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# COMPARISON OF PHYSICAL AND CHEMICAL PROPERTIES OF CRUDE COLD-PRESSED VEGETABLE OILS USED TO DRIVE AGRICULTURAL TRACTORS

*Summary*

*Crude vegetable oil may be used to drive self-ignition engines adjusted to this fuel. The aim of this study was to perform a comparative analysis of selected properties of cold-pressed crude vegetable oils used as biofuels. Physico-chemical properties of rapeseed oil (RO), sunflower oil (SO) and corn oil (CO) were compared. Density, kinematic viscosity, flash point, cold filter plugging point, calorific value, content of water, phosphorus, calcium and magnesium in oil were determined. Kinematic viscosity curves of crude oils at temperatures from 5°C to 50°C were defined. The kinematic viscosity was the lowest for corn oil and the highest for sunflower oil.*

***Key words:*** *rapeseed oil, corn oil, sunflower oil, biofuel*

## 1. Introduction

The prospects of using crude vegetable oils for driving diesel engines is a reasonable action that reduces a negative impact of the man on the environment. Crude vegetable oil can be used to drive self-ignition engines adjusted to this fuel [6, 13, 4]. Crude oil is produced with equipment or installations used to produce oil on a farm for own purposes [14]. This oil is produced through pressing oilseed crops on the basis of available technologies, i.e. single- and multi-stage oil pressing and oil extraction [7]. Vegetable oil is produced by means of screw and piston presses. Screw presses are the most common because they are designed for the continuous production. The simplest technology is cold oil pressing, where oil yield (mass percentage of oil to the mass of oilseeds) equals to around 30% [10].

A good quality oil is obtained as a result of the cold oil pressing [8, 17, 20, 22,]. The quality and life of cold pressed vegetable oil are affected by conditions and parameters of pressing, temperature, pressing time, hygienic production conditions and oil storage temperature [21]. The preliminary heating of seeds prior to their pressing affects the oil content, among others, the increase of the content of free fatty acids [19] and the increase of the content of impurities, i.e. pigments, water, sulphur and phosphorus in oil [5, 23]. The obtainment of oil suitable for self-ignition engines depends on the quality of rapeseeds. Factors that determine the quality of seeds are as follows: degree of maturity, presence of injured seeds, humidity and storage conditions [9].

Vegetable oils in comparison with mineral diesel fuel are characterized by lower content of volatile ingredients, higher density and viscosity, lower calorific value and higher pour point, cloud point and flash point. These properties mainly result from over fourfold higher average molar mass [11]. Due to processes of making sediments in a combustion chamber, phosphorus content in oil is significant. In case of cold pressed rapeseed oil this content ranges from 14.57 $mg\cdot kg^{-1}$ to 162 $mg\cdot kg^{-1}$ [15]. However, a fundamental problem of using crude vegetable oil in the engine is its high viscosity. The viscosity of rapeseed oil at 20°C is around 18 times greater than the viscosity of diesel fuel. The viscosity affects fuel flow resistances in lines, filters and holes of the atomiser, the process of injection and fuel atomization and lubrication of injection pumps [18]. The high viscosity of fuel indirectly affects the occurrence of sediments in the engine combustion chamber and on injection inlets [2]. Since the viscosity of oil is highly dependent on temperature, in case of engines driven by vegetable oil additional systems for heating up oil are applied or a mixture of vegetable oil and diesel fuel is recommended to be used [3, 12, 16].

For a few years agricultural tractors driven by pure vegetable oil have been tested [1, 3, 13]. A failure rate of tractors is considerably affected by the fuel quality. The aim of tests was to compare selected properties of cold pressed vegetable oils with respect to their use as pure biofuels for SI engines in agricultural tractors.

## 2. Methods

The aim of this study was to conduct a comparative analysis of selected physico-chemical properties of crude vegetable oils (oils filtered from solids impurities and derived directly from the press) produced from the rapeseeds (OR), sunflower (OS), corn (OK). Samples were from the industrial production of raw material for biofuels. The oil was cold-pressed from a different varieties of oilseeds. The first stage aimed to compare various parameters: flash point (FP) (ISO 2592:2000), cold filter plugging point (CFPP) (PN-EN 116), calorific value (ISO 1928:2009), content of water (PN-EN ISO 662:2001), calcium and magnesium with the ICP-OES method and to determine oil density with the non-normalised weight and volume method. The phosphorus content (PN-EN 14107) was also tested. It was necessary to take some reducing actions due to a considerable content of this element in the tested oils. Phosphorus was removed from the tested oils by bleaching [14]. The kinematic viscosity of oils was determined with a rotational viscometer RC1 in the standard measuring system CC48 in a dynamical system. The analysis consisted in recording at equal time intervals 800 measurement points of the dynamic viscosity at random temperatures with an accuracy of 0.1°C. Samples, following their insert into a measuring apparatus, were firstly heated up to 50°C and then cooled down to 5°C. On the basis of the collected data and density of tested substances the kinematic viscosity was calculated by with the Rheo 3000 software. Results were fixed at every one degree at temperatures from 50°C to 5°C.

The presentation of kinematic viscosity values at 40°C is not an objective ratio. Since the oil viscosity is highly dependent on the range of temperature of the use of combustion engines, it has been acknowledged that the area under the kinematical viscosity graph in a function of temperature is a much better ratio that delineates a viscosity difference of the tested biofuels. Areas calculated from the integral of a given logarithmic function of the trend line were compared. The distribution of the kinematic viscosity in a function of temperature was tested from 5°C, where viscosity values hinder pumping oil through the filter and lines, to 50°C, where viscosity values of the tested oils are similar to one another.

### 3. Tests results

The tests of parameters of crude vegetable oils with respect to their use as biofuel in this form allowed significant physicochemical properties of the tested oils to be determined. On the basis of tests of phosphorus, the content of which in rapeseed oil was 9.9 ppm, 15.9 ppm in sunflower oil and 440 ppm in corn oil, phosphorus was determined to be reduced. Oils were affected by bleaching earth and its adding to vegetable oils resulted in absorbing phospholipids that were removed from the oil as a result of the filtration [14]. The results of the tested vegetable oil properties are shown in Table.

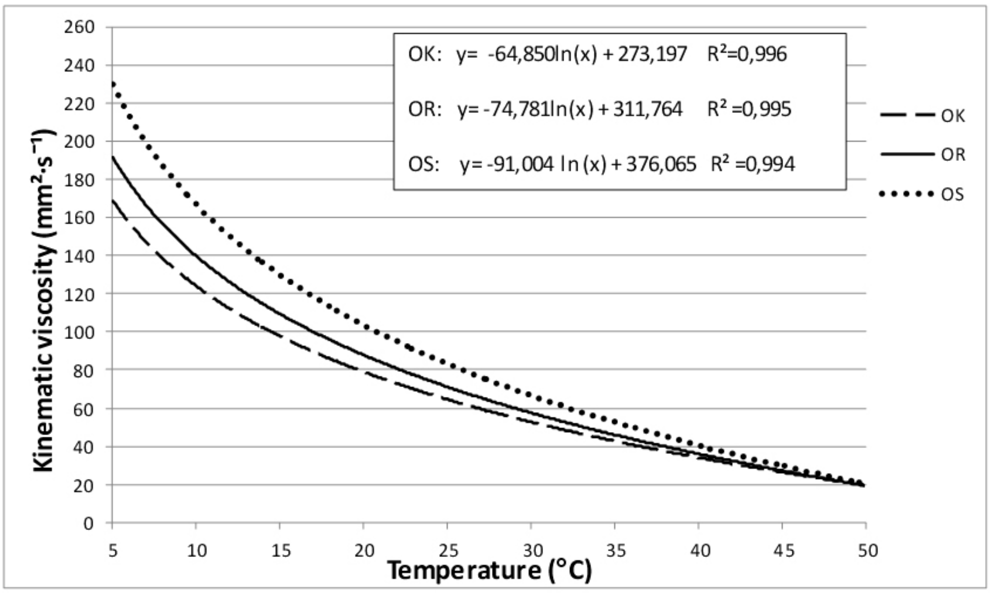
The density of three crude vegetable oils was similar to one another and amounted to around 917 kg·m$^{-3}$±0.5. The kinematic viscosity of individual oils at 40°C was different. Sunflower oil had the highest viscosity of 41.08 mm$^2$·s$^{-1}$, corn oil had the lowest viscosity of 33.81 mm$^2$· s$^{-1}$ and rapeseed oil had the viscosity of 36.46 mm$^2$· s$^{-1}$. The flash point of the tested oils was above 180°C. The calorific value of the tested oils amounted to around 40 MJ·kg$^{-1}$±3. The water content of three tested oils was below 0.1 mg· kg$^{-1}$. The cold filter plugging point of rapeseed oil and sunflower oil was 27°C and of corn oil was 20°C. Some trace amounts of phosphorus in rapeseed oil and sunflower oil were detected, whereas following the reduction the content of phosphorus in corn oil was 9.3 mg·kg$^{-1}$. The remaining tested elements in crude oils were in trace amounts.

The kinematic viscosity of the tested vegetable oils is strictly affected by temperature and is correlated at the level of -0.95±0.002 within the tested range of temperature. The adjustment of the logarithmic function of the kinematic density changes with respect or the temperature of all oils is $R^2$>0.99 with respect to the value of the received results. The area under the graph of kinematic density curves of vegetable oils in a function of temperature from 5°C to 50°C was the lowest for corn oil, larger by 13% for rapeseed oil and larger by 29% for sunflower oil than the area of corn oil. At 50°C the value of the kinematic density of the tested oils was similar to one another and equalled to 25.5 mm$^2$·s$^{-1}$± 1.7. Whereas, at 5°C the value of the kinematic density amounted to CO 161.51 mm$^2$·s$^{-1}$, RO 184.9 mm$^2$·s$^{-1}$, SO 224.14 mm$^2$·s$^{-1}$ (Figure).

*Table. Vegetable oil properties used at study*

| Parameters | Rapeseed oil (OR) | Sunflower oil (OS) | Corn oil (OK) |
|---|---|---|---|
| Density at 15°C (kg·m$^{-3}$) | 917 | 917 | 918 |
| Kinematic viscosity at 40 °C (mm$^2$· s$^{-1}$) | 36,46 | 41,08 | 33,81 |
| Flash point (°C) | 184 | 188 | 190 |
| Cold Filter Plugin Point (°C) | 27 | 27 | 20 |
| Calorific value (kJ· kg$^{-1}$) | 39557 | 39721 | 40229 |
| Water content (mg ·kg$^{-1}$) | 0,10 | 0,06 | 0,08 |
| Phosphorus content (mg· kg$^{-1}$) | <0,4 | <0,4 | <9,3 |
| Magnesium content (mg ·kg$^{-1}$) | 1,98 | 1,77 | 1,68 |
| Calcium content (mg ·kg$^{-1}$) | <15 | <15 | <15 |

*Source: own study*




*Source: own study*

*Figure. Kinematic viscosity curves of vegetable oil: OK - corn oil, OR - rapeseed oil, OS - sunflower oil*

## 4. Conclusions

The kinematic viscosity of the tested oils in a function of temperature from 5°C to 50°C was the lowest for corn oil, whereas in case of rapeseed oil and sunflower oil this viscosity was higher by 13% and 29%, respectively. At above 50°C the distribution of the kinematic viscosity was similar to each other and any further oil heating will reduce this parameter equally in all the tested oils.

DIN 51605 standard provides that the kinematic viscosity of crude oils used as fuel equals to maximum 36 $mm^2 \cdot s^{-1}$. On the basis of the conducted tests it may be stated that crude corn oil could be pure fuel for SI engines, whereas this parameter needs to be improved for sunflower oil and rapeseed oil.

Vegetable oils are high-energy fuel that may be used to drive combustion engines and due to their high flash point they are not explosive fuels and their storage is considered to be safe.

Having performed the preliminary analysis of the crude vegetable oil it is stated that phosphorus needs to be reduced because it adversely affects working elements of the engine. The tested crude oils included phosphorus equalled to RO 9.9 ppm, SO 15.9 ppm and CO 440 ppm. As a result of the reduction, the phosphorus content in rapeseed oil and sunflower oil was trace, whereas in corn oil it was below 9.3 $mg \cdot kg^{-1}$.

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