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A Comparative Study on the use of Butyl Esters of Soyabean and Sunflower Oils as Biodiesel Fuel for Compression Ignition Engine

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To study the feasibility of using two edible plant oils as diesel substitute a comparative study was made. Oils were exacted from the seeds of soyabean (Glycine Max, Family: Leguminoceae) and sunflower (Helianthus annuus, Family: Asteraceae/Compositeae). Oils were esterified (butyl esters) before blending with pure diesel in the ratio of 10:90, 15:85, 20:80, and 25:75 by volume. Pure diesel was used as control. Studies have revealed that on blending vegetable oils with diesel a remarkable improvement in their physical and chemical properities took place. Cetane number came to be very close to pure diesel. Engine (C.I.) was run at different loads (0, 4, 8, 12, 16, and 20 kg) at a constant speed (1500 rpm) separately on each blend and also on pure diesel. Studies have revealed that soyabean oil at 20% blend with diesel gave best performance in terms of low smoke intensity, emission of HC and NO_x. All the parameters tested viz., flash point, total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency and cylindrical peak pressure were improved. Results have further indicated that at 20% blend engine showed a closer performance to pure diesel. 20% blend of soyabean oil exhibited better performance than sunflower oil blends. However, both the oils at 20% blends with diesel can be used as a diesel substitute. There studies have thus indicated that esterified soyabean oil at 20% blend satisfies the important fuel properties as per ASTM D975 specifications of biodiesel as it lead to the improvement of engine performance and emission characteristics without any modification in engine.

Keywords: Vegetable oil; Biodiesel; Transesterification; Performance analysis; Butyl ester soyabean oil; Butyl ester sunflower oil; Combustion characteristics.

1 Introduction

Biodiesel reduces global warming gas emissions such as carbon dioxide. When biodiesel is harvested, processed and burnt, some of the CO_2 released into the atmosphere is recycled by growing plants. These plants inturn are again processed into biodiesel, and the cycle continues. Biodiesel also virtually eliminates acid rain-causing sulfur dioxide emissions. On the other hand with the use of fossil fuels, all the CO_2 generated escapes into the atmosphere. In order to reduce dependence on fossil fuel, country like USA, Europe are using surplus edible oils (like soybean, sunflower and rapeseed) for the production of biodiesel [1, 2].

Studies have shown that the usage of vegetable oils is possible but not preferable [3, 4]. The high viscosity (about 11 to 17 times higher than diesel fuel) of vegetable oils and the low volatility affects the atomization and spray pattern of fuel, leadiPng to incomplete combustion

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and severe carbon deposits, injector choking and piston ring sticking. Furthermore, acrolein (a highly toxic substance) is formed through thermal decomposition of glycerol [5-8].

Following, different methods have been employed to reduce the high viscosity of vegetable oils:

(i) Dilution of 25 parts of vegetable oil with 75 parts of diesel fuel [5];

(ii) Microemulsions with short chain alcohols (e.g. ethanol or methanol) [5];

(iii) Thermal decomposition, which produces alkanes, alkenes, carboxylic acids and aromatic compounds [8];

(iv) Catalytic cracking, which produces alkanes, cycloalkanes and alkylbenzenes [9] and

(v) Transesterification with ethanol or methanol [10]

Among all these alternatives, the transesterification seems to be the best choice, as the physical characteristics of fatty acid esters (biodiesel) remain very close to those of diesel fuel and the procedure of their application is relatively simple [5]. Furthermore, the methyl or ethyl esters of fatty acids can be burnt directly in unmodified diesel engines, with very low deposit formation [11].

Several types of vegetable oils, with a diversified composition of fatty acids, can be employed for the preparation of biodiesel. Methyl/Ethyl esters of oils obtained from sunflower [12, 13], rice bran [14], palm [15], mahua [16, 17], jatropha [18], karanja [19], soybean [5, 9, 20-22], rapeseed [11, 23], rubber seed [24(a), (b)] have been successfully tested as biodiesel on C.I. engines and their performance was studied.

Bhatt *et al.* [17] studied the suitability of mahua oil as alternative fuel for diesel engine. They mentioned that mahua could be easily substituted up to 20% in diesel without any significant difference in power output, brake specific fuel consumption, and brake thermal efficiency. The performance of engine with mahua oil blends improved with the increase in compression ratio from 16:1 to 20:1. Breuer [25] studied the effect of fuel properties on heat release through experiments conducted with rapeseed oil and its methyl ester.

Sinha and Agarwal [26] investigated the in-cylinder pressure and heat release patterns of 20% rice bran oil methyl ester-diesel blend. Shashikant and Hifjur [27] developed a technique to produce biodiesel from mahua oil having high free fatty acids (19% FFA). The high FFA level of crude mahua oil has reduced to less than 1% in a 2-step pretreatment process of esterification using acid catalyzed (1% v/v H_2SO_4) reaction with methanol (0.30-0.35 v/v) at 60 ºC temperature and one hour reaction time. This process gave an yield of 98% mahua biodiesel, which has comparable fuel properties with that of diesel and are within the limits prescribed by the American and European standards for biodiesel.

Vaughn *et al.* [28] arrived at the ignition delay of a number of Bio-Esters by droplet ignition delay experiments. Kinoshita *et al.* [29] evaluated the combustion characteristics of biodiesels derived from coconut oil and palm oil. Ghosal *et al.* [30] studied the performance of diesel engine by using mahua ethyl ester (biodiesel) and its blends with diesel fuel. Theirs studies have revealed that mahua methyl ester (20% mahua methyl ester and 80% diesel) can be used as an alternative diesel fuel with little sacrifice in brake specific fuel consumption. Investigations of Rao *et al.* [31] on pongamia, jotropha and neem methyl esters as biodiesel on CI engine have revealed that their diesel blends showed reasonable efficiencies, lower smoke, CO and HC. Pongamia methyl ester showed better performance compared to jatropha and neem methyl esters.

Anbumani and Singh [32] investigated the use of vegetable oils as biofuel for C.I. engine. Their studies have revealed that among the different vegetable oils, sunflower blend at 15% by volume with diesel fuel exhibited best combustion and performance in terms of total fuel consumption, specific fuel consumption, brake thermal efficiency and cylinder peak pressure etc. Kuma *et al.* [33] selected cottonseed oil for biodiesel production. Transesterification results showed that with the variation of catalyst, methonal, variation of biodiesel production was realized. A maximum of 76% biodiesel was produced with 20% methonal in the presence of 0.5% sodium methaoxide.

2 Methodology-Transesterification of Vegetable Oils

Two plant oils viz., soyabean and sunflower were selected for the present studies. A total of four different blends (10%, 15%, 20%, and 25%) with diesel were made. Oils were esterified (Esoy and Esun) before blending. The main aim of transesterification was to lower the viscosity of vegetable oils for their butyl esters so as to obtain very close to diesel fuel [34, 35]. Esterification also improved their physical properties as follows (see Table 1):

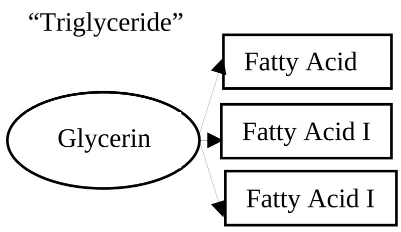
Table 1 Properties of vegetable oils as compared with diesel (ASTM D975).

Before blend			
Properties	Diesel	Soyabean	Sunflower
Cetane Number (CN)	45-55	49	33.4
Specific Gravity	0.83	0.93	0.963
Viscosity (20°C) mm^2/sec	4.7	28.3	30.6
Calorific value (MJ/kg)	42	35.63	34.83
Carbon %	86	75.2	76.34
Hydrogen %	14	10	11.43
After blend (20% by volume with diesel)			
Cetane Number (CN)	45-55	56	52
Specific Gravity	0.83	0.888	0.92
Viscosity (20°C) mm^2/sec	4.7	9.1	7.2
Calorific value (MJ/kg)	42	36.47	36.98
Carbon %	86	77.32	78.314
Hydrogen %	14	12	12.8

$$\begin{array}{lllllllll} CH_2OOR & & & & & & & & CH_2OH \\ | & & & & & & & & | \\ CHOOR & + & 3CH_3OH & \rightarrow & 3CH_3OOCR & + & & & CHOH \\ | & & & & & & & & | \\ CH_2OOR & & & & & & & & CH_2OH \\ \text{Triglyceride} & & \text{Butanol} & & \text{Butyl Esters} & & & & \text{Glycerol} \end{array}$$

Transesterification is the process of using an alcohol (e.g. methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide (NaOH) or sodium methoxide (NaOMe), to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oil with glycerol as a by-product which reduces the high viscosity of oils [36, 37]. This method reduces the molecular weight of the original oil to 1/3 of its former value, reduces the viscosity by a factor of ca. 8 and increases the volatility and cetane number to levels comparable to diesel fuel. Conversion does not greatly affect the gross heat of combustion [36, 38, 39]. Figure (1) shows scheme of transesterification of vegetable oil.

B. Freedman et al. [41] reported that transesterification reaction variables that affect yield and purity of the product esters from cotton seed, peanut, soyabean and sunflower oils include molar ratio of alcohol to vegetable oil, type of catalyst, temperature and degree of refinement of the vegetable oil [40, 41]. With alkaline catalysts (either sodium hydroxide or methoxide), temperature of 60°C or higher, molar ratios of at least 6 to 1 and with fully refined oils, conversion to methyl, ethyl and butyl esters was essentially complete in 1 hr. At moderate temperatures (32°C), vegetable oils were 99% transesterified in ca. 4 hr with an alkaline catalyst. Transesterification by acid catalysis was much slower than by alkali catalysis.



$$\textit{Transesterification}:$$
$$1\ \textit{Mole Triglyceride} + 3\ \textit{Mole Butanol} + \textit{Catalyst}$$
$$\rightarrow 3\ \textit{Mole Butyl Ester} + 1\ \textit{Mole Glycerin} + \textit{Catalyst}$$

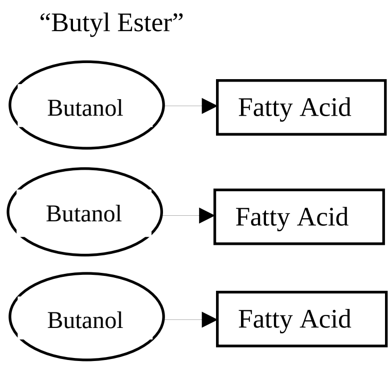


Figure 1 Scheme of transesterification of vegetable oil.

3 Experimental Procedure and Setup (Figure 2)

3.1 Technical Specifications of the Engine

Study was conducted on a 4-stroke, single cylinder, CI engine (Kirloskar Oil Engines Ltd. India). Type: single acting, totally enclosed, high speed, 4 stroke, vertical, C.I. engine; bore and stroke-78x82 mm, number of cylinders-1, capacity-425cc, maximum power-7.5 BHP, compression ratio-15.5:1, speed-1500 rpm, cooling system capacity-5 liters, crank case oil capacity-3 liters.

An eddy current dynamo meter was coupled to the engine to apply the load on the engine for loading the engine. The fuel flow rate was measured by timing the consumption for known quantity of fuel (10 cc) from a burette.

The main purpose of smoke measurement was to quantify the black smoke emitting from the diesel engine. Visibility was the main criterion in evaluating the intensity of smoke. Bosch meter was used for measuring the diesel engine smoke. It consists of a sampling pump and evaluating unit. The sampling pump was used to draw nearly 300 cc of exhaust gas by means of a spring operated pump and released by pneumatic operation of a diaphragm. The gas sample was also drawn through the filtering paper darkening it. The spot made on the filter paper was evaluated by means of a precalibrated photocell reflectometer to give precise assessment of the intensity of the spot. The intensity of the spot was measured on a scale of 10 in arbitrary units, called Bosch smoke units for white to black.

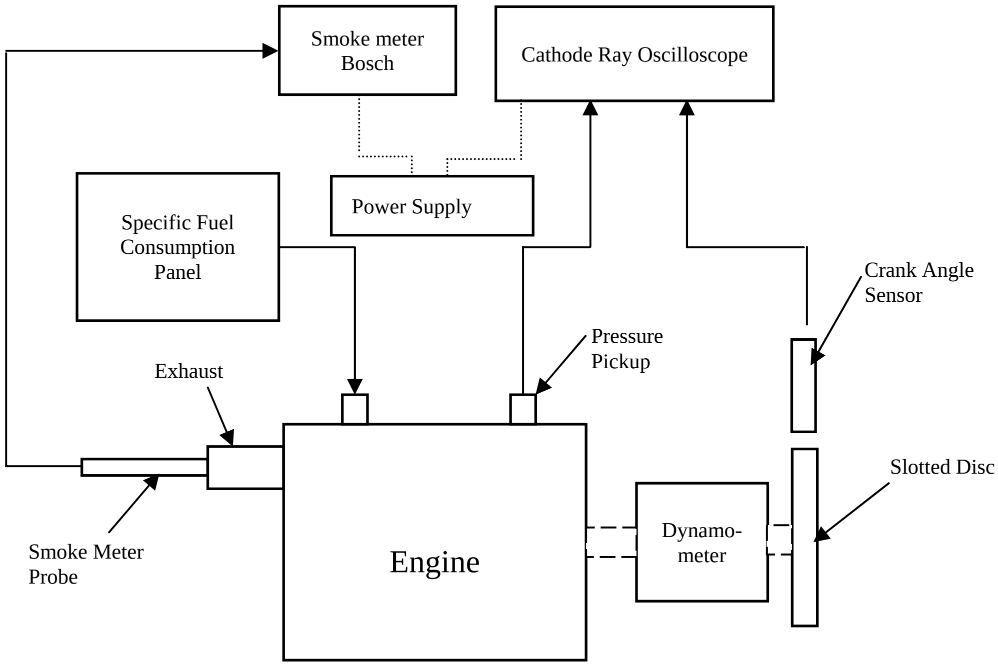


Figure 2 Experimental setup.

The performance data were analyzed regarding smoke density, brake thermal efficiency, and specific fuel consumption of all fuels. Smoke meter was used to measure the smoke density of the exhaust. HORIBA-MEXA-324 FB was used for the measurement of CO and HC emissions.

Piezoelectric transducer was used to measure the pressure released in an engine cycle. Cathode ray oscilloscope (CRO) was used to obtain the graph. The potential difference between the outer and inner curved surfaces of the cylinder was a measure of the gas pressure.

3.2 Engine Test Procedure

Present studies (see Figure 2) were carried out to investigate the performance and emission characteristics of a stationary single cylinder diesel engine run on two different vegetable oils (soyabean and sunflower) and their blends with diesel (10:90, 15:85, 20:80, and 25:75 by volume) and also on diesel fuel alone. The engine was coupled to an eddy current dynamo meter. Before initiating the studies, the engine was started and allowed to warm up for about 15 minutes. The engine was operated first on diesel fuel alone, followed by the two vegetable oils blends. In order to evaluate the performance of oil blends and pure diesel fuel, following parameters were recorded:
(i) Cetane number (CN), (ii) Flash point (FP), (iii) Smoke intensity, (iv) Total fuel consumption (TFC), (v) Specific energy consumption (SEC), (vi) Specific fuel consumption (SFC), (vii) Brake thermal efficiency (BTE), and (viii) Cylindrical peak pressure (CPP).

The engine was tested under six different load (0, 4, 8, 12, 16, and 20 kg) conditions at a constant speed of 1500 rpm, for each percentage of blending. Thereafter, time taken for 10cc of fuel consumption was noted for each load. The procedure was repeated for various blends used in studies.

4 Results and Discussions

Two plant oils viz., soyabean and sunflower were selected for there studies. Transesterification of these oils was carried out for their four different blends (10%, 15%, 20%, and 25% by volume) with diesel. The properties were compared with diesel fuel. It was observed that most of the properties were almost similar to pure diesel fuel (see Table 1).

4.1 Cetane Number

CN of vegetable oils and their blends with diesel fuel was calculated and found almost equal in comparison with diesel fuel after blending (see Table 1). This validates the feasibility to run a diesel engine on esterified vegetable oils after blending with diesel fuel [23].

4.2 Flash Point

Since the flash point of vegetable oils in the raw form was comparatively higher then diesel fuel, therefore, it calls for transesterification so that the diesel engine could be safely run on vegetable oils blends (see Table 1).
The experimental investigation was carried out for four different blends of Soyabean and Sunflower (10%, 15%, 20%, and 25% by volume) with diesel. The performance was evaluated and compared with diesel fuel (see Table 1).

Table 1 Performance comparison of Soyabean and Sunflower with diesel.

Load (Kg)	Diesel	Esoy 10%	Esun 10%	Esoy 15%	Esun 15%	Esoy 20%	Esun 20%	Esoy 25%	Esun 25%
0	4	2	3	3	4	3	4	4	5
4	5	3	4	4	5	5	6	5	7
8	6	5	7	5	6	6	7	7	9
12	8	6	8	6	7	7	8	8	10
16	10	8	10	8	10	9	10	10	11
20	20	10	12	11	12	11	13	12	13

4.3 Smoke Intensity

Not much variations in smoke intensity was observed among the two oils and their blends, however, a marginal decrease in smoke intensity took place in 20% blend, more so in case of Soyabean oil blend (see Figure 3).

4.4 Total Fuel Consumption

The total fuel consumption at different BHP with all percentages of blending was found to be slightly decreased from 0.081 kg/hr to 0.0205 kg/hr. Improvement in TFC was perhaps due to better combustion of the fuel, because of an increase in calorific value of vegetable oils due to esterification, resulting in reducing the ignition delay (see Figure 4 and Table 2).

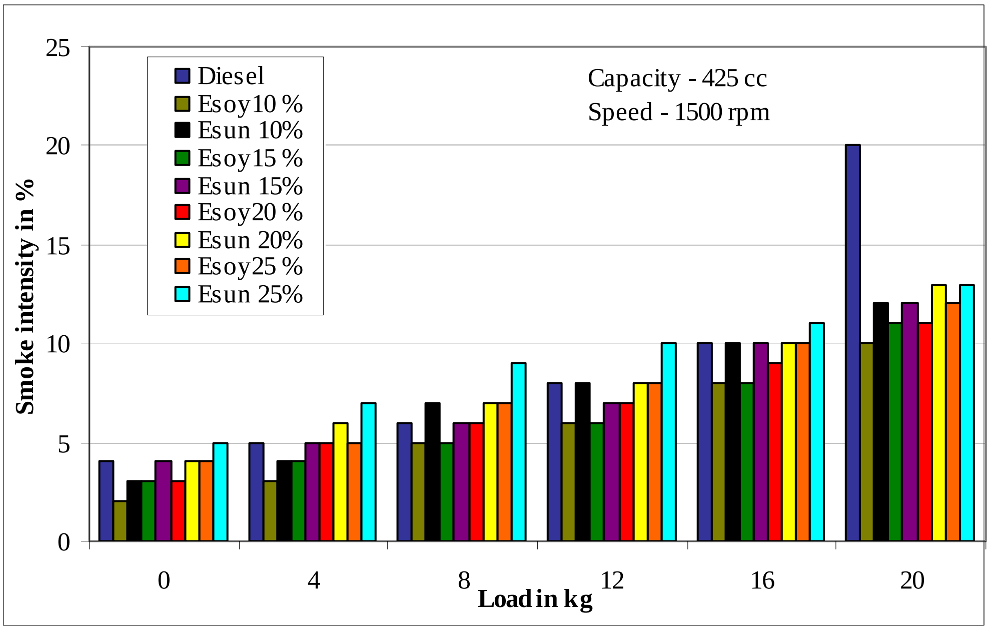


Figure 3 Variations in smoke intensity at four different blends of vegetable oils with respect to load.

Table 2 Variations in TFC with respect to BHP for four different blends of the vegetable oils.

BHP in KW	Diesel	Esoy 10 %	Esun 10%	Esoy 15 %	Esun 15%	Esoy 20 %	Esun 20%	Esoy 25 %	Esun 25%
0	0.6608	0.637	0.639	0.6	0.604	0.579	0.58	0.594	0.598
0.932	0.6916	0.644	0.65	0.613	0.613	0.5911	0.595	0.606	0.61
1.864	0.7434	0.684	0.701	0.653	0.669	0.628	0.639	0.644	0.65
2.796	0.7826	0.722	0.735	0.715	0.735	0.685	0.736	0.7199	0.742
3.728	0.8746	0.878	0.882	0.861	0.886	0.833	0.869	0.857	0.89
4.659	1.1438	1.145	1.138	1.124	1.127	1.053	1.16	1.112	1.155

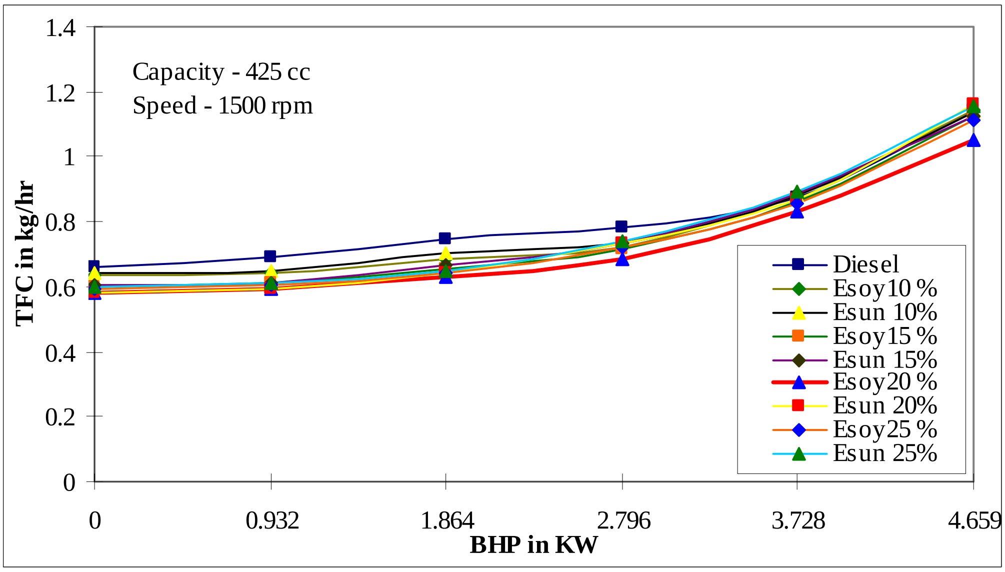


Figure 4 Variations in TFC with respect to BHP for four different blends of the vegetable oils.

4.5 Specific Energy Consumption

A decrease in SEC with increase in load was observed up to a load level of about 16 Kg, and thereafter, a slight increase was observed. The initial decrease in SEC may be attributed to the complete and high combustion of fuel, but once the load reached at full load level the time taken for complete combustion of fuel was decreased, hence there is a slight increase in SEC (see Figure 5 and Table 3). Viscosity and specific gravity of the vegetable oils perhaps also played an important role in affecting the performance of engine at full load condition.

Table 3 Variations in SEC with respect to BHP for four different blends of the vegetable oils.

BHP in KW	Diesel	Esoy 10 %	Esun 10%	Esoy 15 %	Esun 15%	Esoy 20%	Esun 20%	Esoy 25 %	Esun 25%
0									
0.932	31164	27850.31	28165.19	26256.44	26302.18	25084.55	25302.03	25458.5	25691.04
1.864	16749.6	14772.77	15193.85	13987.45	14332.08	13294.02	13523.15	13512.58	13670.46
2.796	11751.6	10413.59	10587.2	10190.85	10488.84	9653.99	10430.14	10065.89	10409.98
3.728	9853.2	9485.25	9536.56	9191.75	9488	8823.11	9240.39	8969.22	9349.34
4.659	10311	9888.87	9859.83	9631.36	9648.13	8981.37	9835.27	9321.72	9702.88

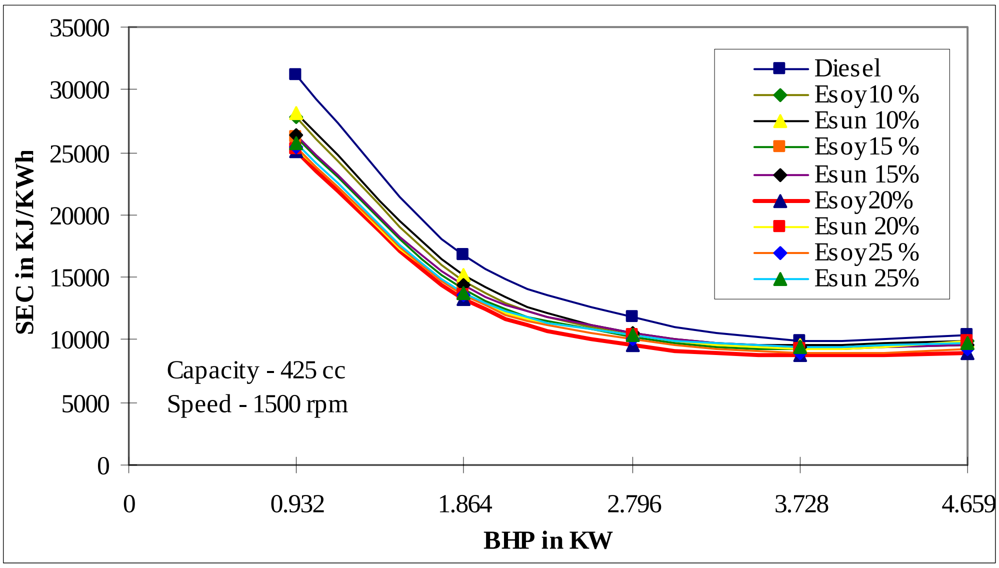


Figure 5 Variations in SEC with respect to BHP for four different blends of the vegetable oils.

4.6 Specific Fuel Consumption

SFC at different loads with all percentage of blending was found slightly decreased from 0.152 kJ/kW-hr to 0.07 kJ/kW-hr. This improvement in SFC is perhaps due to the better combustion of the fuel, may be due to the oxygen present in the blend. Esterification also helps to lower the temperature reaction and better combustion. The cetane number of esterified soyabean oil was high; hence SFC in its 20% blend was reduced from 0.103 to 0.015 Kg/KW-hr (see Figure 6 and Table 4).

Table 4 Variations in SFC with respect to BHP for four different blends of the vegetable oils.

BHP in KW	Diesel	Esoy 10 %	Esun 10%	Esoy 15 %	Esun 15%	Esoy 20 %	Esun 20%	Esoy 25 %	Esun 25%
0									
0.932	0.742	0.69	0.697	0.657	0.657	0.634	0.638	0.65	0.654
1.864	0.3988	0.366	0.376	0.35	0.358	0.336	0.342	0.345	0.348
2.796	0.2798	0.258	0.262	0.255	0.262	0.244	0.263	0.257	0.265
3.728	0.2346	0.235	0.236	0.23	0.237	0.223	0.233	0.229	0.238
4.659	0.2455	0.245	0.244	0.241	0.241	0.227	0.248	0.238	0.247

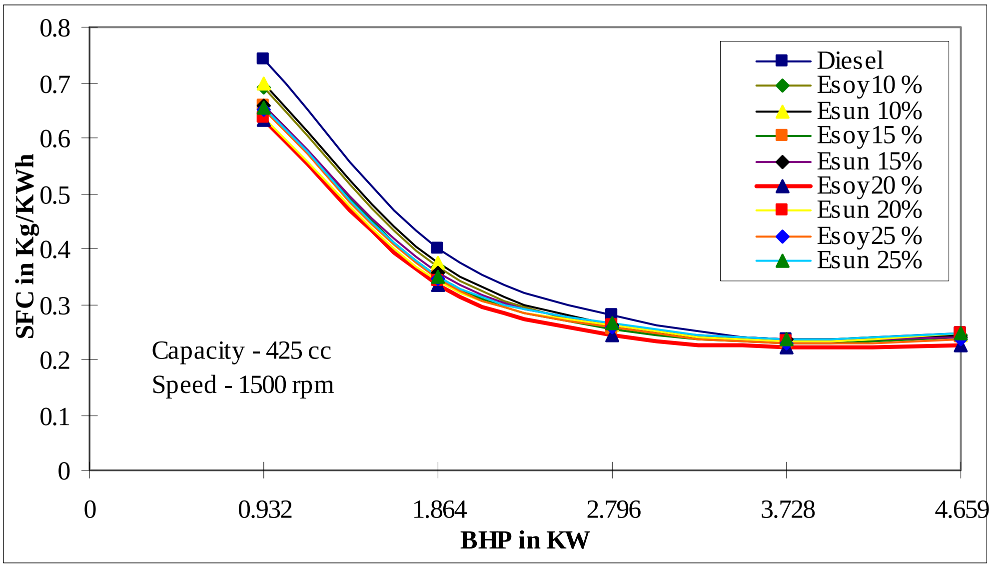


Figure 6 Variations in SFC with respect to BHP for four different blends of the vegetable oils.

4.7 Brake Thermal Efficiency

An increase in BTE with increase in load was observed up to a load level of about 16 Kg, and thereafter a decrease was observed. The initial increase in BTE may be attributed to the complete and high combustion of fuel, but once the load reached at full load level; the time taken for complete combustion of fuel was decreased, hence a slight drop in BTE was observed. Oxygen present in the blends perhaps also helped in complete combustion of fuel at no load and also at partial load conditions. At full load conditions the change of state from molecule oxygen to atomic oxygen lead to a decrease in BTE. Specific gravity of the vegetable oils perhaps also played an important role in affecting the performance of engine at full load levels (see Figure 7 and Table 5).

4.8 Cylindrical Peak Pressure

CPP was found to be increased at all the load levels from 2 to 10 bars with blended fuel as compared to diesel. Increase in the pressure may be attributed to improved combustion of the fuel due to the presence of oxygen in the esterified vegetable oils. The presence of oxygen in the fuel particle perhaps has enhanced the low temperature reaction to proceed in the proper direction. A maximum increase of pressure from 4 to 7 bars was observed at full load level of 20% blend (see Figures 8 (a), (b), and (c) and Tables 6 (a), (b), and (c)).

Table 5 Variations in BTE with respect to BHP for four different blends of the vegetable oils.

BHP in KW	Diesel	Esoy 10%	Esun 10%	Esoy 15%	Esun 15%	Esoy 20%	Esun 20%	Esoy 25%	Esun 25%
0	0	0	0	0	0	0	0	0	0
0.932	11.55	12.907	12.773	13.695	13.671	14.346	14.218	14.135	14.001
1.864	21.491	24.305	23.689	25.713	25.055	27.006	26.479	26.603	26.28
2.796	30.623	34.539	33.89	35.225	34.207	37.139	34.484	35.698	34.532
3.728	36.535	37.87	37.655	39.003	37.837	40.72	38.942	39.983	38.387
4.659	34.913	36.291	36.473	37.338	37.174	40.067	36.458	38.509	36.966

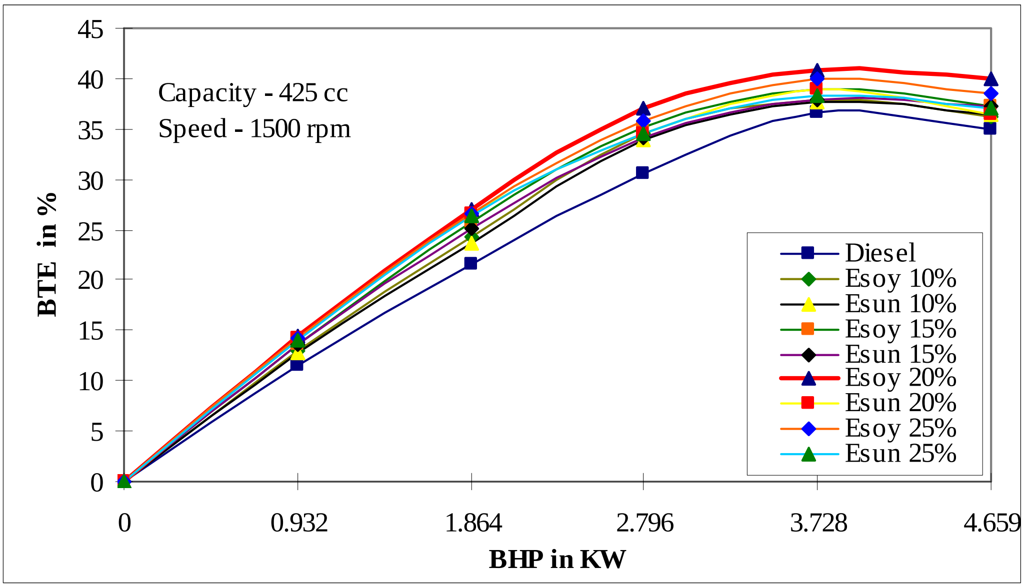


Figure 7 Variations in BTE with respect to BHP for four different blends of the vegetable oils.

Table 6(a) Variations in CPP at initial load with respect to crank angle for four different blends of the vegetable oils.

Crank angle	Diesel	Esoy 10%	Esun 10%	Esoy 15%	Esun 15%	Esoy 20%	Esun 20%	Esoy 25%	Esun 25%
-180	4	5.2	4.8	5.2	4.8	5.2	4.8	5.2	4.8
-150	5	6.3	5.8	6.3	5.8	6.3	5.8	6.3	5.8
-120	8	8.9	8.7	8.9	8.7	8.9	8.7	8.9	8.7
-90	10	10.7	10.5	10.7	10.5	10.7	10.5	10.7	10.5
-60	12	13.3	12.9	13.3	12.9	13.3	12.9	13.3	12.9
-30	16	17.4	16.9	17.4	16.9	17.4	16.9	17.4	16.9
-15	24	25.6	25.2	25.6	25.2	25.6	25.2	25.6	25.2
0	41	42.6	42	42.6	42	42.6	42	42.6	42
5.7	60	67	66	65	63	67	66	64	63
15	45	50.1	45.9	50.1	45.9	50.1	45.9	50.1	45.9
30	29	32	31.4	32	31.4	32	31.4	32	31.4
60	25	26	25.9	26	25.9	26	25.9	26	25.9
90	19	24	22.4	24	22.4	24	22.4	24	22.4
120	15	18.2	17	18.2	17	18.2	17	18.2	17
150	9	13.5	12.9	13.5	12.9	13.5	12.9	13.5	12.9
180	7	12.3	12	12.3	12	12.3	12	12.3	12

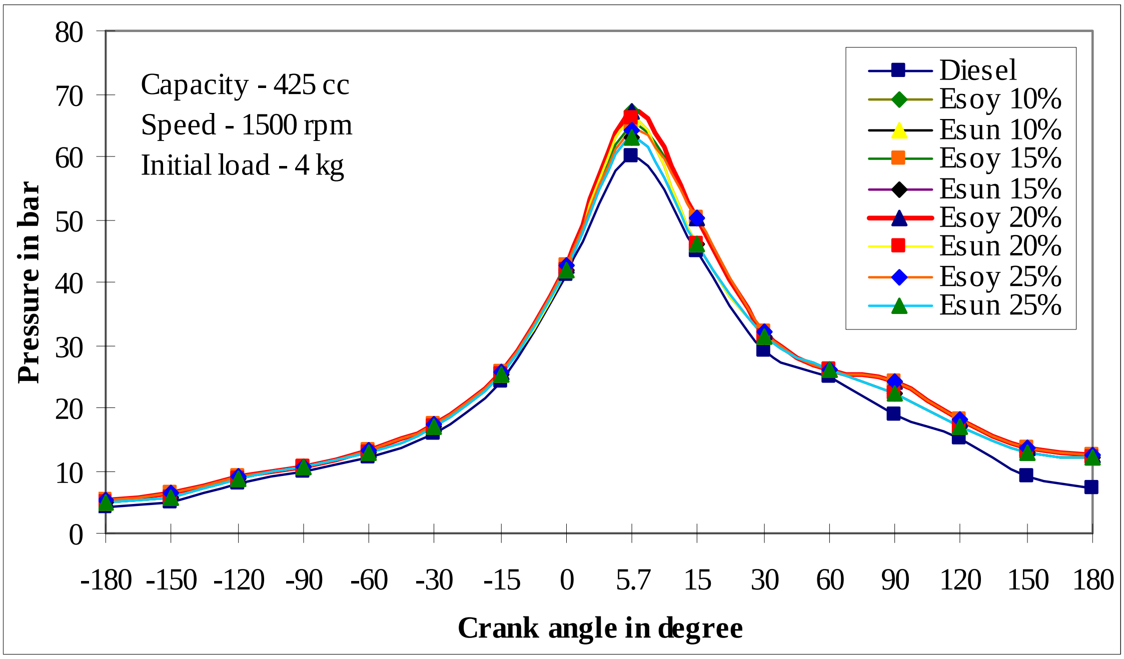


Figure 8(a) Variations in CPP at initial load with respect to crank angle for four different blends of the vegetable oils.

Table 6(b) Variations in CPP at partial load with respect to crank angle for four different blends of the vegetable oils.

Crank angle	Diesel	Esoy 10%	Esun 10%	Esoy 15%	Esun 15%	Esoy 20%	Esun 20%	Esoy 25%	Esun 25%
-180	4	5.2	4.8	5.2	4.8	5.2	4.8	5.2	4.8
-150	5	6.3	5.8	6.3	5.8	6.3	5.8	6.3	5.8
-120	8	8.9	8.7	8.9	8.7	8.9	8.7	8.9	8.7
-90	10	10.7	10.5	10.7	10.5	10.7	10.5	10.7	10.5
-60	12	13.3	12.9	13.3	12.9	13.3	12.9	13.3	12.9
-30	16	17.4	16.9	17.4	16.9	17.4	16.9	17.4	16.9
-15	24	25.6	25.2	25.6	25.2	25.6	25.2	25.6	25.2
0	41	42.6	42	42.6	42	42.6	42	42.6	42
7	68	74	72	74	71	75	72	74	72
15	45	50.1	45.9	50.1	45.9	50.1	45.9	50.1	45.9
30	29	32	31.4	32	31.4	32	31.4	32	31.4
60	25	26	25.9	26	25.9	26	25.9	26	25.9
90	19	24	22.4	24	22.4	24	22.4	24	22.4
120	15	18.2	17	18.2	17	18.2	17	18.2	17
150	9	13.5	12.9	13.5	12.9	13.5	12.9	13.5	12.9
180	7	12.3	12	12.3	12	12.3	12	12.3	12

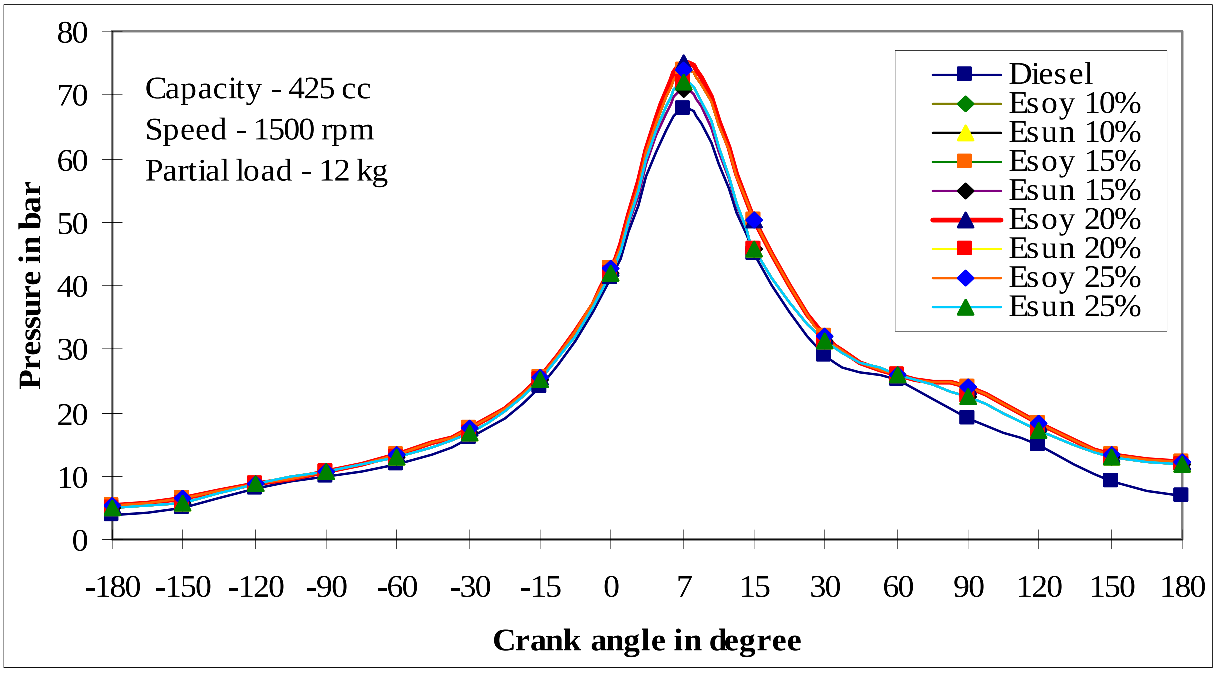


Figure 8(b) Variations in CPP at partial load with respect to crank angle for four different blends of the vegetable oils.

Table 6(c) Variations in CPP at full load with respect to crank angle for four different blends of the vegetable oils.

Crank angle	Diesel	Esoy 10%	Esun 10%	Esoy 15%	Esun 15%	Esoy 20%	Esun 20%	Esoy 25%	Esun 25%
-180	4	5.2	4.8	5.2	4.8	5.2	4.8	5.2	4.8
-150	5	6.3	5.8	6.3	5.8	6.3	5.8	6.3	5.8
-120	8	8.9	8.7	8.9	8.7	8.9	8.7	8.9	8.7
-90	10	10.7	10.5	10.7	10.5	10.7	10.5	10.7	10.5
-60	12	13.3	12.9	13.3	12.9	13.3	12.9	13.3	12.9
-30	16	17.4	16.9	17.4	16.9	17.4	16.9	17.4	16.9
-15	24	25.6	25.2	25.6	25.2	25.6	25.2	25.6	25.2
0	41	42.6	42	42.6	42	42.6	42	42.6	42
9	72	78	77	78	76	79	78	77	76
15	45	50.1	45.9	50.1	45.9	50.1	45.9	50.1	45.9
30	29	32	31.4	32	31.4	32	31.4	32	31.4
60	25	26	25.9	26	25.9	26	25.9	26	25.9
90	19	24	22.4	24	22.4	24	22.4	24	22.4
120	15	18.2	17	18.2	17	18.2	17	18.2	17
150	9	13.5	12.9	13.5	12.9	13.5	12.9	13.5	12.9
180	7	12.3	12	12.3	12	12.3	12	12.3	12

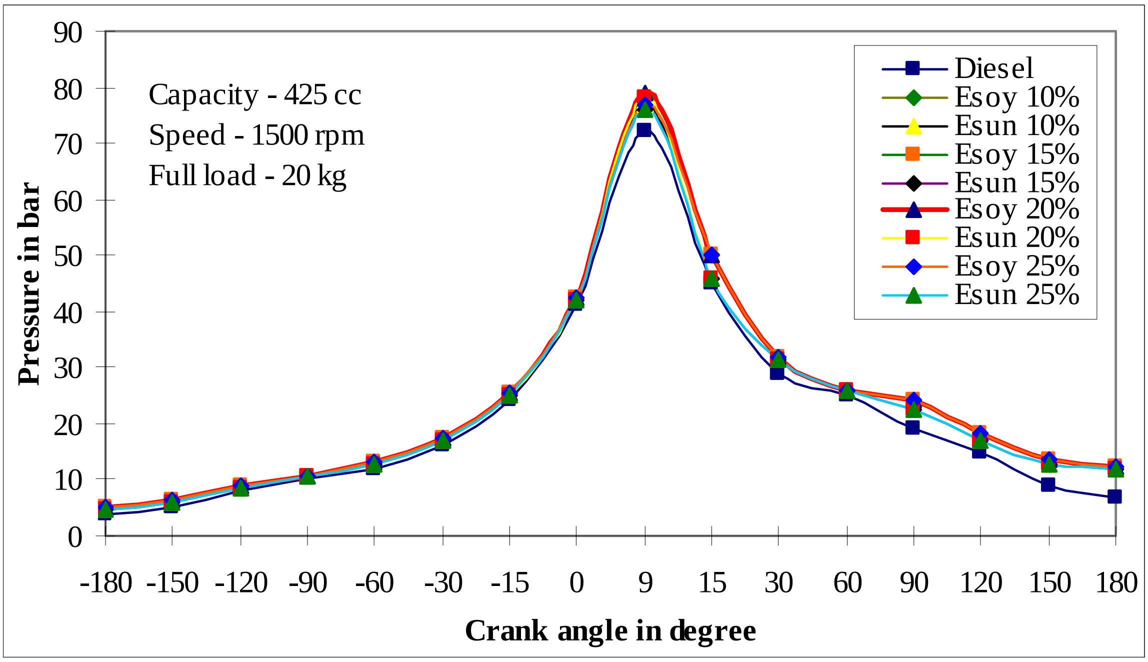


Figure 8(c) Variations in CPP at full load with respect to crank angle for four different blends of the vegetable oils.

5 Conclusions

In the present studies soyabean and sunflower oil with their four blends with diesel were used. Oils were esterified before blending with diesel. Studies have revealed that soyabean oil at 20% blend with diesel gave best performance in terms of low smoke intensity, emission of HC and NO_x. All the parameters tested i.e., cetane number, flash point, total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency, and cylindrical peak pressure were improved.

- Engine run smoothly by using esterified soyabean oil (Esoy) and sunflower oil (Esun) as a fuel after blending with diesel at 20% without any engine modifications.
- Vegetable oils used in the study showed better performance characteristics than pure diesel alone.
- Among the vegetable oils used, esterified soyabean oil at 20% blend showed the best total fuel consumption, specific fuel consumption, brake thermal efficiency and cylinder peak pressure, and lower emissions and carbon deposit buildups.
- By using esterified soyabean oil and esterified sunflower oil as a fuel, a marginal decrease in the smoke intensity was also observed.
- Diesel engines run on vegetable oils offer acceptable engine performance and emissions for short-term operation. Long-term operation may result in operational and durability problems.
- Compared with diesel fuel, vegetable oils and their esters produce less engine noise, less smoke, less hydrocarbons, and carbon monoxide emission, while slightly higher oxides of nitrogen (NO_x) and higher thermal efficiency was observed.
- The transesterification process, used for making biodiesel, is simple and cost effective to solve viscosity problems with vegetable oils.
- The cost of dual fuel can be considerably reduced than when pure diesel is used.

- Esterified soyabean oil and esterified sunflower oil as a biodiesel satisfies the important fuel properties as per ASTM D975 specification of biodiesel and also improves the performance and emission characteristics of engine significantly [42].

Appropriate blending ratios and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from soyabean and sunflower seed oil can provide a useful substitute for diesel for developing an economically viable and ecofriendly biofuel technology. Irrespective of all the difficulties mentioned in the study, vegetable oils after suitable processing and blending may prove to be an alternative option for diesel fuel in the near future because they are the renewable resources of energy.

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چکیده

به منظور مطالعه قابلیت استفاده از روغن دو گیاه خوراکی به عنوان جایگزین برای دیزل مطالعه مقایسه‌ای صورت پذیرفته است. روغن‌ها از دانه‌های سویا (نام علمی: Glycine Max، خانواده: لگومینوسیا) و آفتابگردان (نام علمی: Helianthus annuus، خانواده: کامپوزیته) گرفته شده‌اند. روغنها قبل از مخلوط شدن با دیزل خالص با نسبت حجمی ۱۰:۹۰، ۱۵:۸۵، ۲۰:۸۰ و ۲۵:۷۵ استری شده‌اند. مطالعات نشان داده‌اند که مخلوط کردن روغنهای گیاهی با دیزل باعث افزایش قابل توجه خواص شیمیایی و فیزیکی آن شده است. عدد ستان به سوخت دیزل بسیار نزدیک شده است. موتور (احتراق داخلی) در بارهای مختلف (۰، ۴، ۸، ۱۲، ۱۶ و ۲۰ کیلوگرم) و سرعت ثابت (۱۵۰۰ دور بر دقیقه) با هر یک از مخلوطهای فوق و با دیزل خالص به کار گرفته شده است. مطالعات آشکار کرده‌اند که روغن سویا در مخلوط ۲۰٪ با دیزل بهترین راندمان در شدت دود، انتشار HC و NO_x داشته است. تمامی عوامل مورد آزمایش شامل: نقطه اشتعال، کل مصرف سوخت، مصرف انرژی ویژه، مصرف سوخت ویژه، راندمان حرارتی توقف و حداکر فشار سیلندر افزایش پیدا کرده‌اند. همچنین نتایج نشان‌داده‌اند که مخلوط ۲۰٪ نزدیکترین راندمان را به دیزل خالص دارد. مخلوط ۲۰٪ روغن سویا راندمان بالاتری نسبت به روغن آفتابگردان دارد. به هر حال، هر دو روغن با مخلوط ۲۰٪ می‌توانند به عنوان جایگزین برای سوخت دیزل به کار روند. در نتیجه مطالعات نشان داده‌اند که روغن استری شده سویا با مخلوط ۲۰٪ خصوصیات تعیین شده در ASTM D975 را برآورده می‌کند و باعث افزایش راندمان و خصوصیات انتشار بدون انجام هیچ گونه تغییری در موتور دیزل شده است.