THE DETERMINATION OF THE EFFECTS OF VISCOSITY, DENSITY AND FLASH POINT PROPERTIES ON CALORIFIC VALUE IN METHYL ESTERS

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Abstract:
Parameters as a fuel economy, exhaust emissions, enough yield taking from using alternative fuels in vehicles are dependent directly properties of using alternative fuel. Therefore, properties of using alternative fuels need to be close or suitable to those of self fuels in vehicles. So, properties of alternative fuels need to be determined. Right of these determines need to be done in the boundary of measurement where its standard is obvious. These measurements pose problems for fuel producers due to being time consuming, being very expensive, exhibiting sensitivity and requiring special and trained personal. In this study, in order to support the solution of the above mentioned problems, relations between the properties of the fuel have been determined henceforth it has been aimed determination of other properties via using these relations. For this aim Cotton oil ME, Hazelnut oil ME, Mustard ME, Palm ME, Canola ME, Soybean ME, Olive oil ME, Sunflower ME, Frying waste oil ME, Serving as food waste oil ME, Used olive oil ME, Used canola ME, Canola ME were produced and their properties were determined. Also by using literature data of Peanut ME, Babassu ME, Suet ME, Rubber seed ME, Karanja oil ME, Mahua oil ME, Nahor oil ME and Almond oil ME statistic relations between methyl esters fuel properties were statistically determined.

Keywords: *Biodiesel, density, cinematic viscosity, flash point, methyl esters, heating value*

INTRODUCTION

Today, technologic developments have brought about energy problems. Especially, the motor vehicles use fossil-based fuels. The formation of these kinds of fuel requires a long-period of time. The number of the systems using fossil-based fuels is increasing and thus we are running out of fossil-based fuels. That is why researchers have looked for alternative energy sources. One of these alternative fuels is biodiesel which is a renewable fuel. Biodiesel is an alternative ñgreenò fuel produced from herbal oils, animal oils and waste oils by means of reaction with catalyst and alcohol **[1-5]**.

It is also important that this alternative fuel can be used in already available vehicle without any extra cost. In vehicles, to have an adequate efficiency from alternative fuels, the parameters such as exhaust emissions, fuel economy are directly dependent on the features of alternative fuel. Therefore, the alternative fuelsô properties should be close and suitable to the properties of the one originally used in the vehicle. That is why the properties of the alternative fuels are to be determined. The determination of these properties is to be carried out according to standard measurement methods. The fact that these measurements require a long time, sensitiveness, experienced and educated staff, and their high cost is another problem for alternative fuel producers **[6-11]**.

The determination of the properties of the fuels is done with different devices. Generally the cost of these devices is high. Besides, the determination of in this study, the relationship among the properties of these fuels are determined to contribute to the solution of the problems mentioned above and thanks to these relationships, it was aimed to determine the other properties **[12-15]**.

MATERIAL AND METHODOLOGY

Material

According to the previous studies, in the use of herbal oils as fuels, the important point was the determination of the herbal oil which is the closer to the diesel fuel properties. For this aim to be fulfilled, the fuel properties of herbal oils are to mixed with each other and with petrol-based fuels. However, as the oxidation time is very short, it shows a kind of instability. Besides, the cetane number is very low. Such properties as high number of cetane, high oxidation time, low viscosity, low freezing point and low flow point highlight safflower, nut, rape, soybean, sesame, cotton, sunflower, palm and peanut oil as diesel fuel.

In this study, the fuel properties of cotton oil ME, nut ME, cruet ME, palm ME, canola ME, safflower ME, peanut ME, babassu ME, suet ME, soybean ME, rubber seed, olive oil waste ME, sunflower ME, poppy ME, karanja oil ME, mahua Oil ME (MOME), nahor (beach sheoak) oil ME, waste oil used for frying, food waste oil methyl ester (RCOME), used olive oil ME, used canola ME, canola ME, almond oil ME as biodiesel were chosen as material. The viscosity, density, moisture amount, thermal value, flashing point, clouding and flowing point and ash amount of the biodiesel were measured (Table 1) **[16-19]**.

The equipments and devices used in the study

- Methyl ester production reactor
- Viscosity meter
- Hydrometer
- Flash point test device
- Clouding and flowing point test device
- Copper corrosion test device
- Ash amount determining device
- Water amount determining device
- Calorimeter
- Sulphur-carbon device
- Washing unit
- Digital scale

Chemical and washing substances used in the study

- Methanol; Merck brand of methanol with CH_3OH 99.5% purity, with a density of 0.791-0.793 kg/liter, with a distillation interval between 64-65 ^oC was used.
- Sodium hydroxide; AK chemical brand of sodium hydroxide with NaOH molecule weight of 32.04 g/mol, core substance of 99.5 % was used.

Methodology

The essential of the production of the methyl ester is the preparation of the catalyst which is used in the reaction of herbal oil with methyl or ethyl alcohol. The esterification of the oils called biodiesel is done with either methanol or ethanol. In this reaction, aside or alkali materials can be used as catalyst. In the previous studies, it was revealed that the use of alkali catalyst yield better results such as shortening the time of reaction, increasing the conversion of herbal oil to biodiesel **[1, 20-21]**.

The Determination of Fuel Properties

In the measurement of the viscosity of the fuels, Stanhope-Seta brand Redwood No: 1 model viscosity meter was used. The device was calibrated to be able measure as Redwood/second. Hydrometer was used to measure the density of the fuels produced.

The flash point of the biodiesel was determined with a Koehler brand portable type flare point determiner device. The measurements were repeated at least for three times.
To determine the ash amount, the ash amount determiner device in the laboratory of the Karaman Vocational High School was used.
To determine the water amount the water amount determiner device in the laboratory of S.U. Karaman Vocational High School was used.
In the measurement of the Low Heating Value (LHV), LECO AC-350 thermal efficiency test device which measures according to ASTM D2015-85 standards was used.
In the determination of sulphur carbon amount, LECO SC-144DR test device which measures according to ASTM D5453-93standards was used.

Table 1 Methyl ester samples and their properties

Methyl Ester (ME)	Viscosity mm^2/s (40 °C)	Density kg/m^3 (15 °C)	Flash point (FP) (°C)	LHV (Low Heating Value) (MJ/kg)
Cotton oil ME	3.69	880	164	39.16
Nut ME	3.59	860	128	38.70
Mustard ME	4.10	881	173	38.06
Palm ME	4.90	870	170	35.74
Canola ME	4.63	885	155	38.24
Safflower ME	4.03	880	180	36.98
Peanut ME	4.90	883	176	38.10
Babassu ME	3.60	879	127	31.80
Suet ME	4.63	877	161	37.20
Soybean oil ME	4.08	885	174	37.56
Rubber seed	5.81	885	170	36.50
Olive oil waste ME	5.29	882.3	169	39.67
Sunflower ME	4.22	880	170	35.92
Opium ME	3.50	888	150	37.30
Karanja oil ME	3.80	882	134	35.88
Mahua Oil ME (MOME)	5.20	865	127	36.90
Nahor oil ME	4.10	897	142	35.25
Frying oil waste ME	4.30	880	150	38.25
Food waste oil ME (RCOME)	4.60	883	152	37.90
Waste Olive oil ME	5.29	880.1	169	37.50
Canola waste oil ME	6.30	885	190	36.50
Canola oil ME	4.48	888	162	38.24
Almond oil ME	2.34	880	180	37.30

RESULTS AND DISCUSSION

The numeric data obtained was assessed with Tarist program and the statistical results and the regression equations among them were created and the results obtained from these equations were interpreted (Figure 1 ï Figure 6).

Equation (1) gives the relationship between heating values (HV) and density (D). It was seen that the relation between these two properties was found to be significant (r^2= 0.959, %1).

$$HV = -0.000165 + 0.100830 \times D - 0.000067 \times D^2 \quad (1)$$

When the effect of flash point on thermal value was examined (Eq. 2); the relation between these two features was found to be significantly high (r^2= 0.967, 1 %).

$$HV = -0.038410 + 0.458471 \times FP - 0.001395 \times FP^2 \quad (2)$$

As for the effect of flash point and kinematics viscosity (KV) on heating value (Eq.3), it was found out that there was significant relation (r^2= 0.967, 1%).

$$HV = -0.039178 + 0.143684 \times KV - 0.010012 \times KV^2 + 0.453380 \times FP - 0.001380 \times FP^2 \quad (3)$$

Kinematics viscosity and density affected heating value (significant at r^2= 0.959 and 1% level) (Eq. 4).

$$HV = -0.000168 + 1.116102 \times KV - 0.106581 \times KV^2 + 0.095106 \times D - 0.000064 \times D^2 \quad (4)$$

It was found out that flash point and density significantly affect heating value (Eq 5). (r^2= 0.972, 1%).

$$HV = 0.000920 + 0.018476 \times D - 0.000057 \times D^2 + 0.806302 \times FP - 0.002480 \times FP^2 \quad (5)$$

It was seen that the flash point, density and kinematics viscosity are related to heating values according to linear regression (Eq. 6). (r^2= 0.958, 1%).

$$HV = 0.102749222 + 0.046936771 \times KV + 0.037588108 \times D + 0.023431365 \times FP \quad (6)$$

Today the determination of the various properties of fuels can be achieved with very expensive testing equipments. Besides, considering that these devices are imported from abroad, it is evident that they cause extra economic burden for the economy of our country. The fact that not all the firms have these devices and that the producers need to determine whether their products meet biodiesel standards increase the cost of biodiesel production. Besides, the determination of the properties of the biodiesel takes times. In this study, the relations between the features of the biodiesel were examined to get rid of the disadvantages mention above. The results suggest that;

1. In biodiesel fuels, formulas which were confirmed to be statistically-reliable and were derived from regression equations after tiring, long-lasting and expensive measurements can be used.
2. The number of biodiesel samples and repetitive measurements are to be high and the fault percent is to be low.
3. When using the relationships fount out, the result must be compatible with the previous measurements (deviations up to 5 % can be tolerated)

In the determination of some of the features of biodiesel, the relations (of density, kinematics viscosity, flash point, the lower heating value) can be used.

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References

[1]. Acaroĵ lu, M, Renewable Energy Sources (in Turkish), 610 pages, Nobel Yayēn, ISBN: 978-605-395-047-9, Ankara, **2007**
[2]. Acaroĵ lu, M., Ünaldē, M., Progress in Biomass and Bioenergy Research, Chapter V, "The Energy Balance and Fuel Properties of Biodieselò , 141- 155, **2006**, ISBN: 1-60021-328-6, Nova Publishers, USA
[3]. Mittelbach, M., Remschmidt, C. Biodiesel ï The Comprehensive Handbook, Second Edition, Graz, Austria (325 page), ISBN 3-200-00249-2, **2005**
[4]. Channiwala, S.A., Parikh, P.P., A unified correlation for estimating HHV of solid, liquid and gaseous fuels. Fuel, **2002** 81: 1051-1063.
[5]. Demirbaк, A., Fuel properties and calculation of higher heating values of vegetable oils, Fuel, **1998**, Vol. 77, Number: 9/10.
[6]. Dmytryshyn, S.L., Dalai, A.K., Chaudhari, S.T., Mishra, H.K., Reaney, M.J., Synthesis and characterization of vegetable oil derived esters: evaluation for their diesel additive properties, Bioresource Technology, **2004**, 92: 55ï 64.
[7]. Demirbaк, A., Calculation of higher heating values of biomass fuels. Fuel, **1997,** Vol. 76 No:5 431-434.
[8]. Demirbaк, A., A direct route to the calculation of heating values of liquid fuels by using their density and viscosity measurements, Energy Conversion & Management, **2000,** 41: 1609-1614.
[9]. Allen, C.A.W., Watts, K.C., Ackman, R.G., Pegg, M.J., Predicting the viscosity of biodiesel fuels from their fatty acid ester composition, Fuel, **1999,** 78: 1319ï 1326.
[10]. Demirbaк, A., 2006, Theoretical Heating Values and Impacts of Pure Compounds and Fuels, Energy Sources, **2006,** Vol. 28, Number 5/April 1, 459 ï 467.
[11]. Sheng, C., Azevedo, J.L.T., Estimating the higher heating value of biomass fuels from basic analysis data, Biomass and Bioenergy, **2005,** 28: 499ï 507.
[12]. Zhu, X., Venderbosch, R., A correlation between stoichiometrical ratio of fuel and its higher heating value, Fuel, **2005,** 84 1007ï 1010.
[13]. Pramanik, K., Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine, Renewable Energy, **2003,** 28: 239ï 248.
[14]. Lang, X., Dalai, A.K., Bakhshi, N.N., Reaney, M.J., Hertz, P.B., Preparation and characterization of bio-diesels from various bio-oils., Bioresource Technology, **2001,** 80: 53-62.
[15]. Friedl, A., Padouvas, E.,Rotter, H., Varmuza, K., Prediction of heating values of biomass fuel from elemental composition, Analytica Chimica Acta, **2005**, Vol. 544, Issues 1-2, 191-198.
[16]. Kerschbaum, S., Rinke, G., Measurement of the temperature dependent viscosity of biodiesel fuels, Fuel, **2004,** 83: 287ï 291.
[17]. Graboski, M. S. and McCormick, R.L. ñCombustion of fat and vegetable oil derived fuels in diesel enginesò. Progress Energy Combustion Science, **1998,** 24:125-164.
[18]. Arro, H., Prikk, A., Pihu, T., Calculation of qualitative and quantitative composition of Estonian oil shale and its combustion products. Part 1. Calculation on the basis of heating value, Fuel, **2003,** 82: 2179ï 2195.

[19]. Arro, H., Prikk, A., Pihu, T., Calculation of qualitative and quantitative composition of Estonian oil shale and its combustion products. Part 2. Calculation on the basis of technical analysis data, Fuel, **2003,** 82: 2197ï 2204.

[20]. Uçar, G., Bazē Biyomotorin Yakėtlarėnda Yoĵ unluk,Viskozite ve Parlama Noktasėnėn Isėl Deĵ ere Etkisinin Belirlenmesi Üzerine Bir Araıtėrma, S.Ü. Fen Bilimleri Enstitüsü, Otomotiv ABD, Msc thesis, **2006** (in Turkish)

[21]. Parikh, J., Channiwala, S.A., Ghosal, G.K., A correlation for calculating HHV from proximate analysis of solid fuels. Fuel, **2005**, 84, 487ï 494.

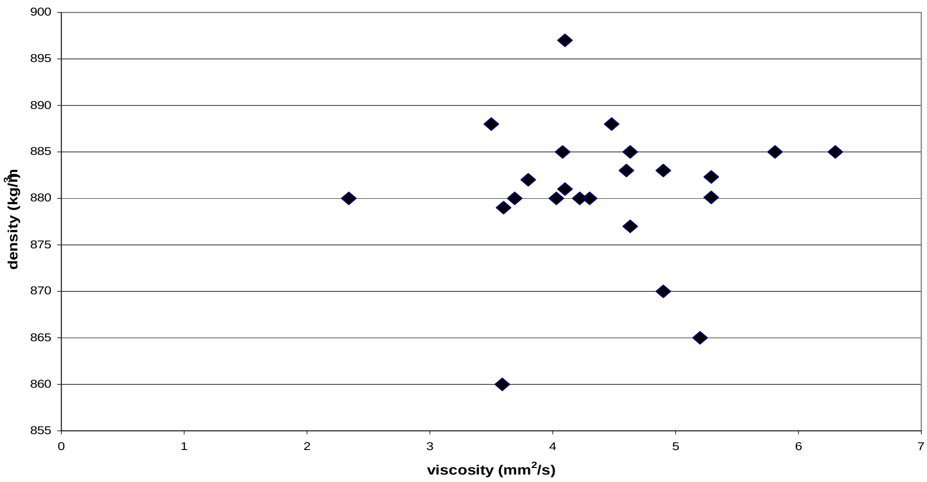

Fig 1 The variation of density with viscosity for vegetable oil methyl esters

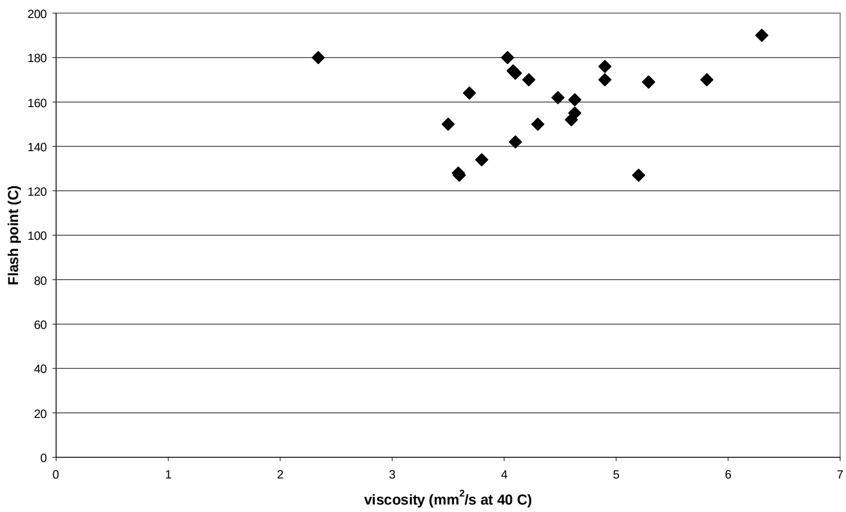

Fig 2 The variation of flash point with viscosity for vegetable oil methyl esters

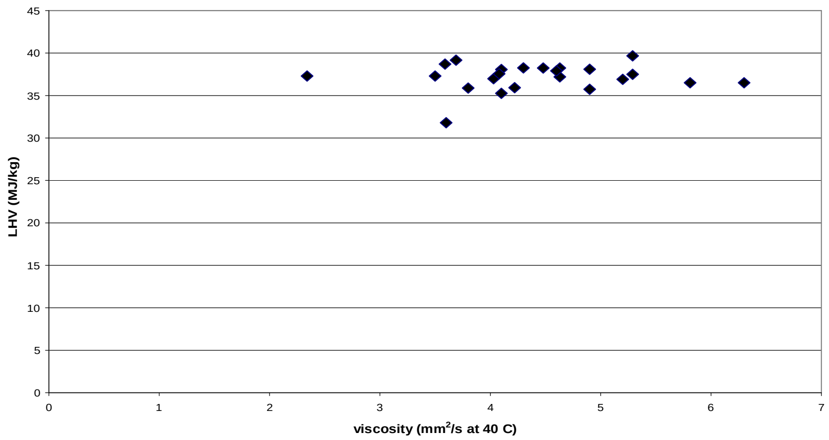

Fig 3 The variation of LHV with viscosity for vegetable oil methyl esters

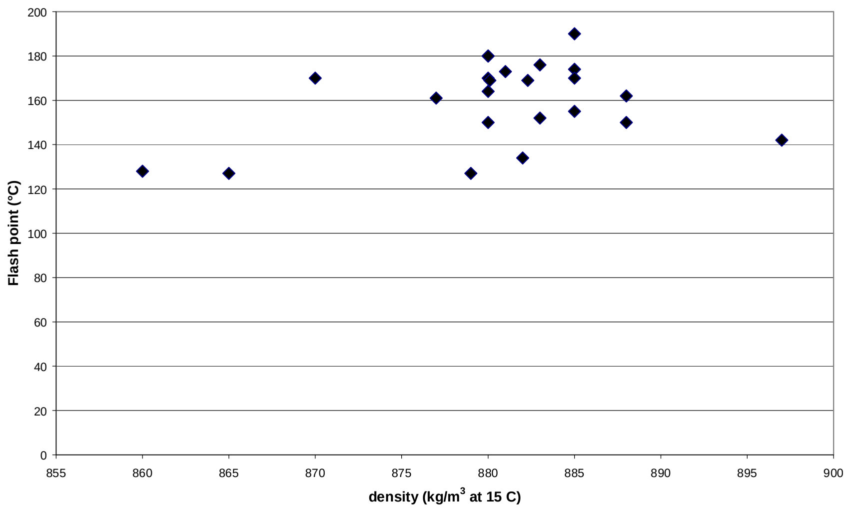

Fig 4 The variation of flash point with density for vegetable oil methyl esters

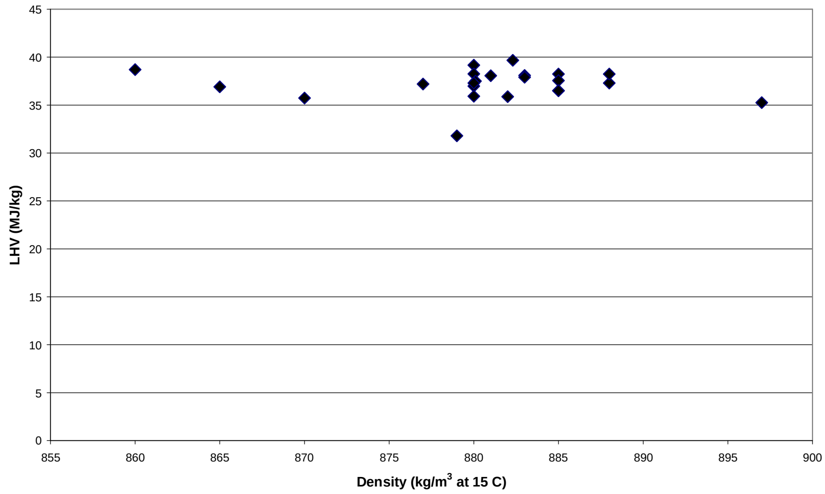

Fig 5 The variation of LHV with density for vegetable oil methyl esters

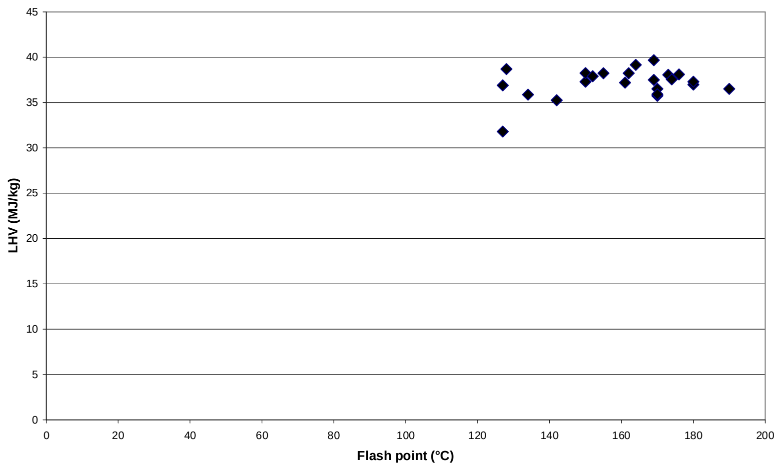

Fig 6 The variation of LHV with flash point for vegetable oil methyl esters