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# ASSESSMENT OF THE SUITABILITY OF THE FUELS WITH COMPONENT POWER ENGINES

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***Abstract***

*The article presents the results of laboratory tests of selected properties of fuels available on the market and fuels with higher density component B100 obtained from rapeseed oil (10, 30, 50 and 100%). An analysis of the cetane number, viscosity, and weight of the ash remaining after combustion of fuel samples was made. It was found that the cetane number of pure biocomponent is higher than diesel oil of mineral origin and it slowly decreased along with a decrease in the Extras component. All tested samples of fuels have appropriate cetane number to power internal combustion engines with compression ignition. The viscosity of the fuel samples measured at a temperature of 30°C increased along with an increase in the content of biocomponent and approached the limit values for fuels. According to the results presented by other authors in their studies ash mass decreased along with an increase in the content of the component. Only premium diesel showed less ash mass than other fuel. The study includes also the energy value and the calorific value of liquid fuels with addition of a biocomponent, which power diesel engines. The results of the tests indicate a slight decrease in the calorific value of the fuel along with an increase in the content of biocomponent, which does not affect the ability to power the engines. Laboratory tests have proved that use of methyl esters of fatty acids in diesel fuel is the right choice to power diesel engines.*

***Keywords:*** *transport, biocomponent, diesel, energy, calorific value, viscosity, cetane number*

## 1. Introduction

The concept to use vegetable oil to power internal combustion engines was initiated in 1889 after Rudolf Diesel had constructed a unit powered by peanut oil. However, only after development of technology for refining crude oil, diesel oil was considered as a universal fuel to be used in internal combustion engines. The XX century witnessed a dynamic growth of petrochemy and oil extraction as the most powerful branches of industry. Due to high viscosity, better atomization of the air-fuel mixture and higher calorific value of petroleum-derived fuels have become very popular and gained advantage over the vegetable oil. Those activities led to reduction of vegetable oil use in favour of petroleum-derived fuels. Despite a large advantage of diesel oil over vegetable oil, works on application of vegetable oils in combustion engines were continued [12, 13]. Fuel from a chemically processed oil known as biodiesel, that is a fuel with parameters combining vegetable fuel and diesel fuel turned out to be the most effective solution [3, 15]. Processing of diesel fuel by reaction with methanol, thus creating methyl esters (process of oil transesterification with simple alcohols) was patented in 1937 by G. Chavanne from the University in Brussels [7].

According to authors [23] B100 (biodiesel without addition of diesel oil) and B20 (diesel oil with 20% addition of biodiesel) can be used to power most machines and agricultural vehicles of New Holland make.

Methyl esters of fatty acids, according to Directive 2009/28/WE, are allowed to be sold in

Poland in the form of a mixture of diesel oil with addition of 5% of biodiesel. Implementation of recommendations specified in the Directive of the European Union involves a gradual increase in use of liquid fuels [18, 19 24, 25], which come from renewable sources. This Directive also defines qualitative requirements for diesel oil with maximum 7% of methyl esters of fatty acids.

Methyl esters of fatty acids are produced in result of transesterification of a vegetable oil with light alcohol methanol. Properties of biodiesel and diesel oil are similar, therefore methyl esters, having better lubrication properties than diesel oil, can be used in diesel engines as the only fuel or as a mixture with a petroleum derived fuel [1].

Production involves adjusting their properties to technological and technical specifications of the devices where they are to be burnt [17, 20]. Viscosity, cetane number and calorific value are considered the most important parameters of engine fuels. Production technology of a vegetable oil methyl ester produced from rapeseeds aims at obtaining an oil with physical and chemical properties comparable with a petroleum-derived fuel, which is of significance for diesel engines adjusted to combustion of diesel oil [8, 10, 11]. Rapeseed biofuels can have different names (biodiesel, ecodiesel, bioester, diester, rapeseed methyl ester RME) [2], it cannot, however, be confused with unprocessed rapeseed oil which is not technologically adjusted to be used in modern high-pressure engines [5, 6, 9, 14, 16].

## 2. Materials and methods

The goal of the tests was to determine usability of a mixture of diesel oil of mineral origin and bioesters. The tests were performed for mixtures with different contents of diesel oil and bioesters in order to test their behaviour an influence on power compression engines. According to the research hypothesis accepted for the study, mixtures of diesel oil and bioesters can be used to power compression ignition engines with no significant loss of functional qualities of the equipment. It was also assumed that there exists the most beneficial % share of a biocomponent in the fuel used in compression ignition engines.

Five fuel samples containing form 100% of diesel oil of non-renewable origin to 100% of bioester B100 produced on the basis of rapeseed oil were tested. Content of particular samples is shown in Tab. 1.

*Tab. 1. Content of the tested fuel samples (own research)*

| | |
|---|---|
| Mixture I | 100% diesel oil |
| Mixture II | 90% diesel oil 10% methyl esters of fatty acids |
| Mixture III | 70% diesel oil 30% methyl esters of fatty acids |
| Mixture IV | 50% diesel oil 50% methyl esters of fatty acids |
| Mixture V | 100% 50% methyl esters of fatty acids |

The samples were observed in order to define possible negative phenomena of delamination, gelation and others. The samples were put into containers protecting them from light and air for approximately 72 hours, in constant temperature 21ºC. The solutions were examined after 12 hours. In Fig. 1, there are exemplary samples after observation.

Properties affecting the engine operation were identified in the next stage of the tests. Calorific value and the mass of ash left after burning the fuel, cetane number and viscosity were tested. Assessment of calorific value of the samples was performed by means KL-12Mn, calorimeter by burning 1 g of fuel in the atmosphere of oxygen, in a glass pot. After each test, the mass of ash produced in effect of burning was defined. Tests were repeated three times for each fuel. Measurement of the viscosity coefficient was performed with the use of rotating viscometer, in temperature of 30ºC, three times. Measurements of the cetane number were made by the engine method for fuels according to Tab. 1 (in repetitions).

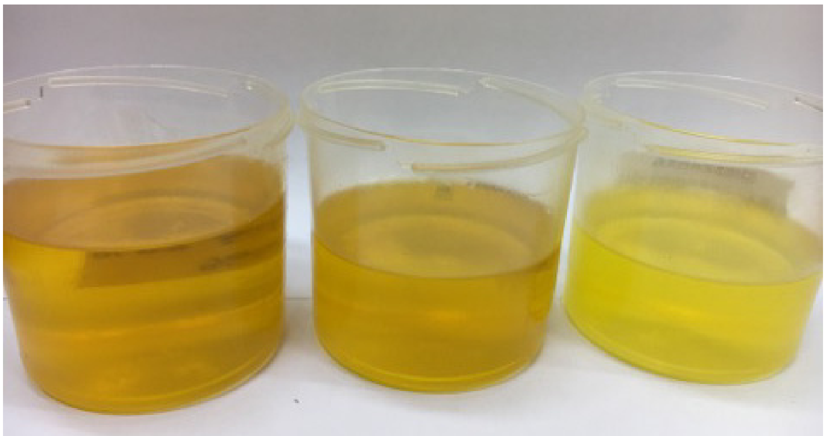

*Fig. 1. Mixtures of diesel oil and methyl esters of fatty acids*

Mean values of the obtained tests results are presented in Tab. 2 and 3.

*Tab. 2 Mean quantities of energetic value, ash mass and viscosity*

| | Calorific value [MJ·kg$^{-1}$] | Ash mass [kg·10$^{-3}$] | Viscosity [cSt] |
|---|---|---|---|
| Mixture I | 43.096[a] | 0.0038[a] | 6.47[a] |
| Mixture II | 43.197[a] | 0.0039[a] | 6.37[a] |
| Mixture III | 41.957[b] | 0.0012[b] | 7.80[b] |
| Mixture IV | 40.588[b] | 0.0014[b] | 8.57[b] |
| Mixture V | 37.903[c] | 0.0015[b] | 1.87[c] |

*Tab. 3. Mean values of cetane number*

| | Cetane number |
|---|---|
| Mixture I | 53.50[a] |
| Mixture II | 53.99[a] |
| Mixture III | 54.97[ab] |
| Mixture IV | 55.95[b] |
| Mixture V | 58.40[c] |

## 3. Results

The obtained tests results were subject to statistical analysis by means of ANALWAR program basing on Excel sheet. The significance of differences was considered using Tukeya test at the significance level of 0.05.

On the basis of observations carried out in the first stage of the test it was found that colour of the samples III, IV and V changed already after the first 12 hours (the samples slightly darkened). However, no delamination or coagulation mentioned by other authors [22] was observed.

The calorific value of the tested fuels, the ash mass and viscosity did not change statistically significantly for biocomponent content 0 and 10%. For biocomponent content 30% and 50% a drop in calorific value by approximately 3.4% was observed as compared to samples I and II. However, for sample V the drop was 12.1%. Similar results were obtained by Demirbas [4].

The course of the fuel calorific value and viscosity changes is demonstrated in Fig. 2 and 3. The ash mass is different for fuels with biocomponent content higher than 30% (samples III, IV and V) and is lower by about 63% for fuels with higher content of biocomponent. This is confirmed by tests carried out by Hansen et al. [21].

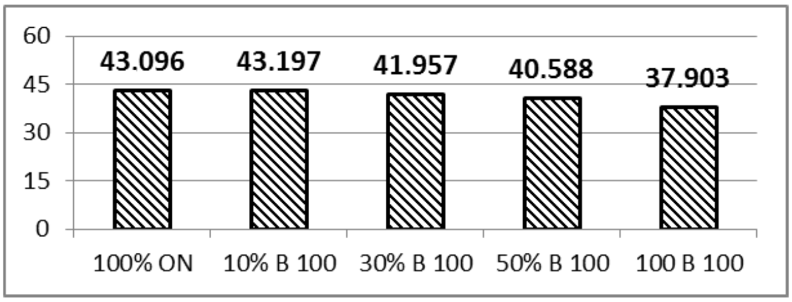


*Fig. 2. Dependence of energetic value on biocomponent content*

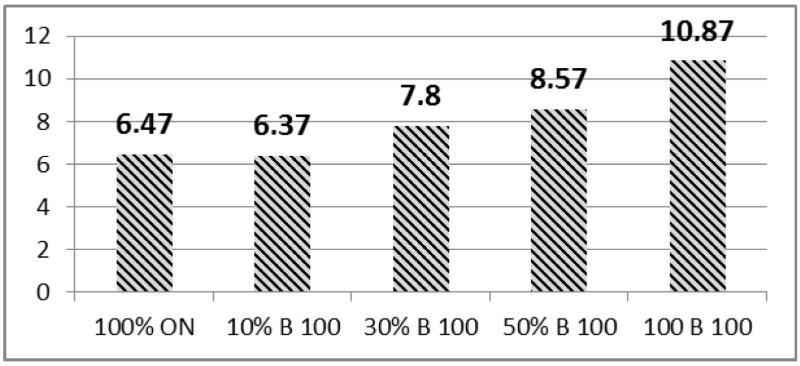


*Fig. 3. Dependence of viscosity on biocomponent content*

Values of the cetane number for a fuel with biocomponent content up to do 30% (samples I, II and III) do not differ statistically significantly. No statistically significant differences in the cetane number were found for samples III and IV either, though it was significantly higher than for samples I and II. According to the authors' own research, it was a pure biocomponent that was characterized by the highest value of cetane number (sample V). Between sample I (100 ON of mineral origin) and V (100 biocomponent) the difference in cetane number was nearly 9.1%. Mean values of cetane number are presented in Fig. 4.

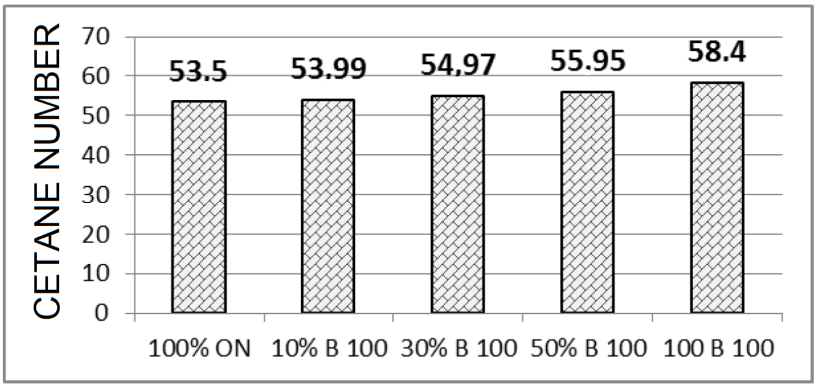


*Fig. 4. Mean values of cetane number for variable contents of a biocomponent in a fuel*

## 4. Conclusions

On the basis of a rapeseed oil, it was found that an increase in content of biocomponent in a fuel resulted in a slight drop in the fuel calorific value. The tests revealed a statistically significant increase in the fuel viscosity along with an increase in biocomponent content above 30%. Viscosity was increasing for temperatures above 30ºC. For lower temperatures such an increase it can, in an extreme case, block the fuel filter. The tests showed that positive changes were reported for the mass of ash produced in effect of burning. An increase in biocomponent content up to 30% in a fuel resulted in a significant drop in the ash mass. No further drop in ash mass was observed for higher contents of biocomponent. Cetane number was found to be increasing along with an increase in biocomponent content in the fuel. A statistically significant increase in cetane number was found for biocomponent content higher than 50%. The tests show that fuels with biocomponent content up to 30% do not adversely affect the engine performance, and the fuel created from rapeseed oil under certain conditions can be used in diesel engines.

**References**

[1] Baczewski, K., Kołdoński, T., *Paliwa do silników o zapłonie samoczynnym*, WKŁ, Warszawa 2004.
[2] Carraretto, C., Macor, A., Mirandola, A., Stoppato, A., Tonon, S., *Biodiesel as alternative fuel: Experimental analysis and energetic evaluations*, Energy, Vol. 29, 2004.
[3] Demirabs, A, *Biofuels, securing the planet's future Energy needs*, London, Springer Verlag Limited, 2009.
[4] Demirbas, A., *Importance of biodiesel as transportation fuel*, Energy Policy, Vol. 35 (9), 2008.
[5] Haller, P., Jankowski, A., Kolanek, C., Walkowiak, W., *Potential Non-Toxic Aqueous Emulsion as a Diesel Fuel,* Journal of KONES, Vol. 22, No. 3, DOI: 10.5604/12314005.1165969, pp. 45-48, Warsaw 2015.
[6] Haller, P., Jankowski, A., Kolanek, C., Walkowiak, W., *Research of Water-Fuel Microemulsions as Fuel for Diesel Engine,* Journal of KONES, Vol. 16, No. 3, DOI: 10.5604/12314005.1138110, pp. 165-170, Warsaw 2012.
[7] Hansen, B., Jensen, A., Jensen, P., *Performance of diesel particulate filter catalysts in the presence of biodiesel ash species*, Fuel, Vol. 34 (1), 2013.
[8] Jankowski, A., *Chosen Problems of Combustion Processes of Advanced Combustion Engine*, Journal of KONES, Vol. 20, No. 3, DOI: 10.5604/12314005.1136852, pp. 203-208, Warsaw 2013.
[9] *Creating of Chosen Parameters of Water Fuel Microemulsion on Combustion Processes, Emission Level of Nitrogen Oxides and Fuel Consumption of CI Engine,* Journal of KONES, Vol. 18, No. 4, pp. 593-600, Warsaw 2011.
[10] Jankowski, A., *Heat transfer in combustion chamber of piston engines*, Journal of KONES Vol. 17 No. 1, pp. 187-197, Warsaw 2010.
[11] Jankowski, A., *Influence of Chosen Parameters of Water Fuel Microemulsion on Combustion Processes, Emission Level of Nitrogen Oxides and Fuel Consumption of CI Engine*, Journal of KONES, Vol. 18, No. 4, 593-600, Warsaw 2011.
[12] Jankowski, A., Kowalski, M., *Creating Mechanisms of Toxic Substances Emission of Combustion Engines,* Journal of KONBiN No. 4(36), DOI 10.1515/jok-2015-0054 pp. 33-42, 2015.
[13] Jankowski, A., Kowalski, M., *Environmental Pollution Caused by a Direct Injection Engine,* Journal of KONES, Vol. 22, No. 3, DOI: 10.5604/12314005.1168461, pp. 133-138, Warsaw 2015.
[14] Jankowski, A., Kowalski, M., *Influence of the Quality of Fuel Atomization on the Emission of Exhaust Gases Toxic Components of Combustion Engines,* Journal of KONBiN No. 4(36), DOI 10.1515/jok-2015-0055, pp. 33-50, 2015.
[15] *Microemulsion as a Means of NOx Reduction in Exhaust Emission of Diesel Engines,* Journal of KONES, Vol. 23, No. 3, DOI: 10.5604/12314005.1216479, pp. 225-232, Warsaw 2016.
[16] *Modelling of Combustion Processes of Liquid Fuels,* Journal of KONES, Vol. 19, No. 4, DOI: 5604/12314005.1138352, pp. 239-244, Warsaw 2012.
[17] Jankowski, A., *Reduction Emission Level of Harmful Components Exhaust Gases by Means of Control of Parameters Influencing on Spraying Process of Biofuel Components for Aircraft Engines,* Journal of KONES, Vol. 18, No. 3, pp. 129-134, Warsaw 2011.

[18] Jankowski, A., *Study of the influence of different factors on combustion processes (Part one),* Journal of KONES, Vol. 16, No. 1, pp. 209-216, 2009.
[19] Jankowski, A., *Study of the influence of different factors on combustion processes (Part two),* Journal of KONES, Vol. 16, No. 3, pp. 135-140, Warsaw 2009.
[20] Juliszewski, T., Zając, T., *Biopaliwo rzepakowe*, PWRiL, Poznan 2007.
[21] Piętak, A., Radkowski, S., *Wieloaspektowa analiza stosowania paliw alternatywnych w Polsce ze szczególnym uwzględnieniem biopaliw*, Warszawa 2006.
[22] Ramos, M., Fernández, C., Casas, A., Rodríguez, L., Pérez, A., *Influence of fatty acid composition of raw materials on biodiesel properties*, Bioresource Technology, Vol. 100 (1), 2009.
[23] Rathbauer, J., Krammer, K., Pranhl, H., Worgetter, M, *Local and innovative biodiesel*, Biomass Logistics Technology, 2006.
[24] Zurek, J., Jankowski, A., *Experimental and Numerical Modelling of Combustion Process of Liquid Fuels under Laminar Conditions,* Journal of KONES, Vol. 21, No. 3, pp. 309-316, DOI: 10.5604/12314005.1134559, Warsaw 2014.
[25] Zurek, J., Kowalski, M., Jankowski, A., *Modelling of Combustion Process of Liquid Fuels under Turbulent Conditions,* Journal of KONES, Vol. 22, No. 4, DOI: 10.5604/12314005.1168562, pp. 355-344, 2015.