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11. COMPARATIVE CHARACTERISTICS OF PROPRTIES OF JET FUEL BIO-ADDITIVIES BASED ON PLANT OILS

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The work is devoted to the investigation of basil physical-chemical properties of various bio-additives for jet fuels was studied, in particular fatty acids methyl esters and fatty acids ethyl esters of rapeseed oil and fatty acids ethyl and fatty acids iso-butyl esters of camelina oil. The modern situation in aviation industry and its impact on environment is shown. It is found that properties of bio-additives significantly differ from properties of conventional jet fuel and, thus, they can't be used as a complete substitute of jet fuels. It is possible to use bio-additives to substitute jet fuel in quantity up to 30 %.

INTRODUCTION

From the very beginning of its appearance, the aircraft was tied to the oil refining industry. Without the products of the latter, in the literal sense of the word it would remained on the ground. In recent years, there has been a tendency in the field of aviation transport to reduce the costs of operating aviation equipment. Both military and civilian aircraft are actively seeking ways to minimize these costs. To date, about a quarter of the cost of the flight is the price of fuel. Due to the fact that petroleum resources as raw materials for fuel production are exhausted, their price is constantly increasing. In this regard, in the near future, the aviation industry will face the need to replace traditional aviation fuels with alternatives. In addition, the state of the environment is of great concern. The production of fuels is associated with the extraction of fossil fuels from the earth's interior, which leads to an increase in the amount of CO2 in the atmosphere, which results in an increase in the global greenhouse effect on the planet.

Today, one of the ways to address aviation's environmental impact, as well as the issue of exhaustion of traditional energy resources, is to switch to alternative fuels. So the world's leading countries and aviation industry organizations are calling on the public to consider the need to introduce alternative aviation fuels. Implementation of biofuels in the aviation industry will allow in the future to increase the efficiency of the use of motor fuels, the operation of the air transport and energy sectors, as well as to minimize the man-made impact on the environment.

LITERATURE OVERVIEW

The global volume of passenger air transportation annually increases by 4–5 %. This leads to an increase in fuel consumption, resulting in an increase in emissions from the aviation industry. Their share of total emissions is 2 %, and in the near future may reach 3 %. Among the main pollutants included in the aircraft exhaust gases are:

- CO_2 (Carbon dioxide);
- H_2O (Water vapor);
- CO (Carbon monoxide);
- NOx(Nitrogen oxides);
- HC (Hydrocarbons);
- SOx (Sulfur oxides);
- Soot, solid particles of fuel.

One of the ways to solve the problem of aviation's impact on the environment is the introduction of alternative aviation fuels.

FEEDSTOCK AND TECHNOLOGY OF BIO-ADDITIVES PRODUCTION

The diversity of technologies ensures the possibility of producing alternative fuels for jet engines using many types of raw materials. Among the range of raw materials, nowadays scientists consider the most promising plants with high content of oils, such as camelina, rape, jatropha, sunflower, etc., as well as algae and some types of industrial and domestic waste.

To date, there are a number of technologies for the production of alternative aviation fuels, in particular, the esterification of vegetable oils, hydro-purification of fatty raw materials and the processing of biomass by the Fischer-Tropsch synthesis.

In this paper, samples of biofuels that were produced by the technology of esterification of such types of oils as camelina and rapeseed were used and investigated. For esterification methyl, ethyl and iso-butyl alcohols were used

Camelina belongs to energy crops with high oil content. Its main consumers today are biofuel producers. Usually camelina is used in agriculture as a crop rotation culture, which prevents the decreasing of the fertility of the soil and provides increased resistance of other crops to diseases and pests. In addition, camelina is unpretentious to climatic conditions, that is, it does not require careful cultivation and care. It is known that camelina seed contains 40–50 % of oil, which provides an oil yield of about 1250 l/ga. Another advantage of this crop is the possibility of using sunflower (a by-product of the oil extraction process) as a feed for farm animals and poultry. According to scientists, such characteristics of the camelina will ensure the "sustainability" of the process of production of aviation biofuels without creating competition for the food industry. This culture has become widespread in the United States, Canada and some European countries.

During the last 10-15 years rapeseed was the main agricultural crop for the production of biofuels. During 2000–2010, the leading producers of rapeseed oil were Canada, the USA and European countries such as Germany, France, Czech Republic, Poland, Great Britain. According to chemical composition and basic technical characteristics, rapeseed oil is suitable for the production of alternative fuels. Now the question arose about the expediency of growing rapeseed as biofuel raw materials. Scientists pay attention to the fact that the rapeseed culture requires special conditions of cultivation, it requires constant fertilization, using pesticides and other chemicals, substantially depletes the soil in areas traditionally used by agro-industrial complexes. Analyzing the data, the researchers concluded that rapeseed is a competition for the needs of the food industry, and the process of production and use of biofuels is not sustainable. Numerous studies were conducted on the selection of rapeseed crops with improved physico-chemical and agronomic characteristics. The performed works allowed to increase the content of oil in the seeds and yield of the crop, thereby increasing the average yield of oil to 1201-1301 l/ga.

RESULTS AND DISCUSSION

The next stage of the work was the study of the physical and chemical properties of the following jet fuels bio-additives obtained by the above mentined methodology:

- Fatty acids methyl esters (FAME) of rapeseed oil
- Fatty acids ethyl esters (FAEE) of rapeseed oil;
- Fatty acids ethyl esters (FAEE) of camelina oil;
- Fatty acids iso-butyl esters (FAIBE) camelina oil.

The research was carried out accoeding to the physical and chemical properties typical for aviation fuels, in particular fuel for jet engines: density, viscosity, freezing point, lower heat of combustion and flash point. The results are shown in fig. 1–5

As we can see in fig. 1, the values of the density of the studied samples of bio-additives vary in the range 870–884 kg/m3. In this case, FAIBE of camelina oil are characterized by the lowest value of density. This can be explained by the presence of 4 groups of CH2 in the alcohol radicals of FAIBE, compared with one group in FAME and two groups in the FAEE, thus reducing the compactness of the mutual placement of butyl esters molecules. Taking into account the requirements for the density of petroleum fuel for jet engines (775–840 kg/m3) we can conclude that it is more rational to use FAIBE of camelina oil bio-additive.

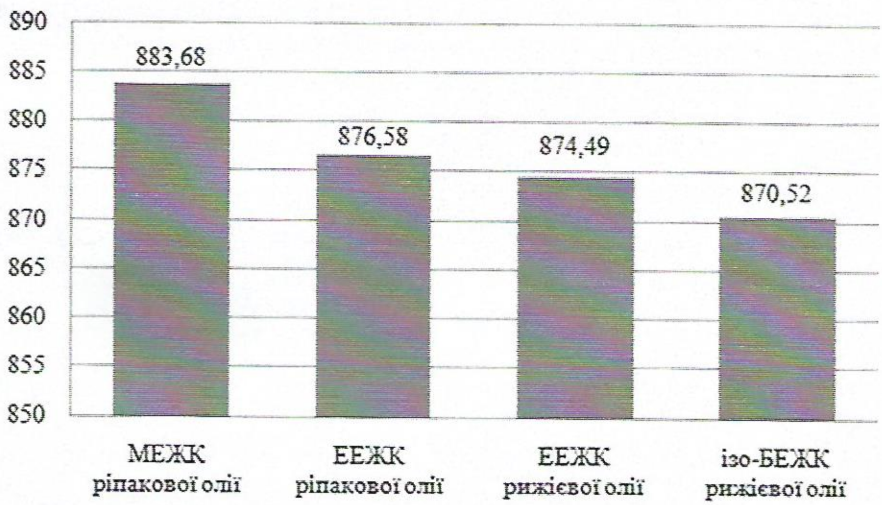

Fig. 1. Density of samples of bio-additives at temperature 15 °C, kg/m^2

In fig. 2 shows the value of the viscosity of the studied samples of bio-additives, which lie in the range of 6.4–8.2 mm^2/s. These values are rather high compared to conventional fuel for jet engines (1.5-1.7 mm^2/s).

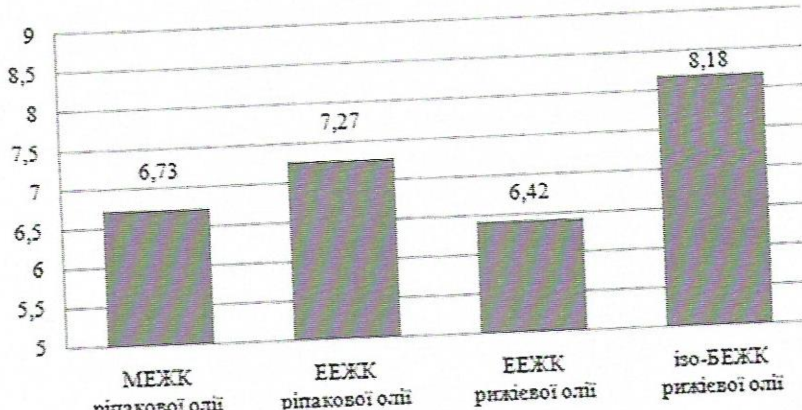

Fig.2. The viscosity of samples of bio-additives at temperature 20 °C, mm^2/s

The reason for this is the chemical structure of fatty acids esters. The length of the chain determines the large size of the compounds, which determines the greater energy of their intermolecular interaction. It is evident that the FAME of rapeseed oil and FAEE of camelina oil have the lowest viscosity values. The highest viscosity value of FAIBE is observed due to the length of the butyl radical.

In fig. 3 the results of the study of the freezing point of bio-additives are presented. The bio-additives supplements differ by considerably higher freezing point compared to petroleum fuels for jet engines (the norm for which is not higher -47 °C). Such high freezing point of bio-additives are predetermined by the chemical structure of molecules. The length of the hydrocarbon chain and the alcohol radical. Fatty acids esters determine the large size of the compounds and result in a strong interaction between the molecules.

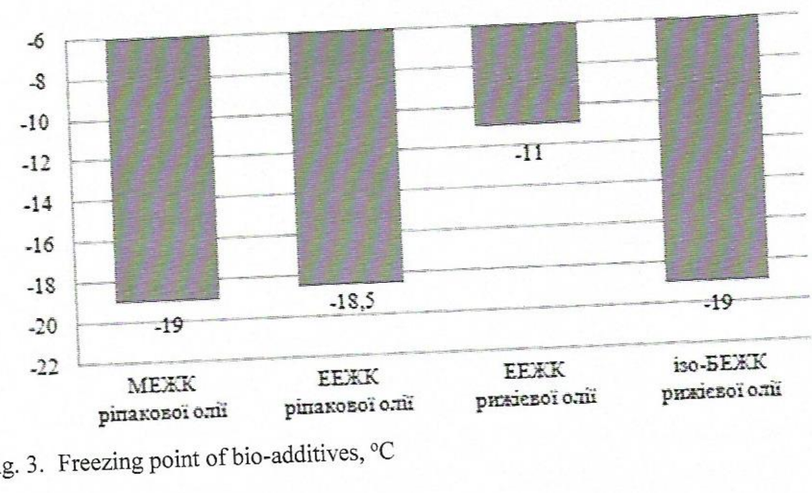

Fig. 3. Freezing point of bio-additives, °C

In fig. 4 presents the results of research on the heat of combustion of bio-additives. The bio-additives are characterized by essentially lower values of combustion heat compared to petroleum fuels for jet engines (the norm for which is not less than 43200 kJ/kg). This is due to differences in bio-additives: fatty acids esters contain ~12 % hydrogen in their composition, and fuel for jet engines ~14 %. The composition of esters includes 11–11.5 % of oxygen, which is almost absent in conventional fuel. FAIBE has the highest calorific value, since their molecules contain four groups of CH_2, which makes the mass fraction of hydrogen the largest, and oxygen, on the contrary, is the smallest among all samples of bio-addivies samples.

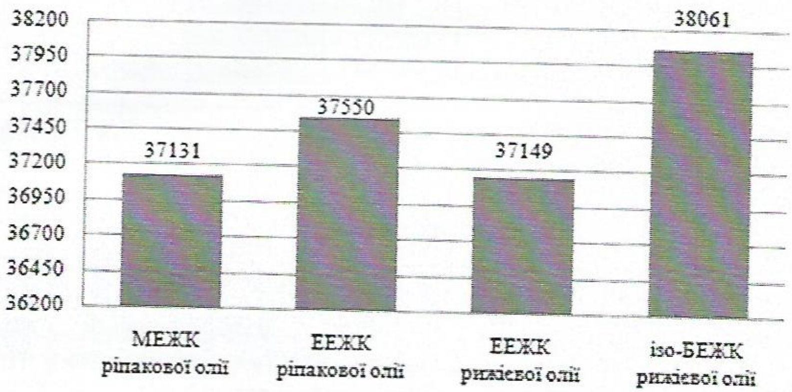

Fig. 4. Lower heat of combustion of bio-additives, kJ/kg

On fig. 5 shows the results of the study of the flash point of bio-additives. The bio-additives based on rapeseed and camelina oil differ considerably by higher values of flash point compared to petroleum jet fuels (the norm is within the range of 28–38 °C). This can be explained by the differences in the chemical structure of the fatty acids esters and conventional fuel for jet engines, in particular the longer length of the hydrocarbon chain of the fatty acids esters molecules and their higher flash point. The low temperature of the flash of FAEE of camelina oil can be explained by the presence in the bioadditive of a small amount of alcohol remaining after its receipt.

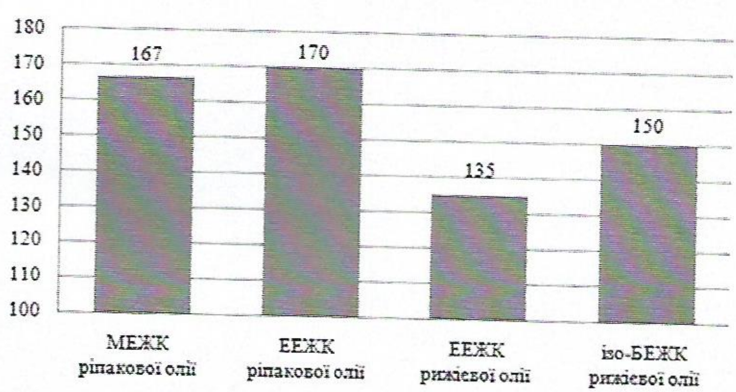

Fig. 5. The flash point of bio-additives, °C

The obtained results were analyzed in comparison with the quality indicators of conventional jet fuel, and the requirements of the standard. In general, the performance of all biocomponents is significantly different from that of AJE fuels, which means that biocomponents can be used not as a pure replacement but as an additive to traditional jet fuels.

Table 1. Comparison of obtained results

Parameter	Standard	Jet-A1	FAME of rapeseed oil	FAEE of rapeseed oil	FAEE of camelina oil	FAIBE of camelina oil
Density for 20 °C, kg/m^3	775–840	795	883,68	876,58	874,49	870,52
Viscosity for 20 °C, mm^2/s	No less 1,25	1,5	6,73	7,27	6,42	8,18
Freezing point, °C	No more minus 47	-62	-19	-18,5	-11	-19
Lower heat of combustion, kJ/kg	No less 42800	43225	37131	37550	37149	38061
Flash point, °C	No less 38	43	167	170	135	150

CONCLUSIONS

In a result of the work the complex of basic physical-chemical properties of various bio-additives for jet fuels was studied, in particular fatty acids methyl esters and fatty acids ethyl esters of rapeseed oil and fatty acids ethyl and fatty acids iso-butyl esters of camelina oil. It is shown that properties of bio-additives and its differences from conventional jet fuel properties are explained by the chemical nature of fatty acids esters, mainly the length of the molecules chains and presences of double bonds in molecules.

It is shown that properties of bio-additives significantly differ from properties of conventional jet fuel and, thus, they can't be used as a complete substitute of jet fuels. However, it is possible to use bio-additives to substitute jet fuel in quantity up to 30 %. It seems to be reasonable to use camelina oil bio-additives rather than rapeseed oil taking into account its sustainability, agricultural properties and physical-chemical properties of bio-additives.

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CHARAKTERYSTYKA PORÓWNAWCZA WŁAŚCIWOŚCI LOTNICZYCH BIODODATKÓW PALIWOWYCH NA PODSTAWIE OLEJÓW ROŚLINNYCH

Streszczenie

Praca poświęcona jest badaniom właściwości fizykochemicznych bazylii dla różnych dodatków biologicznych do paliw lotniczych, w szczególności estrów metylowych, kwasów tłuszczowych i estrów etylowych oleju rzepakowego oraz izobutylowych oleju lniankowego. W pracy pokazano nowoczesną perspektywę w przemyśle lotniczym i jej wpływ na środowisko. Stwierdzono, że właściwości biododatków znacznie różnią się od właściwości konwencjonalnego paliwa do silników lotniczych, a zatem nie mogą być stosowane jako całkowity substytut paliw odrzutowych. Możliwe jest stosowanie biododatków do zastąpienia paliwa do silników lotniczych w ilości do 30%.