



PERFORMANCE AND EMISSION STUDIES OF ALGAE (NODULARIA SPUMIGENA) BIODIESEL IN CONSTANT SPEED CI ENGINE EQUIPPED WITH DIESEL PARTICULATE FILTER

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Abstract

As a solution to the faster rates of depletion of fossil fuels the biofuels (biodiesels) have become potential alternates. To become the feasible alternatives these fuels must be explored for energy improvement, safe environment. These biofuels also must be available in

desired quantities to meet the demands. The algae-based stocks have gained attention for producing right amounts of biodiesel. The objective of this study is to find the performance and combustion characteristics of biodiesel derived from algae type *Nodularia Spumigena* in a constant speed diesel engine. The results of the experiments suggest that biodiesel derived from *Nodularia Spumigena* is a good substitute for diesel for making blends. The significant observations are decrease in fuel consumption at full load as 13% for B20, 10% for B10 compared with B0. NOx emissions are reduced by 26% using diesel particulate filter (DPF) at full load for B20. The smoke, HC emissions are low for blended fuels compared with neat diesel. The DPF significantly reduced the smoke emissions by 32% for B0 at full load.

Keywords: *Nodularia Spumigena*, Biodiesel, CI Engine Performance, Engine Emissions, DPF

1 INTRODUCTION

Serious concern over the consequences of the usage of fossil fuels leads the stakeholders to go for biofuels. However, more than 80% of the energy utilized today comes from fossil fuels such as coal, natural gas, and petroleum which most countries rely profoundly on as their prime fuel sources [1]. The immediate negative impact is evident that greenhouse gases which have been tormenting the ecosystem of the globe. It is observable that the biofuels could lessen the combustion-related emissions as per the past, recent research outcome [2-5]. The biofuels are the fuels extracted from the sources like a vegetable, algae etc. which are renewable. The production of biodiesel from micro Algae attained new impression as it lowers emissions of CO₂ into the environment because the cultivation of algae in large scale can absorb nature CO₂ in the photosynthesis process. Many researchers have found that biodiesel from micro Algae is one of the best choices. A right quantum of work is required in this area to show algae biodiesel to use in diesel engines without many complex changes.

1.1 BIODIESEL FROM NODULAR SPUMIGENA

Algae are the types of marine plants, which do not have seamless roots, stems, shoots etc. and these differences in size from microscopic to the level of meters in length. Through photosynthesis they can store lipids in the form of Tri Acyl Glycerides (TAG's) after which the considerable amount of biodiesel can be obtained [7-14]. The growth of microalgae suits in rich nitrogen to phosphorous ratio (N/P) ponds because the rate of biomass generation is higher in these lakes [8]. Proper attention contributed studying the lipid profiles of many species, but none of it to date has found to be satisfactory regarding the required levels of production. Most of the locally available strains can be genetically modified for competent lipid production [15]. Algae biodiesel is still not yet an economic competitor compared with diesel in spite of endless efforts made in both macro and micro level studies on different algae species, and there is need to explore alternative technologies which suits the usage of algae in present diesel engines [16-23].

1.2 The procedure for extracting biomass from Algae and Transesterification

The species selected is *Nodularia Spumigena* owing to its availability in the local environment and also the optimized laboratory process of production of the same in the required quantities. The algae after collection from local ponds (Geographical Location 16.24 N 80.56 E) were further grown in open pond system. It was dried in the atmosphere and is powdered. A 50 g sample of the dried up algae is placed in the cap of the Soxhlet apparatus. The cap is made as of thick filter paper, which is loaded into the core chamber of Soxhlet extractor. The Soxhlet extractor system is placed in a bottle containing extraction solvent. The solvent is heated still it refluxes, the solvent hexane forms fumes, which moves up to a condensation point, and overflows into the chamber housing the cap. The space containing the solid material is filled with warm solvent. The compounds of algae are absorbed by warm hexane. When the

Soxhlet chamber filled with solvent, then it is emptied by the siphon sidearm, with hexane flowing back to the distillation flask. This sequence is repeated with varying time, at each point a portion of the oil is dissolved in hexane. After many such cycles, the oil was concentrated in the distillation flask. Soon after the extraction hexane was separated, yielding the extracted compound. The unsolvable portion of the algae remains in the cap.

The powder is inserted into the flask; the pipes are connected one is water inlet and another one is an outlet for the setup. Biomass powder is kept in the Soxhlet apparatus, the temperatures of the apparatus are maintained between 50-600C. The extract obtained from the Soxhlet apparatus is collected and placed in the rotary evaporator. The lipid extracted was mixed with 0.25g pure sodium hydroxide pellets and 24 ml methanol for 20 minutes. The mixture was kept in an incubator shaker at 45-500C and stirred at 300 rpm for 3 hours. The solution was then set aside for 16 hours in a separator funnel to settle the biodiesel (methyl ester) and sediment layers. The biodiesel after disposal of the sediments was washed with 5% water until it appears to be clear. The biodiesel was then dried up in open atmosphere. The prepared biodiesel is analyzed for properties density, kinematic viscosity, flash point and fire point etc. The photograph of biodiesel prepared is shown as figure 1. Fuel properties of the methyl ester of *Nodularia Spumigena* are given in table 1.

Table: 1 Properties of Algae Biodiesel

Parameter	Units	Diesel	Biodiesel	Test Method
Kinematic Viscosity @ 40°C	cSt	3.4	37.13	ASTM 1)445
Flash Point	°C	47.0	246.5	ASTMD92
Fire Point	°C	63	257.5	ASTMD92
Sulphur content	% by mass	30	0.26	ASTM D129
Gross Calorific Value	kcal/kg	44000	8930	IS 1448(P-6)
Volatile Content	% by mass	0.70	0.56	In-house method
Density @15 0C	g/cc	830.00	920.5	IS 1448(P-32)
Calculated Cetane Index	-	47	40	IP 364

2 EXPERIMENTAL SETUP

Figure 1 shows the details of the experimental setup, the complete specifications of engine and emission analyzer are given in table 2 and 3. The emissions are measured using AVL type five gas and smoke meters.

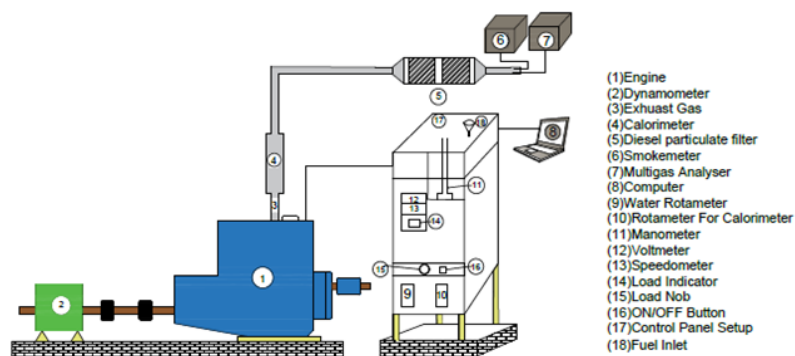


Figure 1: Experimental setup

Table 2. Engine Specifications

Engine	Kirloskar, Single-Cylinder, Four-stroke Constant Speed, Water Cooled Bore 87.50(mm), Stroke 110.00(mm) Compression Ratio 17.50, Swept volume 661.45 (cc)
Dynamometer	Type Eddy Current
Propeller Shaft	With universal joints
Air Box	MS fabricated with orifice meter and manometer
Fuel Tank	Capacity 15 lit with glass fuel metering column
Temperature Sensors	Thermocouple, Type K
Temperature indicators	Digital, multichannel with selector switch

Table 3. Specifications of Gas Analyzer

Parameter	Manufacturer	Value	Method of Measurement
NOx	AVL	ppm	Chemiluminescence
HC	AVL	ppm	FID
CO	AVL	% vol	NDIR
Smoke	AVL	Percentage	Opacity

3 Experimental Results

3.1 Brake Specific Fuel Consumption

At no load condition, the BSFC of diesel is at 0.5 Kg/kW-hr and with the load BSFC is gradually decreased and increased after 12 kg. The fuel consumption at 12 kg seems to be optimal for all fuels used, the options B10, B20 showed improvement in terms of economy. The notable observation is decrease in fuel consumption at full load as 13% for B20, 10% for B10 compared with neat diesel (B0). BSFC graph is shown in figure 2.

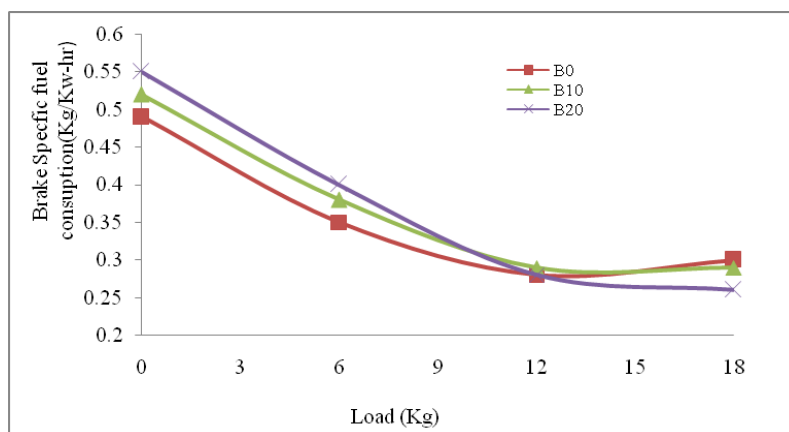


Figure 2: Load VS BSFC

3.2 Brake thermal efficiency

Brake thermal efficiency is a measure of the combustion system effectiveness as the amount of chemical energy converted into mechanical energy. The variations of brake thermal efficiency of the engine with B0, B10, B20 as shown in the Figure 3, the best values observed with B0 (0.45%) and lowest with B20 (0.35%) at full load.

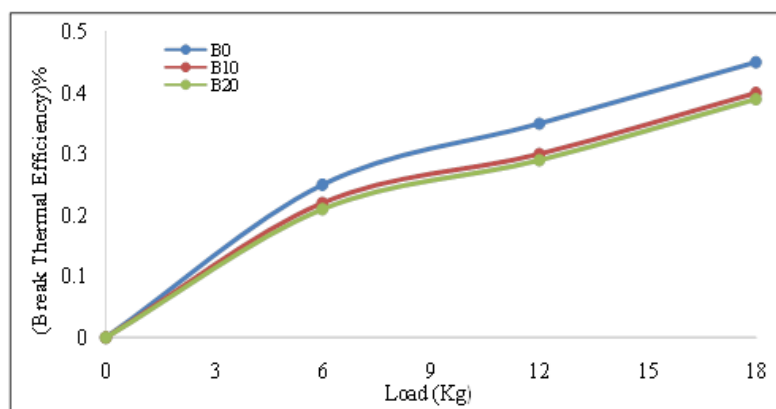


Figure 3: Load VS BTHE

4 EMISSION OBSERVATIONS

Figure 4 shows CO versus load, the value for B0 is 0.4% initially and later increased up to 1.6%. The CO is comparatively increased with B0, B10 and B20 and the same is reduced with DPF. Figure 5 shows the graph of CO_2 versus load, the B0 and B20 showed increase in CO_2 with load. B20 with DPF observed reduction in the CO_2 to some extent. Figure 6 shows NOx emissions with load, at 0, 6, 12 & 18 kg the emissions of NOX with B20 is slightly up, and with DPF it shows decreasing trend. The HC emission using B0, B10 & B20 is shown in Figure 7. The figure clearly indicates the increase in the HC emissions with the increase with a load for B0, B10 & B20. NOx emissions are reduced by 26% using DPF at full load for B20.

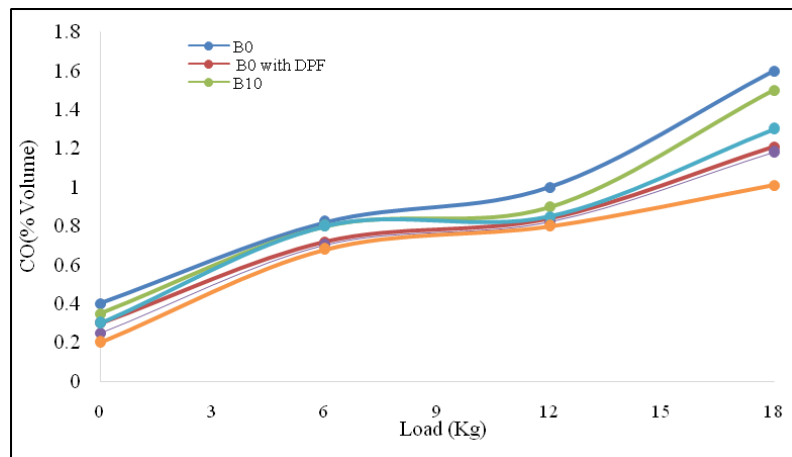
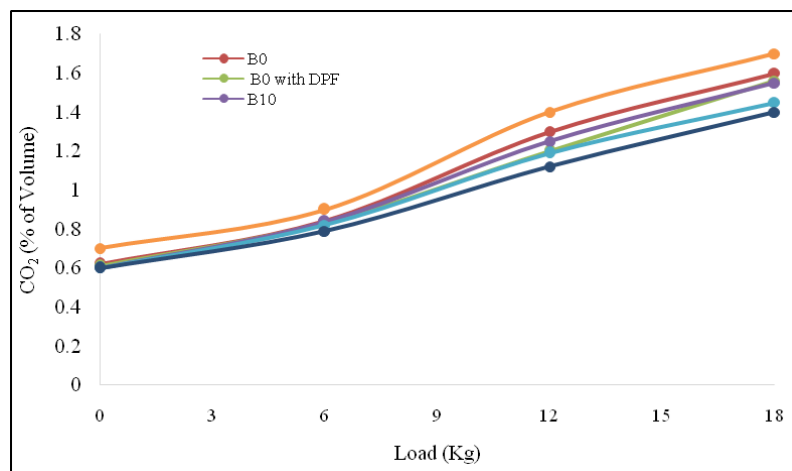


Figure 4: Load Vs CO

Figure 5: Load Vs CO₂

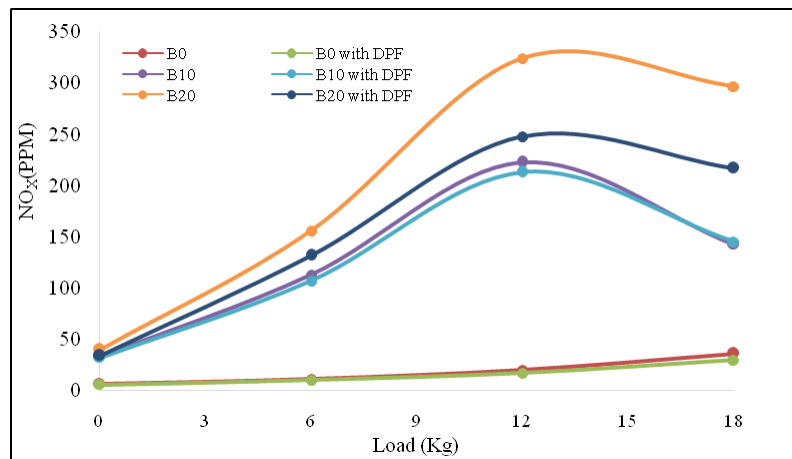


Figure 6: Load Vs NOX

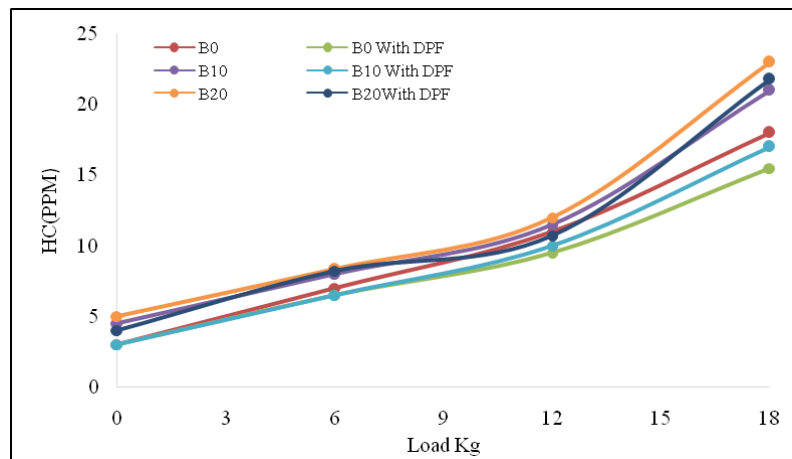


Figure 7: Load VS HC

With the load emissions of O_2 for diesel with and without DPF is decreased as observed in Figure 8. While with biodiesel, O_2 emissions are decreasing compared to diesel. With load smoke emissions of B0 is comparatively up and with DPF these are reduced. The trend is same with all fuel options which can be seen in Figure 9. The smoke, HC emissions are low for blended fuels compared with neat diesel. The DPF significantly reduced the smoke emissions by 32% for B0 at full load.

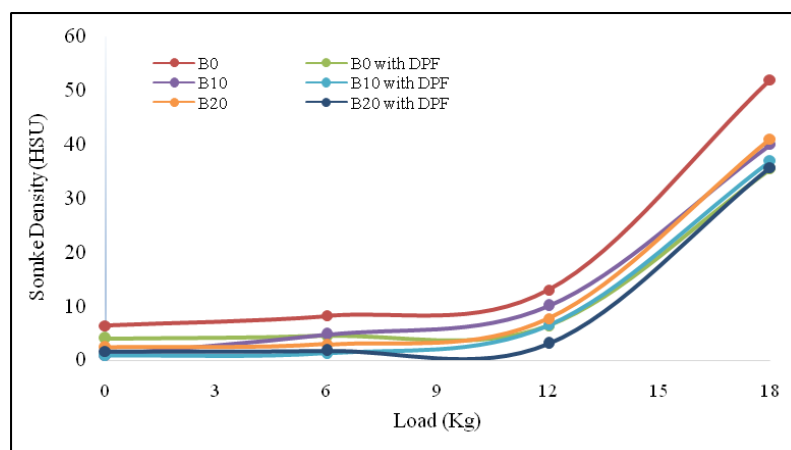


Figure 8: Load Vs O2

5 CONCLUSIONS

The experiments were conducted on a single cylinder diesel engine with fuels algae biodiesel and diesel. The observations of this work are

- Biodiesel is prepared from the algae stain *Nodularia Spumigena* under prescribed laboratory and open air conditions and the properties are measured.
- The engine system is fitted with a DPF to reduce the smoke emissions.

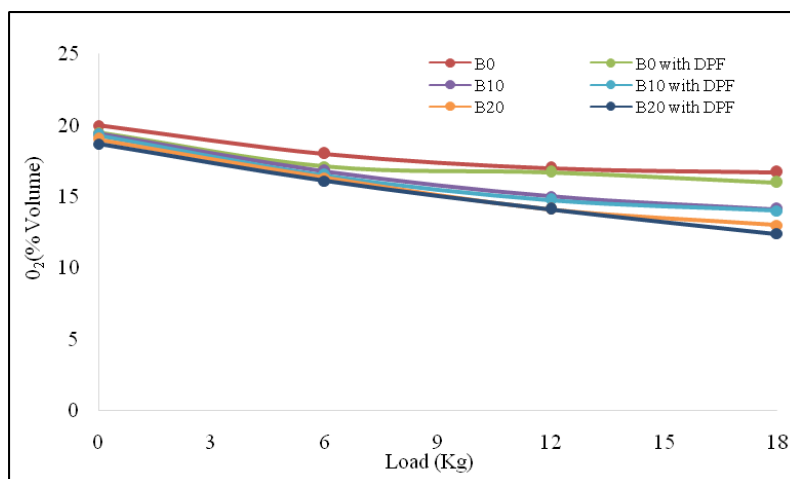


Figure 9: Load Vs Smoke Density

- The BSFC and BTE are observed to be good with blending of algae biodiesel with diesel which is close to previous research results.
- The emissions of CO are low with blends and CO_2 has been increased with blending which is remarkable sign.
- The NOx emissions increased with blending and smoke emissions are lowered with blending.
- The reduction of smoke emissions is better with algae biodiesel blends.
- Significant reductions of smoke emissions are possible with DPF.

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Abbreviations:

DPF	Diesel Particulate Filter
IC	Internal Combustion
SI	Spark Ignition
CI	Compression Ignition
CO	Carbon Monoxide
HC	Hydro Carbons
NOx	Oxides of Nitrogen
PM	Particulate Matter
HSU	Hartidge Smoke Unit
PPM	Particulate Per Million
SFC	Specific Fuel Consumption
IP	Indicated Power
BP	Brake Power
RPM	Rotations Per Minute
Kg	Kilogram
kW	Kilo Watt

