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# COMPARATIVE ANALYSIS OF PHYSICAL AND CHEMICAL PROPERTIES OF JATROPHA OIL

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***Abstract:*** *Jatropha is a member of Euphorbiaceae family. Its oil is used to produce biodiesel. Physical and chemical properties of oil are important to determine the quality of oil. For this purpose we determined density of oil by pycnometer. Kinematic viscosity is measured by Ubbelohde capillary viscometer. The other properties discussed in this paper are iodine value, oxidation value, acidity and flash point. Comparative analysis of the properties with existing fuel practices shows its suitability for diesel engine.*

***Key words:*** *jatropha, oil properties, comparative analysis.*

## 1. Introduction

Global climate changes and geopolitical factors have forced countries to exploit renewable energy resources [5]. Biofuels obtained from edible crops are already being in practice in transport industry. These biofuels increase the fuel security at the expense of food security [17]. This problem can be solved by using non edible crops to produce biofuel.

Jatropha is a non edible crop which grows under subtropical conditions [14]. Portuguese surfers came to Mexico and cultivated jatropha plants. Then it was spread to other continents as well. People used its oil in the lamps and stoves. It is also used in soap production and medicines. Now, jatropha is being cultivated on estimated area of 900, 000 hectares in Myanmar, India, Indonesia, Madagascar, Zambia, Tanzania, Mozambique, Brazil and Pakistan. It is a tree of approximately 5 meters. Its growth depends upon the environmental and soil conditions. It has characteristics of making milky soap and production of phytotoxins Physical and chemical properties are important to determine oil quality [7], [12].

Malaysia and India are major producers of jatropha oil. Jatropha has various advantages over other biofuels. As non edible oil, Malaysian and Indian governments are playing their roles to increase its production [14], [15]

Jatropha seeds are imported from Thailand. Oil is extracted by solvent extraction method. The physical and chemical properties of the oil are measured for determining its suitability to use it directly in diesel engine. Density of jatropha oil is measured as 0.921 g/cm$^3$. This density is higher than other vegetable oils. Kinematic viscosity is measured with the help of Ubbelohde viscometer. Kinematic viscosity is measured as 40.1 Cst which is higher than other vegetable oils. Its iodine value is 103 mg Iod/g.

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Oxidation stability index is measured as 179 minutes which is higher than diesel fuel. Acidity of fresh extracted oil is determined as 1.4 mg KOH/g. Flash point is measured as 149 °C which lower than literature value. Higher values of oxidation stability index and flash point make its storage and handling easier than diesel fuel. Higher values of density and kinematic viscosity make it difficult for its direct usage in diesel engines [2], [3], [20]. A comparative analysis of properties with existing fuel practices for suitability of its usage in diesel engines is shown in this paper.

## 2. Properties of Jatropha Oil

### 2.1. Density

Vegetable oils are being used in diesel engines. Higher density value makes injection difficult. We determined the density of jatropha oil according to the standard SR EN ISO 3657 with the help of pycnometer. Empty pycnometer was weighed with the precision of 0.0002 g. Then it is filled with distilled water and finally with the sample of jatropha oil. The excess of sample coming out of capillary tube is then cleaned with the help of filter paper. The relative density is measured by following formula:

$$RD = \frac{m_2 - m_1}{V + \rho_{air}} \text{ g/cm}^3, \qquad (1)$$

where,

$m_1$ = mass of pycnometer in grams;

$m_3$ = mass of pycnometer with sample of jatropha oil;

$V$ = volume of pycnometer in $cm^3$;

$\rho_{air}$ = 0.0012g/$cm^3$.

The density of jatropha oil is determined as 0.921 g/$cm^3$. According to ASTM-4052 standard, density of jatropha oil is 0.92 g/$cm^3$. A comparison between densities of vegetable oils and diesel fuel is given below in Figure 1 [3], [20].

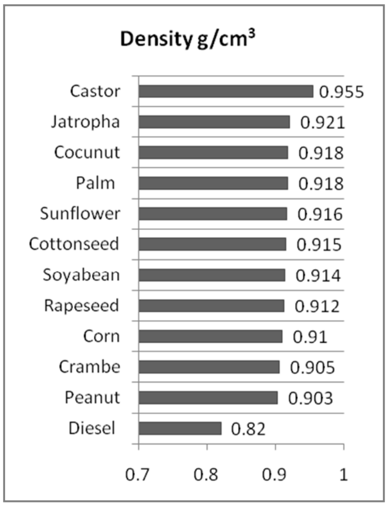


Fig. 1. *Density comparison chart*

Density of jatropha oil is higher compared to other vegetable oils and diesel fuel. Higher value of density can cause problems in injection of the fuel. This problem can be solved by preheating jatropha oil. Experiments showed that engine performance can be increased by preheating of jatropha oil. The oil can be heated by using exhaust gas heat. This preheated jatropha oil can directly be used as substitute to diesel fuel in diesel engines [18].

### 2.2. Kinematic Viscosity

Viscosity is a resistance of a substance to flow or measure of the resistance of a fluid to deformation under shear stress. Kinematic viscosity is the measure of the rate at which momentum is transferred through a fluid [11]. Vegetable oils have higher viscosity than viscosity of diesel fuel. Higher value of viscosity causes decrease in injection rate. This results in lower efficiency of engine [3].

Kinematic viscosity of jatropha oil is determined with the help of Ubbelohde viscosity meter. Experiment was performed at 40 °C and value of kinematic viscosity is 40.1 cSt. Viscosity of jatropha oil is 35.98 cSt according to ASTM D-445 standard [16]. In our experimental setup, the value of viscosity is higher than standard value. Higher value of viscosity can cause problems in injection nozzle and combustion chamber.

According to ASTM D-445 standard, kinematic viscosity of diesel fuel is 3.21 cSt at 40 °C [4]. This value is much lower than that of jatropha oil. Direct usage of jatropha oil in diesel engines can cause problems in injection pump and combustion chamber. Preheated jatropha oil up to 90 °C can be used to avoid these problems [2]. A comparison between viscosities of different fuels at 40 °C is shown in Figure 2 [8].

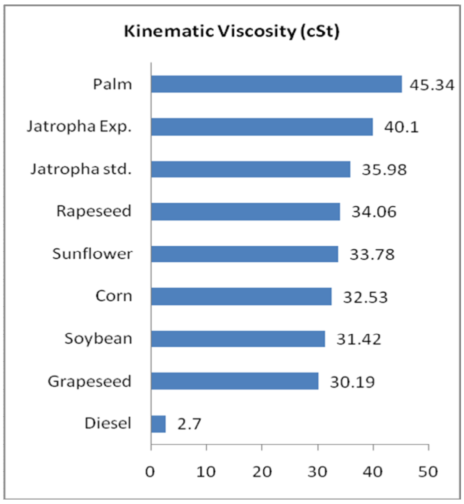


Fig. 2. *Kinematic viscosity comparison*

### 2.3. Iodine value

This value indicates total degree of unsaturation in vegetable oils and fats [9]. We measured iodine value of jatropha oil according to Romanian standard SR EN ISO 3961. I took 0.25 mL of sample for analysis. I mixed 10 $cm^3$ of solvent (chloroform) to the sample until complete dissolution. Then we added 25 $cm^3$ of Hanus solution with the help of burette. After a short period, we performed titration of the solution with sodium thiosulfate until it became yellowish. Then we performed titration with starch solution until it become completely blue. In the same time, we conduct two blank tests with same quantity of solvent and Hanus solution in same conditions but without fats. Iodine value is calculated with the help of following formula:

$$I = \frac{0.129(V - V_1) \times n \times 100}{m} \text{g/100g}, \quad (2)$$

where,

$V$ = Volume of thiosulphate consumed during titration of blank test;

$V_1$ = Volume of thiosulphate used during titration of analysis without fats;

$m$ = Mass of sample;

$n$ = Normality of thiosulphate.

Calculated iodine value is 103 mg Iod/g. There is no ASTM standard procedure for determining iodine value but it should be in the range of 55-120 mg Iod/g. Higher iodine value of oil indicates the greater degree of unsaturation [10], [21]. Viscosity of oil increases with increase in iodine value. A comparison between iodine values of vegetable oils and experimental value for jatropha oil is shown below in Figure 3 [3].

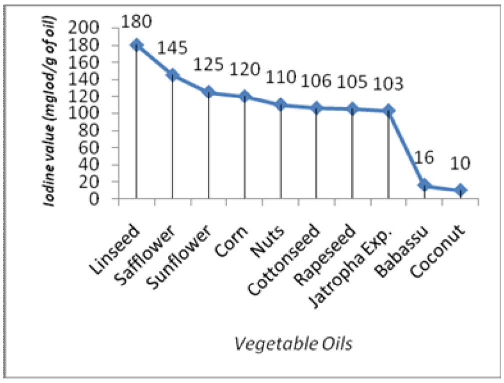


Fig. 3. *Iodine value comparison*

Iodine value increases with the increase in number of double bonds. Experimental analysis showed that there is a linear relationship between $NO_x$ emissions and iodine value. The relationship of engine performance and iodine value depends upon nature of fatty acids present in oil. It's better to have lower iodine value than maximum limit of ASTM standard. According to European standard, maximum limit of iodine value is 120 mg Iod/g [19]. Experimental Iodine value for jatropha oil is less than maximum limit of European standard.

### 2.4. Oxidation Stability

Oxidation state indicates the degree of oxidation of an atom in a chemical compound. We determined the oxidation number of jatropha oil by Zurcher-Hadron Method. The method permits the establishment of the induction period which corresponds with the initiation step of the oil's auto-oxidation stability.

To determine the stability in oxidation, an installation is used which uses oxidized oil samples at the temperature of 110 °C. Air stream is passed through the samples at 8 litters per hour. The reaction took place in a reactor where formed fatty acids are absorbed in a measurement cell in the presence of distilled water. The conductibility is measured with the help of Radelkis conductometer. The time interval between the beginning of solution's conductibility and sudden increase in formation of volatile acids is measured. Oxidation stability index (OSI) for jatropha oil is 179 minutes. A difference between oxidized (mechanical extraction) and fresh extracted (Solvent extraction) jatropha oil is shown below in Figure 4.

Auto oxidation of oil can decrease the quality of oil. Unsaturated oils are more likely to be oxidized. OSI depends upon heat, moisture, exposure to air and presence of dust particles [6]. Usage of

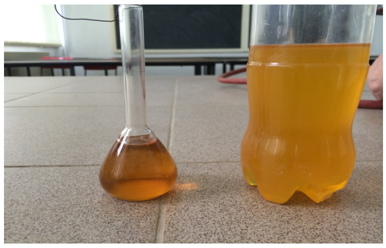

Fig. 4. *Oxidized (right) and fresh extracted jatropha oil (left)*

oxidized oil results in poorer lubrication and it can damage filters. Oxidized oil has higher viscosity which can cause problems in injection [13].

### 2.5. Acidity

Acidity of oil is an important parameter to determine the quality of oil. To determine the acidity of jatropha oil we took 5 mL of sample in Erlenmeyer glass. We added 500 $cm^3$ of solvent in it. Then we performed titration with NaOH until solution become pink. Results can be expressed in the form of acidity number.

$$A = \frac{56.11 \times V \times n}{m} \text{mgKOH/g}, \qquad (3)$$

where,

$V$ = Volume of NaOH solution used in titration;

$n$ = Normality of NaOH solution;

$m$ = mass taken for analysis;

$A$ = Acidity value.

Acidity value for jatropha oil is 1.4 mg KOH/g. Acidity is due to presence of fatty acids in oil. Acidity can cause damage to engine feed circuit. The literature limits of acidity for jatropha oil are within the range of 0.92-6.16 mg KOH/g [1].

### 2.6. Flash Point

The smallest value of temperature at which fuel becomes ignitable when exposed to a flame is termed as flash point. We determined the flash point of jatropha oil according to the standard SR 5489-2009. It is calculated by following expression:

$$t_{760} = \frac{t_p - (p - 760)}{30}, \tag{4}$$

where,

$t_{760}$ = flash point at 760 torr;

$t_p$ = flash point at pressure $p$;

$p$ = pressure at which experiment is conducted.

Determined value of Flash point for jatropha oil is 149 °C. According to ASTM standard, value of flash point for jatropha oil is 150 °C. Due to higher value of FP fuel is easier to handle in storage and transportation than diesel fuel [10]. Flash point of diesel fuel is 50.5 °C according to standard ASTM D-93 [22]. ASTM D-6751 standard value of flash point for biodiesel is 130 °C (minimum) [15]. Jatropha oil has higher value of flash point than diesel fuel and biodiesel standard value. Higher flash point of fuel makes handling, security and storage easy.

## 3. Conclusions

Properties of jatropha oil vary with its type. Density and kinematic viscosity of jatropha oil is higher than existing practices in fuel industry. Higher values of density and kinematic viscosity make injection difficult. Higher oxidation value makes it unstable. Better storage and extraction techniques can make it more qualitative fuel. Direct usage of jatropha oil is possible if it is heated up to 90 °C.

Acidity of jatropha oil is within the range of international standards. Properties of jatropha oil can be improved by improving genetics of seeds, extraction technique and storage of jatropha oil. We extracted oil by solvent extraction method on small scale. For its industrial production, industry and government have to play its active role.

Romania is dependent upon fossil fuels for its energy needs in transport sector. Jatropha cultivation and production of jatropha oil can increase renewable energy mix in transport sector. Romania has a lot of land to cultivate jatropha crop. Governmental and educational institutions have to play its role for production of this non-edible biofuel.

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## References

1. Acosta, R.M., Ramirez, S.J., et al.: *Extraction and Characterization of Oils from Three Mexican Jatropha Species*. In: J. Mex. Chem. Soc. **54** (2010) No. 2, p. 88-91.
2. Agarwal, D., Agarwal, A.K.: *Performance and Emission Characteristics of Jatropha Oil (Preheated and Blends) in a Direct Injection Compression Ignition Engine.* In: Applied Thermal Engineering **27** (2007), p. 2314-2323.
3. Blin, J., Brunschwig, C., et al.: *Characteristics of Vegetable Oils for Use as Fuel in Stationary Diesel Engines-Towards Specifications for a Standard in West Africa.* In: Renewable and Sustainable Energy Reviews **22** (2013), p. 580-597.
4. Chauhan, B.S., Kumar, N., et al: *A Study on the Performance and Emission of a Diesel Engine Fuelled with Jatropha Biodiesel Oil and its Blends.* In: Energy **37** (2012), p. 616-622.
5. Colsea, S.E., Ciocoiu, C.N.: *An Overview of the Romanian Renewable Energy Sector.* In: Renewable and

Sustainble Energy Reviews **24** (2013), p. 149-158.

6. Dwivedi, G., Sharma, M.P., et al.: *Impact of Cold Flow Properties of Biodiesel on Engine Performance*. In: Renwable and Sustainable Energy Reviews **31** (2014), p. 650-656.
7. Eijck, J.V., Romijn, H., et al.: *Global Expierience with Jatropha Cultivation for Bioenergy: An Assessment of Socio-Economic and Environmental Aspects.* In: Renewable and Sustainable Energy Reviews **32** (2014), p. 869-889.
8. Esteban, B., Riba, J.R., et al.: *Temperature Dependence of Density and Viscosity of Vegetable Oils.* In: Biomass and Bioenergy **42** (2012), p. 164-171.
9. Farrus, M.O., Villorbina, G., et al: *Determination of the Iodine Value of Biodiesel Using $^{1}H$ NMR with 1,4-Dioxane as an Internal Standard.* In: Fuel **89** (2010), p. 3489-3492.
10. Garba, N.Z., Gimba, E.C., et al.: *Production and Characterization of Biobased Transformer Oil from Jatropha Curcas Seed*. In: Journal of Physical Science **24** (2013) No. 2, p. 49-61.
11. Kazys, R., Rekuviene, R.: *Viscosity and Density Measurement Methods for Polymer Melts.* In: Ultragarsas (Ultrasound) **66** (2011) No. 4, p. 20-25.
12. Kibuje, R.M., Kariuki, S.T., et al.: *Influence of Fuel Properties on the Burning Characteristics of Sour Plum (Ximenia Americana L.) Seed Oil Compared with Jatropha Curcas L. Seed Oil.* In: Renewable Energy **78** (2015), p. 128-131.
13. Kovac, O., Sarvan, V., et al.: *Influence of Biodiesel on the Oxidation stability of Engine Oils*. In: Goriva I maziva **52** (2013) No. 3, p. 219-230.
14. Madarasz, J., Kumar, A.: *Stability of Biodiesel from Non Edible Oils.* In: International Journal of Energy Science **1** (2011), p. 186-191.
15. Mofijur, M., Masjuki, H.H., et al.: *Prospects of Biodiesel from Jatropha in Malaysia.* In: Renewable and Sustainable Energy Reviews **16** (2012), p. 5007-5020.
16. Nasim, M.N., Yarasu, R.B., et al.: *Combustion and Performance of Diesel Engine with Preheated Jatropha Curcas Oil using Waste Heat from Exhaust Gas.* In: Journal of Petroleum Technology and Alternative Fuels **4** (2013) No. 7, p. 119-114.
17. Nonhebel, S.: *Global Food Supply and Impacts of Increased Use of Biofuels.* In: Energy **37** (2012), p. 115-121.
18. Pradhan, P., Raheman, H., et al.: *Combustion and Performance of Diesel Engine with Preheated Jatropha Curcas Oil using Waste Heat from Exhaust Gas.* In: Fuel **115** (2014), p. 527-533.
19. Rao, P.V., Clarke, et al.: *Influence of Iodine Value on Combustion and $NO_x$ Emission Characteristics of a Diesel Engine*. In: The 40th Australasian Chemical Engineering Conference. Adelaide (2010)
20. Shah, N.S., Joshi, A., et al.: *Synthesis of Jatropha Oil Based Biodiesel Using Environmentally Friendly Catalyst and their Blending Studies with Diesel.* In: Energy and Power **3** (2013) No. 1, p. 7-11.
21. Siraj, S., Uttarwar, L., et al.: *Effect of Acid and Iodine Value of Karanja Oil Methyl Ester (KOME) and its Statistical Correlation with Gross Calorific Value*. In: International Journal of Research in Engineering and Technology **2** (2013), p. 680-685.
22. *** *Flash point Standards.* Available at: http://www.tamson-instruments.com. Accessed: 25-02-2015.