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# EFFECT OF FATTY ACID METHYL ESTERS (FAME) ON PHYSICAL AND CHEMICAL PROPERTIES OF AVIATION TURBINE FUELS

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***Abstract***
*In recent years there is tendency to adjust domestic petroleum products to meet world and European standards that establish high requirements regarding environment protection. At the same time, it is tendency to introducing wider spectrum of biocomponents that in turn enables to reduce harmful influence on environment. The work described in this paper, among others, consists in evaluation of effect of various concentration of FAME in aviation turbine fuel on its physical and chemical properties. The research work includes effect of FAME on fuel properties regarding the refinery process (density, distillation, flash point, composition, and the like) but also on properties important in regard to engine operation (kinematic viscosity, acid number, oxidation stability, gum content, freezing point, and the like). The work covers also the effect of selected antioxidants and depressants on FAME containing fuels on turbine engines operation. Considering the environment protection, the work includes evaluation of FAME presence on sulphur content, carbon and ash content. In order to establish stability - resistance to different ambient conditions - such blends undergo cyclic temperature changes. Results will be used to evaluate the possible use of biofuels in turbine engines.*

***Keywords:*** *environment protection, biocomponents, biofuels- alternate fuels, greenhouse effect, emissiongases*

In recent years there is tendency to adjust domestic petroleum products to meet world and European standards that establish high requirements regarding environment protection. At the same time, it is tendency to introducing wider spectrum of biocomponents that in turn enables to reduce harmful influence on environment [1, 3, 4,5].

Climate change is one of the biggest challenges that mankind is facing. There is necessity to prepare relevant steps aiming at carbon dioxide emission reduction. Both air and sea transport have similar share in $CO_2$ emission. This is because the motive technology and employed fuels are not covered by ecological standards. The transport sector has growing share in European and global carbon dioxide emission. One of the ways to reduce this emission is usage of biofuels as components of typical fuels (biofuels of first generation). Growing transportation means emission of harmful exhaust gas components, not only the carbon dioxide and water, but also the nitrogen oxides, particles as well as hydrocarbons. Such emissions cause lowering air quality and contribute to anthropogenic increase of greenhouse effect [2,4]. So as to the transport would be neutral to environment regarding the emission of greenhouse gases, the work is conducted with aim to use alternate fuels. In short time we need the fuel that could partially substitute for currently used aviation fuel.

The work described in this paper consists in evaluation of effect of various concentration of FAME in aviation turbine fuel on its physical and chemical properties. The research work includes effect of FAME on fuel properties regarding the refinery process (density, distillation, flash point, composition, and the like), but also on properties important in regard to engine operation (kinematic viscosity, acid number, oxidation stability, gum content, freezing point, and the like). The work covers also the effect of selected antioxidants and depressants on FAME containing fuels on turbine engines operation. Considering the environment protection, the work includes evaluation of FAME presence on sulphur content, carbon and ash content. In order to establish stability - resistance to different ambient conditions - such blends undergo cyclic temperature changes. Results will be used to evaluate possible use of biofuels in turbine engines.

This work covers analysis of change in physical and chemical parameters of aviation fuel Jet A-1 containing various amounts of FAME: 2 %, 5 %, 10 %, 15 %, and 20 %. The Jet A-1 fuel from different plants and FAME from different manufacturers were used in the work. Blends of fuel with FAME were tested in regard to physical and chemical properties. The effect of FAME content on such properties is evaluated basing on plots picturing changes of relevant properties of tested blends.

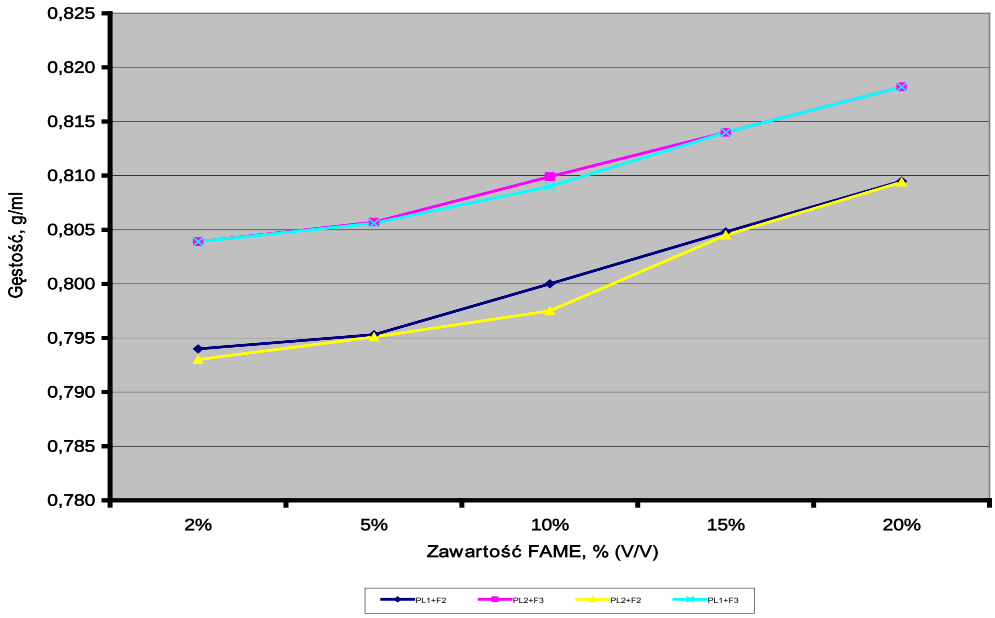


*Fig. 1 Density vs. FAME content*

More esters content in mixtures means relevant density increase. Blend density mostly depends on FAME density. Densities of blends of two different Jet A-1 fuels with the same FAME, and the same FAME content are very similar. All obtained densities fall into the specification requirements 0.775 - 0.840 g/ml.

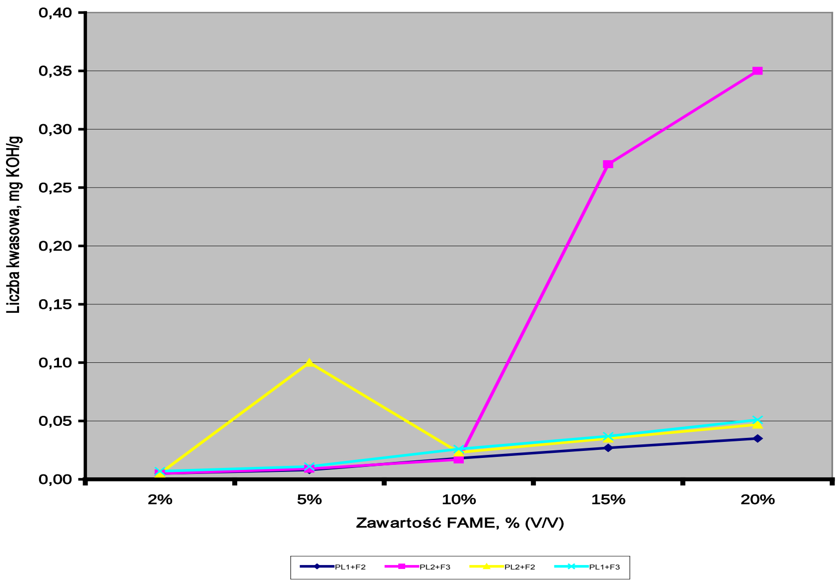


*Fig. 2 Acid number vs. FAME content*

Despite the used fuel it is difficult to find any dependence on FAME content. Blends of PL1 fuel with esters demonstrated the best behaviour where there was continuous increase of acid number with amount of added FAME. As to PL2+F3 blend, there was sudden increase of acid number for FAME content above 10 % (v/v). As to PL2+F2 blend, after sudden decrease for 5 % (v/v) FAME content, consequent increasing FAME content results in small acid number increase. The acid number value exceeds the specification requirement max. 0.015 mg KOH/g only in case of PL2+F3 blend.

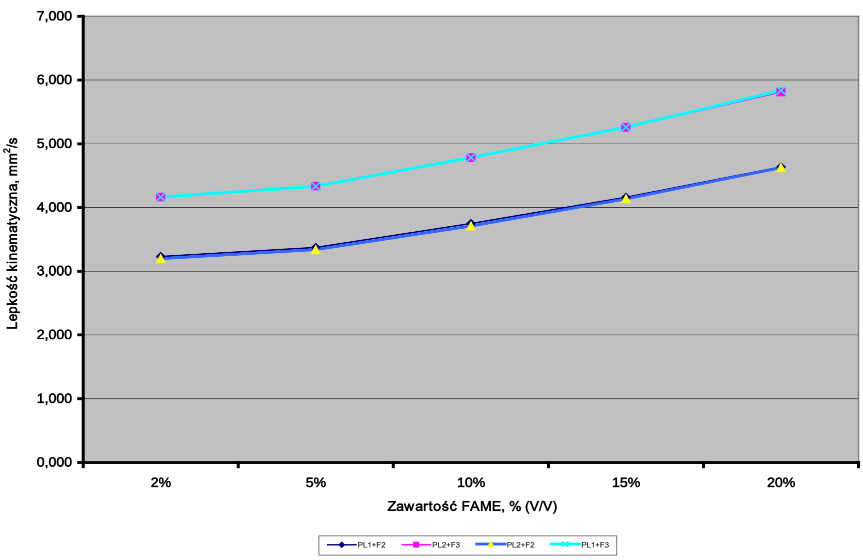


*Fig. 3 Kinematic viscosity vs. FAME content*

Viscosity of all kind of blends gets higher with ester content increase. For two different Jet A-1 fuels and the same FAME blend viscosity depends mostly on FAME viscosity. Viscosities of blend containing the same amount of FAME are very similar. Viscosities of blend fall into the fuel specification requirement max. 8.0 $mm^2/s$ for FAME content up to the 20 % (v/v).

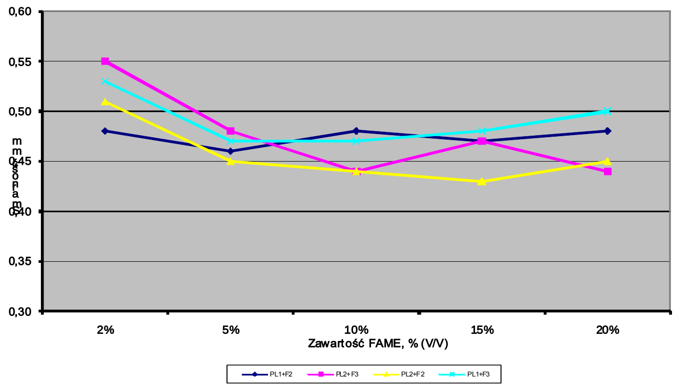


*Fig. 4 Lubricity vs. FAME content*

It is impossible to explicitly describe the effect of FAME content on BOCLE lubricity. For every mixture lubricity increases with FAME content initially that is indicated by decreasing scar diameter. Then, for different blends, lubricity starts to decrease, but at different FAME content. It should be accepted that such fluctuation are caused by "randomness" which is acceptable by test method precision and at the same time it is possible to eliminate it by performing more repetitions and making statistical evaluation. Blend of PL2 and FAME F2 demonstrated the best lubricity which shows increase up to 15 % (v/v) FAME content.

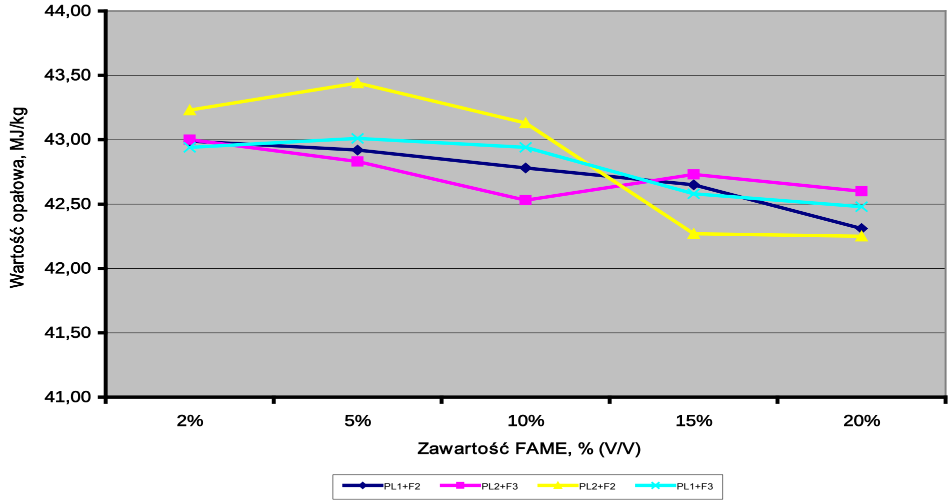


*Fig. 5 Net heat of combustion vs. FAME content*

Blend containing PL2 fuel and FAME F2 demonstrated the best combustion properties at the initial stage. But the smallest difference in combustion properties was demonstrated by blend of PL2 fuel and FAME F3. Net heat of combustion is stable up to 10 % (v/v) FAME content only for blend of PL1 fuel and FAME F3. As it can be seen at the plot, the change of net heat of combustion of the blend depends greatly on properties of employed FAME.

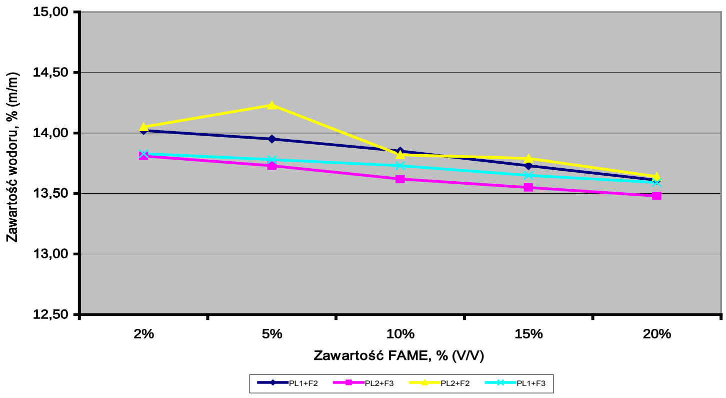


*Fig. 6 Hydrogen content vs. FAME content*

Generally it can be said that hydrogen content decreases with increase of FAME concentration in fuel. Though, the obtained values comply with minimum requirements for aviation turbine fuels.

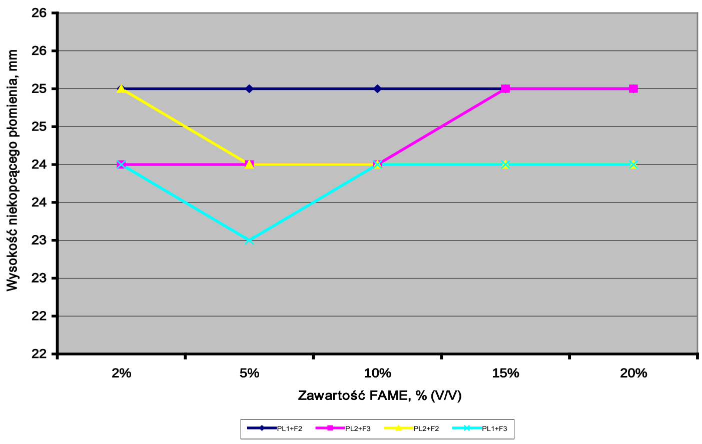


*Fig. 7 Smoke point vs. FAME content*

It is difficult to explicitly describe obtained values of smoke point and their dependence on FAME content for all samples. The best behaviour was demonstrated by blend of PL1 fuel and esters F2 which achieved minimum requirements for fuel at whole range. So it can be assumed that esters presence have little effect on value of this parameter.

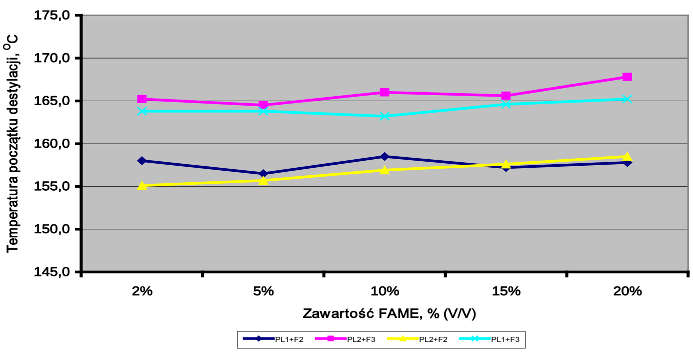


*Fig. 8 Initial boiling point vs. FAME content*

In case of presented blends the initial boiling point demonstrates slight uptrend. At the same time the used FAME has an effect on initial boiling point. In case of the same ester and different fuels, temperatures for individual FAME concentrations demonstrate considerable differences. This is because FAME presence doesn't contribute to distillation run these temperature ranges.

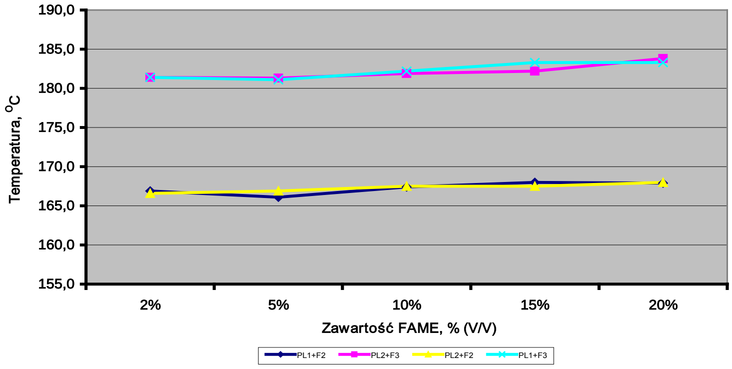


*Fig. 9 Temperature of 10 % (v/v) evaporation vs. FAME content*

This parameter demonstrates slight uptrend for presented blends. Esters have small effect on this parameter, whereas the properties of aviation fuel have decisive influence on it.

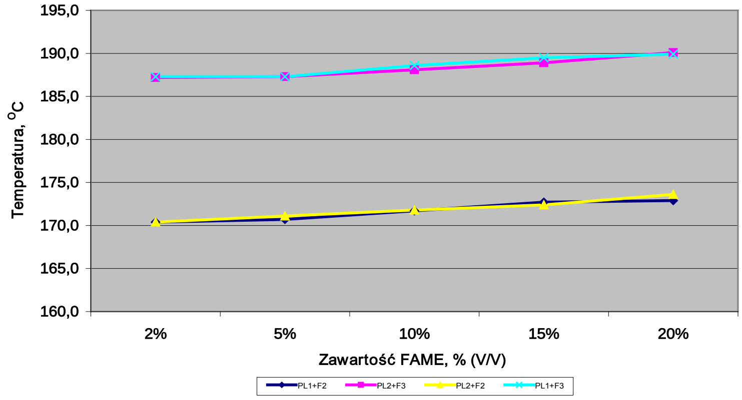


*Fig. 10 Temperature of 20 % (v/v) evaporation vs. FAME content*

In case of this parameter it also demonstrates slight uptrend. At the same time, effect of used FAME is more noticeable. The temperatures of 20 % evaporation are considerably different at various content of the same FAME in different fuels.

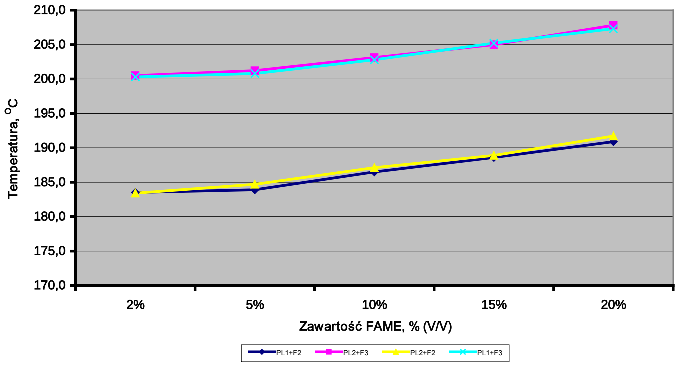


*Fig. 11 Temperature of 50 % (v/v) evaporation vs. FAME content*

According to tendency shown in fig. 9 and 10 we can see bigger effect of FAME presence on test results, though the petroleum fuel properties are still the most important.

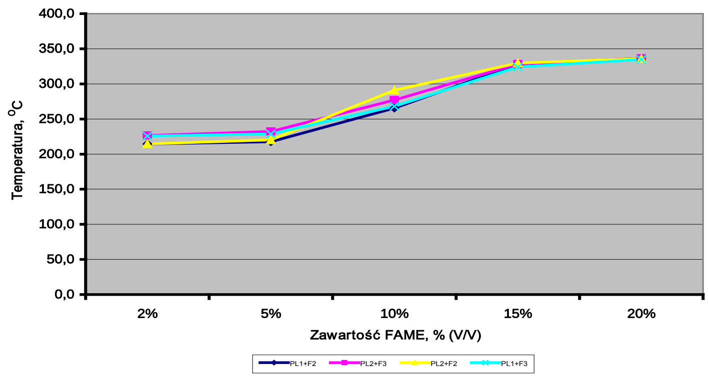


*Fig. 12 Temperature of 90 % (v/v) evaporation vs. FAME content*

Presented blends demonstrated significant uptrend regarding the 90 % (v/v) evaporation temperature. The FAME effect on blend distillation run at this final fragment of distillation curve is already distinctly visible. It means that more intensive distillation of heavier fractions of biocomponents.

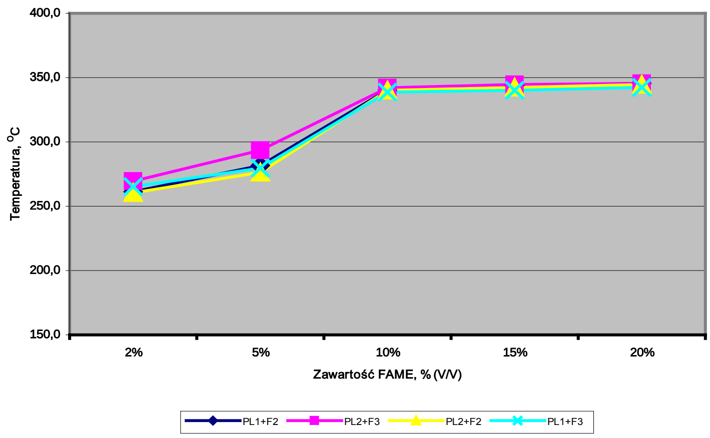


*Fig. 13 Final boiling point vs. FAME content*

In case of presented blends there is sudden increase of FBP values for FAME content up to 10 % (v/v), and then the increase of FBP is minimal for all blends.

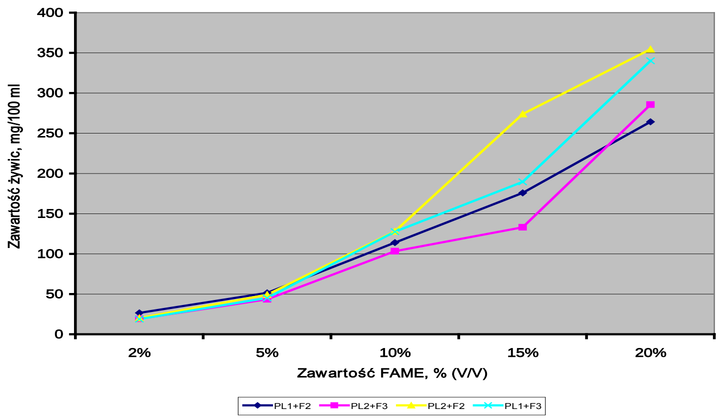


*Fig. 14 Existent gum vs. FAME content*

There was large uptrend of existent gum for almost every blend. Such trend is not confirmed by thermal stability (JFTOT) results for the blends. Though the existent gum exceeded acceptable values for aviation turbine fuels it should be noticed that such considerable quality deterioration wasn't observed in case of oxidation stability. Probably, it's because the test method is suited especially to petroleum aviation fuels. This method may be not suitable to biocomponents with quite different chemical structure (for instance, because of too low temperature of evaporating medium - superheated steam).

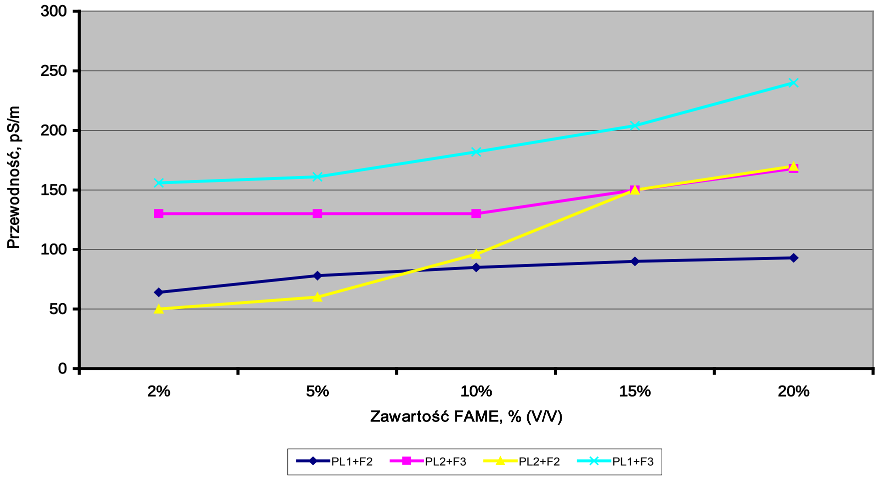


*Fig. 15 Conductivity vs. FAME content*

Conductivity demonstrates uptrend with FAME content increase in blends. There is no relationship between kind of fuel and FAME. Probably it is because of too large surface tension of esters in relation to petroleum fuels [6].

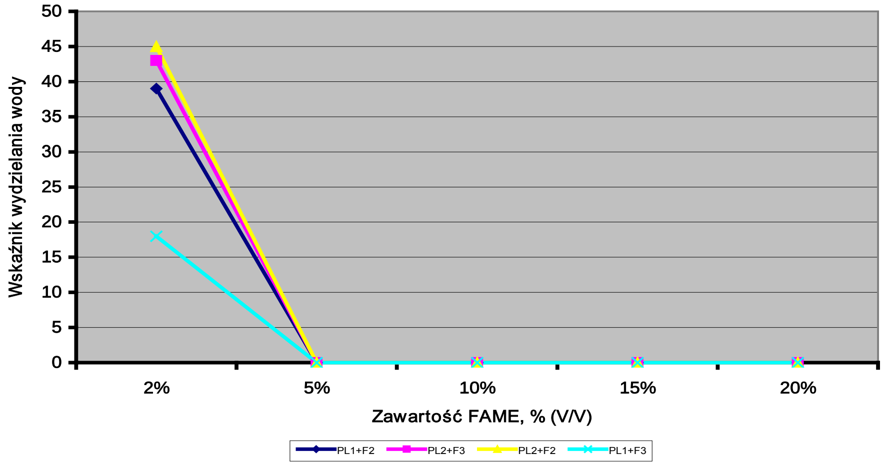


*Fig. 16 Water separation index vs. FAME content*

The index decreases suddenly after addition of 5 % (v/v) of esters, and reaches zero for every blend. This can disturb operation of coalescing - separating filters. Influence of FAME on water separation index can arise due to high surface tension of esters.

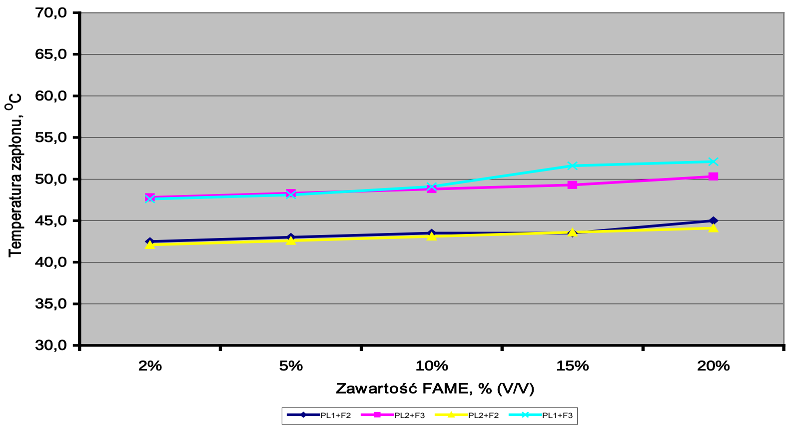


*Fig. 17 Flash point vs. FAME content*

The flash point increases with FAME content for every blend. Blend's flash point depends mostly on flash point of FAME. In case of two different Jet A-1 fuels and the same FAME, flash points of individual blends with equal FAME content are very similar. The reason is that flash point of FAME is considerably higher than aviation fuel, and has decisive influence on vale of this parameter for blends.

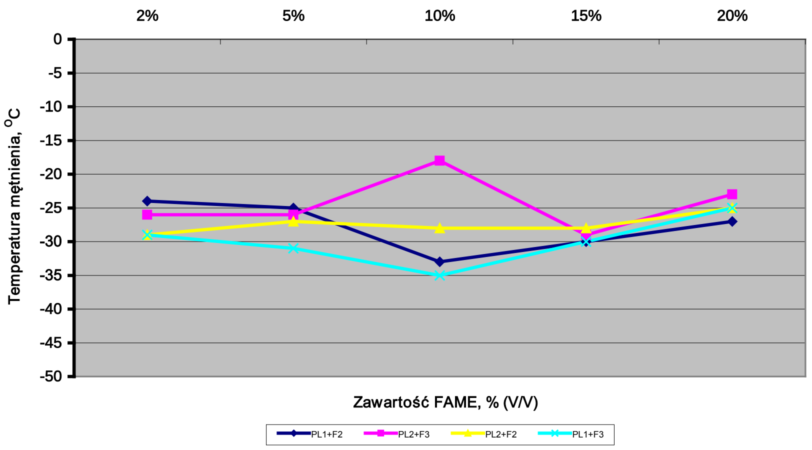


*Fig. 18 Cloud point vs. FAME content*

It is difficult to evaluate relationship between cloud pint and FAME content. Every blend behaves slightly in different way. Different chemical character of both components can be the reason.

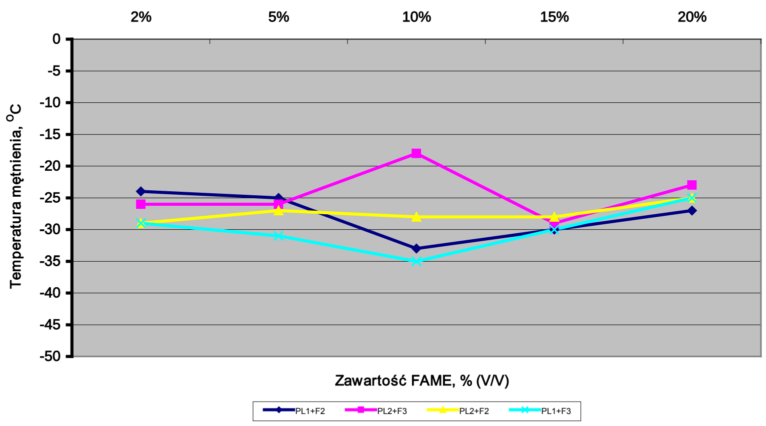


*Fig. 19 Pour point vs. FAME content*

Pour points are practically unchanged. The differences depend mostly on type of used ester, and not on fuel type.

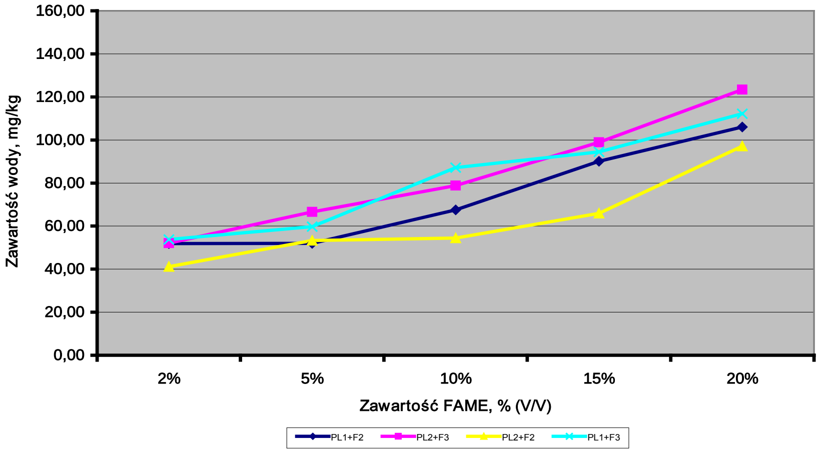


*Fig. 20 Water content vs. FAME content*

Water content increases with FAME concentration increase. The increase is considerably higher for FAME concentration more than 5 % (v/v). Blends containing the same ester demonstrate similar water content uptrend. It means that ester, as hygroscopic product, contain more water. Furthermore, solubility of water in ester is higher than in petroleum fuel, so ester is the source of water in blend.

## SUMMARY

Basing on presented results it can be assumed that all blends of fuel containing FAME meet requirements of specification NO-91-A258-4 for aviation turbine fuels, excluding such parameters as water separation index and existent gum.

Lowered smoke point may cause slight problem with slight increase of carbon deposits in system, what can cause damage of system components.

Existent gum considerably exceeds aviation turbine fuel specification requirements. This can deteriorate air-fuel mixture combustion and lead to carbon deposits.

Due to different chemical character of FAME, and used test methods suitable for petroleum fuels, above conclusions should be verified by performing engine tests.

Depending employed fuel, fuel blends containing FAME up to 5 % (v/v) demonstrate the lowest tendency to form crystals at low temperatures

According to knowledge basing on the research work, it seems that use of FAME in aviation will be considerably limited. However, it doesn't exclude use some different biocomponents or use biofuels in engines employed for other than airborne purposes.

## References

[1] *Wrota Podlasia – Ekologiczny transport*. http://www.wrotapodlasia.pl/pl/wiadomości/z+brukseli/ekologiczny_transport.htm.
[2] T. Stylińska, *Latanie na cenzurowanym*, onet.pl Tygodnik Powszechny, 23.09.2008.

[3] J. Ostaszewicz, *Środki dla redukcji emisji szkodliwych substancji w transporcie lotniczym*, Start-Biuletyn-Nr 1/2003-Trans. Lotniczy.
[4] Alternatywne paliwa lotnicze – *Konwencjonalne i alternatywne źródła energii*. http://www.postcarbon.pl/2008/01/23/alternatywne -paliwa-lotnicze.
[5] *Problemy ogólnoresortowe, Strategia ograniczania emisji* $CO_2$ *w sektorze transportu*. Główna Biblioteka Komunikacyjna.
[6] C. Kajdas, T. Wiśniewski, *Wpływ dodatków estrowych na napięcie powierzchniowe oleju napędowego*. PROBLEMY EKSPLOATACJI, nr 1, 2003.