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Biodiesel originated from Jatropha oil as the alternative fuel for diesel engines

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Abstract
Biodiesel is a liquid fuel with similar features and can be used instead of traditional diesel. Biodiesel is prepared by deriving from some types of bio-grease (vegetable oil, animal fat), usually done through transesterification by reacting with the most common methanol alcohol. Biodiesel has many advantages for the environment compared to conventional diesel: Biodiesel from rapeseed produces much less emissions than fossil fuels. Dust in the exhaust gas is reduced by half, hydrocarbon compounds are reduced to 40%. Biodiesel is almost non-sulfur, non-toxic and can be easily biodegradable. Biodiesel is now considered one of the most environmentally friendly fuels on the market, reducing CO2 emissions, thus reducing greenhouse gas emissions, with little or no compounds of sulfur (<0.001% compared to 0.2% in Diesel oil), the content of other compounds in waste smoke such as CO, SO_X, HC has not been burned, soot is reduced significantly, so it is beneficial Very large to the environment and human health, does not contain aromatic HC so it does not cause cancer, has the ability to self-decomposition and non-toxic, reduce water and soil pollution, reduce the consumption of petroleum products.

Keywords: biodiesel, alternative fuel, physical properties

1. Introduction

Although Biodiesel, or "biodiesel", is a fuel produced from vegetable oils, animal fats and cooking oils. Some argue that biodiesel is simply a mixture of unrefined fats and oils mixed with diesel, but if you try to do so and use it for diesel engines, you will immediately have to pay big sums of money to engine repair. In fact, to be used to make biodiesel, oils and fats must be refined into methyl or ethyl ester. In the United States, soybean oil is the most common ingredient for purifying methyl ester, while in Europe and Canada; it is often used to produce biodiesel rapeseed (Canola). During the metabolism of many oils is converted into methyl ester by chemical reaction with methanol (with catalysts such as Na (sodium) or KOH (potassium hydroxide), then water, glycerin, methanol and some Other residues will be separated before biodiesel becomes a qualifying fuel for diesel engines, and there are about 200 biodiesel plants in the US - from Washington state to Iowa to North. Carolina - with a registered capacity of producing about 3 billion gallons of fuel, the industry is supporting nearly 48,000 jobs, generating billions of dollars in GDP, household income and tax revenue. This industry is growing significantly with continued production growth in many areas, from production to transport, agriculture and services.

It is recognized the environmental benefits of biodiesel by classifying it as premium biofuels, making biodiesel the only commercially available fuel for Vietnam to produce. meets the agency's advanced criteria. Biodiesel reduces greenhouse gas emissions by at least 57% and up to 86% when compared to diesel - making it one of the most effective and effective ways to solve problems. Climate change immediately. In addition, biodiesel significantly reduces the main lung tail pollutants from diesel, especially from older diesel engines. This is important because it has continuously invoked diesel engines - mainly from old trucks, and other vehicles - as one of the nation's most dangerous pollutants. Biodiesel is produced by a variety of resources. This diversity has increased significantly in recent years, helping to create an agile industry that constantly seeks new technologies and supplies. In fact, the industry's demand for cheap, reliable fats and oils is stimulating promising studies of next generation feed sources such as algae and camelina. Biodiesel is made through a chemical process called transesterification, whereby glycerin is separated from vegetable oil or vegetable oil. This process leaves two products - methyl ester (chemical name for biodiesel) and glycerin (a valuable by-product that is often sold for use in soaps and other products). The demand for renewable energy due to limited known petroleum reserves is increasingly high. As calculated with the current actual rate of consumption, the discovered global oil reserves are expected to last at least 44 years [1]. Almost all countries must face to problems such as declining supplies of fossil fuels, high cost of dependency on their importance, air pollution, etc. Biofuels seem a good solution to all these problems so they are interested in many countries. Biofuels are referred as liquid or gaseous fuels that are primarily produced from biomass. At present, there are only bioethanol and biodiesel produced as a fuel on an industrial scale. Biodiesel is one of the candidate energy sources that meet both sustainable criteria and biodegradable and non-toxic [2].

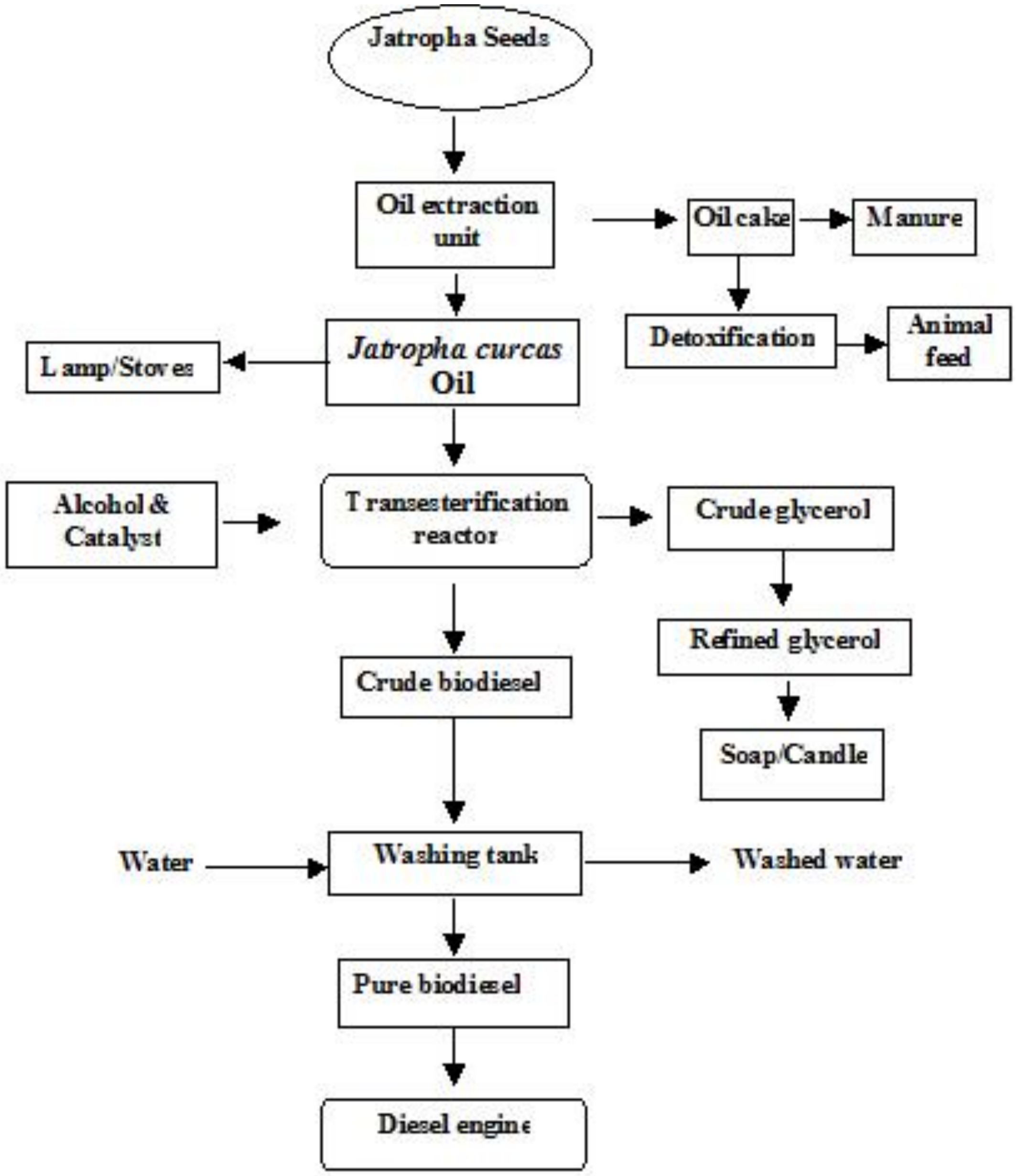

Fig 1: Biodiesel production from Jatropha

Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. Biodiesels have become more attractive recently because of their environmental benefits and the fact that they are made from renewable resources. Biodiesels have the potential to replace a fraction of the petroleum distillates and petroleum-based petrochemicals in the near future. Biodiesels presently does not compete with petroleum-based fuels because they are more expensive. However, with recently increases in petroleum prices, uncertainties surrounding petroleum availability and climate changes, there is renewed interest in using biodiesel in diesel engines. Although many researches pointed out that it might help to reduce greenhouse gas emissions, promote sustainable rural development, and improve income distribution, there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduce of engine power for biodiesel, as well as the increase of fuel consumption, is not as much as anticipated. The paper presents results obtained from a method applied for improving the properties of pure biodiesel aiming a direct use as a fuel in conventional diesel engines. Some typical properties such as viscosity, surface tension and density are considered to establish the relationship between them with temperature. This will be able to show the range of optimum temperature to heat up biodiesel.

Biodiesel History [11]

1900: Diesel engine demonstrated on peanut oil at the Paris Exhibition
1912: Rudolph Diesel suggests use of vegetable oils may be important for fuel.
1937: Belgian Patent 422,877 granted to G. Chavanne for using esters of vegetable oils as motor fuels.
1938: Urban bus fueled with esters of palm oils operates between Brussels and Leuven and Walton reports on “The Fuel Possibilities of Vegetable Oils”.
1942: Seddon paper on “Vegetable Oils in Commercial Vehicles”. At the same time, Chowhurry et al report on Indian vegetable oil as fuels for diesel engines.
1947: Chang and Wan report on using Tung oil for motor fuel in China
1951-1952: Two theses at Ohio State University, “Dual Fuel for Diesel Engines Using Cottonseed Oil with Variable Injection Timing” and “Dual Fuel for Diesel Engines Using Corn Oil with Variable Injection Timing”
1980: Bruwer et al. from South Africa report on utilization of sunflower seed oil as a renewable fuel for diesel engines includes tests with esters of sunflower oils
1981: North Dakota “Flower Power” project begins
1984: Wagner, Clark, and Schrock article “Effects of Soybean Oil Esters on the Performance, Lubricating Oil and Wear of Diesel Engines” and Geyer, Jacobus, and Lestz article “Comparison of Diesel Engine Performance and Emissions from Neat and Transesterified Vegetable Oils”
1984: Bio-Energy (Australia) Pty. Ltd. advertises equipment for producing “Bio-Diesel”
1988: Wang (China) article on “ Development of Biodiesel Fuel”
1991: Worgetter describes “Project Biodiesel”
1991: Freiberg, “The Truth About Biodiesel - An Opportunity for Entrepreneurs” published in Ag Biotechnology News
1992: National Soydiesel Development Board (NSDB) organized
1994: NSDB becomes the National Biodiesel Board (NBB)
1994: University of Idaho completes coast-to-coast and back on road test with 100% biodiesel fueling a Cummins-powered Dodge pickup
1994: Conference on “Commercialization of Biodiesel: Establishment of Engine Warranties” sponsored by the University of Idaho, Moscow, Idaho
1995: Yellowstone National Park Biodiesel Project begins
1996: Conference on “Commercialization of Biodiesel: Environmental and Health Effects” at Mammoth Hot Springs, Yellowstone National Park
1997: Conference on “Commercialization of Biodiesel: Producing a Quality Fuel” at Boise, Idaho
1998: Beginning of Kenworth/Caterpillar Simplot 200,000-mile test with HySEE biodiesel in a heavy-duty truck
1998: CCC buy-down program for producers of biodiesel
2000: Biodiesel passed Tier 2 health effects testing requirements of the Clean Air Act through efforts of NBB
1999: Biodiesel production surpasses 0.5 million gallons
2000: Biodiesel production surpasses 2 million gallons
2002: ASTM Standard D-6751 for Biodiesel approved
2004: American Jobs Creation Act provides a federal subsidy of $1 per gallon for biodiesel fuels made from virgin oils and $0.50 per gallon for other biodiesel fuels.
2006: Two billion gallons of biodiesel production capacity in the U.S either completed or under construction

2. Properties of Biodiesel

Chemically speaking, biodiesel refers to a vegetable oil - or animal fat-based diesel fuel consisting of long-chain alkyl esters. Biodiesel is typically made by chemically reacting with an alcohol producing fatty acid esters.

Triglycerides + 3ROH → Glycerin + $3R_1COOR$
$C_3H_5\ (OR_1)_3$ $\quad C_3H_5\ (OH)_3$ $\quad$ (biodiesel)

The advantages of biodiesel as diesel fuel are liquidity, ready availability, renewability, lower sulfur and aromatic content, and biodegradability. The main disadvantages of biodiesel as diesel fuel are higher viscosity, higher surface tension, lower volatility, coking on injectors, oil ring sticking, and thickening and gelling of the engine lubricant oil. Biodiesels are manufactured from many different sources: from edible vegetable oils and fats (1); inedible vegetable oils and fats (2); biomass (3) and algae (4). Properties of some selected biodiesel are given in Table 1 and Table 2 including the standard test method for determination of these properties.

Table 1: Comparisons of properties of biodiesel with diesel fuel

Type of biodiesel	**Viscosity (mm^2/s)**	**Density (g/ml)**	**Surface tension (mN/m)**	**Cetane number**
SuME	6.6	0.880	31	49
SoME	7.1	0.884	31	46
PaME	7.7	0.880	30	62
PeME	6.9	0.876	29	54
JME	7.5	0.885	29.5	52
Diesel	3.5	0.860	27	43

Where SuME is sunflower methyl ester, SoME is soybean methyl ester, PaME is palm methyl ester, PeME is peanut methyl ester and JME is jatropha methyl ester

Table 2: Compare the fuel properties of biodiesel with diesel fuel at 40°C

Fuel properties	**Diesel**	**Biodiesel**
Fuel composition	C 10- 21 HC	C 12- 22 FAME
Lower heating value(MJ/kg)	43	37 - 40
Kinematic viscosity at 40^0C (mm^2/s)	2.5-4	6.0-9.5
Density at 15^0C(kg/m^3)	850	878-890
Water, by wt (ppm)	161	0.05% max
Carbon, (wt %)	87	77
Hydrogen, (wt %)	13	12
Oxygen, (wt %)	0	11
Sulphur, (wt %)	0.05 max.	0
Flash point,(^{0}C)	60 to 80	100 to 170
Cloud point,(^{0}C)	-15 to 5	-3 to 12
Pour point,(^{0}C)	-35 to -15	-15 to 16
Cetane number	40 to 55	48 to 60

Table 2 shows that the biodiesel is highly oxygenated fuel compared to diesel and higher biodiesel flash point makes it storage less risky than diesel. All these properties indicate that the biodiesel is a suitable substitute of diesel. Furthermore, many countries, such as Germany, Italy, France, USA, India etc, have developed the biodiesel specification and are almost comparable in Table 3.

Table 3: Comparison of fuel properties of biodiesel of different standards

Standard	Density at 15^0C (g/cm^3)	Kinematic viscosity at 40^0C (mm^2/s)	Flash point (^{o}C)	Cetane number
Austria (ONC-1191)	0.85-0.89	3.5-5	100	≥49
India (BIS-15607)	0.87-0.89	1.9-6	130	≥40
France (EU-15412)	0.87-0.89	3.5-5	100	≥49
Germany (DIN-EN-590)	0.87-0.89	3.5-5	110	≥49
Italy (UNI-10946)	0.86-0.89	3.5-5	100	N.A
USA(ASTM-424720)	0.88	1.9-6	130	≥47

2.1 Viscosity

Viscosity is the quantity shown the resistance to the flow of liquid. The higher the viscosity is, the more unfavorable the use is because it reduces the possibility of dispersing while injection into the combustion as well as increasing the ability of the sedimentation in the equipment. Viscosity is inversely proportional to temperature. The higher the temperature is, the lower the viscosity is and opposite. The viscosity of biodiesel was approximately 2 to 3 times the viscosity of diesel fuel, so it is necessary to reduce the viscosity of biodiesel when it is used in diesel engine as an alternative fuel. To calculate the viscosity dependence of temperature, some models show [4]:

Exponential mode

$$\mu(T) = \mu_0 \exp(-bT) \quad (1)$$

Andrade model

This model uses the experimental formula to calculate the viscosity μ with under 2% error [6]. However, this model is only true for each type of fuel so each fuel type will have different experimental coefficients.

$$\log \mu = A + \frac{B}{T} \quad (2)$$

2.2. Surface tension

Surface tension (σ) is defined as the force exerted in the plane of the surface per unit length. Therefore, while the surface tension of the fuel is high, the mist injection will be less so this adversely affects the quality of the combustion in diesel engines. Surface tension is proportional to viscosity and inversely proportional to temperature.

Joel Escobedo & G. Ali Mansoori model

This model is applied to calculate the surface tension of organic compounds, so it can be used to calculate the surface tension of biodiesel [5], [6]:

$$\sigma = [P(\rho_l - \rho_v]^4 \text{ (mN/m)} \quad (3)$$

Flingoh & Chong Chiew model

This model uses the following empirical formula:

$$ST = A + B.T + C.T^2 + D.T^3 \quad (4)$$

2.3. Density

Density of biodiesel is higher than diesel about 3-7% at the same temperature. There is some method to calculate density, such as:

$$\rho_1 = \rho_0 / (1 + \beta (t_1 - t_0)) \quad (5)$$

3. Experimental Setup and Procedures

3.1 Materials

In this study, commercially available biodiesel from coconut oil, Jatropha oil methyl ester (JOME), has been used for analysis. For JOME, eight samples were measured and prepared in term of density, surface tension and viscosity.

3.2. Density measurement

For measuring density, the ASTM D1298 standard procedure was used. A glass hydrometer with specific gravity range of 0.7 to 1.0 g/cm^3 with an accuracy of three decimal places were used in the measurement. To collect temperature dependent data, a 100ml graduated cylinder containing a JOME sample was placed in a temperature controlled bath. The water bath temperature could vary from 40^0C to 80^0C. The test was repeated twice and the 5 average values were taken.

3.3 Viscosity measurement

The ASTM D 445 standard was used to measure kinematic viscosity of the JOME samples. This method is commonly used to measure the kinematic viscosity of liquid petroleum products. The kinematic viscosity is determined by measuring the time taken for a known volume of JOME flowing under gravity to pass through a calibrated glass capillary viscometer tube. CANNON Viscometer tube were used for this purpose. This viscometer constants is 0.0359 and kinematic viscosity range from 2 to 30 cSt. The water bath temperature used has a temperature range from 40^0C to 80^0C. For the experimental data to be acceptable the ASTM D 445 standards require the tests to be done two times and the first and second measurements should be within an accuracy of 0.02 cSt. If the accuracy condition is satisfied the average of the two tests was taken. The tests were repeated two times and the average value was taken as representative value.

3.4. Surface tension

For measuring surface tension, there are some of methods such as Du Nouy ring, Whilhelmy plate, Spinning drop, Pendant drop, Bubble pressure, Stalagmometric, Sessile drop. This paper uses Du Nouy ring method with a tension meter based on the ASTM D971 standard procedures. A copper wire ring is inserted below the interface and held horizontal. Then the ring is pulled up through the surface and the force is measured continuously by a balance. During the pull out of the ring the measured force increases, run through a maximum and decreases. The force maximum corresponds with the surface tension of JOME.

4. Results

The experimental results are conducted with JOME. The physical and chemical properties of the JOME are given in the Table 4.

Table 4: Physical and chemical properties of the JOME

Properties	Methods	Unit	Result
Lower heating value	ASTM D 240	MJ/kg	38
Cetan number	ASTM D 976	-	51
Cloud point	ASTM D 97	°C	0
Flash point	ASTM D 93	°C	100
Density	ASTM D 1298	g/cm^3	0.88
Viscosity	ASTM D 445	mm^2/s	7.2
Surface tension	ASTM D 971	mN/m	29

It can be seen in Table 4 that JOME has quite similar physical properties to diesel fuel; however, viscosity, surface tension and density are quite high which need to be improved. In Table 5 and in Fig 1 to Fig 3, measured results of kinematic viscosity, surface tension and density of JOME according the temperature of the fuel.

Table 5: Viscosity, surface tension and density of JOME at different temperature

Temperature (°C)	Kinematic viscosity (cSt)	Density (g/cm^3)	Surface tension (mN/m)
40	7.2	0.880	29
50	6.1	0.875	28.6
60	5.2	0.871	28.1
70	4.5	0.867	27.6
80	3.9	0.863	27.0

It is observed from Table 5 that from the temperature of 70 - 80^0C, the kinematic viscosity, density and surface tension of the JOME satisfy the requirements of a fuel used in diesel engine based on TCVN5689-2005 and QCVN 1:2009. Thus, in order to use JOME in diesel engines, it is necessary to heat the fuel up to 70-80^0C. The heating system can integrate the electricity – exhaust energies, electricity - steam energies or electricity - heating oil energies.

Biodiesel density is moderately higher than conventional fuels at 300K (880 kg/m^3 versus 790 kg/m^3 for kerosene). An increase in fuel density will have a slight direct effect on spray compactness and penetration, resulting in less air resistance, since for the same volume, the fuel mass flow will be increased. The relative properties of normal diesel fuel and the trendlines of JOME's measured properties are also plotted, from which the empirical formulas between density, kinematic viscosity, surface tension and temperature are observed as following:

Density of JOME:

$$\rho = -0.42t + 898.3 \quad (6)$$

Surface tension of JOME:

$$\sigma = -0.05.t + 32.08 \quad (7)$$

Kinematic viscosity of JOME:

$$\mu = 12.86\exp(-0.01t) \quad (8)$$

Where t is temperature in °C unit.

These above formulas are important to target the required heating temperature of JOME aiming the use in dedicated diesel engines.

5. Conclusions

In this paper, the properties of JOME has been analyzed and compared with those of diesel fuel to find a way to use directly JOME in diesel engine. The heating up method to JOME has been proposed. For the first step, three important properties of JOME including kinematic viscosity, density and surface tension were measured at different temperature. The results show that, in order to use JOME in diesel engines, it is necessary to heat JOME up to 50^0C to 60^0C.

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