Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231– 6345 (Online)
An Open Access, Online International Journal Available at www.cibtech.org/sp.ed/jls/2014/04/jls.htm
2014 Vol. 4 (S4), pp. 3935-3941/Farid et al.
Research Article

BIODIESEL PRODUCTION FROM *LINUM USITATISSIMUM* AND EFFECT OF LINSEED OIL METHYL ESTERS AND ITS VARIOUS BLENDS WITH GASOLINE ON FUNCTIONAL FEATURES OF DIESEL ENGINE

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ABSTRACT
Vegetable oils are combined with an alcohol (methanol) to produce chemical compounds known as esters, and when these esters are used as fuels are call biodiesel. In this study, biodiesel fuel has been extracted from *Linum usitatissimum* and produced via trans-esterification mechanism; consequently its important features were adapted with standard ASTM D-6751. Followed by trust on high quality of the produced fuel, function of engine of TYM tractors at 100% maximum load using 0%, 25%, 50% and 75% biodiesel and diesel compounds was tested and evaluated. The results indicated that functional features of engine (power, torque, specific fuel consumption) using various fuel compounds have worked out close to each other, known similar to the function of engine with diesel. On the whole, with regard to the results from functional parameters of engine, it seems that use of Biodiesel production from *Linum usitatissimum* combined with gasoline can be a suitable method to consume them in diesel engines without any substantial deformation in engine and fueling system.

***Keywords**: Biodiesel Production, Linum usitatissimum, Diesel Engine, Linseed Oil Methyl Esters*

INTRODUCTION
In recent years, due to reduction of fossil fuels and renewability of these fuels on one hand and environmental problems arisen from burning these fuels in vehicles' engine and emission of toxic gases from vehicles' exhaust on the other hand, a large body of studies have been conducted to supply suitable resources from alternative fuels in different countries throughout the world (Ameya and Sanjay, 2013; Liaquat *et al.*, 2012; Bindhu *et al.*, 2011).
About 100 years ago, vegetable oils were used as fuel by Rudolf Diesel, the inventor of the diesel fueled engine; use of vegetable oils in an engine is impractical, because these oils contain free fatty acids, phospholipids, sterols and other impurities, and use of these substances is followed by some defects, due to excessive corrosion due to the high viscosity of the moving parts, defects in engine ignition system due to existing contaminants in the oil, early contamination of lubricating oil ,low volatility and low combustion efficiency, chemical activity of unsaturated hydrocarbons, Formation of carbon deposits on engine parts and viscosity of oil rings. Hence, these oils are transformed to biodiesel via esterification process (Ameya and Sanjay, 2013).
According to standard, biodiesel implies combination of mono-alkyl esters of long chain fatty acids derived from reaction of an alcohol with renewable lipid (Bindhu *et al.*, 2011; Gulab *et al.*, 2009; Xue *et al.*, 2011). In most of cases, the main sources of renewable lipid develop from animal fats and vegetable oils. A major part of these oils is developed from triglycerides. Hence, under this reaction, in addition to ester, another valuable product, Glycerin, is produced (Bindhu *et al.*, 2011; Gulab *et al.*, 2009). Biodiesel is generally produced via trans-esterification method; Vegetable oils or animal fats transform to a biodiesel with an alcohol (Ethanol or methanol) and by presence of various Acidic and basic catalysts. These fuels contain oxygen, causing burning of fuels, mentioned that selection of raw materials to produce biodiesel relies on geographical position, so that canola is used in Europe, and soya in U.S, and palm in Asia (Bindhu *et al.*, 2011). The standard features that biodiesel must have to be known as biodiesel are measured by standard ASTM D6751 as U.S biodiesel standard and standard EN 14214 as

Europe's biodiesel standard (Bindhu *et al.*, 2011; Gulab *et al.*, 2009; Soriano and Akash, 2011). Biodiesel, due to having the advantages below, is known as the best alternative for diesel fuel.
1-renewability of this type of fuel, 2-appropriate energy balance, 3-emissions of greenhouses and toxic have a huge decrease than fossil fuels, 4-use of this fuel is possible without any change in engine, 5-use of these fuels in combination with diesel fuel causes burning of fuel (1,2,3).
A variety of studies on effect of biodiesel fuel and its various compounds with diesel fuel on performance and pollutants of diesel engine have been conducted. A study by Xue *et al.,* (2011) has been conducted, in which the results from 162 articles published in scientific journals were examined, and the results indicated that a majority of scholars have come to an end in this way:
1-use of biodiesel fuel causes reduction of power and increase of fuel consumption. 2-using biodiesel, emission of pollutants HC, CO and PM decreases. 3-using biodiesel, increasing emission of pollutant NOx will come to realize. 4-a number of scholars believe that increasing amount for emission of CO_2 equals to decreasing the amount for emission of CO_2 (Xue *et al.*, 2011). In a study by Ameya and Sanjay (2013), the amount of power and torque in various biodiesel and diesel compounds has been an amount less than diesel, where specific fuel consumption was shown with increase.
The present study aims to examine effect of linseed oil methyl esters and its various blends with Gasoline on Functional features of diesel engine.

MATERIALS AND METHODS

This study has been conducted at two stages, i.e. biodiesel was produced from *Linum usitatissimum* at the first stage, and the produced biodiesel to test and evaluate function of engine in tractor was used at the second stage. In this study, *Linum Usitatissimum* was purchased from a local area in Khalkhal County, where extracting oil and transforming it to biodiesel were fulfilled in food laboratory, faculty of agriculture, university of Shoushtar. After powdering *Linum usitatissimum* via domestic mills, transferring mass from the powdered substances to the solvent was fulfilled using Soxhlet device and N-hexane solvent, and the solvent was separated from oil via distiller. Finally, oil return was obtained 33%. The extracted oil was transformed to biodiesel via trans- esterification method. To use biodiesel fuel in tractor's engine, features of the produced biodiesel were determined based on the considered standards, thereby after producing biodiesel via trans- esterification method, some of its important features such as density, kinematic viscosity, flash point, cloud point, pour point and the amount of sulfur have been measured, and their results were adapted with international standard ASTM D-6751. In table 1, features of Biodiesel produced from *Linum usitatissimum* together with the associated standards and acceptable return, have been represented. With regard to the results represented in this table, it can observe that the major features of biodiesel produced from *Linum usitatissimum* are relevant with the standards ASTM D-6751. Hence, ensuring from standardization of the fuel, this fuel is used in engine of tractor TYM as shown in image 1.

Image 1: Dynamometer attached to tractor to measure the parameters under study

Table 1: Features of produced biodiesel and comparing it with the limits of standard biodiesel

Feature	Unit	Diesel	Range of standard biodiesel	Methyl Esters of Linseed	Method of experiment ASTM
Density	g/cm^3	0/828	---	0/863	D4052
Kinematic viscosity	cm^2/s	3/274	1.9-6	2/35	D445
Flash point	centigrade	44	Under 130	28	D93
Cloud point	centigrade	-2	---	-3	D2500
Pour point	centigrade	-3	----	-12	D97
Amount of sulfur	weight percent	0/84	Under 0.05	0/04	D2622
Calorific Value	Mj/Kg	44/774	-----	40/625	D240
Distillation range	centigrade	154-158	----	342-345	D86
Cetane Number	---	60	Over 47	51/4	D976
acid value	milligrams of potassium hydroxide per gram (mg KOH/g)	0/18	Under 0.8	0/15	D664

Using Biodiesel Fuel and Testing Functional Features

To perform test, an experiment with three repetitions in factorial form in a totally random form was conducted at 100% overload in engine of tractor TYM. Factors of experiment include dynamometer speeds (factor A) at seven levels (380, 420, 460, 500, 540, 580 and 620 RPM) and volume percent of *Linum usitatissimum* with diesel(factor B) at four levels(0, 25, 50 and 75%). Functional features of engine was tested and examined at Mechanization Development Centre Country. Tractor TYM made by southern Korea in 2013 with 7/42 power and engine speed 2600 rpm; to measure amount of fuel consumption, the fuel gauge with tank 200 cc and stopwatch. To measure engine's functional features, dynamometer, Sigma 5 n j froment dynamometer was used.

Calculation of specific fuel consumption

Energy return of tractors based on time and consumption unit is called specific fuel consumption, which is represented based on L/kwhr, kg/kwhr or gr/kwhr. In this study, unit of grams per kilowatt-hour was used. Specific fuel consumption is represented with PSFC (PTO Specific fuel consumption), and is calculated via the equations 1 and 2.

$$M_f = Q_f \times \rho_f \qquad (1)$$

$$PSFC = \frac{M_f}{P} \quad \text{or} \quad PSFC = \frac{M_f \times 1000}{P} \qquad (2)$$

Mf=rate of fuel consumption (kg/h) Q_f: rate of fuel consumption(l/h)

ρ_f : Density of fuel (kg/l) P: power from dynamometer (kw)

PSFC: special fuel consumption in terms of g/kwh

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RESULTS AND DISCUSSION

Results

Data from testing the tractor's engine indicated that power and torque in all the biodiesel and diesel compounds than net diesel fuel decrease, and the amount of specific fuel consumption increases. Table 2 represents analysis variance for testing functional features of tractor.

Table 2: Variance analysis of engine's functional features

Source of variation	Functional feature	Sum of squares SS	Variance MS	Calculated F	PR > F
	Power	2599	433	1664	<0/0001
Factor A(speed)	Torque	1321874	220312	11546	<0/0001
	Special use	315158	52526	3230	<0/0001
	Power	6/85	2/285	8/78	0/0002
Factor B(biodiesel)	Torque	5229	1743	91/36	<0/0001
	Special use	8717	2906	178/75	<0/0001
	Power	3/07	0/170	0/66	0/8297
Mutual effect A*B	Torque	326	18/140	0/95	0/5305
	Special use	318/09	17/67	1/09	0/4017

With regard to the variance analysis table and comparison of f-values for the agent of power, it is observed that the calculated f for the factor "dynamometer speed (factor A)" has been significant, yet the calculated f the factor "ratio of biodiesel to diesel fuel (factor B)"is not significant, and the mutual effect of factors is not also significant.

Table 3: Comparison of mean of power in factor "ratio of fuel with Duncan"

Ratio of fuel	**0%**	**25%**	**50%**	**75%**
Mean of data	23/73	23/66	23/30	23/02
Duncan	A	A	B	B

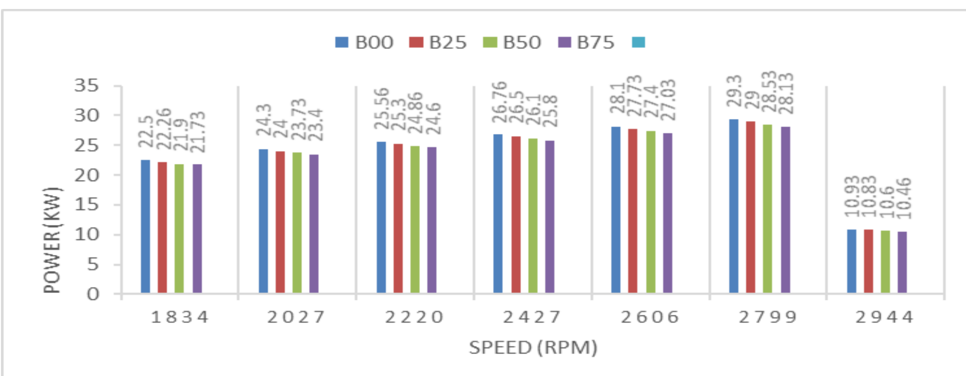

Figure 2: Relationship between compounds of biodiesel and diesel fuel on Power take off shaft

Results of comparison of means of power in the factor "ratio of biodiesel to diesel" have been represented in table 3, and changes of power in various ratios for biodiesel and diesel fuel in various engine speeds have been represented in figure 2. Comparison of means indicates that there is no significant difference on means between B0 and B25, and these are deemed the same in sake of function; yet there is a significant difference between "B0 and B25" and "B50 and B75". There is no significant difference between B50 and B75, so that B50 and B75 have worked out the same in sake of function. By increasing the percent of biodiesel blended with gasoline, a decreasing trend raises in power. This little decrease in 25% biodiesel and diesel blend can have a decrease for about 0.25%. This decrease can be due to low heat value of biodiesel and incomplete burning due to high density of these fuels. Decreasing torque and power in the compound of 15% biodiesel from waste vegetable oil and diesel is less than torque and power in use of diesel for about 1.44% and 1.54% (Liaquat *et al.,* 2012). Murillo *et al.,* (2007) showed that decreasing the produced power equals to 7.14% for biodiesel fuel in total load. Where the heath value of the biodiesel fuel has been 13.5% less than gasoline (Murillo *et al.,* 2007). Najafi *et al.,* (2007) examined effect of biodiesel from sunflower on the engine of diesel, and concluded that use of pure biodiesel fuel in full load dynamometer compared to gasoline causes a decrease for about 0.4% in power, where this difference is not significant. With regard to variance analysis table, functional features of Power take off shaft, there is a significant difference on calculated f for the factors of speed of dynamometer(factor A) and ratio of biodiesel to diesel (factor B) in sake of function of engine. Yet, mutual effect of two factors is not significant, i.e. two factors have worked out independently. To compare means of torque, Duncan test is used. Results from comparison of means of torque in table 4 and changes of in torque of power take off shaft in various ratios of biodiesel and diesel fuel have been represented in various rounds of engine in figure 3.

Comparison of means in factor "ratio of biodiesel to diesel" indicates that there is a significant difference between all the means, and the more biodiesel increase in the blend with gasoline, a decreasing trend rises in torque. This decrease in the blend with 25% biodiesel and diesel has had a decrease for about 4.42%. This can be due to thermo-physical properties of blends such as low heat value.

kochak and his colleague(2008) indicated that power and torque of engine using biodiesel from Waste Cooking Oil Methyl Ester than pure gasoline has a decrease for about 4.3 to 5.4%, and the reason for this can be due to high viscosity and low heating value of biodiesel. In another study, Jamil and his colleague (2006) stated that decreasing power produced from biodiesel fuel is due to its low heat, that they stated that the produced power and torque are about 3% to 6% less than gasoline. Murillo *et al.,* (2007) indicated that decreasing the produced power equals to 7.14% for the biodiesel fuel than gasoline in the full load. With regard to the variance analysis table and calculation of f-value, it can observe that factor A and factor B are significant. Yet, mutual effect of two factors is not significant, i.e. two factors have worked out independently.

Table 4: Comparison of mean of power in factor "ratio of fuel with Duncan test"

Ratio of fuel	**0%**	**25%**	**50%**	**75%**
Mean of data	472/90	466/52	458/71	452
Duncan	A	B	C	D

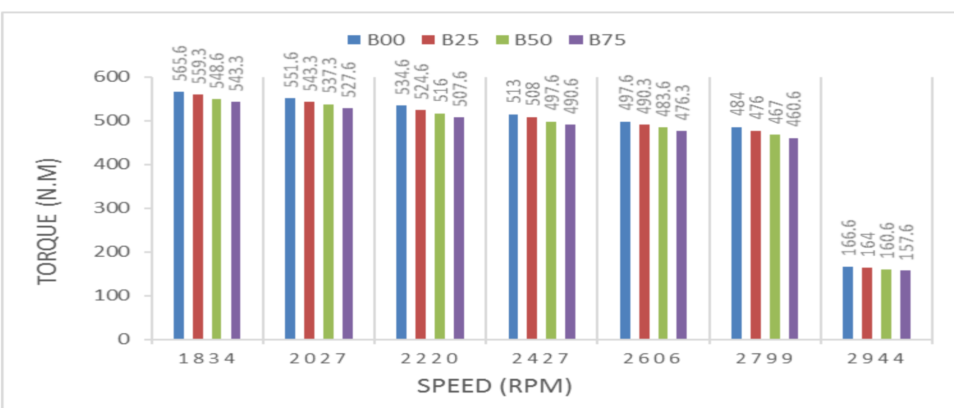

Figure 3: Relationship between compounds of biodiesel and diesel fuel on torque of Power take off shaft

1- To compare means of special fuel consumption, Duncan test is used. Results of comparison of means in table 5 and changes in special fuel consumption in various ratios of biodiesel and diesel fuel in various rounds of engine have been shown in figure 4. Comparing means using Duncan test, it can observe that there is a significant difference on all the means at levels of B in special fuel consumption, that increasing biodiesel in blend with gasoline raises an increasing trend in special fuel consumption. This increase in blend made of 25% biodiesel and diesel has an increase for about 7.62%. It seems that this increase is due to Thermo- physical properties of blends such as low heat value and high biodiesel density of *Linum usitatissimum*. Clark *et al.*, (1997), using biodiesel from Soya, reported a decrease of power for about 7.8% and increase of special fuel consumption for about 10% than gasoline. Raheman and Phadatare (2004), using karanja oil, obtained an increase for about 13% in torque and increase for about 7.4% in special fuel consumption concerning compound B20.

Table 5: Comparison of mean of special fuel consumption in factor B concerning Duncan test

Ratio of fuel	**75%**	**50%**	**25%**	**0%**
Mean of data	380/76	372/38	362/19	353/81
Duncan	A	B	C	D

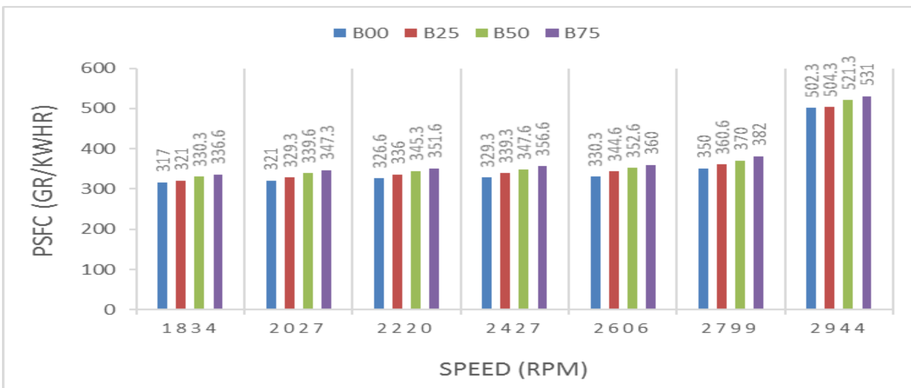

Figure 4: Relationship between compounds of biodiesel and diesel fuel on special fuel consumption

Conclusion

In this study, function of engine of tractor TYM using various compounds of diesel and Biodiesel production from *LinumUsitatissimum* was examined and evaluated, and the results of research indicated that function of compound of 25% biodiesel with diesel has the least difference with function of diesel, and this compound was recognized as the best compound due to low special fuel consumption than other compounds. To sum up, based on the results from the functional parameters of engine, it seems that use of *Linum usitatissimum* in blend with gasoline is a suitable method for consuming them in diesel engines without significant change in engine and fuel system. Another point is that by generalizing the data obtained for tractor to other heavy vehicles, it can conclude that by producing biodiesel from *Linum usitatissimum* in mass extent and use of this fuel in a blend with diesel fuel, it can help for reducing the need for importing fuel, and also it can help for reducing consumption of fossil fuels also by using this renewable fuel.

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