercial diesel. The biodiesel produced from the seaweed was analyzed for emission which was done on a four- stroke, single cylinder air-cooled Kirloskar Diesel engine fitted with an AVL Gas analyser Digas 444 Software Version. It was found that the emission of carbon monoxide, carbon dioxide and hydrocarbons was less for pure biodiesel and biodiesel blends than for commercial diesel. Only Oxides of Nitrogen emission was higher which can be rectified by suitable engine design or by adding additives.

Keywords: algal biodiesel, transesterification, engine testing, emission analysis, eco-friendly

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INTRODUCTION

Ever increasing diesel consumption, large outflow of foreign exchange and concern for environment have prompted developing countries like India to search for a suitable environmental friendly alternative to diesel fuel [1]. Biodiesel is the name for a variety of ester based oxygenated fuel from renewable biological sources. It can be used in compression ignition engines with little or no modifications [2]. The main advantages of using biodiesel are its renewability, better quality exhaust gas emission, its biodegradability and the organic carbon present in it is photosynthetic in origin [3]. Biodiesel gives good mileage and releases less exhaust emissions. The fatty acid methyl esters of seed oils and fats have already been found suitable for use as fuel in diesel engine [4]. Several vegetable oils were evaluated as potent fuel sources and it was reported that use of these oils caused carbon build up in the combustion chamber [5]. Research on sunflower seed oil indicated that it can be used as a fuel source for short-term use as long term durability test indicated severe problems due to carbonization of combustion chamber [6,7]. Used rapeseed oil was also used as a diesel fuel replacement in Germany with mixed results [8]. Similar results were reported on different oils like pea nut oil, cottonseed oil, sunflower oil, rapeseed oil and sun flower oil respectively [9-15]. It was reported that power out puts were nearly the same for palm oil, blend of palm oil and diesel fuel, and 100% diesel fuel [16]. Vegetative oil fuel blends had encouraging results in short term testing [17, 18]. Research was also done on a one to one blend of vegetable oil and diesel fuel to study the piston rings deposits. Engine performance tests showed that power output slightly decreased when using vegetable oil fuel blends [19]. Hydrocarbons, carbon monoxide and oxides of nitrogen emissions from karanja oil methyl ester was reported to be slightly higher as compared with petrodiesel [20].Since the earlier feedstock's sustainability suffered in terms of land availability, water, fertilizers and limited reserves, the present work deals with the production of algal biodiesel which is a third generation biodiesel which can be investigated due to good amount of lipid content for conversion to biodiesel. Moreover, the seaweed requires less growth and land requirements in comparison with its competitors.

EXPERIMENTAL SECTION

Materials

The green seaweed *Caulerpa peltata* was collected from Gulf of Mannar, Rameshwaram, India. The seaweeds were washed with sea water first and then with distilled water .It was shade dried with final drying in an oven at 60 ºC for 24 hours. The seaweeds were ground into fine powder using mortar and pestle.

Method

Extraction of algal oil and conversion to biodiesel

The dried algae were ground with a mortar and pestle as much as possible and the oil was extracted by the solvent extraction method using hexane and ether as the solvent in the ratio 1:1.The oil is filtered and the bio mass collected is weighed. Biodiesel was prepared as per the procedure given in literature [21, 22]. After shaking, the solution was kept for 15hr to settle the bio-diesel, glycerol, foam and sediment layers clearly in a settling flask. The two layers formed were carefully separated and the bio-diesel was kept separately and the sediment (glycerol, pigments, foam etc.,) was measured. The bio-diesel was washed by 5% water until it becomes clean of foam. Bio-Diesel was dried by using dryer and finally kept under running fan for 12hr.The bio-diesel obtained was measured using a measuring cylinder .Then it was stored in a dried container for further analysis. The fuel properties were tested according to ASTM D6751 standards.

Engine Testing

Biodiesel can be blended in many proportions with commercial diesel. B100 is pure biodiesel. B10 blend is 10 volume percentage pure biodiesel blended with 90 volume percentage of commercial diesel. Similar blends of B20 and B50 were prepared and engine tests were conducted. A constant speed, single cylinder, water cooled, direct injection diesel engine was used for the performance tests. The amount of fuel consumed in unit time is measured by a graduated burette. Experimental runs were conducted on B10, B20, B50, B100 and commercial diesel. Initially, the runs were conducted on commercial diesel to generate reference data. After that, tests were carried with B10, B20, B50, B100 blends with load increase on engine brake drum. Fuel efficiency based on engine test was interpreted in terms of thermal efficiency and fuel consumption. The specification of the engine is shown in table 1.

Table 1.Technical specification of diesel engine

Engine	Specifications
Make	Kirloskar
Bore x Stroke	114.3x139.7 mm
Compression ratio	17.5:1
Rated Power	4.476 KW
Rated Speed	1500 rpm
Injection pump	Distributor type
Injector type	Multihole nozzle with bar filter

Emission Testing

Carbon monoxide (CO), hydrocarbon (HC) and oxides of nitrogen (NOx) are termed as the primary pollutants of air. Carbon dioxide (CO_2) is a green house gas which leads to global warming. The engine was started and the emissions of carbon monoxide, carbon dioxide, oxides of nitrogen and hydrocarbons were monitored for various loads. Emission analysis was done on a four- stroke, single cylinder, air-cooled Kirloskar Diesel engine fitted with an AVL Gas analyzer Digas 444 Software Version. The concentration of the various pollutant gases was analyzed by software version which was fitted to the engine. Emission test for CO, CO_2, HC and NOx were studied for *Caulerpa peltata* biodiesel. The tests were conducted for B10, B20, B50, B100 and commercial diesel (C.D.) by varying the load on the engine from 0 to 100 % load. The tests were carried out in the same engine for the same test conditions. The pollutants were monitored by the AVL gas analyzer.

RESULTS AND DISCUSSION

Fuel properties

The large size of vegetable oil molecules (typically three or more times larger than hydrocarbon fuel molecules) and the presence of oxygen in the molecules suggest that some fuel properties of vegetable oil would differ markedly from those of hydrocarbon fuels [23]. The conversion of triglycerides into methyl or ethyl esters through the transesterification process, reduces the molecular weight to one-third that of the triglyceride and also reduces the viscosity by a factor of about eight and increases the volatility marginally [3] .The fuel properties of *Caulerpa peltata* algal oil was determined according to ASTM D6751 standards which is represented by Table 1. It was found that glycerol content, flash point and cetane index were slightly higher than commercial diesel [24].

Table 2.ASTM D6751 test results for *Caulerpa peltata* biodiesel

Parameter	*Caulerpa peltata* Algal biodiesel	ASTM D6751	Units
Kinematic viscosity	2.82	2.5 - 6.0	CSt
Sulphur content	0.0007	.0015	% mass (max)
Water content	0.043	0.05	% vol (max)
Total Glycerol	0.26	0.24	% mass (max)
Iodine value	64	<115	g/100 g
Acid Number	0.45	0.50	mg KOH/g
Flash point	180	min 100	°C
Cetane index	51	47 min	
Calorific Value	42700		KJ/kg
Visual Appearance	Golden brown	Brownish Yellow	------

(Source: Annam Renita .A, Asian Journal of Chemistry,2012)

Engine testing

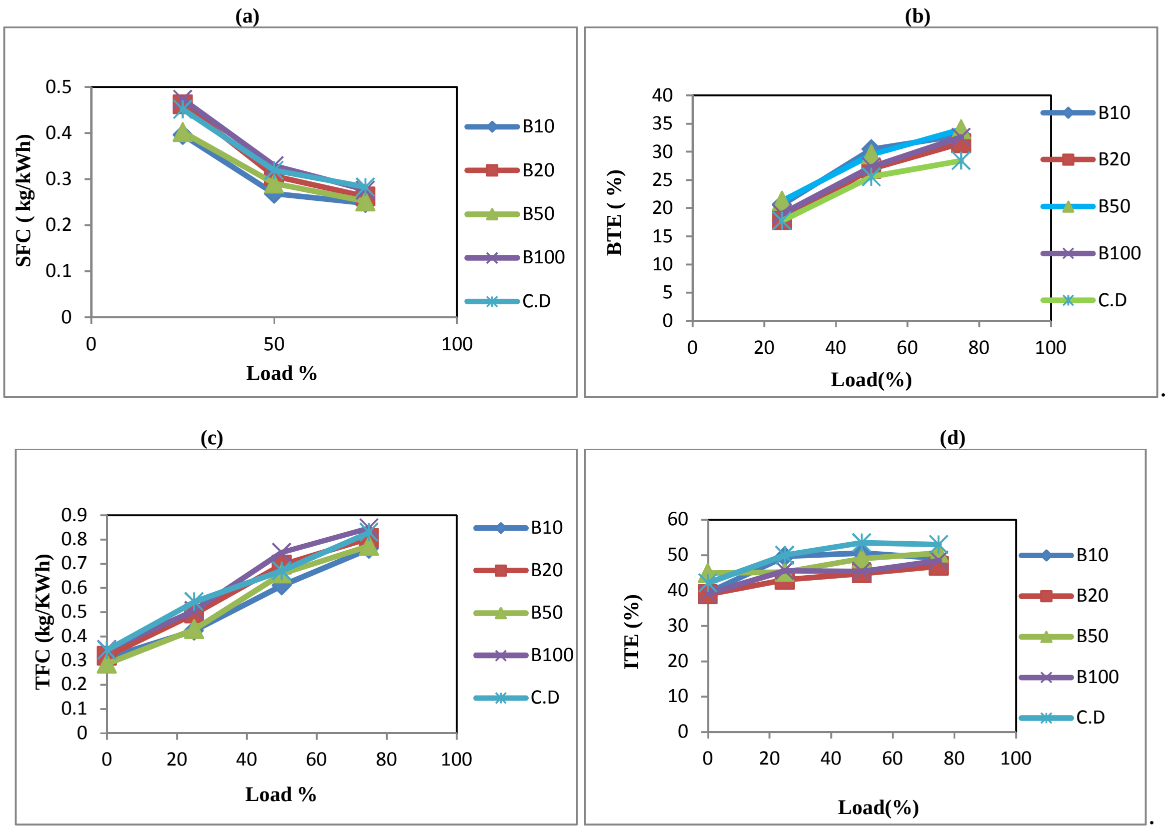

Figure 1 (a) Effect of load on specific fuel consumption (b) Effect of load on brake thermal efficiency(c) Effect of load on total fuel consumption(d) Effect of load on indicated thermal efficiency

Caulerpa peltata biodiesel has a lower calorific value than commercial diesel. This could be the reason behind the decline of specific fuel consumption as shown in Figure 1.a.Specific fuel consumption (SFC) is an important indicator of fuel efficiency. At maximum load condition, B100 (pure biodiesel) produces high SFC than commercial diesel fuel. Lower values of specific fuel consumption indicate lower fuel consumption for a pre-determined work obtained by using commercial diesel. Figure 1.b. illustrates the variation of brake thermal efficiency with B10, B20, B50, B100 with commercial diesel. It can be observed that brake thermal efficiency increases with load addition. At maximum load, B20 and B50 blends produce lower brake thermal efficiency than commercial diesel. This could be due to increase of developed power on addition of applied load. Figure 1.c shows the variation of Total Fuel Consumption with different loads for different biodiesel blends (B10, B20, and B50), pure biodiesel and commercial diesel. The decline in total fuel consumption is also attributed to the low calorific value of fuel. Thermal efficiency plays a vital role in the determination of the efficiency of a fuel. Indicated thermal efficiency for all biodiesel blends, pure biodiesel and commercial diesel showed a similar trend which is shown in Figure 1.d.

Emission Analysis

Commercial diesel (C.D.) emits more CO than pure biodiesel (B100) and biodiesel blends (B10, B20 andB50) as shown in Figure 2.a. The reason is biodiesel has fuel bound oxygen which oxidizes CO to CO_2. CO is seen to increase with load addition because in all IC engines air-fuel ratio decreases with increasing load. Oxides of Nitrogen (NOx) emissions are seen to increase with increasing load for pure biodiesel B100 as shown in Figure 2.b. For B10,B20 , B50 and commercial diesel it is seen to increase till 75% load and decrease for 100% load. The reason could be the presence of high amount of unsaturated fatty acids in the algal biodiesel. NOx emissions can be reduced by reducing the fuel injection timing and fuel combustion temperature. Retardation of injection timing of the fuel could lead to decrease in NOx emissions [25,26] .Exhaust gas recirculation also helps in reducing NOx emissions [27]. Only oxides of nitrogen (NOx) are reported to increase which is due to oxygen content in biodiesel [28-36].

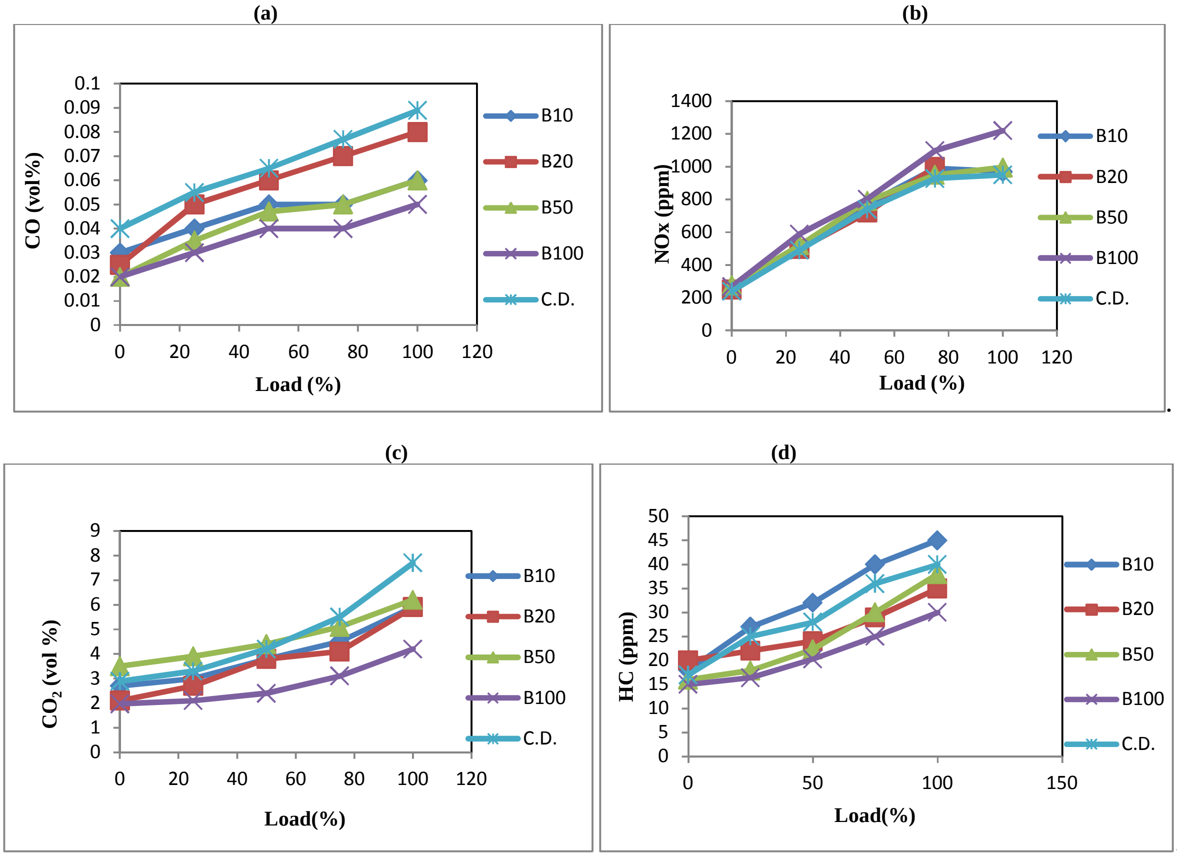

Figure 2 (a) Effect of load on carbon monoxide emission (b) Effect of load on oxides of nitrogen emission (c) Effect of load on carbon dioxide emission (d) Effect of load on hydrocarbon emission

CO_2 emission increases with increase in load because algal biodiesel has additional oxygen for combustion to be complete. For both C.D. and B10, CO_2 emission is seen to increase with load much higher than B20, B50 and B100 as shown in Figure 2.c. B100 has the lowest emission of CO_2 which indicates that pure biodiesel will not contribute to global warming. Hydrocarbon emission with increasing load follows a uniform rise. B10 emits more hydrocarbon than B20, B50, B100 and C.D as shown in Figure 2.d. This could be due to inbound hydrocarbon structure of the fuels. B100 has the lowest emission of hydrocarbon which makes it an environmentally friendly fuel.

B100 has the lowest emission of hydrocarbon which makes it an environmentally friendly fuel. Oxides of sulphur (SOx) is one of the primary pollutant which causes serious health problems to living beings and causes damage to structures in the form of acid rain and corrosion. Biodiesel has the major advantage of having very less concentration of sulphur in comparison with commercial diesel. Additional processes and money are invested to prepare low sulphur commercial diesel. Sulphur content in *Caulerpa peltata* biodiesel is negligible of the order of 0.0007 mass % [24]. From the present research work conducted on *Caulerpa peltata* biodiesel, emission of oxides of sulphur, carbon monoxide, carbon dioxide and hydrocarbons were less compared to commercial diesel fuel. Emissions of nitrogen oxides alone are comparatively higher to that of commercial diesel which can be rectified by exhaust gas recirculation or by retarding injection timing of fuel.

CONCLUSION

The performance of methyl esters obtained from *Caulerpa peltata* was studied on a four stroke diesel engine. Engine testing was done with pure *Caulerpa peltata* biodiesel (B100), *Caulerpa peltata* biodiesel blends (B10, B20, B50) and commercial diesel. Brake thermal efficiency of B20 and B50 biodiesel blends were lower than commercial diesel. Brake thermal efficiency of pure biodiesel and B10 biodiesel blend were comparable with commercial diesel. All other engine tests gave comparable results with commercial diesel. The emission tests indicated that B20 biodiesel is a less polluting fuel compared to commercial diesel. Pure biodiesel emissions were less compared to commercial diesel except for oxides of Nitrogen. So it can be concluded that B100 and biodiesel blends can be used in compression ignition engines with minor engine modifications.

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