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Bio-Diesel Production and Performance Analysis of I.C Engine Running On Diesel Fuel Blended with Different Fractions of Esterified Gingili Oil

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Original Research Article

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Abstract: Bio-fuels are the most promising renewable energy which may provide a viable mode of alternative system and can be a real substitute to fossil fuels. Nevertheless, this technology ought to overcome a number of hurdles before it can compete in the fuel market and can be broadly organized. Consequently, the present research was attempted to evaluate the esterified oil obtained from 'Gingili (Sesame) seed' (botanically called *Sesamum indicum*, L. belongs to family Pedaliaceae) for various physico-chemical parameters followed by performance of diesel engine with variable blends. Accordingly, the oil generated from the seeds of Gingili was subjected for transesterification with methanol in presence of catalyst NaOH. The fuel properties of Gingili (Sesame) bio-diesel can meet up with the specification of ASTM such as, Color (pale brown), Specific Gravity at 15^0 C0.88, Kinematic viscosity@40^0C 5.22, Cetane number 53.20, Sulphur, wt% 0.0083, Cloud point 12, Pour point -10, Lower Heating Value (KJ/Kg) 40676.848, Flash point 240^0C, Fire point 184^0C. Further, an imperative performance of diesel engine was recorded with increase in ratio of fuel blends of 10%, 20%, 30%, 40% & 50% respectively. In addition, the comparative analysis was also carried-out between both Gingili (Sesame) bio-diesel and petroleum diesel with diesel engine system at variable loads and the performance characteristics of the engine were analyzed. The engine test results showed significant thermal efficiency in Gingili biodiesel compared to petroleum diesel with respect to performance and emission parameters. The emission parameters like, Carbon monoxide (CO), Oxides of Nitrogen (NOx), hydrocarbons (HC) was found to be low when compared to petroleum diesel. In conclusion, Gingili biodiesel found to be most significant source as compared to petroleum diesel on the basis of over all performance and emission parameters deliberated *via* analysis.

Keywords: Bio-fuels, Sesame biodiesel, Diesel engine, Physico-chemical parameters, Emissions.

INTRODUCTION

The world faces the crises of energy demand, rising petroleum prices and depletion of fossil fuel resources. Amongst an assortment of energy consuming sections 'Transportation' is unique and it is largely dependent on the conventional petroleum product. It has got a greater impact in the country's economy and the petroleum based fuels stored in the earth are limited reserves and they are irreplaceable. Besides, the ever increasing population and the growing rate with respect to consumption of fossil reserves are being depleted considerably and it is feared that, they will be completely exhausted soon. An urgent attention along with alternative approaches is most obligatory to reinstate the conventional fuels [1-7].

The successful alternative fuel is one which should fulfill both environmental and energy security that needs further without sacrificing its operating performance. Currently, every nation has unlocked their eyes on biodiesel as main replacement of crude oil specially diesel. Eventually, as per the previous reports, biodiesel is found to be most significant and economical compared to diesel fuel with respect to its production and applications exclusively for diesel engines. Besides, it is eco-friendly, biodegradable and it is much less harmful to the environment if spilled for any cause [8-12].

Therefore, Biodiesel obtained from vegetable oils that have been considered as a most promising alternate fuel. In general, fuel contains carbon, hydrogen, sulphur, oxygen and nitrogen that are collectively appended as a combustible substance which generates heat energy when burnt in the presence of oxygen [13, 14]. Furthermore, depending on the fuel types, the percentage of Carbon (C) ranges from 50-95%, Hydrogen (H_2) 2-6%, Oxygen(O_2) 2- 4%, Sulphur (S) 0.5-3% and Nitrogen (N) 5-7%. A potential bio-diesel substitutes diesel oil, consisting of either ethyl or methyl ester of fatty acids made from unused or used vegetable oils and followed by animal fats. Therefore, the biodiesel is produced by the transesterification reaction of triglycerides of oils derived from either vegetable or fats with the help of a catalyst [15, 16, 13]. Further, this process makes vegetable oil and animal fat into esterified oil, which can be used as diesel fuel or blending with regular diesel fuel for Internal Combustion (IC) engines [17-19].

Gingili Oil

Gingili is an edible vegetable oil derived from sesame seeds (hence called Sesame oil) botanically called *Sesamum indicum* L. (family: Pedaliaceae) and commonly known as 'Benne', teel oil. The sesame oil is being used as cooking oil in Southern India and it is often used as a flavor enhancer in Chinese, Korean and to a lesser extent as Southeast Asian cuisine. The Sesame oil is composed of the following fatty acids: linoleic acid (41% of total), oleic acid (39%), palmitic acid (8%), stearic acid (5%) and others in petite amounts [20]. The market for sesame oil is mainly located in Asia and the Middle East where the use of domestically produced sesame oil has been a tradition for centuries. About 65% of the annual US sesame crop is processed into oil and 35 percent is used in food. From studies, it was accomplished that, biodiesel can play a increasingly a good role in support of meeting energy demand in transport areas and also there have been a consistent trends for the performance of biodiesel engine and different range of gases emission during varied biodiesel blends and operating conditions or driving cycles. Since, the proposed study comprises a wide range of approach in the biodiesel industry, it gives the basic idea about biodiesel production from the Sesame seed oil by admitting the measurement on both performance & emission characteristics. Besides, it can also be used as research reference for biodiesel investigations relating to production and parametric analysis from various bio-resources. Therefore, the study has been undertaken to evaluate the optimized production and performance analysis in the Gingili esterified oil derived from Sesame seeds.

MATERIALS AND METHODOLOGY

The 'Gingili' oil used in this present study was procured from the local market of Tumkur city, Karnataka, India. All the chemicals and reagents used were of analytical grade (Merck or Sigma Aldrich) procured from authorized dealers, Bengaluru (Karnataka), India.

The preliminary experiment was carried-out at the division of Bio-energy Research, Bhoomigeetha Institute of Research & Development (BIRD), Tumkur and the analytical tests were conducted at Maharaja Institute of Technology Thandavapura, Mysuru (Vivesvaraya Technological University, Belagavi, Karnataka), The fuel properties like viscosity, flash point, fire point, cloud point, pour point etc. were determined by using equipments such as Redwood Viscometer for kinematic viscosity, Pen sky-Martens apparatus for flash point etc. As per the standard protocol, the chief characteristic feature like, calorific value of both Biodiesel & petro-diesel was determined respectively.

Gingili Oil extraction: The dried sesame (*Sesamum indicum* L.) seeds of healthy and uniform sized were subjected for grounding using a mechanical blender. Then, the oil was obtained through soxlhet's method *i.e.*, 100 g of ground seeds were placed into a cellulose paper-cone and extracted using light petroleum ether (b.p 40-60ºC) in a 5-l Soxhlet's extractor for 8 h [21, 22]. The oil was then recovered by evaporating the solvent using rotary evaporator and the residual solvent was removed by drying in an oven at 60ºC for 1 h by flushing with 99.9% nitrogen.

Further, the thermal properties of the oil samples were evaluated by differential Scanning Calorimetry. The purge gas used was 99.99% nitrogen with a flow rate of 100 ml. min G1 and a pressure of 20 psi. The sample weights ranged from 5-7 mg were subjected to the following temperature assortment and the frozen oil sample was heated at 50ºC in an oven until it is completely melted. Oil sample was placed in an aluminium volatile pan and was cooled to -50ºC and held for 2 min, it was then heated from -50 to 50ºC at the rate of 5ºC.min G1 (normal rate) [23] and held -50 ºC isothermally for 2min and cooled from -50 to 50ºC at the rate of 5ºC.min G1 [24].

The heating and cooling thermograms for the normal and the fast (hyper DSC) scan rates were recorded and the onset, peak and offset temperatures were efficiently tabulated. These values will provide information on the temperature at which the melting process starts, then the temperature at which most of the TAG have melted. The complete melting temperature of the oil was recorded. Later, the seed compositions was analysed with respect to moisture content, crude protein and carbohydrate ash respectively [25].

Transesterification process

The Transesterification process is the reaction of a triglyceride (oil/fat) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule and their bases with three long chain fatty acids are attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine.

The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester or biodiesel and crude glycerol. In most production processes, either methanol or ethanol type of alcohol is used (methanol produces methyl esters & ethanol produces ethyl esters) and its base catalyzed by either potassium or sodium hydroxide. The Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production; either base can be used for the methyl ester. A common product of the transesterification process is Sesame Methyl Ester (SME) produced from raw Sesame seed oil reacted with methanol [26]. The following scheme is the general steps of the transesterification of vegetable oil to produce methyl esters of fatty acids that are termed as biodiesel (Fig-A, B & C).

Fatty acid + Alcohol → Ester + Water; Triglyceride + ROH → Diglyceride + RCOOR1

Diglyceride + ROH → Monoglyceride + RCOOR2; Monoglyceride + ROH → Glycerol + RCOOR3

In the process of esterification or biodiesel preparation; the oil was subjected for heating to the desired temperature (60°C) before starting the reaction. At this point, the prepared contents of methanol and potassium hydroxide were added to the oil under mechanical stirring (300 rpm). The time of the transesterification reaction was 1h, using a 6:1 molar ratio of methanol/oil and 1% (KOH w/w oil) as a catalyst. Further, the vegetable oil reacts with simple alcohol like methanol in the presence of a catalyst. The fatty acid of the vegetable oil was replaced with the (OH) group of the alcohol producing the glycerol and methyl fatty acid ester. The concentration of catalyst effects the yield of ester and therefore, it is very important for experimental optimization as the concentration of catalyst is admitted as less than the required value, the reaction between vegetable oil and alcohol will not be completed if the concentration of catalyst is more than the required value, the saponification process will takes place which will lead to soap formation [20].

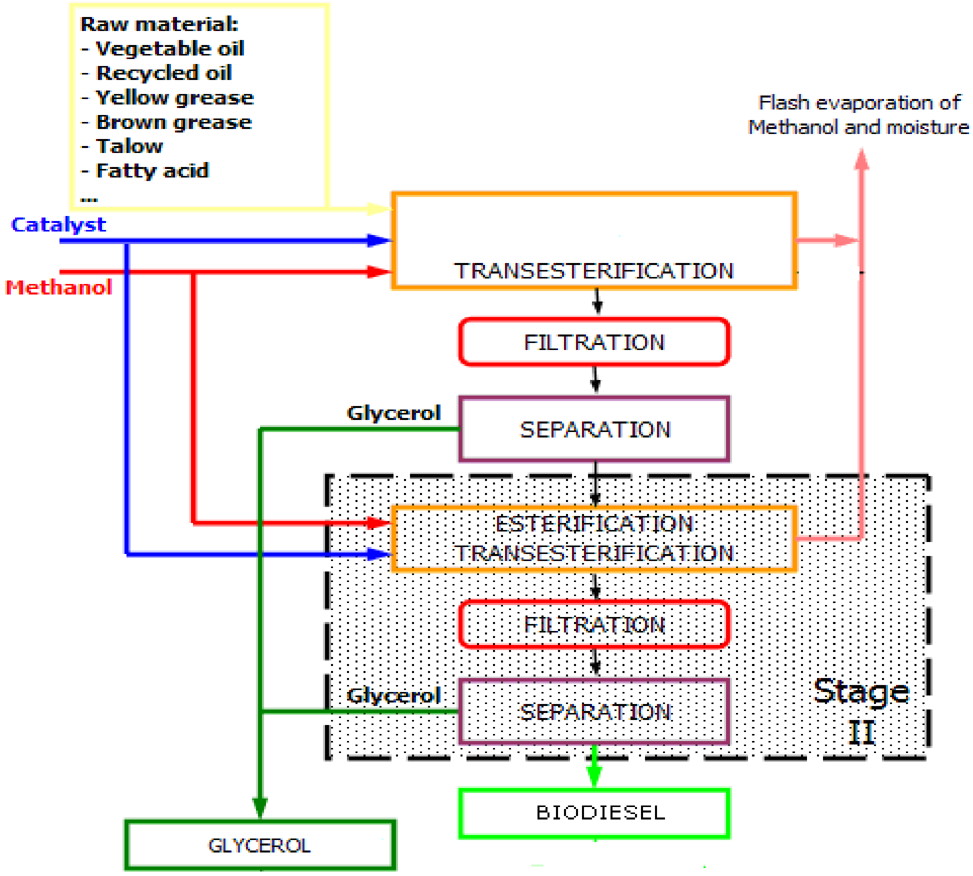


Fig-1: A chart showing Biodiesel production

Hence the optimization of catalyst concentration *via* varied reaction mixture was employed. The parametric process and their effects were studied to standardize the transesterification process. There are infinite number of experiments for different concentration and number of parameters which gives different yields. By this process, the least number of experiments are obtained with maximum ester yield as well as the recovering of ester with least possible viscosity [21]. In order to standardize the catalyst concentration, four levels of catalyst (KOH) concentration (0.75%, 1%, 1.25%, 1.5%) was set with the reaction time of 30 minutes, 40 minutes, 50 minutes and 60 minutes respectively. Subsequently, the concentration of alcohol 10%, 15%, 20% & 25% and temperature of 60^0C were taken into consideration during the course of study (Table-1 & 2).

Purification of Sesame Biodiesel

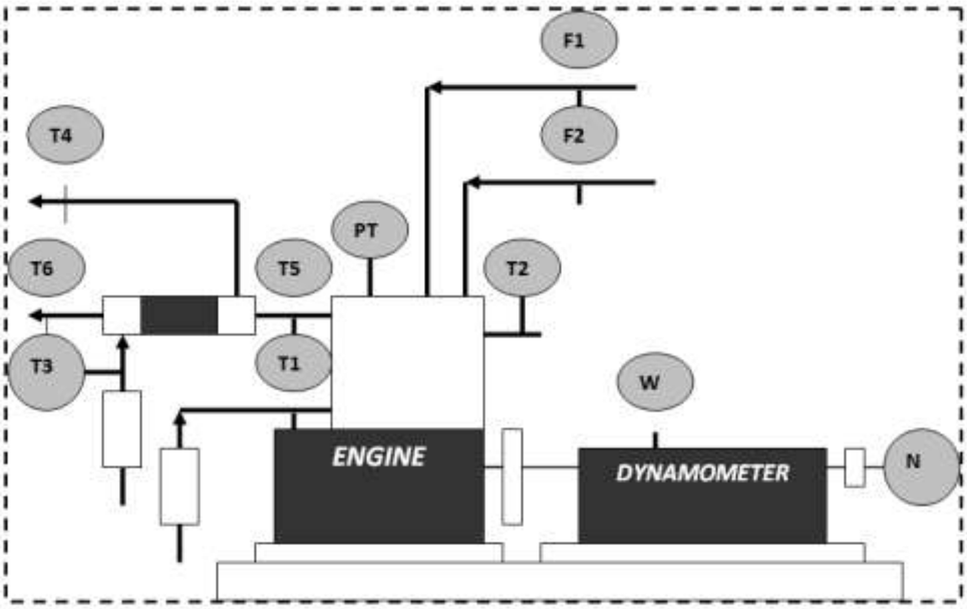
At the last part part of the reaction, the glycerine was divorced from the methyl esters in a decantation funnel. The less impenetrable phase, composed by esters was then, separated and stored for further analysis followed by purification. Further, the water purification was done using a sample of 50g of biodiesel was transferred to a separating funnel and rinsed with 1% phosphoric acid (H_3PO_4) at 55°C. After phase separation and removal of aqueous layer, the sample of Sesame bio-diesel was washed twice with hot water [8]. The washed bio-diesel was heated at 90°C in a water bath for 30 min inorder to eliminate water and then stored for subsequent analysis as well as purification parameters which were completed in duplicate [27].

Characterization of Esterified Sesame Oil

The physical properties of the raw samples, biodiesel and its blends with petro-diesel were measured by using American Society for Testing and Materials "ASTM" standard methods, including kinematic viscosity (using U tube viscometer), flash point, fire point, pour point and cloud point, acid value, density, specific gravity, total sulfur content, cetane number respectively.

Experimental set up for Evaluating performance of I.C Engine

Initially, the water supply was adjusted to the engine and all the connections were checked in particular for fuel and water. In addition, the engine and the generator components were made ready for conducting the actual test. Further, the fuel tank was filled with required fuel to be tested; subsequently, the c224 software was employed and the online mode was selected. The values were entered during running mode and configured in the selection approach. The process was displayed in the overview screen is as follows [28, 18].



Engine line diagram: Engine Test Set up (Computerized) Single Cylinder Four stroke Diesel Engine model-224
T1-Jacket water inlet temperature in ^{0}C
T2-Jacket water outlet temperature in ^{0}C
T3-Calorimeter water inlet temperature in ^{0}C
T4-Calorimeter water outlet temperature in ^{0}C
T5-Exhaust gas to calorimeter inlet temperature in ^{0}C
T6- Exhaust gas from calorimeter outlet temperature in ^{0}C
F1-Fuel flow in Kg/hr; F2-Air flow in Kg/hr
W-Dynamometer load in N; N-Speed of engine in rpm

The engine was running at no load condition and time taken to consume 10cc of fuel using stop clock was adjusted. The engine pace along with constant speed for different engine loads was maintained. The input to engine like cooling water, calorimeter readings was accomplished. At no load conditions, the data in computer using log key was stored after completion of first reading & gradually the load was increased on engine and after few minutes stable and steady state was maintained. Then, the data was stored using log key and the above steps were repeated for various loads.

Gradually the load was reduced and the engine was clogged.

Engine Performance Analysis

The engine performance indicated that, the promising effects of a fuel blends in the engine and showed the trend on possibility of using Sesame oil to replace diesel oil without any engine modifications. It is necessary to determine brake torque (*T*), engine brake power (*P*), brake specific fuel consumption (*bsfc*) and brake thermal efficiency (*th*) respectively. These several parameters can be obtained by measuring air and fuel consumption followed by analysis of torque, speed of the engine and heating value of the oil. The performance parameters were calculated using standard equations are as followed.

Brake Torque

Torque is an indicator of the function of brake and it is defined as the product of force and perpendicular distance. The brake torque is calculated by the moment of engine arm connected to weight scale is given as: $T=Fd$

Where T is brake torque in Nm, F is force of engine arm applied to the load in N and d is the distance of engine arm from center of the rotor to the load.

Engine Brake Power

Engine brake power (B*P*) is the power available at the crank shaft which is given by BP=2πNT/60 where B*P* is the engine brake power in kW; T is the torque in N-m and N is angular speed of the engine in rpm.

Brake Specific Fuel Consumption

$$P = \frac{2\pi NT}{60 \times 1000}$$

Brake specific fuel consumption (bsfc) is the comparison of engine to show the efficiency of the engine against with fuel consumption of the engine in g/kW-hr where (*fm)* is the fuel consumption rate in g/hr is given as:

$$bsfc = \frac{\dot{m}_f}{P}$$

Brake Thermal Efficiency

The brake thermal efficiency is defined as the ratio of brake power to the heat supplied by the burning fuel. It is given as:

nB*th*=BP/(mf x CV) X 100.

Where BP is the Brake power in KW; mf is the Mass of the Fuel in Kg.Sec and CV is Calorific Value in KJ/kg.

The experiments were conducted by operating engine with the blended testing fuel. The operating conditions comprise; engine speed 1500 rpm rate was set. The loads were applied from 500 W and stepped up until reached the maximum load. The air box and orifice plate flow meter was applied for air flow measurement. The fuel consumption was measured from the differential expression of the fuel in time. A chromel-alumel thermocouple was installed to measure the exhaust gas temperature. The engine was run for 5 minutes to reach the steady state of test condition before collecting data. At the end of the test, the engine was run with diesel fuel for some time to flush out from the engine.

RESULTS AND OBSERVATION

In the present study, it has been demonstrated that, the biodiesel was efficiently produced from the oil of Gingili (Sesame) seeds. Thus, the virtual study was conducted to check the efficiency of Gingili biodiesel by analyzing different key parameters. Hence, the impact of diverse parameters on the production of biodiesel and its characterization was done. Further, the evaluation on efficiency and emission parameters was represented systematically. Initially, the Biodiesel was produced from Sesame seed oil of locally growing cultivar (Cv: Sesame-white wild) by methanol *via* transesterification using potassium hydroxide KOH and sodium hydroxide NaOH as alkaline catalysts as per the standard protocol. It was observed that, the yield of produced sesame biodiesel was influenced by variable reaction mixture and associated methodological parameters which facilitated the best and superlative possible reaction conditions for obtaining biodiesel at optimum level (Fig-D & E).

Production of Biodiesel from Gingili (Sesame) Oil

A preset volume of about 100ml Gingili oil was taken in a round bottom flask and 0.6 grams of NaOH pallets was weighed using electronic balance. Subsequently, 20ml of methanol was taken in a beaker, to this; NaOH pellets were added and dissolved the mixture by continuous stirring process. Later, methanol and NaOH mixture was added to a round bottom flask containing Gingili oil. The flask was kept on magnetic stirrer using a magnetic bit and clouts the mixture for about 30min without heating. Thereafter, the mixture was subjected to heating for 60minutes by maintaining of temperature between 50-60^{0}C, and then, the mixture was poured into the separating funnel. The mixture is then allowed to settle by gravity in a separating funnel overnight and the Glycerol was divorced and the methyl ester was collected from the funnel. Then, the collected methyl ester was heated up to 90^{0}C in order to evaporate methanol present if any. The heated methyl ester was filtered using filter paper and left over bio-diesel was subjected for washing with water and dried under sun to remove water present if any. Finally, the filtered methyl ester was collected in a suitable bottle and the yield of biodiesel was found to be 1450 ml. (Table-4).

Fig-A: Habitat of Gingili (Sesame)

Fig-B: Sesame Crop bearing Pods containg seeds inside

Fig-C: Sesame Seeds in cross section

Fig-D: Gingili Seeds after harvesting

Fig-E: Raw oil of Gingili after extraction

Fig-F: Magnetic stirrer

Fig-G: Separating funnel

Fig-H: Separating funnel

Fig-I: Filtering of collected Methyl ester

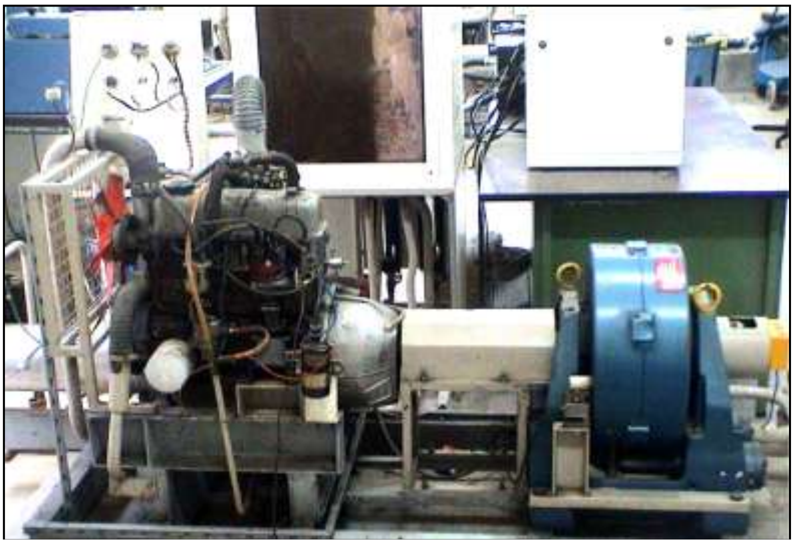


Fig-J: Showing Experimental test Rig (IC Engine) for evaluating Technical parameters

Biodiesel Characterization studies

The physico-chemical properties of the Sesame raw oil samples followed by esterified oils (biodiesel) were analyzed by comparing with petro-diesel and were measured as per American Society for Testing and Materials "ASTM" standard protocols (Table-1, 2 &3).

Table-1: Showing Characteristics of Gingili oil

SL.No.	Characteristic ($g.kg^{-1}$)	Obtained value	Reported Value
1	Yield of Oil (%)	48	50
2	Moisture Content	6.40	7.20
3	Crude Protein	19.6	20.8
4	Total Carbohydrate	14.2	18.2
5	Lipid content	49.16	56.24
6	Iodine value ($gI_2\ kg^{-1}$)	91.20	96.44
7	FFA (%)	1.58	1.65
8	Saponification value (mg KOH kg^{-1})	422.78	450.10
9	Peroxide Value (mg O_2/g)	2.65	2.82
10	Ash Content	4.10	5.80
11	Refractive Index (@ 40^oC)	1.424	1.556
12	Specific Gravity (25^oC)	0.8422	0.8625
13	Viscosity (@ 40^oC)	22.43	26.40

Table-2: Physical properties of Gingili oil seed cultivar selected for the study

Sl. No	Parameters	Cultivar
1	1000 seeds weight (g)	Local white-4.16
2	True density ($kg.m^{-1}$)	1426

Table-3: Fuel Characteristics of Gingili Oil and its Methyl ester

SL. No.	Parameters	Sesame Oil	Biodiesel	ASTM
1	Color	Pale brown	Light brown	--
2	Specific gravity	0.880	0.910	--
3	Density (15^oC)	0.865	0.870	--
4	Kinematic Viscosity(40^oC)	5.22	4.65	1.8-6.0
5	Heating Value (MJ/kg)	38.66	40.65	--
6	Flash Point (^oC)	240.20	185.60	130.10min
7	Fire Point (^oC)	184.40	190.10	--
8	Pour Point (^oC)	-10.10	-12.25	--
9	Cloud Point (^oC)	1.20	-6.50	--
10	Cetane number	53.20	50.86	47min
11	Sulphur, wt%	0.0083		--

The engine was subjected for running approximately for 90min duration and 15 minutes at each was fixed for load setting with respect to each of the prepared fuels blending ratios, the average value was taken and the accuracy in the outcome was maintained. Further, Brake power, indicated power, Total fuel consumption, Specific fuel consumption, Actual volume, Swept volume, Brake thermal efficiency, Indicated thermal efficiency, Volumetric efficiency and Mechanical efficiency were calculated using based on the observations recorded (Graph-1-6).

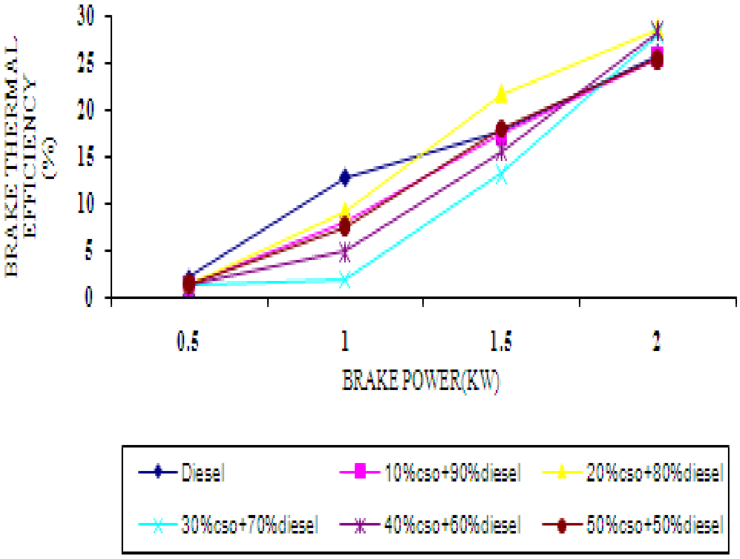
The fire point and flash point of the Gingili esterified oil was noted and compared with the previous reports in the light of recent literature (Graph-7 & 8).

Table-4: Design of Experiments by Taguchi Orthogonal Array

SL. No.	Reaction Temperature (^{0}C)	Catalyst Conc (%)	Alcohol Conc. (%)	Time (Min.)	Yield (%)	Viscosity
1.	60	0.75	10	30	92.76	5.21
2.	60	0.75	15	40	98.44	4.85
3.	60	0.75	20	50	86.10	4.55
4.	60	0.75	25	60	96.62	4.71
5.	60	1.00	10	30	90.80	4.94
6.	60	1.00	15	40	93.15	4.62
7.	60	1.00	20	50	91.21	4.77
8.	60	1.00	25	60	95.40	4.88
9.	60	1.25	10	30	89.85	5.12
10.	60	1.25	15	40	92.17	4.80
11.	60	1.25	20	50	96.12	4.61
12.	60	1.25	25	60	95.81	5.10
13.	60	1.50	10	30	98.99	4.82
14.	60	1.50	15	40	97.95	4.91
15	60	1.50	20	50	88.85	4.77
16.	60	1.50	25	60	97.10	4.96

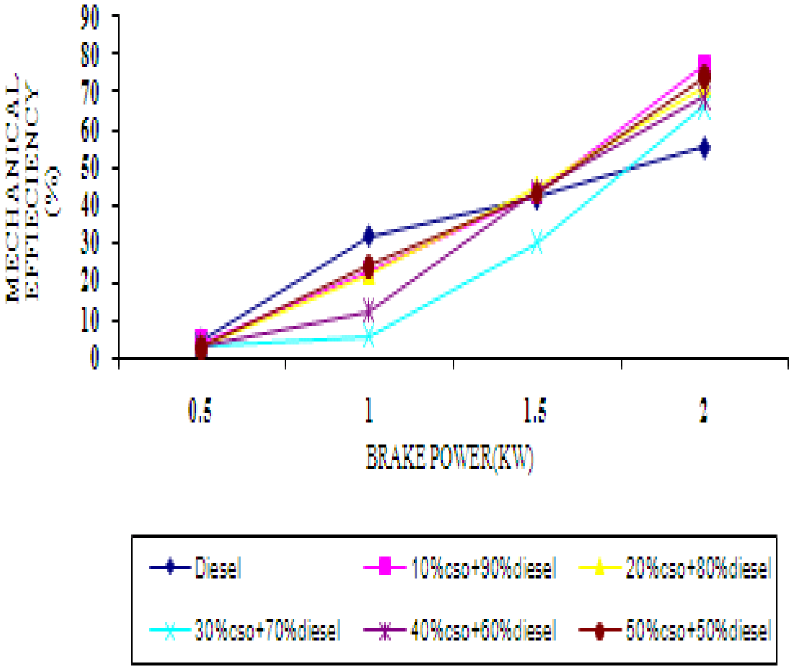
Table-5: Showing Experiment Variables

SL. No.	Components	Variables			
1.	**Catalyst (%)**	**0.75**	**1.0**	**1.25**	**1.5**
2.	**Alcohol (%)**	**10**	**15**	**20**	**25**
3.	**Time duration (Min.)**	**30**	**40**	**50**	**60**



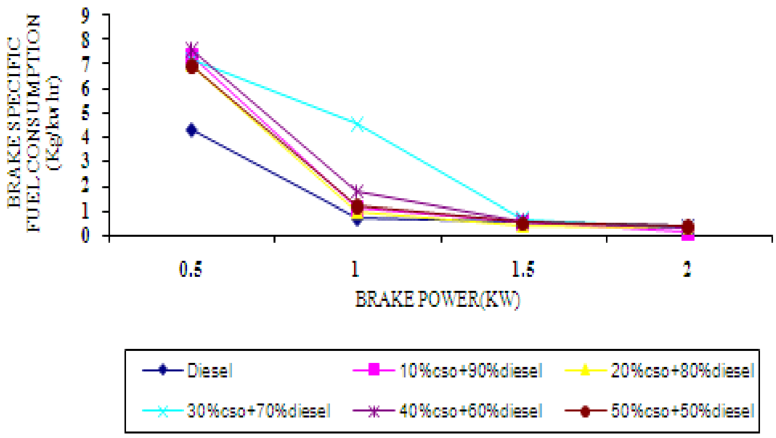
Graph-1: Brake power v/s Brake thermal efficiency

In the Graph-1, the Brake thermal efficiency; (BTF) the increasing trend with increase in brake power (BP) in all the blend ratios followed by diesel was recorded. The slight increase in efficiency was observed in 20% 30% & 40% blends ratios at maximum load conditions and which was higher than the diesel and 10% blend.



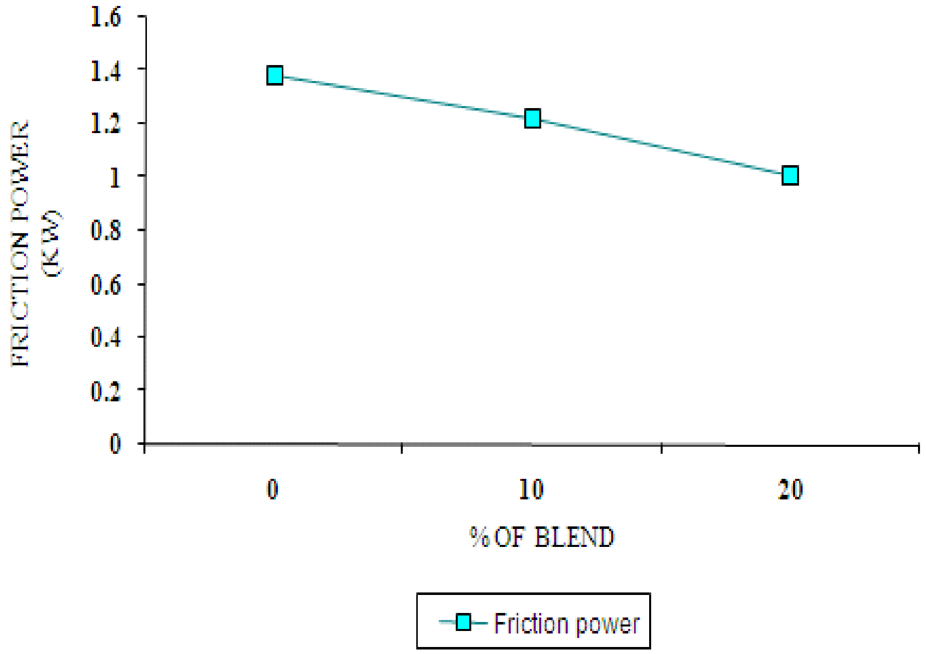
Graph-2: Brake power v/s Mechanical efficiency

In the Graph-2, the mechanical efficiency for all blend ratios was increased with increase in Brake power (BP) followed by diesel. Subsequently, the mechanical efficiency was low-down at low load conditions (30% & 40% blend) whereas, in maximum load conditions, all the blend ratios have facilitated high efficiency compared to pure diesel.



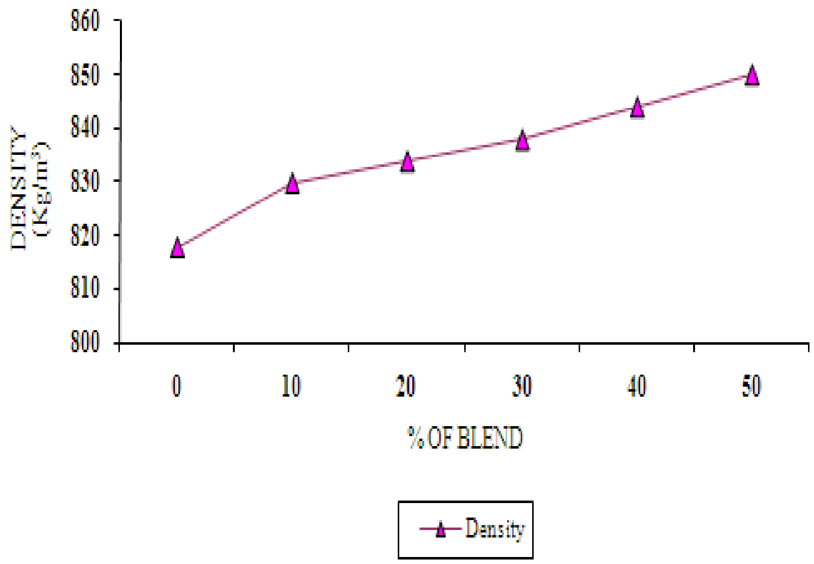
Graph-3: Brake power v/s Brake specific fuel consumption

The Brake power Specific Fuel Consumption (BSFC) was found to be higher initially for 10 to 50% blends as compared with diesel equipped to 1KW of B.P. Further, all the blend ratios exhibited same value of BSFC in the Diesel and lowest value at 2KW of BP was observed in the Graph-3.



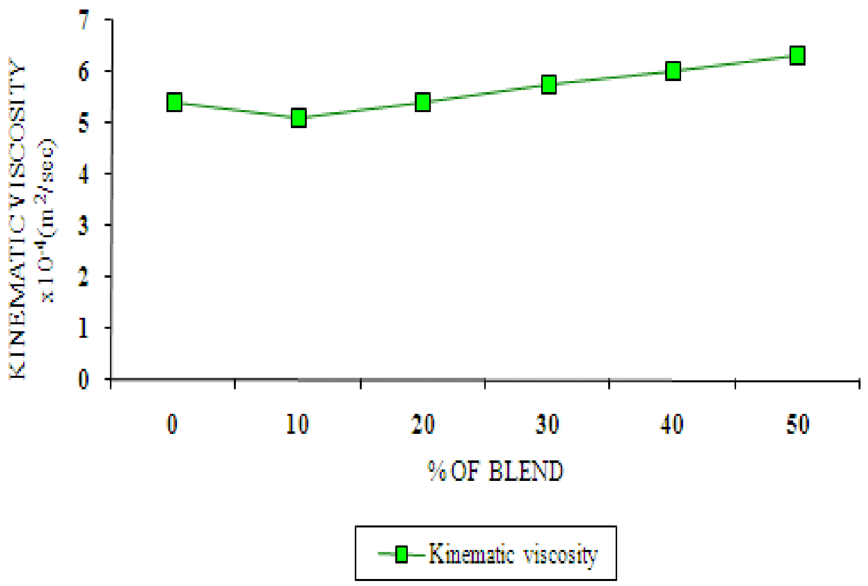
Graph-4: Friction power v/s % of Blend

The decrease in Friction power equipped at 20% blend ratio was observed with increase in % blend of biodiesel and diesel. Further, the constant with respect to Friction power was recorded. Besides, the viscosity was increased with increase in % blend which was acted as a lubricant (Graph-4).



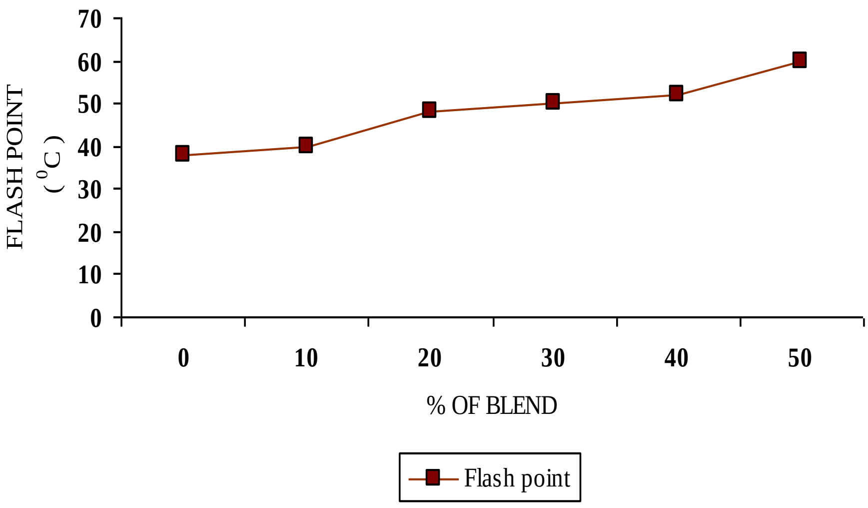
Graph-5: Density v/s % of Blend

In the Graph-5, the increase in blend percentage facilitated increased trend of density which is found to be a lesser amount as compared to the recommendations made by Indian Oil Corporation.



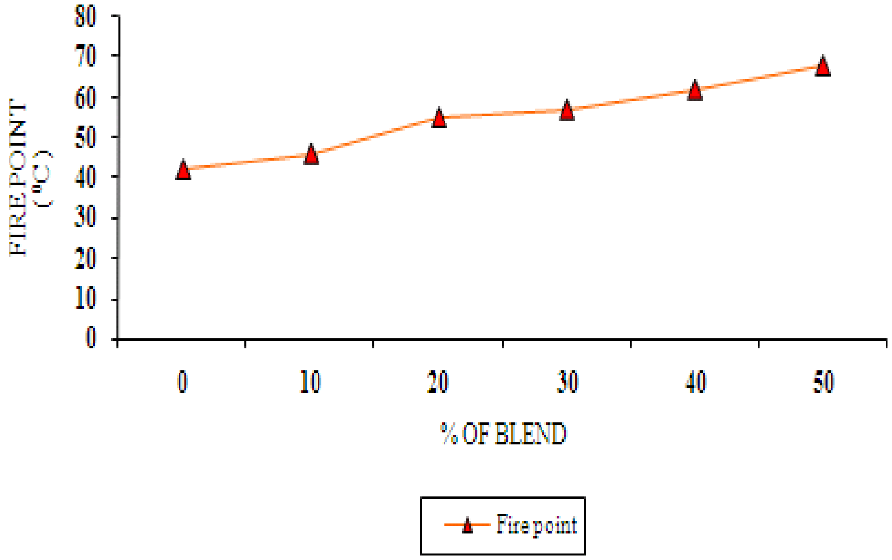
Graph-6: Kinematic viscosity v/s % of Blend

In the Graph-6, it was found that the kinematic viscosity deceased initially and a slight increasing trend was noted with increased blend ratios. This was found to be a lesser amount than the strategy set by Indian Oil Corporation.



Graph-7: Flash point v/s % of Blend

The increase in blend ratio was influenced on the gradual increase in flash point which was found to be a lesser amount than the strategy set by Indian Oil Corporation (Graph-7).



Graph-8: Fire Point v/s % of Blend

The fire point was increased gradually with the increase in blend percentage which was correlated that a lesser amount than the condition recommended by Indian Oil Corporation (Graph-8).

DISCUSSION

In the current study, the seeds of Sesame were subjected for oil extraction in order to obtain bio-diesel via transesterification process. The properties of esterified oil of Sesame were found to be momentous compared to pure diesel which was espoused with ASTM protocols and exhibits almost similar approach with Petro-diesel [29]. Further, the optimized production of biodiesel was achieved with a low cost transesterification protocol which is most significant as compared with earlier attempts [30]. This is due to the purification of biodiesel and found to be trouble-free which facilitated further, maximum recovery when esterification pretreatment was conducted [31, 27]. In addition, the process of transesterification of Sesame seed oil with methyl alcohol provides a significant reduction in viscosity, thereby enhancing the physical properties of esterified oil.

Further, the relative measures of brake specific fuel consumption, brake power, brake thermal efficiency, mechanical efficiency and volumetric efficiency were evaluated as per the standard protocols. It was observed that, the blends of Sesame oil and diesel was found to be noteworthy than that of diesel alone. Amongst the different blends, 10% and 20% was significantly increased and was superior over pure diesel. Besides, the higher brake thermal efficiency was observed than the diesel, and in contracts, the lowest value of brake specific fuel consumption was noticed in all the analytiocal measurements [32, 18, 19, 33].

Later, the emission parameters such as, CO_2, NOx and hydrocarbon emissions showed fascinating result that, the CO_2emissions were considerably lesser than the diesel and significantly decreased with variable blend ratios [17]. The emission of hydrocarbon from the different biodiesel blends was found to be lower compared to the standard diesel which is due to complete combustion process [34]. It was observed that, the lower trend of Carbon monoxide in the variable blends and at 20%, it was noteworthy as compared to other blends and diesel alone [16]. Interestingly, the NOx emission was significantly lower for all the blends than that of diesel for all the loads. This is in accordance with the earlier findings made by the respective researchers [35, 36, 6, 7].

CONCLUSION

The earth is having limited resources of fossil fuel leads to energy crisis in the next few years; it will become compulsory for us to investigate the alternative fuel from bio-resources to overcome the energy crisis. India is having a wide variety of edible and non edible oil seeds, but these seeds have a good potential for fulfilling the over energy demand. In the studies, the analysis on performance of I.C engine with diesel-esterified Gingili (Sesame oil) oil blend was carried-out. The obtained results were compared in the light of recent research reports and thus we conclude on the following points.

- It is impossible to run the existing engine with pure Gingili (Sesame) seed oil because of its high flash and fire point, so blending with diesel is most necessary.
- Transesterification process reduces the viscosity of the oil and it improves the fuel properties of the Gingili oil.
- The flash point, fire point and viscosity of the blended oil slightly increases with increase in percentage of blends, but these values are closer with the values of pure diesel as per ASTM.

- No ash particles are observed for esterified Gingili oil.
- BSFC decreases with increasing BP up to 1.5 KW onwards. Value of BSFC of the blends is same as that of diesel.
- Friction power decreases with increasing percentage of Gingili oil blend. Density, kinematic viscosity, flash point & fire point are increases with increasing in the percentage blend but these values are with in the limit recommended by Indian Oil Corporation.
- Brake thermal efficiency & Mechanical efficiency increases with increasing the brake power & at maximum load blended oil gives the higher efficiency than that of the diesel.
- No Engine modification is required to run up to 50% of blend.
- 40% blend having higher mechanical, brake thermal efficiency & lower BSFC. So, 40% blend can be considered as economical percentage of blend with the diesel.
- Due to use of Gingili oil as blended fuel; economical uplift of rural farmers can be accomplished.
- By using sesame oil as an alternative and promising fuel; the importing of petroleum products from other countries can be minimized to some extent which may help the system to improve the Indian economy.

SCOPE OF FUTURE WORK

As per the review of literature followed by analyzing the data generated from the present study, it is envisaged that, No work is complete without mentioning its drawback. In this study, an attempt has been made to give the alternative to petro-diesel by using esterified Gingili (sesame seed) oil blended with diesel fuel. The transesterification process is the time sensitive and temperature based approach to reduce the viscosity of raw sesame seed oils. In this approach upto 50% of sesame seed oil was blended with diesel which facilitates the running of the engine safely without any engine modifications. When it is above 50% of blend, fuel properties will exceed the properties of the fuel recommended by Indian Oil Corporation. This method can be adopted for other similar type of seeds oil as a blending fuel with the petro-diesel. Further, the slight modification in the engine system and simplifying the transesterification processes; the 100% substitution to the petro-diesel can be achieved.

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