# UPOTREBA BILJNOG ULJA ZA MOTORE

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## SUMMARY

Vegetable oils are a very important component in human and animal nutrition. Furthermore, they represent potential fuels for engines as well. These fuels named as biofuels are renewable energy sources which must gradually replace today's conventional fuels made from crude oil. The higher energy demands in production and problems which arise during their combustion are the main disadvantages of biofuels. Vegetable oils made from rape seeds belong to the most used biofuels for diesel engines in the Czech Republic. The article describes use of rapeseed oil, methyl esters of rapeseed oil (RME) and their mixture with diesel fuel (B30) in diesel engines, their ecological benefits in combustion and necessary modification of some elements in engines. Data used for evaluation were obtained from measurements in the vehicle laboratory. The results were compared with the diesel fuel. As results show, evaluated biofuels have a positive impact on exhaust emissions of engines but at higher consumption.

Key words: rapeseed oil, rapeseed methyl ester, B30, engine efficiency, fuel consumption

## INTRODUCTION

The increasing energy demand of the human population requires seeking new sources of energy or rather renewable energy sources. Renewable energy sources are supposed to replace the traditional conventional sources of energy (crude oil, natural gas, coal, etc.) when they are depleted. This is the reason why the significance of these sources increase. Biomass belongs to renewable energy sources as well and accounts for 75 % of all renewable sources (Petříková, 1999.). Biomass is obtained from certain crops or is obtained from waste of agricultural and primary food production, from residues in forest clearing and landscape maintenance or for municipal and industrial biological waste. Nowadays, biomass is used for direct combustion, transformation into gas, anaerobic digestion, for production of liquid biofuels and other possible industrial use. Discussed topic is production of liquid biofuels and their use in internal combustion engines. Biofuels have some unfavorable properties such as viscosity, heating value, oxidative stability, etc. Biofuels production from vegetable oils is connected to climatic conditions of each agricultural area. So it is dependent on plants growing there. The main plants for vegetable oils production are oilseed rape and sunflower in the EU and palm tree and soybean plants in the tropical and subtropical areas. The most common plant for vegetable oils production is oilseed rape in the Czech Republic. 1.1 ton of vegetable oil is made from 3 tons of rape seeds (Laurin, 2008.).

Considering some unfavorable properties, direct use of raw vegetable oils is not possible in a conventional internal combustion engine. Vegetable oils have higher viscosity and flash point in compari-

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son with diesel fuel. Kinematic viscosity at 40 °C for rapeseed oil is $\upsilon = 35$ mm$^2$.s$^{-1}$ and for diesel fuel only $\upsilon = 3$ mm$^2$.s$^{-1}$ (Laurin et Holubec, 2008.). High viscosity would cause clogging up of filters and the need to use higher injection pressure for ensuring better atomization in the combustion chamber of the engine.

The modification of viscosity is enabled by the installation of dual fuel system with heating. But the main problem of vegetable oil is the high temperature of evaporation. This problem can lead to incomplete combustion and create lots of carbon in the combustion chamber. In a short time (50-100 hours), the engine blows (Rauscher, 2005.). At a higher temperature and in contact with water, the vegetable oil polymerizes and creates clusters of solid substances that may clog up the fuel system and thicken the motor oil. After that the motor oil loses pump ability (Laurin et Holubec, 2008.). Possible countermeasure is using high quality motor oil and simultaneously shorter interval of its replacement. It is necessary to modify vegetable oil for direct combustion in the engine without installating dual fuel system with heating. Pressed and cleaned oil is further esterifying. Triglycerides in the oil react with alcohol (usually methanol). Fatty acid methyl esters and glycerol are final products of this reaction. The obtained methyl esters have much lower viscosity than raw vegetable oil and can be used as a fuel for engines without the need to install special heating equipment in the fuel system (Dumitru, 2010.).

Methyl esters of rapeseed oil (RME) are mainly used in the Czech Republic due to the high rate of rape growing. About 33 % of RME is produced from rape seeds. Rapeseed cakes and meal, fatty acids and glycerol are other products of reaction. Rapeseed cakes and meals can be used as a highly nutritious feed for animals. Glycerol is used in the cosmetic and pharmaceutical industry (Gustav et al., 2006.). After modification of some physico-chemical properties (particularly viscosity) of vegetable oil, problem free engine running is not guaranteed on RME. RME still contains a large amount of resinous substances arising from the oxidation of ethyl ether. These substances create deposits in the engine. Deposits are insoluble in the engine oil and cause thickening of motor oil. Clogging up of fuel functional parts can also arise after the engine being out of operation for a long time (Vlk, 2006). The increase of viscosity at low temperatures, especially in winter, is another problem which worse RME pump ability. With respect to these problems, producers of biofuels have started to produce a mixture of diesel and RME. This mixture is sometimes known as biodiesel of the second generation or B30. RME is often named as biofuel of the first generation. B30 fuel contains at least 31 % of RME. Diesel and additives, which enhance mixture properties, comprise the rest − 69 %. Operation of the engine on B30 does not require any special modification of the engine. Using high quality motor oil and its frequent replacement are still required (Vlk, 2006.).

Nowadays, a compulsory addition of 6 % of RME into diesel fuel is required by Act No. 172/2010 Coll. in the Czech Republic (ČAPPO, 2010.). We can expect gradual increase of RME portion in diesel fuel. In general, most engine producers enable the use of 20% of RME in diesel fuel in the engine with-

**Table 1 Properties of diesel fuel and tested biofuels**

**Tablica 1. Svojstva dizel goriva i testiranih biogoriva**

| Property/Fuel<br>Svojstvo/gorivo | Diesel<br>Dizel | Rapeseed oil<br>Repičino ulje | RME | B30 |
|---|---|---|---|---|
| Specific density at 15 °C [kg.m$^{-3}$]<br>Specifična gustoća na 15 °C [kg.m$^{-3}$] | 840 | 915 | 884 | 855 |
| Heating value [MJ.kg$^{-1}$]<br>Vrijednost grijanja [MJ.kg$^{-1}$] | 42.5 | 36 | 37.3 | 41.2 |
| Viscosity at 40 °C [mm$^2$.s$^{-1}$]<br>Viskoznost na 40 °C [mm$^2$.s$^{-1}$] | 2.24 | 35 | 4.3 | 2.68 |

*Source – Izvor: Laurin et Holubec, 2008;* Čupera *et al., 2010*

out any modification. When we want to use the fuel with a higher RME content, it is necessary to follow producer's instructions to ensure operation of the engine without fault (Bauer et al., 2009.).

The aim of this study is evaluation of engine output parameters, particularly engine output, fuel consumption, engine efficiency and production of particular matter emissions when the engine is operated on rapeseed oil, RME and B30.

## MATERIAL AND METHODS

The measurements were carried out in thelaboratory of the Department of Engineering and Automobile Transport. Tractor Zetor Forterra 9641 was used for measurements.

To obtain the baseline parameters, the engine at first operated on diesel fuel. Load characteristic was measured by the rear PTO shaft according to the OECD methodology. PTO shaft was connected with eddy current dynamometer V500. Measurements of fuel consumption were carried out using two differentially connected mass flow meters Coriolis Sitrans FC MassFlo Mass 6000. Production of particulate matter emissions was measured by the emission system analysis by opacimeter Bosch ESA. After data recorded, the fuel tank was drained and refuelled by new fuel or rather by raw rapeseed oil, RME and B30. The dual fuel system with heating was installed in the tractor to reduce high viscosity of rapeseed oil. During measurements, the rapeseed oil was heated to the temperature between 55 and 73 °C. The temperature of the other fuels was between 20 and 33 °C.

## RESULTS AND DISCCUSION

Engine output, specific fuel consumption (fuel consumption per unit of engine output), engine efficiency and production of particulate matter emissions belong to evaluated parameters. When the engine operated on diesel fuel, the engine reached average engine output of 50.2 kW. Average specific fuel consumption reached was 263 g $kW^{-1}h^{-1}$ and the calculated engine efficiency was 33 %. Changes of

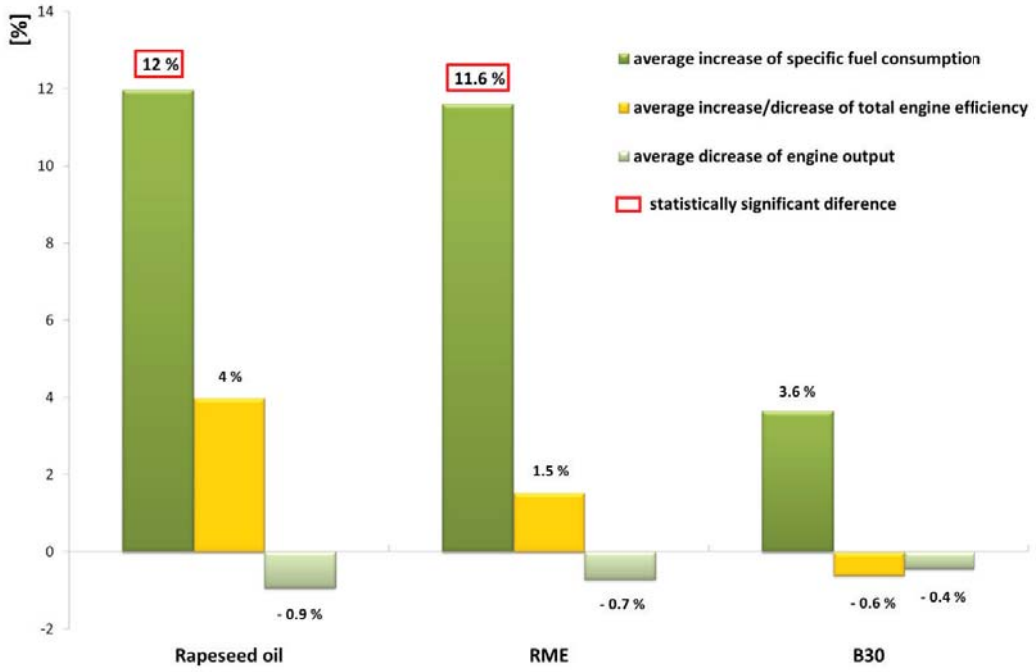


*Figure 1 Comparison of engine output parameter changes for tested biofuels*

*Slika 1. Usporedba promjene parametara rada motora za testirana biogoriva*

**Table 2 Changes in production of particulate matter (PM) emissions**

**Tablica 2. Promjene u proizvodnji emisija čestica**

| Type of biofuel / Vrsta biogoriva | Increase / decrease of PM emissions<br>Povećanje/smanjenje emisija čestica |
|---|---|
| Rapeseed oil / Repičino ulje | – 57 %* |
| RME | – 49 %* |
| B30 | 16 % |

*statistically significant difference at $p < 0.01$; statistički značajna razlika ($p<0.01$)

these parameters, during the operation of the engine on biofuel (rapeseed oil, RME, and B30) are shown in figure 2. Changes of evaluated engine parameters are stated in percentages and they are related to baseline values, which were obtained when engine operated on diesel fuel. Baseline values are 0 %.

Engine output decreased during the engine operation on all tested fuels. This decrease is mainly due to their lower heating value compared to diesel fuel (tab. 1). The highest increase of fuel consumption was reached by rapeseed oil and RME. Injected fuels volume remained the same, but higher specific density caused increase of mass consumption or rather specific fuel consumption. Furthermore, we found that the engine operated on rapeseed oil and RME had higher efficiency than in case of diesel fuel. So the combustion of rapeseed oil and RME is better. Better energy utilization arises from injected fuel in the engine. Reduction of some harmful engine emissions is possible to predict by the higher engine efficiency. T-Tests were conducted to test if the differences in mentioned parameters between diesel and tested biofuels were statistically significant. The results show that only rapeseed oil and RME have statistically significant higher fuel consumption with 99% confidence level. The others changes of output parameters are not statistically significant.

Production of particulate matter (PM) emissions belongs to another parameter which was evaluated. PM have some dangerous mechanical properties and include many inorganic and organic pollutants. Many of them have mutagenic and carcinogenic properties. Particulate matters comprised soot, heavy hydrocarbons (mostly condensed or absorbed by soot), sulphates and wear particles (Adamec et al., 2008.). Changes in production of particulate matter emissions are shown in table 2.

Results and subsequent statistical testing showed that the combustion of vegetable oil and its methyl esters had a positive impact on decrease of PM emissions production. Rapeseed oil and RME have a statistically highly significant difference in comparison with diesel fuel.

The results correlate with the findings in studies by Vojtíšek (2011.) and Laurin et Holubec (2008.). Vojtíšek (2011.) found that the decrease of PM emission in engine operating on rapeseed oil did not occur in all engine modes. He recorded that the production of PM emissions was lower at higher loads and higher revolutions, but when we will use rapeseed oil at low loads of engine, the engine will produce more PM emissions. This problem is related to the high temperature of evaporation of rapeseed oil (boiling point of rapeseed oil is between 250 – 300°C and boiling point of diesel fuel is from 160°C). Due to higher viscosity of rapeseed oil, fragmentation during injection and high temperature of evaporation conduce to incomplete combustion and to creation of harmful emissions.

The results of B30 combustion show that the production of PM emissions is higher than by diesel fuel. These results are incompatible with the studies by Xue et al. (2011.) and Anderson (2012.). Anderson (2012.) found that the use of B30 both in heavy duty and in light duty vehicles conduce to decline of PM emissions production. Laurin et Holubec (2008.) and Xue et al. (2011.) reached similar conclusions – the production of PM emissions decreased with the increase of proportion of RME in the mixture with diesel fuel. In our case, the higher production of PM emissions is likely caused by wrong injection pump adjustment or another fault affecting preparation of air and fuel mixture.

The positive impact on emissions of vegetable oils and their methyl esters is given by the oxygen content in the oils (according to Demibras, 2009., oxygen content of various common vegetable oils is 10.8–12.0 wt. %). Diesel fuel does not contain any oxygen. Oxygen in the vegetable oils structure improves their combustion process and improves combustion efficiency. Due to a better homogeneity of the mixture, production of harmful emission is lower as well as particulate matter and others ($C_xH_y$, CO).

## CONCLUSION

On the basis of the results of measurement and many studies, we can see positive impact of rapeseed oil, methyl ester of rapeseed oil and its mixture with diesel fuel (31:69) on exhaust emissions. Vegetable oil has a positive impact not only on animal nutrition, but on combustion process in the engine as well. Due to lower engine output, higher specific fuel consumption and some engine modification together with using special motor oils, further studies should be done to investigate operation costs in using biofuels.

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## SAŽETAK

Biljna su ulja vrlo važan sastojak u prehrani ljudi i životinja. Osim toga, predstavljaju i potencijalna goriva za motore. Ta su goriva, zvana biogoriva, obnovljivi izvori energije što mogu postepeno nadomjestiti današnja uobičajena goriva iz sirove nafte. Potrebe za više energije u proizvodnji i problemi koji nastaju za vrijeme izgaranja glavni su nedostaci biogoriva. Biljna ulja iz uljne repice pripadaju među najviše upotrebljavana biljna ulja za dizel motore u Češkoj Republici. Članak opisuje upotrebu repičinog ulja, metil estera iz repičinog ulja (RME) i njihovu mješavinu s dizel gorivom (B30) u dizel motoru, njihove dobre ekološke strane pri izgaranju i potrebno modificiranje nekih elemenata u motoru. Podaci korišteni u istraživanju dobiveni su kod mjerenja u laboratoriju za vozila. Rezultati su uspoređeni s dizel gorivom. Rezultati pokazuju da istraživana biogoriva pozitivno utječu na ispušne emisije motora ali uz veću potrošnju.

Ključne riječi: repičino ulje, repičin metilni ester, B30, učinkovitost motora, potrošnja goriva