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Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine

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Abstract

In the present investigation the high viscosity of the jatropha curcas oil which has been considered as a potential alternative fuel for the compression ignition (C.I.) engine was decreased by blending with diesel. The blends of varying proportions of jatropha curcas oil and diesel were prepared, analyzed and compared with diesel fuel. The effect of temperature on the viscosity of biodiesel and jatropha oil was also studied. The performance of the engine using blends and jatropha oil was evaluated in a single cylinder C.I. engine and compared with the performance obtained with diesel. Significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50% volume of jatropha oil. From the properties and engine test results it has been established that 40–50% of jatropha oil can be substituted for diesel without any engine modification and preheating of the blends.

Keywords: Jatropha curcas oil; Biodiesel; Viscosity; Diesel; C.I. engine

1. Introduction

Due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need for suitable

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Nomenclature

SFC	specific fuel consumption
BKW	brake horse power
J/D	jatropha:diesel
C.I.	compression ignition

alternative fuels for use in diesel engines. In view of this, vegetable oil is a promising alternative because it has several advantages—it is renewable, environ-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy [1–5]. Therefore, in recent years systematic efforts have been made by several research workers [6–9] to use vegetable oils as fuel in engines. Obviously, the use of non-edible vegetable oils compared to edible oils is very significant because of the tremendous demand for edible oils as food and they are far too expensive to be used as fuel at present.

From previous studies [10–12], it is evident that there are various problems associated with vegetable oils being used as fuel in compression ignition (C.I.) engines, mainly caused by their high viscosity. The high viscosity is due to the large molecular mass and chemical structure of vegetable oils which in turn leads to problems in pumping, combustion and atomization in the injector systems of a diesel engine. Due to the high viscosity, in long term operation, vegetable oils normally introduce the development of gumming, the formation of injector deposits, ring sticking, as well as incompatibility with conventional lubricating oils [13–17]. Therefore, a reduction in viscosity is of prime importance to make vegetable oils a suitable alternative fuel for diesel engines. The problem of high viscosity of vegetable oils has been approached in several ways, such as preheating the oils, blending or dilution with other fuels, trans-esterification and thermal cracking/pyrolysis.

In the present investigation jatropha curcas oil, a non-edible vegetable oil which has been considered as a potential alternative fuel for C.I. engines, has been chosen to find out its suitability for use as fuel oil. Jatropha curcas is a large shrub or tree native to the American tropics but commonly found and utilized throughout most of the tropical and subtropical regions of the world. Several properties of the plant, including its hardness, rapid growth, easy propagation and wide ranging usefulness have resulted in its spread far beyond its original distribution. The jatropha oil is a slow-drying oil which is odourless and colourless when fresh but becomes yellow on standing. The oil content of jatropha seed ranges from 30 to 50% by weight and the kernel itself ranges from 45 to 60%. The fatty acid composition of jatropha classifies it as a linoleic or oleic acid type, which are unsaturated fatty acids. The fatty acid composition of jatropha oil consists of myristic, palmitic, stearic, arachidic, oleic and linoleic acids. The seeds and oil are toxic due to the presence of cursive and curcasive. However, from the properties of this oil it is envisaged that the oil would be suitable as fuel oil. The oil compares well against other vegetable oils and more importantly to diesel itself in terms of its fuel rating per kilogram or hectare of oil produced. But the greatest difference between jatropha oil and diesel oil is viscosity. The high viscosity of curcas oil may contribute to the formation of carbon deposits in the engines, incomplete fuel combustion and results in reducing the life of an engine.

Therefore, the main objective of the present study was to decrease the viscosity of jatropha curcas oil by dilution with diesel, to see the effect of heating on reduction in viscosities of the blends and to evaluate the engine performance using the prepared blends as fuel.

2. Materials

The jatropha curcas L. oil used in this study was supplied by Girigan Cooperative Society of Adilabad District, Andhra Pradesh, India and commercially available diesel oil was purchased from the nearby petrol bunk.

3. Experimental

3.1. Fuel properties

The important chemical and physical properties of jatropha curcas oil were determined by standard methods and compared with diesel. The analytical results are shown in Table 1. The results show that the heating value of the vegetable oil is comparable to the diesel oil and the cetane no. is slightly lower than the diesel fuel. However, the kinematic viscosity and the flash point of jatropha curcas oil are several times higher than the diesel oil.

3.2. Preparation of jatropha and diesel oil blend

From the literature [10,11] it is evident that dilution or blending of vegetable oil with other fuels like alcohol or diesel fuel would bring the viscosity close to a specification range. Therefore, jatropha oil was blended with diesel oil in varying pro-

Table 1
Physical and chemical properties of diesel and jatropha oil blend

Properties	Diesel	Jatropha. curcas oil
Density (gm/cc), 30°C	0.836–0.850	0.93292
Kinematic viscosity (cSt), 30°C	4–8	52.76
Cetane No.	40–55	38.00
Flash point,°C	45–60	210.00
Calorific value, MJ/kg	42–46	38.20
Saponification value	–	198.00
Iodine No.	–	94.00

portions with the intention of reducing its viscosity close to that of the diesel fuel. The important physical and chemical properties of the biodiesel thus prepared are given in Table 2. The various blends were stable under normal conditions.

4. Results and discussion

4.1. Effect of dilution on viscosity of vegetable oil and biodiesel

It has been seen from Table 2 that the high viscosity of jatropha curcas oil has been decreased drastically by partial substitution of diesel oil. The viscosity of the vegetable oil was decreased on increasing the diesel content in the blend. Though a substantial decrease in viscosity and density was observed with 70:30 jatropha/diesel (J/D) and 60:40 J/D blends, still the viscosity and density are quite a lot higher than that of diesel. A reduction of viscosity of 55.56% and 62.13% was obtained with 70:30 and 60:40 J/D blends, respectively. The corresponding viscosity and the density were found to be 23.447 and 19.222 cSt, and 0.900 and 0.890 g/cc at 30 °C. The viscosity and density of jatropha curcas oil were reduced from 52.76 and 0.93292 to 17.481 cSt and 0.880 g/cc, respectively, with 50:50 J/D blend. A reduction of viscosity of 66.86% was achieved. The viscosity of the 40:60 J/D blend was slightly higher than diesel oil. In this case the viscosity was found to be 13.958 cSt and the percentage reduction of viscosity was 73.55 whereas the viscosity and density of blends comprising 30:70 and 20:80 J/D are close to those of diesel oil. Viscosity of 9.848 and 6.931 cSt and density of 0.862 and 0.853 g/cc were observed with 30:70 and 20:80 J/D, respectively. The corresponding viscosity reductions were 81 and 86.86%. Therefore, 70–80% of diesel may be added to jatropha oil to bring the viscosity close to diesel fuel and thus blends containing 20–30% of jatropha oil can be used as engine fuel without preheating.

4.2. Effect of temperature on viscosity of jatropha curcas oil and various blends

From the properties of the blends shown in Table 2, it has been observed that biodiesel containing more than 30% jatropha oil have high viscosity compared to

Table 2
Properties of jatropha–diesel blends

% of J. curcas oil (v/v)	% of diesel fuel (v/v)	Density (g/cc), 30°C	Viscosity (cSt), 30°C	Viscosity reduction (%)	Observation
70	30	0.900	23.447	55.56	Stable mixture
60	40	0.890	19.222	62.13	Stable mixture
50	50	0.853	17.481	66.86	Stable mixture
40	60	0.880	13.953	73.55	Stable mixture
30	70	0.871	9.848	81.00	Stable mixture
20	80	0.862	6.931	86.86	Stable mixture

diesel. The viscosity of these blends needed to be reduced more in order to make it suitable as biodiesel to be used in the diesel engine. From the literature [10], it was found that heating the fuel makes its spray characteristics more like those of diesel oil, which is the direct result of viscosity reduction. Therefore, efforts have been made to decrease the viscosity by heating the biodiesels. For this, the viscosities of the oils as well as the blends were measured at varying temperature in the range 25–75 °C. The results are shown in Fig. 1. The results show that the viscosity of jatropha oil is higher than diesel oil at any temperature. However, the viscosity of vegetable oil was decreased remarkably with increasing temperature and it becomes close to diesel oil at temperatures above 75 °C. Biodiesel containing 70 and 60% vegetable oil has viscosity close to diesel oil between 70 and 75 °C, and between 60 and 65 °C, respectively. Viscosity values of 50:50 J/D and 40:60 J/D are close to diesel in the range of 55–60 °C and at about 45 °C, respectively, whereas the blend containing 30:70 J/D has viscosity close to diesel at the range of 35–40 °C. Therefore, the blends of 30:70 and 40:70 J/D may be used with slight heating or even without heating, particularly in summer season.

5. Engine test

5.1. Experimental procedure

Constant speed engine tests were carried out using J/D blends, jatropha curcas oil and diesel and the performance of the engine was evaluated in terms of specific fuel

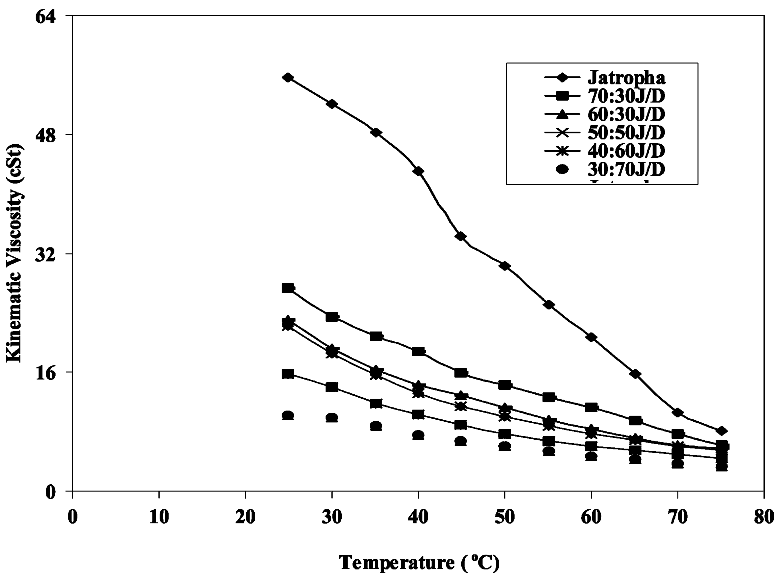

Fig. 1. Effect of temperature on viscosity of jatropha oil and various blends.

consumption, brake thermal efficiency and exhaust gas temperature. The engine used in these experiments was a Kirloskar make engine. This is a single cylinder, water cooled open combustion chamber diesel engine. Technical details of the engine are given in Table 3. The various equipment/instruments used in the experimentation are presented below.

A quartz pressure transducer is fixed into the engine cylinder and is connected to the Y-channel oscilloscope through a charge amplifier to measure the rate of pressure rise and peak pressure. A magnetic pickup is fixed near the engine fly wheel and is connected to the X-channel of the cathode ray oscilloscope to determine the position of TDC. A HM 204, 20 MHz oscilloscope is used for P–O diagram display. A Type 5007 charge amplifier converts the charge yield by the piezoelectric transducer into proportional electric signals. The engine was tested at torque 0–243 rpm and at the rated speed of 1500 rpm only. The engine was sufficiently warmed up at every stage and the cold water temperature was maintained at 55 °C. The fuel injection pressure was maintained at 210 bar throughout the experiment. A Honey Well Chromel-Alumel thermocouple with a digital display meter was used to measure the exhaust gas temperature.

6. Engine test results and discussion

6.1. Effect of brake horse power (BKW) on specific fuel consumption (SFC)

Fig. 2 compares the specific fuel consumption of diesel and various blends of jatropha and diesel oil at varying brake loads in the range 0–3.74. It was observed that the specific fuel consumptions of the oil as well as the blends were decreased with increasing load from 0.77 to 3.078 and tended to increase with further increase in BKW. The fuel consumptions were also found to increase with a higher proportion of jatropha curcas oil in the blend. Though the blends as well as the jatropha curcas oil maintained a similar trend to that of diesel, the SFC in the case of the blends were higher compared to diesel oil in the entire load range. This is mainly due to

Table 3
Technical details of the engine

Make	Kirloskar Oil Engines Ltd, India
Type	Single cylinder open combustion chamber C.I. engine
Rated output	3.68 kW at 1500 rpm
Injection timing	26.4 BTDC
Loading device	Hydraulic dynamometer
Stroke	110 mm
Compression ratio	15:1
Bore	80 mm

BTDC, before top dead center.

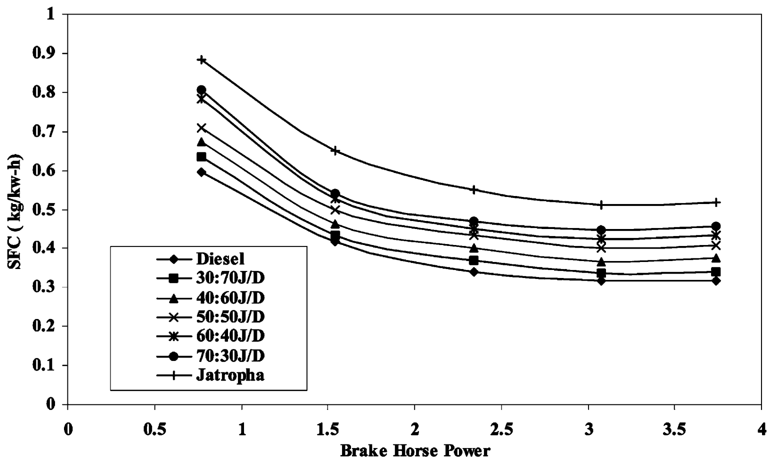

Fig. 2. Effect of brake power on specific fuel consumption for diesel, jatropha curcas oil and various blends.

the combined effects of the relative fuel density, viscosity and heating value of the blends. However, blends containing 30:70 and 40:60 J/D have SFC very close to that of diesel oil. The SFC values were found to be 0.338 and 0.365 at 3.078 BKW; the corresponding value for diesel is 0.316. The specific fuel consumption of 0.693 was observed using 50:50 J/D blend as fuel which is comparable to the SFC obtained with diesel oil under the same load. The higher density of blends containing a higher percentage of jatropha curcas oil has led to more discharge of fuel for the same displacement of the plunger in the fuel injection pump, thereby increasing the SFC.

6.2. Effect of BKW on brake thermal efficiency

The variation of brake thermal efficiency of the engine with various J/D blends and jatropha curcas vegetable oil is shown in Fig. 3 and compared with the brake thermal efficiency obtained with diesel. From the test results it was observed that initially with increasing BKW the brake thermal efficiencies of the vegetable oil, diesel and the blends were increased and the maximum thermal efficiencies were obtained at BKW of 3.078 and then tended to decrease with further increase in BKW. There was a considerable increase in efficiencies with the blends compared to the efficiency of jatropha oil alone, but the brake thermal efficiencies of the blends and the jatropha curcas oil were lower than that with diesel fuel throughout the entire range. The maximum values of thermal efficiencies with 60:30 and 70:30 J/D were observed as 21.45% and 20.53%, respectively. Among the blends tested, in the case of 30:70 J/D, the thermal efficiency and maximum power output were close to the diesel values, followed by the 40:60 J/D blend. Corresponding maximum brake thermal efficiencies of 26.09 and 24.36% were observed with these blends. A reasonably good thermal efficiency of 22.44% was also observed with the 50:50 J/D blend. The maximum thermal efficiency of 27.11% was achieved with diesel, whereas only 18.52% thermal

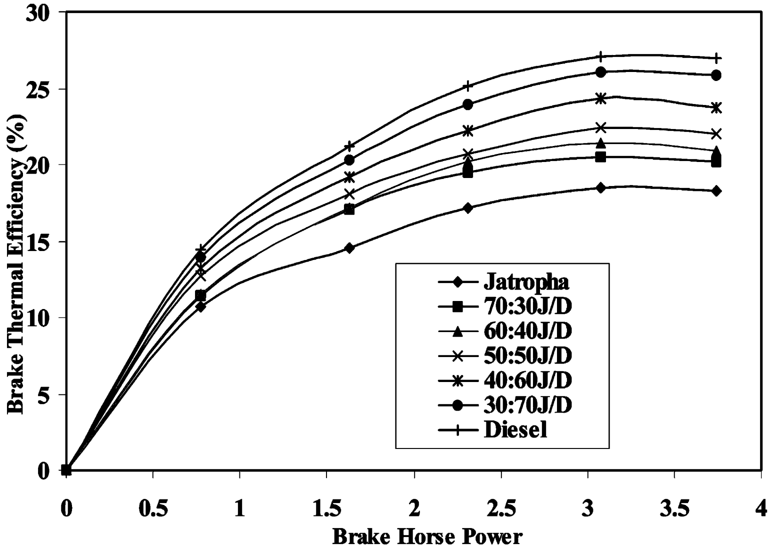

Fig. 3. Variation of brake thermal efficiency with brake power for diesel, jatropha curcas oil and various blends.

efficiency was observed using jatropha curcas oil. The drop in thermal efficiency with increase in proportion of vegetable oil must be attributed to the poor combustion characteristics of the vegetable oils due to their high viscosity and poor volatility.

6.3. Effect of BKW on exhaust gas temperature

Fig. 4 shows the variation of exhaust gas temperature with load in the range of 0–3.74 BKW for diesel, jatropha curcas oil and various blends. The results show that the exhaust gas temperature increased with increase in BKW in all cases. The highest value of exhaust gas temperature of 554 °C was observed with the jatropha oil, whereas the corresponding value with diesel was found to be 425 °C only. This is due to the poor combustion characteristics of the jatropha curcas oil because of its high viscosity. The combustion characteristics of the blends were improved by increasing the proportion of diesel fuel in the J/D blend. The exhaust gas temperature for 20:80 J/D was observed to be very close to diesel oil and the temperatures were comparable to those with diesel oil blends with 30:70 and 40:60 J/D over the entire load. The maximum exhaust temperature was recorded as 550 and 540 °C with 70:30 and 60:40 J/D blends, respectively at 3.74 BKW. With 50:50 J/D, the value was found to be 535 °C. With the blends containing 40:60 and 30:70 J/D the respective maximum exhaust temperatures were shown to be 505 and 475 °C, which are slightly higher than the exhaust temperature achieved using diesel fuel in the engine. The exhaust temperature was found to be 435 with 20:80 J/D blend which is very close to that of diesel oil. The exhaust temperature with the blends having higher percentage of jatropha curcas oil was found to be higher at the entire load in comparison to diesel oil, but the

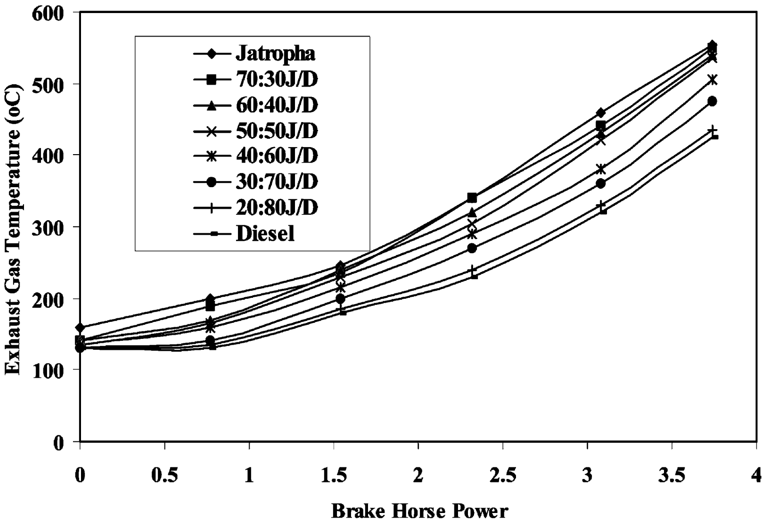

Fig. 4. Effect of brake power on exhaust gas temperature for diesel, jatropha curcas oil and various blends.

deviation was observed to be greater at higher BKW, particularly above 2.32. The higher exhaust temperature with blends containing above 50%v of jatropha oil is indicative of lower thermal efficiencies of the engine. At lower thermal efficiency, less of the energy input in the fuel is converted to work, thereby increasing exhaust temperature.

7. Conclusion

The main aim of the present investigation was to reduce the viscosity of jatropha curcas oil close to that of conventional fuel to make it suitable for use in a C.I. engine and to evaluate the performance of the engine with the modified oils. Significant reduction in viscosity was achieved by dilution of vegetable oil with diesel in varying proportions. Among the various blends, the blends containing up to 30% (v/v) jatropha oil have viscosity values close to that of diesel fuel. The blend containing 40% (v/v) vegetable oil has a viscosity slightly higher than that of diesel. The viscosity was further reduced by heating the blends. The viscosity of the blends containing 70 and 60% vegetable oil became close to that of diesel in the temperature ranges of 70–75 and 60–65 °C, respectively. The corresponding temperatures were found to be 55–60 and 45 °C for 50 and 40% blends, whereas only at 35–40 °C did the viscosity of the 30:70 J/D blend become close to the specification range. Acceptable brake thermal efficiencies and SFCs were achieved with the blends containing up to 50% jatropha oil. Blends with a lower percentage of vegetable oils showed slightly higher exhaust gas temperatures when compared to an engine running with diesel but they were much lower than the jatropha curcas oil in all cases. Therefore, from the engine test results, It has been established that up to 50% jatropha curcas oil can be substituted for diesel for use in a C.I. engine without any major operational difficulties. However, the properties of the blends may be further improved to make use of higher percentage of jatropha oil in the blend using jatropha oil of purer grade which may be obtained by pretreatment of the oil. Moreover, the long term durability of the engine using bio-diesel as fuel requires further study.

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References

[1] Kloptenstem WE. Effect of molecular weights of fatty acid esters on cetane numbers as diesel fuels. J. Am. Oil Chem. Soc. 1988;65:1029–31.
[2] Harrington KJ. Chemical and physical properties of vegetable oil esters and their effect on diesel fuel performance. Biomass 1986;9:1–17.
[3] Masjuki H, Salit. Biofuel as diesel fuel alternative: an overview. J. Energy Heat Mass Transfer 1993;15:293–304.
[4] LePori WA, Engler CR, Johnson LA, Yarbrough CM. Animal fats as alternative diesel fuels, in liquid fuels from renewable resources. Proceedings of an Alternative Energy Conference. American Society of Agricultural Engineers, St Joseph; 1992. pp. 89–98.
[5] Srinivasa Rao P, Gopalakrishnan VK. Vegetable oils and their methylesters as fuels for diesel engines. Ind. J. Technol. 1991;29:292–7.
[6] Masjuki H, Sohif M. Performance evaluation of palm oil diesel blends on small engine. J. Energy Heat Mass Transfer 1991;13:125–33.
[7] Nag A, de Bhattcharya KB. New utilizations of vegetable oils. J. Am. Oil Chem. Soc. 1995;72(12):1391–3.
[8] Takeda Y. Developmental study on jatropha curcas (Sabu dum) oil as a substitute for diesel engine oil in Thailand. J. Agricultural Assoc. China 1982;20:1–9.
[9] Piyaporn K, Narumon J, Kanit K. Survey of seed oils for use as diesel fuels. J. Am. Oil Chem. Soc. 1996;71(4):471–7.
[10] Agarwal AK. Vegetable oils verses diesel fuel: development and use of biodiesel in a compression ignition engine. TIDE 1998;8(3):191–204.
[11] Sinha S, Misra NC. Diesel fuel alternative from vegetable oils. Chem. Engng World 1997;32(10):77–80.
[12] Roger AK, Jaiduk JO. A rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. J. Am. Oil Chem. Soc. 1985;62(11):1563–4.
[13] Ryan TW, Dodge LG, Callahan TJ. The effects of vegetable oil properties on injection and combustion in two different diesel engines. J. Am. Oil Chem. Soc. 1984;61(10):1610–9.
[14] Korus RA, Jaiduk J, Peterson CL. A rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. J. Am. Oil Chem. Soc. 1985;62(11):1563–4.
[15] Rewolinski C, Shaffer DL. Sunflower oil diesel fuel: lubrication system contamination. J. Am. Oil Chem. Soc. 1985;61(7):1120–4.
[16] Ziejewski M, Kaufman KR. Laboratory endurance test of a sunflower oil blend in a diesel engine. J. Am. Oil Chem. Soc. 1983;60(8):1567–73.
[17] Pryde EH. Vegetable oil as diesel fuels: overview. Papers from the symposium on vegetable oils as diesel fuels, presented at the 73rd AOCS annual meeting, Toronto, Canada. J. Am. Oil Chem. Soc. 1983;60(8).