Experimental Investigation of Groundnut Oilcake Extract Blended Diesel Fuel in Ci Di Engine

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Abstract— the present work has focused on residual fatty substances available in ground nut oil cake and attempt has been made to blend the extracts of oil cake with diesel at different proportions namely 5%, 10%, 15%, 20% and 25% by weight added to known volume of diesel without any engine modification. This new fuel is investigated in the diesel engine and its performance and emission characteristics are determined. The physical and fuel properties are determined as per ASTM standards and found to be within the limits prescribed for biodiesel. The quality of all blends is evaluated using gas chromatography and found to have esters of fatty acids similar to groundnut oil. It has been observed that the presence of wax, triglycerides, free fatty acids and molecular oxygen in the fatty substances help in improving the combustion causing reduction in HC, CO and smoke density. However it is observed that there is a marginal increase in NOx emission. With regards to brake thermal efficiency, 15% oil cake extract diesel blend gives better efficiency than neat diesel and other blends.

Key words: groundnut oil cake powder, blended fuel, performance and emission characteristics, Gas Chromatography

I. INTRODUCTION

Stringent economic norms, fuel costs, scarce resources of fossil fuels, increased population have put a limit in the use of conventional fuel and necessitate the search for renewable energy sources for energy security and progress of the nation. Though, in 1900, Rudolf Diesel demonstrated the use of vegetable oil (peanut oil) to run his first ever diesel engine. The use of vegetable oil was not encouraged subsequently due to ready availability of petroleum products discovered later. Literature reviews indicate many experimental works have been carried out on biodiesel derived from different feed stocks reported that the increase in brake specific fuel consumption, decrease in brake thermal efficiency, increased exhaust temperature, higher value of NOx with decreased CO and HC emission[1-9]. The higher oxygen content in biodiesel improves combustion efficiency which compensates for its lower calorific value. It is also reported that performance of diesel engine can be improved with better emission through varying fuel injection timing, injection pressure and fuel inlet temperature to the engine [10-12]. Literature review also indicate investigations carried out on used cooking oil to use it as a biodiesel as a cost effective measure besides avoiding environmental degradation [13-14]. India, being agricultural nation, the extraction residues can become a major source for bio fuels. Oil cakes are typical example. Oil cakes are the products obtained after oil extraction from seeds. Oil cakes are classified as edible and non-edible. Edible oil cakes have a high nutritional value with protein and rich in energy content. It could be identified as a potential stock to make cheaper bio diesel [15]. Many reported findings have been observed on pyro lytic experiments conducted on various oil cakes/residues and bio oil was produced [16-18]. These biofuels require further post treatment to meet fuel standards [19]. Attempts were also made to adopt bio mechanical conversion processes to convert oil cakes into useful form of energy through anaerobic digestion [20]. Literature survey so far indicates that oxygen rich oil cakes with minimum fatty substances have so far not been investigated by blending with diesel oil. In this work, one of the major crops in India, oil cakes of groundnut, at different proportions is mixed with diesel and experiments are conducted to study the performance and emission parameters of a diesel engine and compared with neat diesel.

II. MATERIAL AND METHOD

A. Fuel preparation

The groundnut oil cakes (GOC) are purchased from fodder shop available in the local market. The oil cakes are powdered and pulverized to produce more homogeneous sample and increase the surface area of fat content exposed to diesel. The fuel is prepared by adding known amount of GOC with known amount of diesel at various proportions namely 5%, 10%, 15%, 20% and 25% by weight of diesel. After mixing, it is stirred constantly twice in a day and the mixture is allowed to settle down. This procedure is repeated for five days to ensure the maximum dissolution of oxygen rich residual fatty substances in diesel. Then the fuel is allowed to settle down and all the sediments are filtered and removed. The fuel blend so prepared at different proportions is directly used in diesel engine without any engine modification.

B. Fuel characterization

1) Chemical composition of groundnut oil cake and its extract

The chemical composition of groundnut oil cake obtained after mechanical oil expeller has been reported in Table 1

Moisture	Crude protein	Crude fibre	Fats
7-10	30 – 46	5 - 23	9 - 15

Table. 1: Composition of groundnut oil cake by weight (%)

and the corresponding composition of extracts of groundnut oil cake obtained through hexane solvent is reported in Table 2.

Triglycerides	FFA	Wax	Essential oil	Emulsion

80 - 85	4 – 6	2 – 3	0.1	4 - 5

Table. 2: Composition of extracts of groundnut oil cake by weight (%)

2) Proximate and ultimate analysis of GOC

The proximate and ultimate analysis is conducted to determine the physical properties of oil cakes. The proximate analysis is conducted by ASTM D3172-07a. It provides information on moisture content, ash content, volatile matter and fixed carbon content. The ultimate analysis is also done to determine the elemental composition of material using elementor CHNS analyzer. The oil content of the oil cakes is also measured using sox let apparatus to find the oil content of cake and all details are furnished in the Table 3.

PROPERTY	Results (%)
Moisture	5.75
Ash content	4.82
Volatile Matter	79.32
Fixed Carbon	10.11

Table. 3: Proximate and ultimate analysis of GOC

C	54.12
H	5.42
N	6.73
S	0.36
O	33.37
GCV (kJ/kg)	16700
Oil Content	12.61

3) Physical and Fuel properties of Neat Diesel and GOC blends

The physical and fuel properties of neat diesel, GOC blends at different proportions are found out as per ASTM standards and reported in Table 4.

Property	ASTM Test Procedure	Unit	Diesel	GOC blends				
				5%	10 %	15 %	20 %	25 %
Density	D4052	kg/m^3	0.819	0.819	0.820	0.82	0.821	0.821
Kinematic viscosity @ 40 ^{0}C	D445	cost	3.366	3.39	3.40	3.46	3.58	3.76
Calorific Value	D240	kJ/kg	42700	42145	41504	41120	40650	40155
Catani index	D611		53	52	51	49	46	44

Table. 4: Physical and fuel properties of GOC blends and diesel

4) Gas chromatography and mass spectroscopy analysis

Gas Chromatography is the most widely used method for the analysis of biodiesel due to its higher accuracy (Knothe 2001 & Enweramedu *et al*. 2009). Gas Chromatography (Thermo scientific) (Thermo Trace Ultra GC) coupled with Mass Spectrometer (TSQ quantum axles/ Thermo scientific) has been used to determine qualitative analysis of test fuels. The GC does not detect fatty substances in the form of triglycerides, free fatty acids, wax, emulsion directly as their boiling points are high. Hence the esterification procedure has been adopted to produce methyl esters of fatty acids as their boiling points are low. They can be easily detected and quantified.

The fatty acid methyl ester compounds (FAME(s)) have been identified by GCMS library (NIST & WILEY) and confirmed with standard retention times. All samples have been tested and the presence of methyl esters of fatty acids in each sample are identified and quantified. The same procedure has been followed for all samples in determining the FAME(s). The gas chromatogram spectrum for 15%GOC blend is shown in fig 1 and quantified values are sown in Table 5.

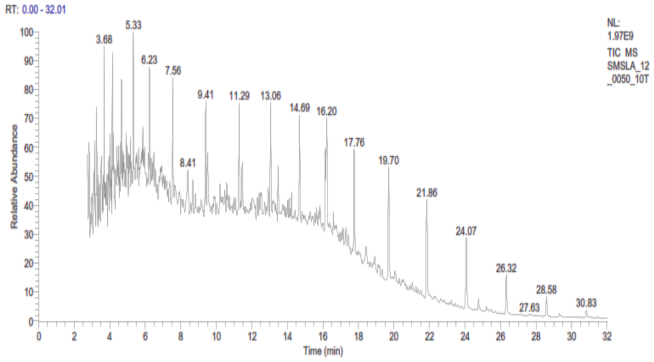


Fig. 1: Gas chromatogram spectrum for 15%GOC blend

Name of test fuel	Details of FAME(s)	Yield (%)	RT(min^{-1})
15%GOC	Methyl Ester of Oleic acid	17.77	16.20
	Methyl Ester of Lignoceric acid	2.34	29.30
	Methyl Ester of Palmitic acid	8.43	13.47
	Methyl Ester of Stearic acid	4.01	16.57
	Methyl ester of Behenic acid	6.01	24.74
	Methyl ester of Linoleic acid	26.17	16.13

Table. 5: Details of FAME(s) available in 15%GOC blend

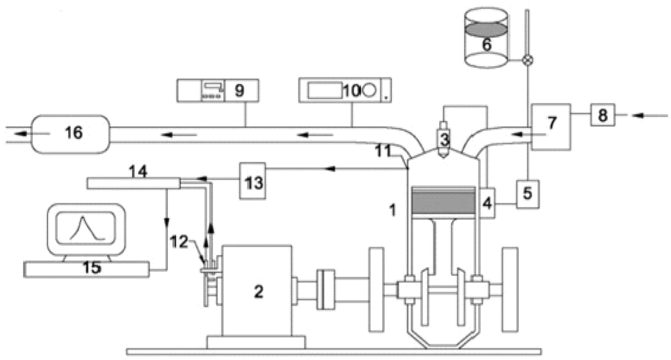
III. EXPERIMENTAL SETUP

A single cylinder, water cooled, four stroke direct injection Diesel engine coupled to a eddy current dynamometer with necessary instruments and sensors is used for conducting the tests. The schematic diagram of the engine set up is shown in Figure 2 with the detailed technical specifications of the engine are given in Table 6.

Type	Four stroke, compression ignition, constant speed, Vertical, water cooled, direct injection
No.of cylinders	One
Bore	87.5mm
Stroke	110mm
Compression ratio	17.5:1

Rated speed	1500rpm
Rated power	5.2kW
Injection timing	23ºb/TDC
Injection pressure	220bar
Cubic capacity	662cc

Table. 6: Engine specification



1	Kirloskar TV1 engine	9	Smoke Meter
2	Eddy current Dynamometer	10	AVL Di gas Analyzer
3	Fuel injector	11	Pressure Transducer
4	Fuel pump	12	TDC Encoder
5	Fuel filter	13	Charge Amplifier
6	Fuel tank	14	Combustion Analyzer
7	Air stabilizing tank	15	Personal computer
8	Air filter	16	Exhaust silencer

Fig. 2: Experimental Setup

The AVL combustion analyzer with 619 Indi meter hardware and Indwin software version is used to measure in cylinder pressure, heat release rate, indicated mean effective pressure etc.,. The data from 100 consecutive cycles are recorded at each angle and averaged. A Non Dispersive Infrared (NDIR- AVL-444 digas analyzer) is used to measure exhaust emissions of unburned HC, CO, CO_2, O_2 and NO_x.

IV. Results and Discussion

A. *Performance Analysis*

1) *Specific fuel consumption*

Fig. 3 shows the variation of BSFC for various GOC blends and diesel. It is observed that the BSFC for all blends of GOC except 25%GOC blend is better than neat diesel due to addition of GOC. It is also observed that the maximum reduction in BSFC for 15%GOC blend at peak load is recorded as 3.95% compared to neat diesel. This is attributed to the presence of TG, FFA and wax which improved the combustion performance. The higher GOC blends above (15%GOC) show inferior fuel consumption due to the possession of emulsive substances. The molecular oxygen present in the TG and FFA are also considered as important reasons for the lower fuel consumption compared to diesel fuel. The rapid gasification, better fuel spray and higher BTE are the additional reasons for lower fuel consumption of 15% blend.

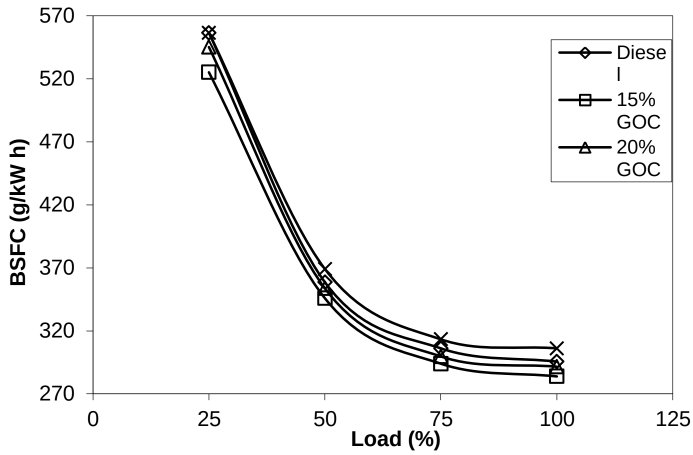


Fig. 3: Variation of BSFC for various proportions of GOC blends with load

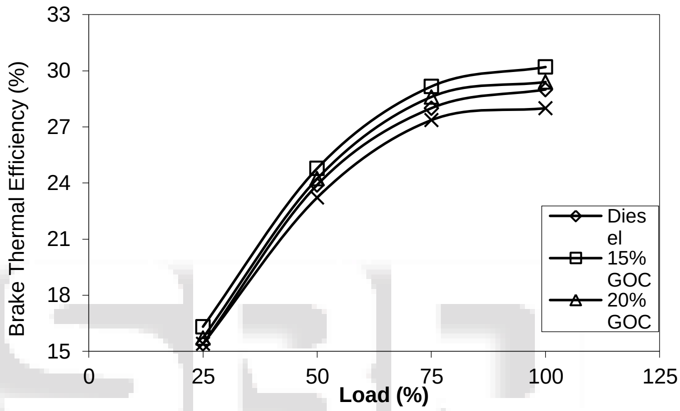


Fig. 4: Variation of brake thermal efficiency for various proportions of GOC blends with load

Brake thermal efficiency

Fig. 4 shows the variation of BTE for various blends of GOC and diesel. It is found that 15%GOC blend offers the best maximum efficiency (4.13% higher than neat diesel and all other blends of GOC). The reason for the improved performance of 15% blend is due to the presence of wax content of fuel. Usually wax increases fuel gasification rate by releasing lighter fractions during combustion. Fragmentation of TG and FFA enhances the combustion behavior and hence 15% blend offered comparatively better performance than that of other blends. The maximum BTE is observed at 15%GOC blend at peak load. It is also found that for all blends and neat diesel, the maximum BTE occurs at maximum load. The presence of molecular oxygen available in residual fatty substances helps to break down heavier molecular structure of TG and FFA in a rapid rate. The higher blends above 15% are not showing improvements due to the possession of more emulsive substances. Usually emulsive substances are decreasing combustion behavior of the fuel and suppress the cetane value of fuel. Further increase in GOC blend result in decrease in BTE than 15%GOC blend but still higher than neat diesel. But 25%GOC blend gives inferior performance due to the presence of more emulsive substances.

B. Emission Analysis

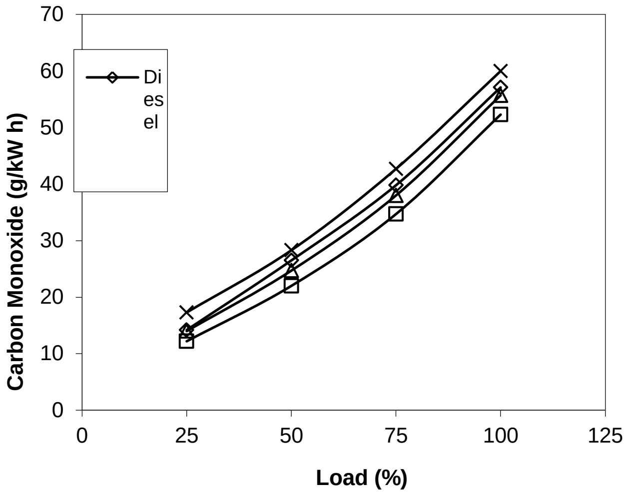


Fig. 5: Variation of CO emission for various proportions of GOC blends with load

1) CO emission

Fig. 5 shows the variation of CO for all blends of GOC and compared with neat diesel. CO formation is due to incomplete or partial combustion of carbon. CO is a toxic substance besides a fuel. Hence by providing sufficient oxygen CO can be combusted into CO_2. The 15%GOC blend shows the lowest CO emission compared to other blends. The higher BTE, higher cylinder pressure and higher rate of heat release produces higher combustion temperature and caused lower CO emissions. The presence of higher combustion temperature helps to produce lighter fraction in a rapid rate and hence whole fuel is ignited in shorter duration of combustion without leaving any partial combusted fuel fraction. The higher blends of GOC show higher CO emission. This is due to heterogeneous charge present inside the cylinder and higher fraction of emulsive substances. The presence of emulsive substances in higher blends prevents the complete combustion. The observed percentage reduction in CO emission at maximum load for 15%GOC blends with respect to diesel is 8.4%.

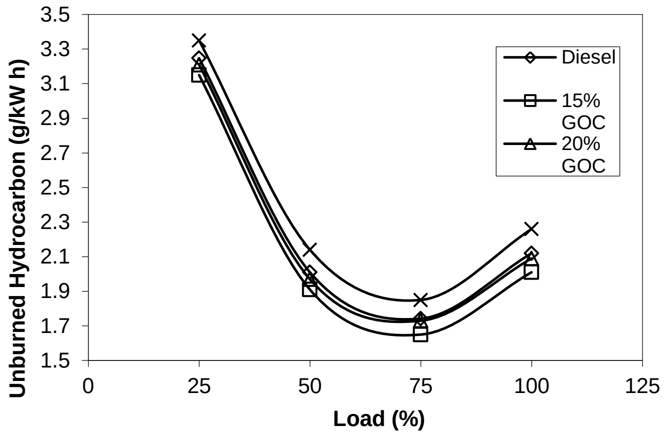


Fig. 7: Variation of NO emission for various proportions of GOC blends with load

2) NO emission

Fig. 7 shows the variation of NO emission for various blends of GOC and compared with diesel. It is seen that NO emission increases as load increases for all blends. The emission of NO for all GOC blends is marginally higher than neat diesel. The increase in NO emission is significant when load is increased above 50% of rated load. This is primarily due to burning of more fuel, increased combustion temperature, as load increased. From the Fig., it is observed that the 15%GOC blend has offered the highest NO emission compared to diesel and other blends. This is due to production of higher cylinder pressure, higher cylinder temperature, and rapid rate of heat release. The rapid rate of heat release produces more combustion temperature and it forms a conducive ambience for the reaction of atmospheric nitrogen with the oxygen. Hence the blend offers higher NO emission than that of other blends. The rapid productions of intermediate compounds from TG and FFA due to molecular oxygen are also the main reasons for higher cylinder temperature.

The higher cylinder pressure, higher heat release rate, shorter burn duration are evident for causing higher combustion temperature. The presence of more emulsive substances in higher blends is the main reason for lower NO emission. However the production of NO from 15%GOC blend is not much higher than diesel due to the presence of emulsive substances in it and the percentage increase at maximum load is 7.43% compared with neat diesel.

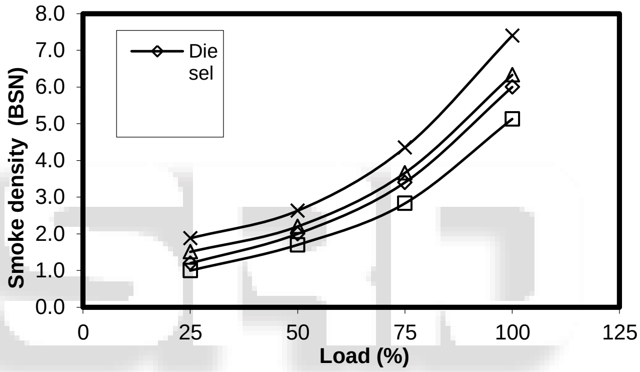


Fig. 8: Variation of Smoke density for various proportions of GOC blends with load

3) Smoke density

Fig. 8 shows the variation of smoke density for the various blends of GOC and compared with diesel. Soot is considered as main substance suspended in the exhaust due to burning of fuel is called smoke. It is observed that 15%GOC blend shows the lowest smoke emission compared to other blends but slightly higher than the diesel. Production of higher cylinder pressure, higher cylinder temperature, rapid rate of heat release and shorter burn duration are the other reasons for lower smoke emissions. Higher blends of GOC are offering comparatively more smoke emissions due to the presence of moisture present in the emulsive substances and wax. The percentage decrease in smoke density for 15%GOC blends at maximum load is 15% compared with diesel.

V. CONCLUSION

Following conclusions have been m,ade

- 15%GOC blend is found to be optimum among the various proportions of GOC blends.
- This blend increases the brake thermal efficiency of the engine and found to be 4.13% higher compared to diesel with a fuel saving 3.95%.

- The reduction in CO, HC and smoke density is observed for this optimum blend at maximum load.
- However a marginal increase in NO emission is observed at maximum load for this blend and found to be 7.43% more compared to diesel.
- Blends containing more than 15%GOC offer inferior performance.

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