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RESEARCH ARTICLE

Development of blends of degummed *Linum usitatissimum* seed oil with diesel: as a potential resource for diesel engine

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Abstract

In this study, an attempt has been made to use water degummed *Linum usitatissimum* seed oil as a potential alternative fuel for diesel engine. Furthermore, the basic fuel properties of water degummed *Linum usitatissimum* seed oil (WDLO) and its diesel blends in proportions (oil/diesel) of 20:80, 30:70, 55:45 and 80:20(v/v) were characterized and evaluated. This process can be an effective method of enhanced its fuel properties (viscosity, calorific value and specific gravity, flash point, cloud and pour point). The results show that the characteristic fuel properties of WDLO20 diesel blend was found close to those of diesel fuel on the basis of experimental analysis. Hence it is also emphasized that the water degumming method offers a potentially low-cost method with simple technology for producing an alternative fuel for compression ignition engines.

1. Introduction

Bio-fuel is a less polluting, locally available, accessible, sustainable, and reliable fuel derived from renewable sources. Liquid biofuels are obtained from agricultural sources, like; vegetable oils, fats, sugar and polysaccharides sources (Adebayo, 2011). Fuel from vegetable oils for diesel engine is not radically new concept, in 1900, Mr. Rudolph Diesel first tested his diesel engine on groundnut oil as an alternative fuel without any problem (Fangui et al,1999; Parawira,2010; Adrade et al,2011]. Due to the energy crisis, many researchers from different countries are still investigating the use of different types of vegetable oils as diesel fuel substitutes. India and other developing countries can secure their energy dream with the production of renewable energy from edible and non-edible vegetable oil such as Karanj, Linseed oil and Jatropha, sunflower oil rapeseed oil palm oil, cotton seed oil and soybean oil (Srivastava and Prasad , 2000; Tiwari et al, 2006 ;Sidibe et al, 2010;Pramanik, 2003). A number of problems associated with using straight vegetable oils (SVOs) directly as a diesel engine fuel. The high viscosity of SVOs compared to diesel oil the main cause reported in the literature for the problems encountered in engines. High viscosity results in poor fuel atomization, incomplete combustion, deposits in the combustion chamber (Pramanik, 2003).There are many potential methods for utilizing vegetable oils as diesel fuel substitutes such as heating, dilution, blending, emulsification and transesterification (Rathore and Madras, 2007).

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Influence of Gum on biofuel

The phosphorus content in vegetable oil indicates the presence of phospholipids (gums).This parameter is very important for fuel use indeed, phospholipids are responsible for the fouling of valves, combustion chamber and cylinders even if the straight vegetable oils are used (gumming phenomenon) (Sidibe et al, 2010). Gums can cause problems during the transportation of fuels by settling and forming deposit on tanks walls or clogging pipelines (Fangui,1999; Srivastava and Prasad, 2000; Mullenix, 2011). In engine where vegetable oil is used, gums or phospholipids can cause catalytic converter issue or coking within the engine (Mullenix, 2011). Several researchers have reported that a high phosphorus (gum) content of the vegetable oil leads to an increased formation of deposit when it is used as fuel in diesel engines (Ali et al, 1994) so it must be removed or reduced from the vegetable oil. Phospholipids (gums) are undesirable constituents of vegetable oil that come from the cell membranes of seed and kernels. They vary in concentration depending on pressing and filtering techniques and it can be remove from oil through degumming process.

The purpose of this article is not only to study the influence of degumming on the phosphorus content, but also consider their effect on the some basic fuel properties of degummed oil. This work is also focused on the development of blends of water degummed *Linum usitatissimum* seed oil with diesel as a potential resource for diesel engine.

2. Material and Methods

Mechanically pressed *Linum usitatissimum* seed oil with a phosphorus content of 100 ppm was used throughout this work. Diesel fuel purchased from the local petrol pump. De-ionized water used as a degumming agent.

2.1 Experimental setup

The reactor used for experiments was a 500 ml three-necked Glass flask (Fig.1) the flask is placed in a water bath. The center neck is fitted with a stirrer. One of the two side necks is equipped with a thermometer and another is closed through the glass stopper.

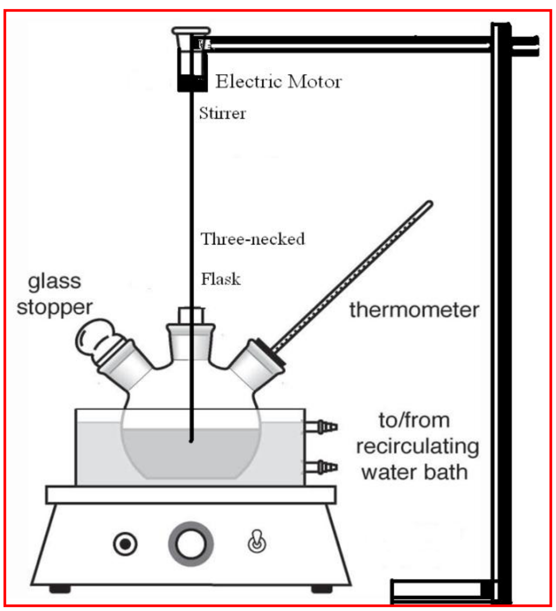


Fig1: Experimental set-up for preparation of water degummed *Linum usitatissimum* seed oil

2.2. Water Degumming of Linum usitatissimum seed oil

A measured amount of crude mechanically pressed *Linum usitatissimum* seed oil was taken into the flask. Heat was supplied to the setup using a heating mantle. Degumming were carried out under different % of hot de-ionized water (2%, 5%, 10wt %) at different temperatures (45^{0}C, 55^{0}C, 65 ^{0}C) and with different stirring times (10, 20, 30 minutes) at different rpm (300,400, 500). Gums separated by lab centrifuge at 4500 rpm. Samples were drawn for phosphorus analysis. The optimal reaction condition identified based on the minimum residual phosphorus (phospholipids) content in the degummed oil (given in Fig.2 and degummed oil samples in Fig.3).

Fig.2. Sequence of water degumming operation

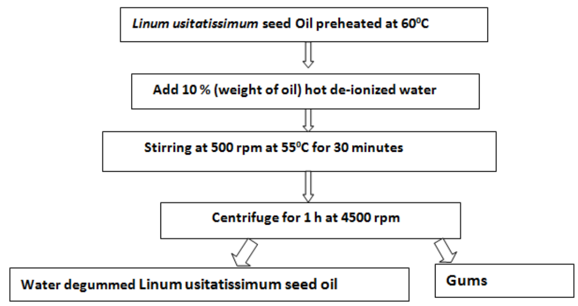
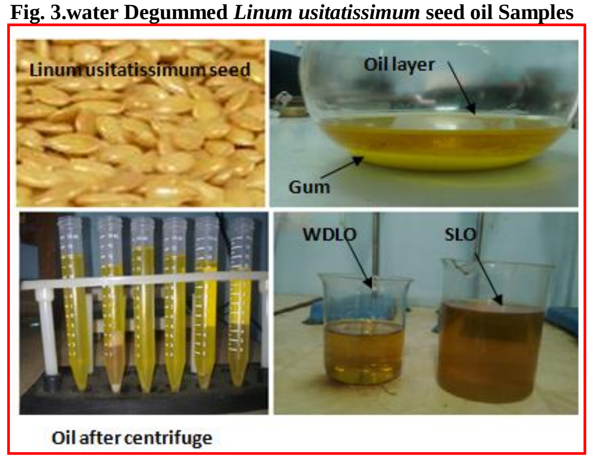
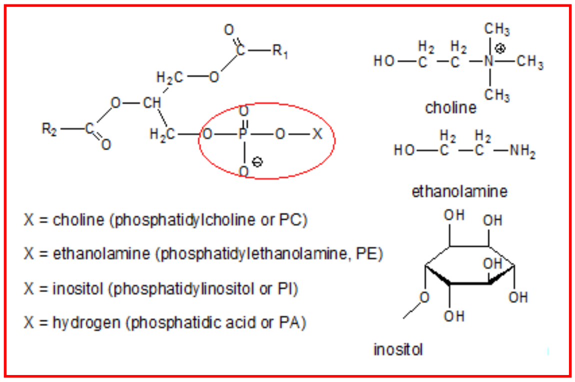


Fig. 3.water Degummed *Linum usitatissimum* seed oil Samples



2.2.1. Chemical structure of gum (phospholipids or phosphatides)

Vegetable oils contain complex organo-phosphorus compound referred to as phospholipids (phosphatides). Phosphorus and fatty acids convert into pasty substances called gums. All Vegetable Oils contains two types of gums (phospholipids), hydratable (HPL) and non-hydratable (NHPL), and they are removed from oil by degumming process [Zufarov et al,2008].The level of hydratable and non-hydratable gums vary depending on a number of factors such as seed quality, seed type and oil milling conditions, but crude vegetable oil contains roughly 90 % hydratable gums while the remaining 10 % consists of non-hydratables.The basic structure of the phosphatides (phospholipids) is *sn*-glycerol-3-phosphate. Two fatty acids are esterified to the hydroxyl groups at positions 1 and 2, while a phosphorus-containing acid is esterified at the hydroxyl group at position 3 (as seen in chemical structure). During water degumming the hydratable Phospholipids react with water and convert into the gum phase (Ernst et al, 2007).



R= fatty acid chains, =Water affinity

Chemical structure of phospholipids

2.2.2. Gum in Linum usitatissimum seed oil

Linum usitassimum seed oil contains a high amount of phospholipids. The most important members of this class of lipids found in *Linum usitassimum* seed oil are phosphatidylethanolamine (PE) phosphatidylinositol(PI) and phosphotidylcholine (PC)(wahid et al, 2012). Most of these (PC and PI phospholipids) are completely hydratable phospholipid and can be removed from the crude oil using a water degumming process and PE is only partly hydratable. The amount of phospholipids(gum) was determined as the total phosphors of oil, phosphorus content in the oil is analyzed (AOCS Official method Ca 12-55) and expressed in parts per million (ppm). The phospholipid or phosphatides content normally could be calculated by multiplying the phosphorus value by factor 25 (Phosphorus (ppm) = phosphatides (%) X 10^4/25).This factor is derived from the ratio of the specific weight of phosphorus and the phasphatides (Hmm. W et al, 2002).

2.3. Water degummed Linum usitatissimum seed oil and diesel blending:

Four blends (20, 30, 55 and 80 %) of WDLO by volume with diesel fuel were prepared and used to characterize the some basic fuel properties. Degumming of oils was required to prevent engine failure even if the vegetable oils were blended with diesel fuel. Blending improves fuel properties to suit the CI engine operation. The diesel blends of WDLO given below in table 1:-

Table1
WDLO-diesel blends

Sample	**Blending with diesel**
WDLO20	20% WDLO and 80% diesel
WDLO30	30% WDLO and 70% diesel.
WDLO55	55% WDLO and 45% diesel.
WDLO80	80% WDLO and 20% diesel.

The following test methods were used to determine the some basic fuel properties of WDLO and its diesel blends, Specific gravity at 15^{0}C (ASTM D1298-85), Viscosity at 40 ^{0}C (ASTM D445), Pour point (ASTM D97), Flash point (ASTM D93), Calorific value measured by Bomb calorimeter (ASTM- D240), Acid number (AOCS Cd 3a-64), Phosphorus (AOCS Official method Ca 12-55), cloud point (ASTM 2500) and pour point (ASTM D97). The fuel properties of the WDLO and diesel fuel are presented in Table 3.

3. Results and Discussion

3.1 Influence of water degumming process on phospholipids (phosphors) content in Linum usitatissimum seed oil

The phosphorus content determined for the WDLO obtained by water degumming of Linum usitatissimum seed oil is about 10.5 ppm, a value that corresponds to the quality requirements imposed by the quality standards as seen table2.

Table2, Phosphatides (phospholipids) content of WDLO

Oil type	**Phosphorus (ppm)**	**Phosphatides* (%)**
Straight *Linum usitassimum* seed oil (SLO)	100	0.25
Water degummed *Linum usitassimum* seed oil (WDLO)	10.5	0.0263

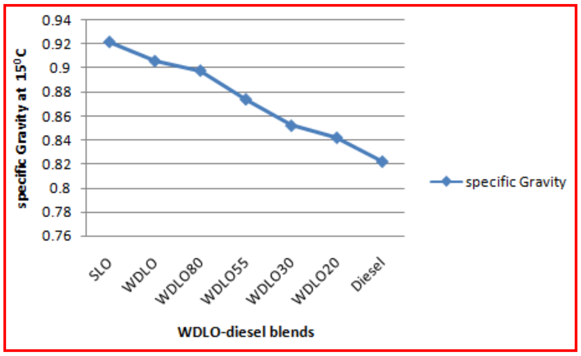
*Phosphorus (ppm) = phosphatides (%) X 10^4/25 (Hmm. W et al, 2002).

3.2 Fuel properties of WDLO- diesel blends

3.2.1 Specific gravity (SG)

In general the specific gravity refers to as the ratio of density of a fuel to the density of water at the same temperature. The temperature usually specified is 15^{0}C. The SG of the WDLO-diesel blends increases with rising of WDLO amount in the fuel blend. There is a linear increase in SG of the blends with the increasing amount of WDLO as seen in Fig.4. Hence, the SG of 20 % WDLO is comparable to that of diesel fuel.

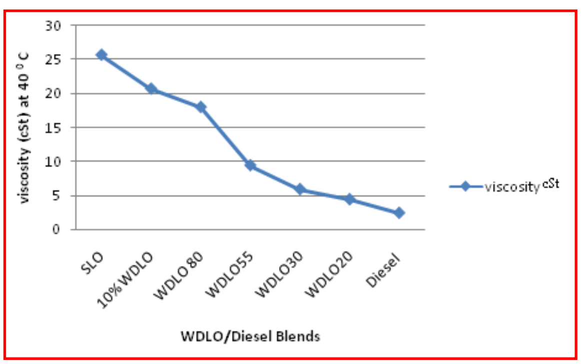
Fig.4. Specific gravity of WDLO and its blends with diesel fuel



3.2.2. Kinematic viscosity

The viscosity of the blend increases as the WDLO amount increases in the fuel mixture as observed from Fig.5, the viscosity of WDLO higher than that of diesel fuel but 20% and 30 % WDLO is very comparable to that of diesel fuel. The Indian standard (IS: 1448 [p: 25] 1976) recommends the range of the viscosity of diesel from 2 to 4 cSt for the use in high speed diesel engines. Thus the comparison of viscosity of WDLO and its blends suggests that WDLO can be blended with diesel in proportion of 20 % and 30% to meet the viscosity requirement as proposed by the Bureau of Indian Standards (IS: 1448 [p: 25]. The viscosity of the WDLO and WDLO20 measured at four standard temperatures and the variation in viscosity with temperature is shown in Fig.5a, as expected, the viscosity of the oil decreased with a temperature increase. It is worthwhile to note that the lowest viscosities were obtained at the 60 ^{0}C.

Fig.5. Viscosity of WDLO and its blends with diesel fuel



3.2.3. Cloud and Pour point

Cloud and pour point are the key flow properties for winter fuel specification. Both are indicating the tendency towards filter plugging and flow problems in the fuel line. The cloud point is the temperature at which haze or a cloud first appears in a sample of oil, when cooled in a prescribed manner and the temperature at which oil will just flow under standardized conditions is known as the pour point. The oil will not flow satisfactorily at temperature below its pour point. The cloud and pour point of the blends increase as the concentration of WDLO increases in relation to the diesel fuels. According to the results, the cloud and pour point reached for the WDLO20 and WDLO30 blends were close to that of diesel as seen in Fig.6. It can be overcome the low-temperature opratability problems of WDLO to blended it with diesel fuel.

Fig.5a. Effect of temperature on Viscosity of WDLO and its 20 % diesel blend

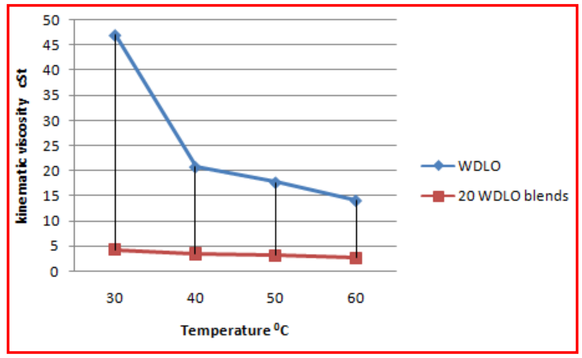
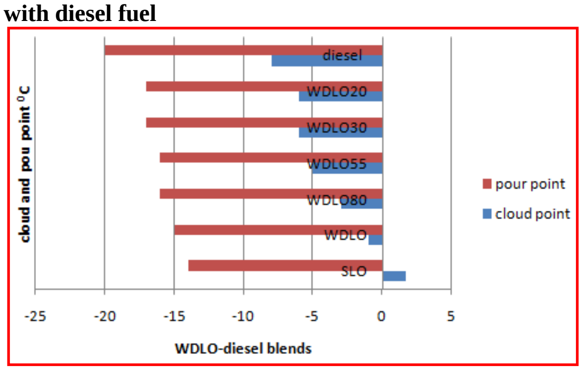


Fig.6. Cloud and Pour point of WDLO and its blends with diesel fuel



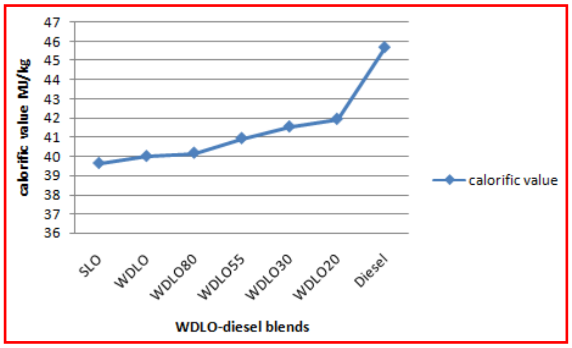
3.2.4. Calorific value

The Calorific value of SLO, WDLO, WDLO20 and diesel were found as 39.63, 40, 41.95 and 45.71MJ/Kg respectively. The calorific value of WDLO is increased by 5.9 % than that of SLO (Fig.7).

3.2.5. Flash and Fire point

The flash and fire point of WDLO are higher than those of diesel fuels but it can be improved by blending it with diesel fuel. The flash points increase significantly for the blends of 55 % and 80% as shown in Fig.8.

Fig.7. Calorific value of WDLO and its diesel blends



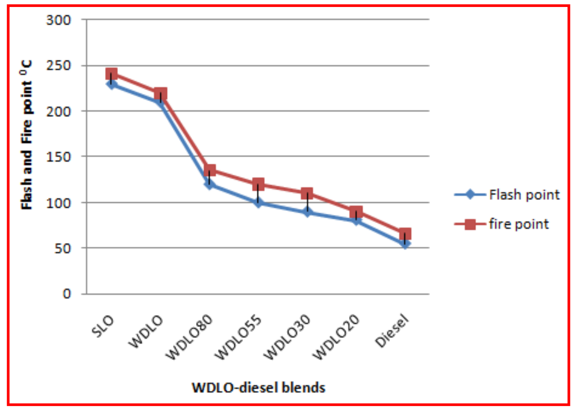


Fig.8. Flash and Fire point of WDLO and its diesel blends

Table.3. Fuel properties of diesel, *Linum usitatissimum* seed oil and WDLO -diesel blends

Fuel Parameters	**Diesel**	**Straight *Linum usitatissimum* seed oil (SLO)**	**Water degummed *Linum usitatissimum* seed oil (WDLO)**	**Water degummed *Linum usitatissimum* seed oil -diesel blends**			
				WDLO 80	**WDLO 55**	**WDLO 30**	**WDLO 20**
Specific gravity at 15^0C(g/ml)	0.816	0.922	0.906	0.898	0.874	0.852	0.842
Kinematic viscosity (cSt) at 40 ^{0}C	2.4-4	25.7	20.7	18.0	9.4	5.9	4.4
Calorific value (MJ/kg)	45.71	39.63	40.00	40.17	40.95	41.55	41.95
Flash point ^{0}C	55	230	210	120	100	90	81
Fire point ^{0}C	68	241	220	135	120	110	90
Cloud point ^{0}C	-8	1.7	-1	-3	-5	-6	-6
Pour point ^{0}C	-20	-14	-15	-16	-16	-17	-17
Acid value mg KOH/g	0.22	1.9	1.7	1.5	1.5	1.4	1.4
Saponification value mg KOH/g	-	188	185	-	-	-	-

4. Conclusion

In this work, it has been shown that basic fuel properties of WDLO-diesel fuel blends provide relevant information about behavior as diesel engine fuels. It is concluded that the water degumming process not only influenced the phosphorus quantity of *Linum usitatissimum* oil but also it enhance its fuel related properties as well. The above results show that the characteristic fuel properties of WDLO20-diesel blend was found to be close to that of diesel. Hence it is identified as a promising and suitable species for a diesel fuel extender. It is also emphasized that the water degumming method offers a potentially low-cost method with simple technology for producing an alternative fuel for compression ignition engines. A lot of research remains to be done in this area.

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