Research Journal of Agriculture
Volume 13, Number 4; April-2022;
ISSN: 2836-6050 | Impact Factor: 5.73
https://zapjournals.com/Journals/index.php/rja/index
Published By: Zendo Academic Publishing

DIESEL ENGINE TOXICITY REDUCTION THROUGH VEGETABLE OIL ENVIRONMENTAL ADDITIVES

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Article Info
Keywords:
Internal Combustion Engines, Diesel Engines, Emissions Reduction, Vegetable Oil Additives

Abstract
Modern engine construction is challenged by the imperative to mitigate emissions of harmful substances from internal combustion engine exhaust gases, necessitating an urgent focus on the reduction of toxic components released into the atmosphere [1, 2]. The toxicity of internal combustion engines is quantified by emissions of specific pollutants, subject to stringent contemporary regulations. Diesel engines (henceforth referred to as "diesels") are gauged by the normalized levels of toxic constituents, encompassing nitrogen oxides (NOx), carbon monoxide (CO), light unburned hydrocarbons (CHx), and solid carbon-based particles (soot). Emissions of sulfur oxides (SOx) are indirectly restricted through fuel sulfur content regulations capped at 8. The progressive intensification of toxicity-related mandates for diesel engines, as evidenced by figures 1 and 2 along with table 1, underscores the exigency to adopt novel engine technologies and approaches to curbing diesel engine toxicity.
In this context, this study underscores the imperative to incorporate strategies that mitigate diesel engine toxicity, delineating potential avenues within the realm of engine design enhancement, operational considerations, and exploration of alternative fuel options [4]. The profound environmental benefits offered by biofuels, specifically those possessing favorable ecological attributes, have garnered substantial attention [5-7]. This research undertakes the objective of evaluating the efficacy of integrating vegetable oils as environmentally beneficial additives within diesel fuels, further probing their ramifications on the technical and economic facets of the machinery.
The conducted research comprises a multifaceted analysis, evaluating the viability of vegetable oil-based additives in diminishing the ecological impact of diesel engines. Through comprehensive empirical investigation, this study not only quantifies the abatement of toxic emissions achieved via these additives but also scrutinizes their influence on the overall operational and financial efficacy of the machine unit. The results of this study hold pivotal implications for both the domain of engine design and environmental conservation,

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providing pragmatic insights into a sustainable pathway for reducing the toxicity of diesel engine emissions.

1. Introduction

One of the main tasks of modern engine construction is to reduce emissions of harmful substances from exhaust gases (exhaust) of internal combustion engines [1, 2]. Indicators of VG toxicity include emissions of toxic components into the atmosphere, limited by modern regulations on the toxicity of VG engines. Normalized toxic components of diesel engines (hereinafter - diesels) are nitrogen oxides NOx, carbon monoxide CO, light unburned hydrocarbons CHx and solid particles based on carbon C (soot). Emissions of sulfur oxides SOx are limited indirectly due to the sulfur content of 8 in the fuel. Dynamics of strengthening of requirements to the maintenance in VG of diesels of normalized toxic components is presented in fig. 1 and 2, as well as in table 1.

These data indicate the need for the introduction of engine tools and methods to reduce the toxicity of diesel diesel engines. The development of measures to reduce the toxicity of VG can be carried out in the following main areas (Fig. 3) [4]: improving the design of the engine, taking into account operational factors and the use of alternative (non-traditional) fuels. From this point of view, biofuels with good environmental qualities are of special interest [5-7].

The aim of the study is to determine the efficiency of use of vegetable oils as environmental additives in diesel fuel and their impact on technical and economic performance of the machine unit.

2. Materials and Methods

Among the biofuels that are most widely used in diesels, we should highlight vegetable oils (PO) and their derivatives - methyl, ethyl and butyl esters [3, 7, 8].

Despite the problems that arise when operating diesels on RO, research continues on their work on 39 these biofuels and their mixtures with other fuels, mainly petroleum diesel fuel (DF) [8-9].

Fig. 1. Dynamics of the introduction in Europe of more stringent requirements for toxicity of HG engine

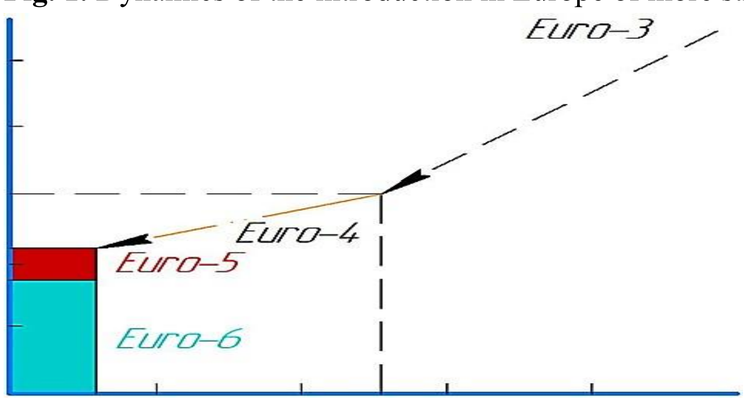

Fig. 2. Norms of harmful emissions from VG of diesel cars and passenger cars in the European test cycle (PM - solid particles, NOx + CHx - total emissions of nitrogen oxides and light unburned hydrocarbons)

Table 1. Requirements for limiting the content of harmful substances in the exhaust fumes of transport diesels in European countries

Standards for HCV toxicity	**Maximum emissions of harmful substances from CO, mg/km**		
	Nitrogen oxides	**Solid particles**	**CarbondioxideCO2**
Euro-4	**NOx**300	25	160…170
Euro-5	220	5	140
Euro-6	170	5	120

Analytical comparison of current European standards for internal combustion engines.

Determining the effectiveness of using vegetable oils as additives is done experimentally using the D245.12C engine and the KI-5542 loading stand, and the program for modeling the injection process and processing the DIESEL-RK results was also used.

3. Results and discussion

It should be noted that the use of rapeseed oil (RO) as a raw material for biofuels has little effect on the sector of their production for food purposes. Technical fuels obtained by extracting oilseeds orpre-squeezed cake with gasoline, hexane or other extractants can act as motor fuel. Low-quality and expired vegetable oils (VO) are suitable for technical use. Frying oils used for frying are a significant raw material base for biofuel production [10-12]. Oilseeds intended for the production of biofuels can be grown in areas unsuitable for food production (in areas with unfavorable environmental conditions, in areas adjacent to highways and industrial enterprises).

When using VO and their derivatives as motor fuel, there are two possible ways - centralized and decentralized production of biofuels [10, 12]. Centralized production of motor fuels with VO is the processing of VO into esters (methyl, ethyl, butyl), used in diesels or as stand-alone fuels, or in a mixture with petroleum. Decentralized production involves the use of "pure" VO or their mixtures with diesel fuel (DF). This direction is usually implemented directly in agro-industrial complexes, where there is a surplus of oils and biofuels can be carried out domestically from their own raw materials. This allows integrated use of agricultural products and reduce transportation costs.

The use of VO as an independent DF is difficult due to differences in physicochemical properties of VO and petroleum DF. This is accompanied by problems that arise during the operation of diesels on the VO. These include the poor quality of the processes of fuel supply and spraying of oils caused by their high viscosity and density, as well as coking of sprays and parts that form the combustion chamber, impaired mobility of the piston rings. In this regard, it is advisable to use the VO as an environmental additive to oil DF [3, 8, 10, 15]. Mixtures of DF with a small addition of VO can solve these problems.

Rapeseed oil (RO) is usually considered when analyzing the possibilities of using different POs for biofuels [3, 8, 16]. At the same time, other types of VO are grown in Ukraine. The structure of production of VO in Ukraine is as follows: the share of sunflower oil (SO) in total VO production is 86.84%, soybean (SoyO)- 7.96%, rapeseed (RO)- 4.84%, mustard (MO) - 0.11%, residual oils (corn, flaxseed (FO), etc.) - 0.25% [15].

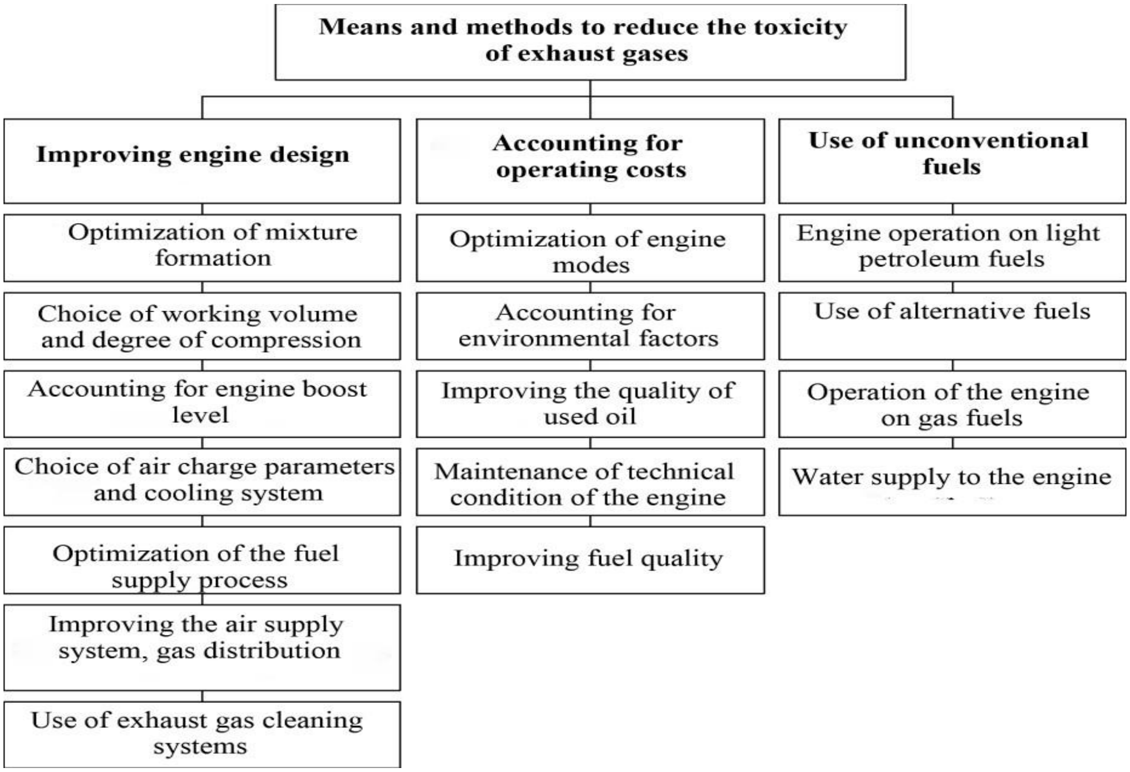

Fig. 3. The scheme of fixed assets and methods to reduce the toxicity of diesel exhaust

The purpose of the work is to evaluate the possibility of using flaxseed (FO), mustard (MO) and saffron (RizO) oils as an ecological additive to oil refinery. Articles [15] already present the results of a study of domestic tractor diesel on mixtures of petroleum DF with these oils. However, there is a need for comparative analysis of these data and optimization of the composition of such blended biofuels.

Flax is an annual (sometimes winter) plant of the flax family. Among them, the most famous are long flax (characterized by high quality fiber), curly flax (used mainly as an oil crop), and flax-mezheumok (oil-fiber culture).

Mustard is a plant of the cruciferous family, which includes such well-known crops as cabbage, radish, radish, turnip, canola and others. The family of cabbages also includes ore, which is an annual herb. This wild plant is very unpretentious, so it has long attracted the attention of breeders and today is successfully cultivated in the fields of Europe.

It should be noted that the physical and chemical properties of FO, MO and RizO are influenced by the variety of oilseeds, growing conditions and processing technology. At the same time, the properties of different VO, in many respects similar, depend on the composition and structure of fats, which, in turn, are determined by the type of plant. All fats are based on esters of glycerol and higher aliphatic acids [14, 15]. Many of these acids were first isolated from fats, so in the literature they are often called "fatty" acids. In the ester composition, one molecule of glycerol C_3H (OH) is associated with residues of three fatty acids, so such compounds are called triacylglycerides. The mass fraction of triacylglycerides in fats is 93 ... 98%. Other substances dissolved in fat and got into it in the process of oil production are called concomitant.

PMs contain mainly fatty acids with an even number of carbon atoms (C□□, C_{16}, C_{18}, etc.). In this case, the composition of VO includes both unsaturated (oleic, linoleic, linolenic, etc.) and saturated fatty acids (myristic, palmitic, stearic, etc.). In saturated fatty acids, the molecules do not have double bonds, and in unsaturated fatty acids there are one or three double bonds. The fatty acid composition of the oils of the main oilseeds of Russia are given in table 2. It should be noted that the oil content (mass content) of flax seeds (up to 50%), mustard (up to 45%) and ryzhik (up to 42%) can be compared with the oil content of sunflower seeds (up to 57%) and rapeseed (up to 50%).

Table 2. Fatty acid composition of various unrefined RO

VO	Mass fraction,% by weight, of fatty acids RO					
	Saturated			unsaturated		
	myristic C14H28O2 або C 14:0	palmitic C16H32O2 або C 16:0	Stearin C18H36O2 або C 18:0	oleic C18H34O2 або C 18:1	linoleum C18H32O2 або C 18: 2	linolenic C18H30O2 або C 18:3
RO	0...0,2	5,6...7,6	2,7...6,5	14,0...39	18,3...74,0	До 0,3
SoyO	0...0,2	1,5...6,0	0,5...3,1	8,0...60,0	11,0...23,0	5,0...13
FO	5,4...11,3	2,5...8,0	0,4...1,0	13,0...36	8,3...30,0	30,0...67
MO	0...1,0	0,5...4,5	0,5...2,0	8,0...23,0	10,0...24,0	6.0
RizO	0...0,2	5,0...7,0	2,0...2,5	12,0...20	12,0...20,0	14,0...22

Note. The name of the fatty acid is followed by the formula of the composition and the conditional formula of the composition, in which the first digit corresponds to the number of carbon atoms, and the second - the number of double bonds in the molecule.

Table 3. Physico-chemical properties of the studied fuels

Property	**Type of fuel**									
	DF	**FO**	**95 % DF + 5 % FO**	**91 % DF + 10% FO**	**MO**	**95 % DF + 5 % MO**	**90 % DF + 10 % MO**	**RizO**	**95 % DF + 5 % RizO**	**90% DF + 10 % RizO**
Density at temperature 20 ° C, kg/m3	830	912	834	837	920	835	839	910	834	838
Kinematic viscosity at a temperature of 20 ° C, mm2/s	3,8	59,0	4,5	6,0	70,0	5,0	7,0	57,7	4,4	5,8
Heat of combustion нижча, МДж/кг	42,5	37,6	42,2	42,0	37,2	42,1	41,9	37,5	42,2	42,0
Cetane number	45	38	-	-	35	-	-	37	-	-
The amount of air required for combustion 1 kg of substance, kg of air/kg	14,31	12,62	14,23	14,16	12,44	14,19	14,11	12,52	14,23	14,13
Composition,% by weight: C H O	87,0 12,6 0,4	77,8 12,0 10,2	86,5 12,6 0,9	86,2 12,5 1,3	77,1 11,8 11,1	86,5 12,5 1,0	86,0 12,5 1,5	77,6 11,8 10,6	86,5 12,6 0,9	86,1 12,5 1,4

It should be noted that the fatty acid composition of FO, MO and RizO differs slightly from the similar composition of RO - the most common in Ukraine (see Table 2). One of the main differences is that these oils contain more unsaturated fats acids. In particular, FO contains up to 67% by weight of linolenic acid, which has three unsaturated bonds, and MO - up to 0.3% by weight. In this regard, FO is less stable in oxidative processes than VO. Low oxidative stability (high oxidation) RizO causes its limited storage time. If the shelf life of unrefined RO is 38 weeks, unrefined FO is only 26 weeks. In this case, expired FO can be used as motor fuel.

In the table. 3 shows some physicochemical properties of LO, GO, RizO and oil DF brand L (summer) according to GOST 305-82. These data indicate that the physicochemical properties of RO differ markedly from petroleum. The cetane number of VO, which characterizes its spontaneous combustion in the combustion chamber (CS) of the diesel, is slightly lower than that of the oil DF.
In addition, VO is differ significantly from petroleum DF in fractional composition. The boiling point of VO is very high (about 280 ... 300 ° C against 180 ... 360 ° C in oil refineries). At atmospheric pressure and temperature more than 300 ° C it is impossible to disperse it into separate fractions because of thermal decomposition of oil.
One of the serious problems of using VO as a fuel for diesel engines is the increased viscosity of VO in comparison with that of oil refineries. This characteristic determines the quality of fuel spraying, mixture formation and subsequent combustion. The calorific value of VO is slightly lower than that of petroleum DF, because the molecules of these oils contain a significant number of oxygen atoms (up to 12% by weight, petroleum DF - 0.4% by weight).
In this regard, the specific specific consumption of VO is significantly higher than that of oil, with approximately equal efficiency of the combustion process (with approximately equal to the effective efficiency (efficiency) of the engine). At the same time, the content of significant amounts of oxygen in VO molecules, which promotes their oxidation during combustion, has a positive effect on the environmental properties of VO as a motor fuel. The positive environmental properties of VO include low sulfur content (0.002% vs. 0.2% in petroleum) and almost complete absence of polycyclic aromatic hydrocarbons, which are carcinogenic.
To assess the possibility of using the studied oils as an environmental additive to petroleum DF tests of diesel D-245.12C (4 CHN 11 / 12.5). This engine manufactured by the Minsk Motor Plant is installed on ZIL-5301 Bychok light trucks, and its modifications are installed on buses.

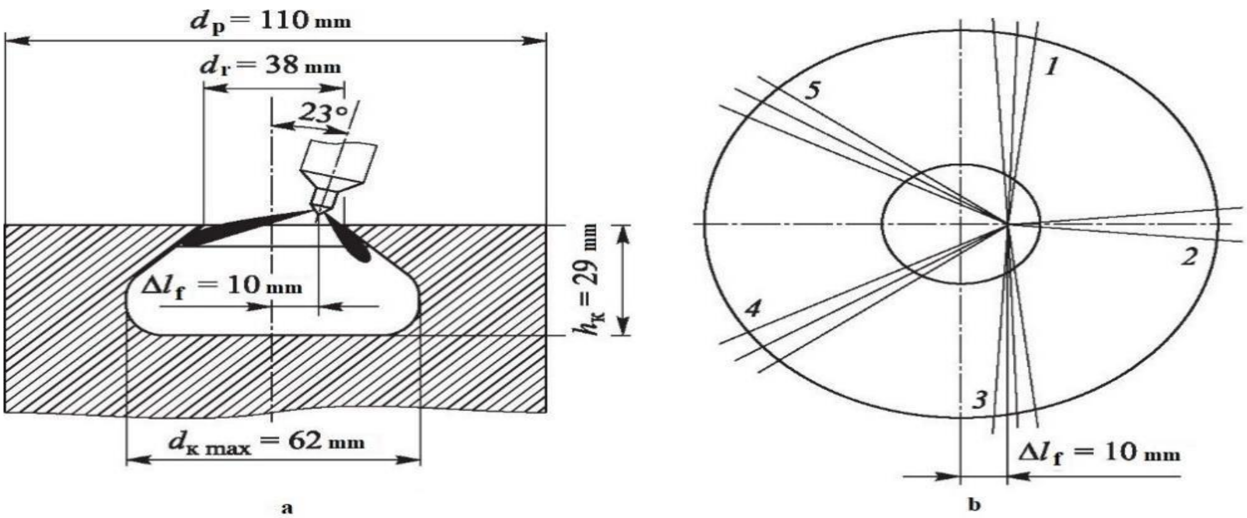

Fig. 4. Schemes of CS type CNIDI diesel D-245.12C with the layout of the injector (a) and the orientation of the jets (1-5) of the spray fuel in the CS (b): dk max and Nk - the maximum diameter of the CS in the piston and its depth; dn is the diameter of the piston; dr is the diameter of the neck of the CS; D / f - removal of the nozzle relative to the axis of the CS

Pavlovsk Automobile Plant and tractors "Belarus" Minsk Tractor Plant. Mixtures of petroleum BF and with a small amount (up to 10% by volume) of different RO were studied. Some properties of these fuels are given in table 3 and the diagram of the diesel CS D-245.12C with the layout of the injector - in Fig. 4.

Table 4. Parameters of the D-245.12C diesel (4 ChN 11 / 12,5)

Engine type	Four-stroke, in-line, diesel
Number of cylinders	4
Cylinder diameter, mm	110
Piston stroke, mm	125
Total working volume, l	4,32
Degree of compression	16
Turbocharged	Turbocharger TKR-6
Short circuit type	CNIDI
The method of mixture formation	Volumetric film
Nominal speed, min-1	2400
Rated power, kW	80
Power supply system	Separate type
PNVT	in-line
Diameter of PNVT plungers	10
The course of plungers PNVT, mm	10
Length of injection fuel lines, mm	540
Nozzle type	FD-22
Injection start pressure, MPa	21,5

The motor stand is equipped with a set of necessary measuring equipment. Exhaust smoke was measured using a MK-3 opacimeter from Hartridgo (UK) with a measurement error of ± 1%, and the concentration in the exhaust gas of nitrogen oxides NOx, carbon monoxide CO, unburned light hydrocarbons, CHx in the exhaust gas - gas analyzer SAE-7532 components ± 1%.

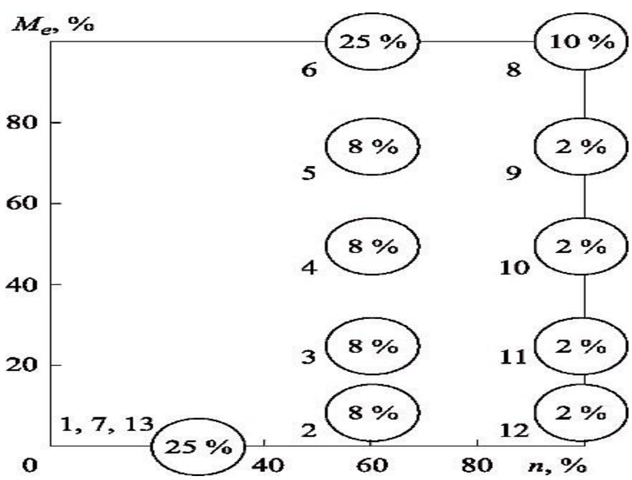

Fig. 5. Stationary European 13-mode cycle (ECE standard B.49), used to assess the toxicity of exhaust gases from diesel vehicles of medium and heavy capacity - with a gross weight of more than 3.5 tons (for each mode marked with a circle, its number is shown; circles the share of time of each mode in percent of total time of operation is resulted); Me - torque on the engine shaft, which characterizes the loading mode of the diesel engine)

Diesel was tested in the external speed characteristics and 13-mode test cycle of ECE D49 of UNECE Regulation 49 (Euro-2) with an adjustable fuel injection advance angle of 0 = 13 ° crankshaft rotation to top dead center and constant position. This test cycle (Fig. 5) includes Indicators of diesel D-245.12C, running on oil DF and its mixtures with VO (13 established modes: three idle modes with minimum speed n = (0.25 ... 0.3) Phnom, five load modes (10; 25; 50; 75; 100% load) at nominal frequency rotation Pnom and five load modes (10; 25; 50; 75;

100% load) at speed n_ (Mmax) = 0.6 ... 0.7 n_nom, which corresponds to the maximum torque. The share of the nominal mode is 10% of the total operating time, and the share of the maximum torque mode is 25%. The results of experimental studies of the diesel engine are given in table 5.

Table 5. Physico-chemical properties of mixed fuels

Indicator	**Fuel**							
	DF	**FO**	**95 % DF + 5 % FO**	**91 % DF + 10% FO**	**MO**	**95 % DF + 5 % MO**	**90 % DF + 10 % MO**	**RizO**
Hourly fuel consumption Century, kg / h	13,1	13,13	13,2	13,0	13,1	13,22	13,16	13,30
Diesel torque Me, Nm	322	321	319	321	321	318	318	317
Specific effective fuel consumption ge, g / (kWh)	248	250	252	248	250	253	252	253,
Effective diesel efficiency	0,34	0,340	0,34	0,34	0,34	0,339	0,338	0,338
Smoke OG KH,% on the Hartridge scale	16,0	12,0	11,0	17,0	15,0	12,0	16,0	15,0
Integrated 13-mode cycle modes (conditional) efficient engine performance: effective fuel consumption ge, g / (kWh)	247,97	248,72	252,26	244,6	247,17	251,08	250,22	255,57
Effective efficiency	0,341	0,343	0,340	0,346	0,346	0,342	0,341	0,335

Analysis of the results of experimental studies of diesel D-245.12C, running on oil DF and its mixtures with VO, shows that the task of choosing the optimal composition of blended biofuels is quite complex and has no clear solution. This is due to the fact that diesel operation is characterized by a set of indicators (criteria) of toxicity of exhaust fumes - normalized emissions of nitrogen oxides NOx, carbon monoxide CO, light unburned hydrocarbons CHx and solid particles or soot or soot (carbon) C (smoke). Requirements for choosing the optimal fuel composition according to these criteria often contradict each other. As a result, the task of choosing the optimal composition of blended biofuels becomes a multi-criteria optimization task [15].

There are various methods of solving multicriteria optimization problems, classified depending on the number of optimized parameters, the number of optimality criteria, the features of their problem and determine the degree of their significance. Regarding the problem of optimizing the composition of mixed fuels developed techniques described in [14, 15], which are based on one of the most effective methods optimization - a method of convolution, where the generalized criterion of optimality is formed as the sum of private criteria.

This paper proposes a method for optimizing the composition of blended biofuels - mixtures of petroleum DF with the studied VO, based on the preparation of a generalized additive criterion of optimality

$$J_o = a_{NO_x}J_{NO_x} + a_{CO}J_{CO} + a_{CH_x}J_{CH_x} + a_{K_x}J_{K_x} \quad (1)$$

where $J_{NO_x}, J_{CO}, J_{CH_x}, J_{K_x}$ – private criteria of optimality for emissions of nitrogen oxides NOx, carbon monoxide CO, light unburned hydrocarbons CHx and soot C (smoke Kx);

$a_{NO_x}, a_{CO}, a_{CH_x}, a_{K_x}$ – weight coefficients of private optimality criteria.

These weights are selected taking into account the data of [4], in which the toxicological significance of toxic components of CO - NOx, CO, CHx, soot (smoke) is estimated as a ratio of 1: 41.1: 1: 3.16: 200. Given these data, expression (1) takes the form

$$J_0 = 41{,}1J_{NO_x} + 1{,}0J_{CO} + 3{,}16J_{CH_x} + 200J_{K_x} \quad (2)$$

The particular optimality criteria included in expressions (1) and (2) are proposed to be determined for each mode using the ratios

$$J_{NO_x} = e_{NO_x}/e_{NO_x дт};\ J_{CO} = e_{CO\,i}/e_{CO\,тд}$$
$$J_{CH_x} = e_{CH_x\,i}/e_{CH_x\,дт};\ J_{K_x} = K_{x\,i}/K_{x\,дт}$$

where $e_{NO_x\,i}, e_{CO\,i}, e_{CH_x\,i}, K_{x\,i}$ – parameters of the diesel engine running on the i -th fuel; $e_{NO_x\,дп}, e_{CO\,дп}, e_{CH_x\,дп}, K_{x\,дп}$ – parameters of the diesel engine running on oil DF.

(3)

Expressions (1) and (2) use the values of integrated emissions of toxic components in the modes of the 13-mode test cycle of ESE D49 and the values of smoke in the mode of maximum torque of the external speed characteristic, which are the most critical. It is taken into account that the fuel efficiency of the studied diesel engine changes relatively slightly when the composition of the biofuels under consideration changes. In the transition from oil DF to its mixtures with a low content of CO_2 (up to 10%) conditionally effective efficiency of the diesel This mind in the 13-mode cycle changes within no more than 3% (see Table 4). Therefore, in the analysis of the properties of these fuels can be used generalized criterion of optimality, which takes into account only the indicators of CO toxicity. This generalized optimality criterion (2) is also convenient to use in relative form

$$J_0 = J_{0i}/J_{0дп} \quad (4)$$

Table 6. Optimization of the composition of mixtures of oil DF with RS for diesel D-245.12C

Type of fuel	e_{NO_x}	J_{NO_x}	e_{CO}	J_{CO}	e_{CH_x}	J_{CH_x}	K_x	J_{K_x}	J_0	J_0
			Mixtures of oil DF with FO							
DF	7,018	1,000	1,723	1,000	0,748	1,000	43,0	1,000	245,26	1,000
95% DF + 5% FO	6,230	0,888	1,631	0,947	0,695	0,929	37,5	0,872	214,78	0,876
91% DF + 9% FO	6,441	0,918	1,511	0,877	0,664	0,888	36,0	0,837	208,81	0,851
			Mixtures of oil DF with MO							
DF	5,911	1,000	2,184	1,000	0,675	1,000	42,0	1,000	245,26	1,000
95% DF + 5% MO	5,760	0,974	2,140	0,980	0,602	0,892	38,0	0,905	224,83	0,917
90% DF + 10% MO	5,689	0,962	2,068	0,947	0,561	0,831	36,0	0,857	214,5	0,875
			Mixtures of DF oil with RizO							
DF	5,911	1,000	2,184	1,000	0,675	1,000	42,0	1,000	245,26	1,000
95% DF + 5% RizO	5,783	0,978	2,127	0,974	0,660	0,978	39,0	0,929	230,06	0,938
90% DF + 10% RizO	5,341	0,904	1,853	0,848	0,585	0,867	37,5	0,893	219,3	0,894

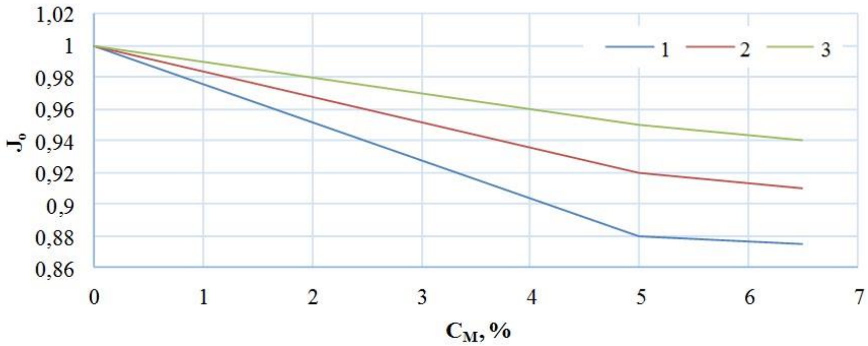

Fig. 6. Dependence of the generalized optimality criterion J_0 on the volume content of flaxseed (1), mustard (2) and saffron (3) oils in a mixture with petroleum DF

When solving the optimization problem using expressions (2) and (4), the generalized optimality criterion is minimized.

The proposed technique is used to optimize the composition of mixtures of petroleum DF with VO (FO, MO, RizO) in diesel D-245.12C. This used the experimental data of table 4. The results of the calculation of particular optimality criteria for expressions (3) and the generalized optimality criterion for formulas (2) and (4) are given in table 5.

The optimization results indicate that for the diesel D-245.12C running on the studied mixtures, the values of the generalized optimality criterion j_o monotonically decrease with increasing content of oils under consideration in the mixture with oil DF. Working on oil DF, the generalized criterion / o is equal to one, and the minimum value of the generalized optimality criterion (j_o about = 0.851) is achieved when using a mixture of 91% oil DF and 9% RizO.

It is noteworthy that as the content of VO in the mixture with petroleum DF increases, the generalized criterion of optimality j_o constantly decreases, but its decrease is most noticeable at low content of VO in the mixed biofuel (see Fig. 5). In particular, when converting diesel D-245.12C from oil DF to a mixture of 95% DF + 5% RizO, the generalized optimality criterion decreases from 1.000 to 0.876, and a further increase in CM to 9% leads to a decrease of only 0.851. This indicates that even a small addition of vegetable oil to the oil DF significantly improves the toxicity of the exhaust gas of the studied diesel.

4. Conclusions

1. The expediency of using VO as an ecological additive to oil DF is shown. Mixtures of oil DF with flaxseed, mustard and saffron oils are considered.
2. Analysis of test results of diesel D-245.12C on mixtures of petroleum DF with these oils confirmed the possibility of improving the toxicity of exhaust fumes - reducing emissions of all normalized toxic components of exhaust fumes: nitrogen oxides, carbon monoxide, unburned light hydrocarbons, smoke fumes.
3. A method for optimizing the composition of mixtures of VO with DF, based on the definition of a generalized criterion of optimality in the form of the sum of private optimality criteria that characterize the emissions of normalized toxic components of diesel exhaust.
4. The results of optimization indicate that for the diesel D-245.12C, working on the studied mixtures, with increasing content of VO in the mixture with oil DF generalized criterion of optimality decreases monotonically. Its minimum value $J_0 = 0.851$ was achieved using a mixture of 91% petroleum DF and 9% RizO. Even a small addition of VO to the DF significantly improves the toxicity of the exhaust of this diesel.

5. The research confirmed the effectiveness of the proposed method of optimizing the composition of blended biofuels, its informativeness in assessing the environmental qualities of blended fuels of different composition and a relatively small amount of calculations.
6. The results of research allow us to conclude that the effectiveness of mixtures of petroleum DF with RO in diesels for various purposes. First of all, these are engines of agricultural machines, which can use mixtures of petroleum BF with technical, low-grade, expired and frying oils.

5. Funding

This research was supported and funded by the Ministry of Education and Science of Ukraine under grant № 0122U000844.

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