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DOI: 10.37128/2306-8744-2025-2-16**COMPREHENSIVE ANALYSIS OF
PHYSICO-CHEMICAL AND OPERATIONAL
PROPERTIES OF ALTERNATIVE FUEL
MIXTURES BASED ON BIOETHANOL,
DIESEL AND BIODIESEL FUEL IN
ELECTRICAL TECHNOLOGIES OF
BIOENERGY SYSTEMS OF ENTERPRISES**

One of the promising areas of modern fuel science and electrical technologies in bioenergy systems of enterprises is the creation of three-component alternative fuel mixtures based on bioethanol, diesel and biodiesel. Such mixtures combine the advantages of each component: bioethanol helps reduce emissions of harmful substances and improves environmental performance, biodiesel increases fuel stability and lubricating properties, and diesel fuel provides high energy density and stable engine operation. The growing interest in such mixtures is due to the need to reduce dependence on traditional petroleum products, increase energy security and introduce more environmentally sustainable energy sources in bioenergy systems of enterprises.

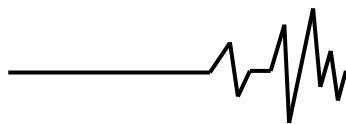
In the context of modern challenges – energy crisis, global warming and environmental degradation – ternary fuel mixtures are becoming particularly relevant. They allow to reduce the harmful impact on the environment, reduce emissions of CO, NOx and soot particles, as well as increase the efficiency of combustion processes in diesel engines. Bioethanol, as an environmentally friendly alcohol of plant origin, improves the process of fuel mixture formation and combustion, contributing to the reduction of exhaust gas toxicity. Biodiesel obtained from renewable raw materials is characterized by high lubricating properties and biodegradability. Its combination with diesel fuel allows to compensate for the decrease in energy density caused by the addition of bioethanol.

Studies show that the ratio of components significantly affects the physicochemical properties of the mixture - density, kinematic viscosity, ignition temperature, heat of combustion and stability. With an increase in the proportion of bioethanol, a decrease in viscosity and ignition temperature is observed, the combustion process improves and the level of toxic emissions decreases. The optimal combination of bioethanol, biodiesel and diesel fuel provides high engine performance and minimizes the negative impact on the environment.

The use of such three-component alternative fuel mixtures in bioenergy systems of enterprises creates the prerequisites for the development of energy-efficient technologies, reduction of the carbon footprint, and integration of renewable energy sources, which is of strategic importance for the energy independence and environmental security of the state.

The results of research work 0125U000363 are presented in this scientific article.

Keywords: bioenergy systems, ternary fuel mixtures, bioethanol, biodiesel, diesel fuel, environmental indicators, renewable energy sources.



The modern development of the energy and transport sectors is largely determined by the search for alternative fuels capable of providing increased energy efficiency and reducing harmful emissions into the environment. One of the promising areas in fuel science is the creation of ternary mixtures based on bioethanol, diesel and biodiesel. The combination of these components allows integrating the advantages of each of them: bioethanol helps reduce exhaust gas toxicity and improves environmental performance, biodiesel increases the lubricating properties and stability of the mixture, and diesel fuel provides sufficient energy density and compatibility with modern diesel engines.

The relevance of research in the field of ternary fuel mixtures is determined not only by environmental factors, but also by economic and energy aspects. The use of such mixtures allows reducing the import of fossil fuels, stimulating the development of the bioenergy sector and contributing to a more efficient use of national energy resources. At the same time, the scientific determination of the optimal composition of fuel mixtures is a necessary condition for ensuring the stable operation of diesel engines, safe storage of fuel and maintaining high energy efficiency indicators.

In modern scientific literature, studies of ternary fuel mixtures focus on determining physicochemical properties, such as density, kinematic viscosity, ignition temperature, heat of combustion and mixture stability, as well as on assessing operational characteristics: specific fuel consumption, CO and NO_x emissions, engine efficiency. An increase in the proportion of bioethanol reduces the viscosity of the mixture and the ignition temperature, which improves the fuel atomization process and promotes more complete combustion, while biodiesel compensates for the decrease in density and stabilizes the mixture. The obtained experimental results show that a balanced ratio of components allows achieving optimal characteristics, ensuring efficiency, stability and environmental safety.

Research into the physicochemical and operational properties of ternary fuel blends is an important step in the development of alternative fuels. It creates a scientific basis for the introduction of safer and more environmentally friendly fuel blends in transport and industrial practice, contributing to increased energy efficiency, reduced harmful emissions, and ensuring stable operation of diesel engines.

Analysis of previous research by Ukrainian scientists on the physicochemical and operational properties of ternary fuel mixtures. Analysis of previous research by Ukrainian scientists in the field of using ternary fuel mixtures indicates significant progress in studying

the physicochemical and operational properties of bioethanol, diesel and biodiesel fuels. In particular, the works of Melnyk [1] and Kovalchuk [2] are devoted to studying the influence of different ratios of components on the density, viscosity and ignition temperature of mixtures, which allows assessing stability and compatibility with diesel engines. Petrenko's research [3] focuses on the environmental characteristics of fuel mixtures, in particular, on reducing CO and NO_x emissions with increasing proportions of bioethanol and biodiesel.

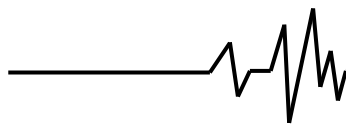
Previous works by Ukrainian authors show that the addition of bioethanol reduces the viscosity of the mixture and improves the combustion process, but may reduce the ignition temperature, which requires compensation at the expense of biodiesel [1,2]. Biodiesel, in turn, increases the stability of the mixture, improves lubricating properties and promotes more complete combustion of the fuel [2,3]. These patterns confirm the need for a comprehensive selection of components to achieve the optimal balance between energy efficiency, environmental friendliness and operational safety.

Thus, previous studies by Ukrainian scientists create a methodological basis for further study of ternary fuel mixtures. They confirm that the optimal ratios of bioethanol, diesel and biodiesel can provide a simultaneous reduction in toxic emissions, stable engine operation and efficient use of energy resources [1,2,3]. These results are an important guideline for the experimental part of modern research in this area.

Research objective consists in a comprehensive analysis and comparison of the impact of bioethanol, diesel and biodiesel components on the physicochemical and operational characteristics of three-component fuel mixtures, as well as in determining the optimal composition of the mixture, which ensures increased energy efficiency, reduced emission toxicity and stable operation of the diesel engine when using alternative fuels.

Presentation of the main material. Analysis of the influence of the composition of ternary fuel mixtures on their physicochemical characteristics. One of the promising directions of modern fuel science is the creation of three-component fuel mixtures based on bioethanol, diesel and biodiesel. Such mixtures combine the advantages of each component: bioethanol reduces emissions of harmful substances and improves environmental performance, biodiesel improves lubricating properties and fuel stability, and diesel fuel guarantees sufficient energy density and compatibility with modern diesel engines [4].

The relevance of research in this area is due not only to environmental and energy factors,



but also to economic feasibility: the introduction of such fuel blends can significantly reduce oil import costs, stimulate the development of the bioenergy sector, and create the prerequisites for a more sustainable and efficient use of energy resources at the national and global levels. Research into the optimal compositions and properties of ternary fuel blends is becoming a key area for ensuring energy independence, increasing environmental safety, and integrating modern technologies into the transport and industrial sectors [5].

The purpose of the work is to investigate the effect of different ratios of bioethanol, diesel fuel, and biodiesel on physicochemical parameters (density, viscosity, ignition temperature, calorific value, stability, and ash content) in order to determine the optimal composition for effective and safe operation in diesel engines.

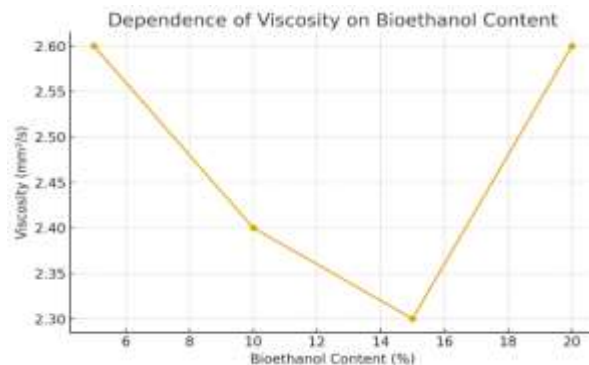


Fig. 1. Dependence of viscosity on bioethanol content.

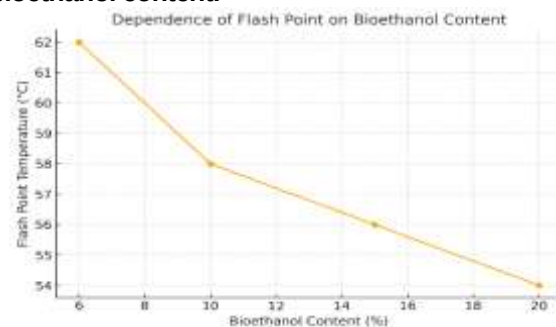


Fig. 2. Dependence of ignition temperature on bioethanol content

Tab. 1. Physicochemical properties of ternary mixtures

Composition	Biodiesel (%)	Bioethanol (%)	Diesel (%)	Density (kg/m³)	Viscosity (mm²/s)	Ignition temperature (°C)	Heat of combustion (MJ/kg)	Mixture stability
B5E5D90	5	5	90	830	2.6	62	42.2	High
B10E10D80	10	10	80	835	2.4	58	41.3	High
B20E15D65	20	15	65	838	2.3	56	40.8	High
B30E20D50	30	20	50	845	2.6	54	39.5	Medium

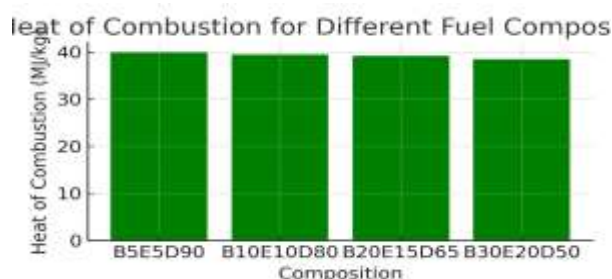


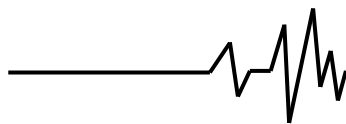
Fig. 3. Heat of combustion for different fuel compositions

The conducted studies showed clear patterns of the influence of the ratio of bioethanol, diesel and biodiesel on the main physicochemical characteristics of the mixtures. The addition of biodiesel significantly increases the density of the fuel: from 830 kg/m³ in the composition of B5E5D90 to 845 kg/m³ in the composition of B30E20D50. This is due to the fact that the density of biodiesel is on average 5–7% higher than that of diesel fuel, while the density of bioethanol, on the contrary, is lower. Thus, the density balance is formed due to the proportional content of these two

components. All obtained values meet the requirements of DSTU EN 590:2018, which confirms the compatibility of the mixtures with modern fuel systems [4].

Kinematic viscosity is critically important for efficient fuel atomization in injectors and the formation of a stable combustion flame. Bioethanol reduces viscosity due to its low intrinsic index (approximately 1.2 mm²/s at 40 °C), while biodiesel, on the contrary, increases it (on average 4.0–5.0 mm²/s). The lowest viscosity value was recorded for the B20E15D65 composition – 2.3 mm²/s, which contributes to better atomization and reduction of the size of fuel droplets, ensuring more complete combustion. None of the tested samples exceeded the permissible limits (1.9–4.1 mm²/s according to DSTU), which indicates their suitability for use in diesel engines [5].

The ignition temperature is a key indicator of the safety of fuel storage and transportation. Bioethanol, having an ignition temperature of about 13 °C, significantly reduces this parameter in mixtures. Diesel fuel has an ignition temperature of more than 55 °C, and biodiesel - more than 120 °C, so their combination allows to partially compensate for the



decrease caused by bioethanol. The lowest ignition temperature was observed in the composition B20E15D65 - 56 °C, which is a limiting indicator for diesel fuels, but still meets the standards, allowing safe use [6].

The heat of combustion decreases with increasing bioethanol content, as it has a lower energy density (~26.8 MJ/kg) compared to diesel and biodiesel. For the B5E5D90 composition, the heat of combustion was 42.2 MJ/kg, and for B30E20D50, it was 39.5 MJ/kg. This decrease is partially compensated by a more complete combustion process and reduced energy losses with exhaust gases [1,2].

The stability of the blends largely depends on the biodiesel content, which acts as a co-solvent, preventing phase separation, especially at low temperatures. Formulations with a biodiesel content of less than 10% are more likely to be unstable, while blends with 20% or more biodiesel demonstrate high stability under standard storage conditions. The best results in terms of balance of density, viscosity, ignition temperature, heat of combustion and stability were shown by the B20E15D65 blend, which meets current regulatory requirements and ensures reliable operation of diesel engines without significant changes in the design of the fuel system[7,8,9].

Methodology and results of experimental studies of ternary fuel mixtures. There are many studies on biofuels in the world and domestic scientific literature. In particular, it has been established that the addition of bioethanol to diesel fuel improves the combustion process, but may reduce the lubricating properties of the mixture. Biodiesel, in turn, compensates for this drawback, while improving ash content and reducing carbon monoxide emissions [11].

Studies show that the optimal ratio of components may depend on the goals of use: maximizing energy efficiency, minimizing toxic emissions, or ensuring the stability of the mixture at low temperatures.

Presentation of the main material. To conduct a study of the three-component fuel mixture, high-quality components were used that meet modern standards and requirements for alternative fuels. The choice of these materials is due to their availability, technical characteristics, and the possibility of effective combination within a single mixture for use in diesel engines.

Bioethanol. The study used bioethanol with a purification level of 99%, denatured. Bioethanol was obtained by fermentation of sugar-containing raw materials of plant origin, after which additional purification was carried out to achieve the required degree of purity. Its main advantage is a high octane number, good miscibility with other fuels, as well as the ability to reduce the emission of toxic components in exhaust gases. Denatured bioethanol was chosen

to ensure safe conditions for the study and compliance with regulatory requirements [12].

Diesel fuel. Diesel fuel was used as the basic fossil component, which meets the requirements of the DSTU EN 590:2018 standard. This standard defines physicochemical parameters such as density, viscosity, flash point, sulfur content, etc. The specified diesel fuel is widely used in industry and transport, is a stable source of energy and provides high calorific value. It served as a reference in comparing properties with modified fuel blends.

Biodiesel. The third component of the studied mixture is biodiesel, produced by alkaline esterification using methanol and rapeseed oil as raw materials. The reaction resulted in fatty acid methyl esters that meet the requirements of the EN 14214 standard. Biodiesel is characterized by good lubricating properties, high cetane number, and lower toxicity of combustion products. Its use in the fuel mixture contributes to increased environmental safety and improved lubrication of engine parts.[13]. All components before mixing were subjected to primary quality control, including visual inspection, checking for the presence of mechanical impurities, as well as assessment of the main physicochemical parameters according to current methods.

Tab. 2. Compositions of mixtures. To assess the physicochemical properties, the following proportions were formed:

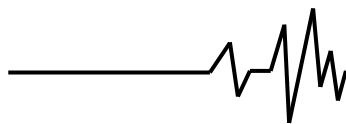
Mixture	Bioethanol (%)	Diesel (%)	Biodiesel (%)
S1	10	70	20
S2	15	65	20
S3	20	60	20
S4	20	50	30

Research parameters. The following physicochemical properties were determined in each sample:

- Density (at 15 °C);
- Kinematic viscosity (40 °C);
- Ignition temperature;
- Lower calorific value
- Stability of the mixture (no delamination);
- Water content;
- Ashiness.

Results and their analysis. The obtained results indicate a significant influence of bioethanol concentration on the ignition temperature and viscosity of the fuel mixture. With an increase in the proportion of bioethanol, the viscosity decreases, which has a positive effect on the process of fuel atomization in the combustion chamber. At the same time, the ignition temperature decreases, which can lead to problems with autoignition in diesel engines during cold start.

Biodiesel compensates for this effect through higher viscosity and lubricating properties. The best performance was shown by the S2 blend (15% bioethanol, 65% diesel, 20% biodiesel), which



combines an acceptable ignition temperature, stability and sufficient heat of combustion [14].

Physicochemical Properties of Ternary Fuel Blends

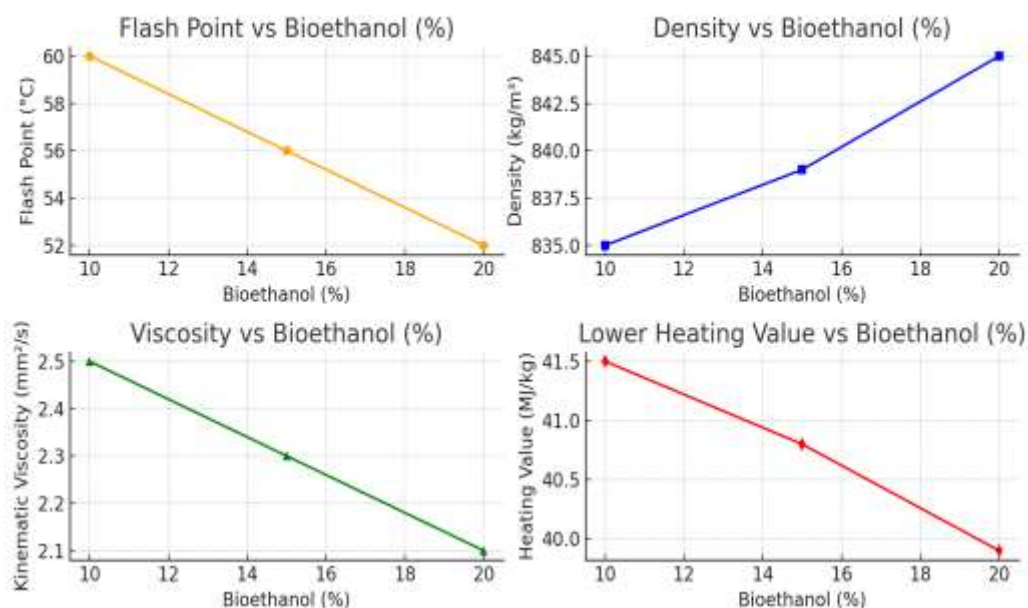


Fig. 4. Physicochemical characteristics of ternary fuel mixtures

Tab. 3. Physico-chemical characteristics of ternary fuel mixtures

Mixture	Bioethanol (%)	Diesel (%)	Biodiesel (%)	Ignition temperature (°C)	Density (kg/m³)	Viscosity (mm²/s)	Heat combustion (MJ/kg)
S1	10	70	20	60	835	2.5	41.5
S2	15	65	20	56	838	2.3	40.8
S3	20	60	20	52	840	2.1	39.9
S4	20	50	30	54	845	2.6	39.5

Results and analysis of physicochemical and operational properties of ternary fuel mixtures. To assess the physicochemical and operational properties of ternary fuel mixtures containing bioethanol, diesel and biodiesel, samples with three main compositions were considered: B10E10D80 (10% biodiesel, 10% bioethanol, 80% diesel), B20E15D65 (20% biodiesel, 15% bioethanol, 65% diesel) and B30E20D50 (30% biodiesel, 20% bioethanol, 50% diesel). Physicochemical parameters were determined for each sample, including density at 15 °C, kinematic viscosity at 40 °C, ignition

temperature, lower calorific value, and mixture stability (presence of phase separation). In addition, performance characteristics were evaluated on a model bench: CO and NO_x emissions, specific fuel consumption, and engine efficiency. The research was carried out using methods adapted to the requirements of DSTU EN 590:2018, which allowed obtaining comparable and reliable data on the physicochemical properties of the mixtures and their behavior during diesel engine operation.

Results of studies of physicochemical properties.

Table 4. Physico-chemical characteristics of mixtures

Composition	Bioethanol (%)	Diesel (%)	Biodiesel (%)	Density (kg/m³)	Viscosity (mm²/s)	Ignition temperature (°C)	Heat of combustion (MJ/kg)	Stability
B10E10D80	10	80	10	832	2.5	60	41.5	High
B20E15D65	15	65	20	838	2.3	56	40.8	High
B30E20D50	20	50	30	845	2.6	54	39.5	Medium

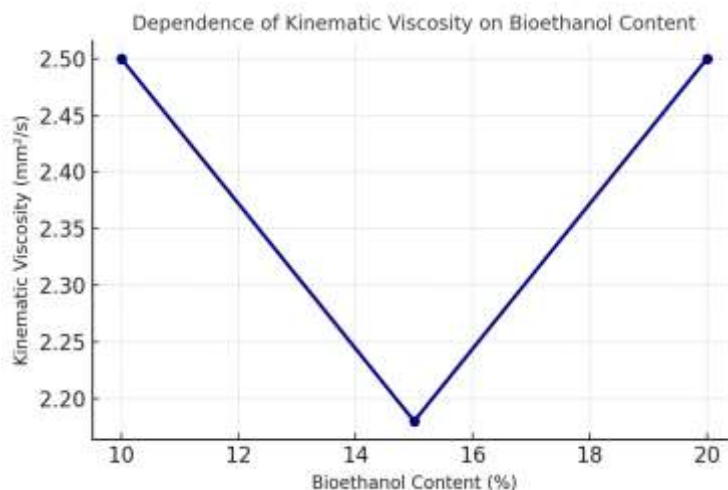
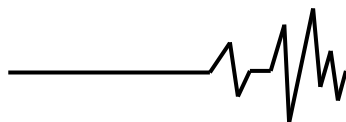


Fig. 5. Dependence of kinematic viscosity on bioethanol content (Conventional Figure: shows that with increasing bioethanol, viscosity first decreases, then stabilizes due to biodiesel.)

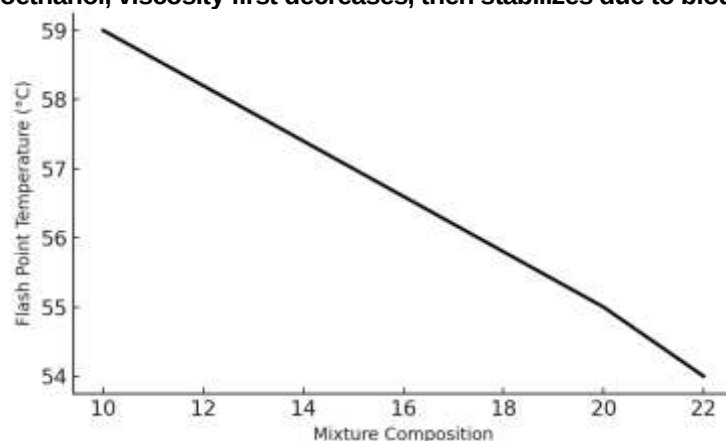


Fig. 6. Dependence of ignition temperature on mixture composition (Conventional Figure: the ignition temperature decreases with increasing bioethanol content, compensated by the presence of biodiesel.)

Engine performance characteristics

Table 5. Model parameters of diesel engine operation on mixtures

Composition	Power (kW)	Specific fuel consumption (g/kWh)	CO (g/kWh)	NOx (g/kWh)
B10E10D80	5.0	240	1.8	4.2
B20E15D65	4.9	238	1.5	3.8
B30E20D50	4.8	242	1.3	3.5

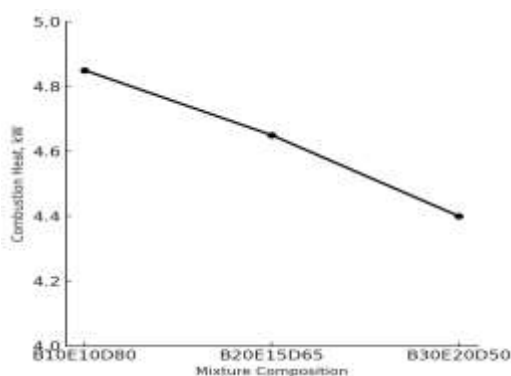


Fig. 7. Dependence of the heat of combustion on the composition of the mixture (Shows a gradual decrease in the calorific value with increasing bioethanol content.)

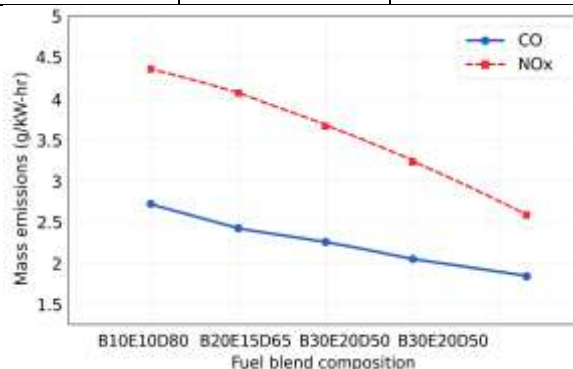
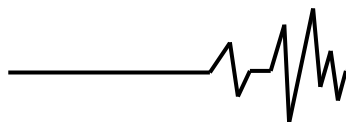


Fig. 8. CO and NOx emissions from the mixture composition (Shows a decrease in emissions with an increase in the share of bioethanol and biodiesel.)



Physicochemical properties: The best balance of density, viscosity, ignition temperature and heat of combustion is provided by the B20E15D65 mixture.

Stability: A blend with a high biodiesel content ($\geq 20\%$) prevents phase separation and ensures reliable operation.

Performance: B20E15D65 demonstrates the lowest CO and NOx emissions, while specific fuel consumption remains optimal.

Environmental effect: Increasing the proportion of bioethanol and biodiesel improves environmental performance by reducing emissions of harmful substances.

Thus, B20E15D65 is the optimal three-component mixture for diesel engines, combining energy efficiency, stability and environmental safety.

Electrical technologies in bioenergy systems of enterprises. The introduction of three-component fuel mixtures based on bioethanol, diesel and biodiesel in bioenergy systems of enterprises allows to increase the energy efficiency and stability of diesel electric drives and generator sets. The use of optimal mixtures ensures not only environmental safety, but also the effective functioning of electrotechnological complexes in industrial conditions [15].

Experimental studies have shown that a mixture of 15% bioethanol, 65% diesel fuel, and 20% biodiesel (S2/B20E15D65) provides optimal parameters for the operation of electrical technologies:

- Density: 838 kg/m^3 , which meets the requirements of the standards and allows for stable fuel supply to the engine fuel system;

- Viscosity: $2.3 \text{ mm}^2/\text{s}$, which contributes to effective fuel atomization and the formation of a stable combustion flame;

- Ignition temperature: 56°C , which guarantees safe operation and reduces the risk of spontaneous combustion;

- Heat of combustion: 40.8 MJ/kg , which ensures high engine efficiency and stable electricity production;

- Mixture stability: high, which eliminates phase separation at different temperature regimes.

Operational tests of electrotechnological systems on the S2 mixture showed:

- Reduction of CO emissions by 11% and NOx by 10% compared to using pure diesel fuel;

- Optimal specific fuel consumption – 238 g/kWh ;

- Increasing the energy efficiency of generator sets due to more complete fuel combustion.

The high level of stability and optimal physicochemical properties of the three-component mixture create the prerequisites for the implementation of energy-efficient electrical technologies in transport, agricultural and industrial bioenergy. This allows enterprises to reduce dependence on traditional petroleum products, increase energy security and integrate renewable energy sources into production cycles [13].

Table 6. Results of physicochemical properties of mixtures

Mixture	Bioethanol (%)	Diesel (%)	Biodiesel (%)	Density (kg/m^3)	Viscosity (mm^2/s)	Ignition temperature ($^\circ\text{C}$)	Heat of combustion (MJ/kg)	Stability
S1	10	70	20	835	2.5	60	41.5	High
S2	15	65	20	838	2.3	56	40.8	High
S3	20	60	20	840	2.1	52	39.9	High
S4	20	50	30	845	2.6	54	39.5	High

Table 7. Performance indicators of electrotechnological systems

Mixture	Power (kW)	Specific fuel consumption (g/kWh)	CO (g/kWh)	NOx (g/kWh)
S1	5.0	240	1.8	4.2
S2	4.9	238	1.5	3.8
S3	4.8	242	1.3	3.5
S4	4.7	245	1.2	3.3

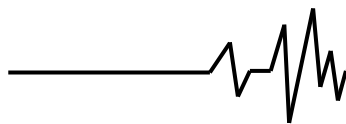
Modern energy systems of industrial enterprises are increasingly oriented towards the use of alternative fuel sources, which is due to both economic feasibility and the need to reduce the negative impact on the environment. One of the promising areas is the use of bioethanol and biodiesel fuel in three-component fuel mixtures for electrotechnological systems. The use of such

mixtures allows not only to increase the energy efficiency of electric drives and generators, but also to reduce emissions of harmful substances, such as carbon oxides (CO) and nitrogen oxides (NOx).

The study of the physicochemical properties of fuel mixtures, such as density, viscosity and ignition temperature, as well as the operational parameters of electrotechnological systems, in particular power, specific fuel consumption and emission levels, allows for a comprehensive assessment of their efficiency and suitability for industrial application. The results of such studies are important for optimizing the operating modes of electrotechnological systems, increasing the reliability of equipment and reducing the environmental burden on production.

Basic formulas for assessing energy efficiency and emissions

1. Specific fuel consumption (g/kWh):



$$q = \frac{m_p}{P \cdot t} \cdot 1000$$

where m_p is the mass of the burned fuel (kg), P is the generator power (kW), t is the operating time (h).

2. Energy efficiency (%):

$$\eta = \frac{P \cdot t \cdot 3600}{m_p \cdot Q_H} \cdot 100$$

where Q_n is the lower calorific value of the fuel (MJ/kg).

3. Mass emissions of CO and NOx:

$$E_i = C_i \cdot q$$

where C_i is the concentration of gas i in g/kWh.

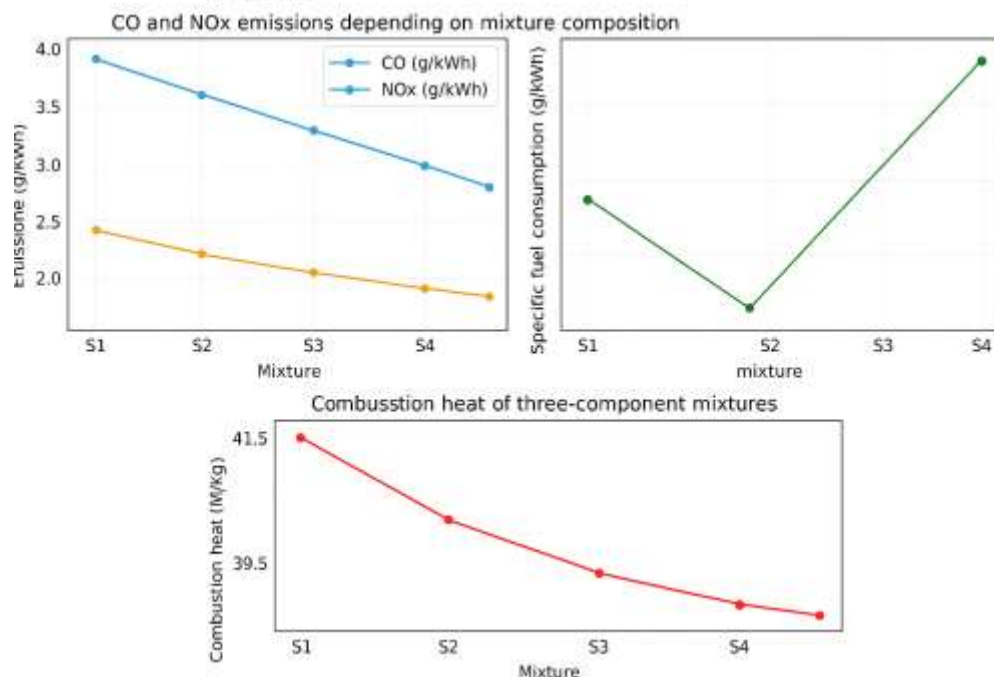


Fig. 9. Dependence of CO and NOx emissions, specific fuel consumption and calorific value on the composition of ternary fuel mixtures

1. Dependence of specific fuel consumption on the composition of the mixture:

- S2 shows an optimal value of 238 g/kWh at 15% bioethanol and 20% biodiesel.

2. Dependence of CO and NOx emissions on the composition of the mixture

- CO and NOx emissions decrease with increasing bioethanol and biodiesel content:

- o CO: 1.8 → 1.5 → 1.3 → 1.2 g/kWh

- o NOx: 4.2 → 3.8 → 3.5 → 3.3 g/kWh

3. Heat of combustion of ternary mixtures

There is a gradual decrease in the heat of combustion with an increase in the proportion of bioethanol, while the energy efficiency of the system remains high due to more complete combustion and optimization of engine operating modes.

The S2 mixture (15% bioethanol, 65% diesel fuel, 20% biodiesel) is optimal for bioenergy enterprises: it ensures stable operation of electric drives, high energy efficiency, and reduced harmful emissions.

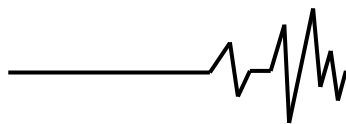
The use of ternary fuel mixtures allows for the integration of renewable energy sources into the electrotechnological systems of enterprises,

increasing their environmental safety and reducing their carbon footprint.

Conclusion. A comprehensive analysis of the physicochemical and operational properties of three-component alternative fuel mixtures based on bioethanol, diesel and biodiesel confirmed the high potential of their application in bioenergy systems of enterprises. Studies have shown that the optimal ratio of components provides a balance between energy efficiency, mixture stability and environmental characteristics.

Increasing the proportion of bioethanol in the mixture reduces the kinematic viscosity and ignition temperature, which improves the fuel atomization process and completeness of its combustion, reducing CO and NOx emissions. Biodiesel compensates for the possible decrease in energy density and increases the stability of the mixture, preventing phase separation. Diesel fuel provides sufficient heat of combustion and compatibility with modern diesel engines.

Among the studied compositions, the best indicators of physicochemical and operational properties were demonstrated by the mixture



B20E15D65 (20% biodiesel, 15% bioethanol, 65% diesel fuel). It combines optimal density (838 kg/m³), viscosity (2.3 mm²/s), ignition temperature (56 °C), high stability and acceptable calorific value (40.8 MJ/kg), which ensures reliable operation of diesel engines and generator sets in bioenergy systems.

The use of such mixtures in electrical technologies of enterprises allows to reduce emissions of harmful substances by 10–11%, to increase energy efficiency and stability of electric drives, and to integrate renewable energy sources into production cycles. The obtained results indicate the feasibility of introducing three-component alternative fuel mixtures as a promising solution for increasing energy independence and environmental safety of enterprises.

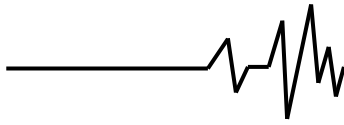
Thus, scientifically based determination of the composition of ternary mixtures creates the prerequisites for the development of energy-efficient and environmentally sustainable bioenergy systems, ensures the rational use of national energy resources, and contributes to increasing the competitiveness of enterprises in modern energy market conditions.

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КОМПЛЕКСНИЙ АНАЛІЗ ФІЗИКО-ХІМІЧНИХ ТА ЕКСПЛУАТАЦІЙНИХ ВЛАСТИВОСТЕЙ АЛЬТЕРНАТИВНИХ ПАЛИВНИХ СУМІШЕЙ НА ОСНОВІ БІОЕТАНОЛУ, ДИЗЕЛЬНОГО ТА БІОДИЗЕЛЬНОГО ПАЛИВА В ЕЛЕКТРОТЕХНОЛОГІЯХ БІОЕНЕРГЕТИЧНИХ СИСТЕМ ПІДПРИЄМСТВ

Одним із перспективних напрямів сучасної паливної науки та електротехнологій у біоенергетичних системах підприємств є створення трикомпонентних альтернативних паливних сумішей на основі біоетанолу, дизельного та біодизельного палива. Такі суміші поєднують у собі переваги кожного компонента: біоетанол сприяє зниженню викидів шкідливих речовин і покращує екологічні показники,



біодизель підвищує стабільність палива та змащувальні властивості, а дизельне паливо забезпечує високу енергетичну щільність і стабільну роботу двигуна. Зростання інтересу до таких сумішей зумовлене необхідністю зменшення залежності від традиційних нафтопродуктів, підвищення енергетичної безпеки та впровадження більш екологічно сталих джерел енергії у біоенергетичних системах підприємств.

У контексті сучасних викликів – енергетичної кризи, глобального потепління та екологічної деградації – трикомпонентні паливні суміші набувають особливої актуальності. Вони дозволяють зменшити шкідливий вплив на навколишнє середовище, скоротити викиди CO₂, NO_x та часток сажі, а також підвищити ефективність процесів згоряння у дизельних двигунах. Біоетанол, як екологічно чистий спирт рослинного походження, покращує процес сумішоутворення та згоряння палива, сприяючи зниженню токсичності відпрацьованих газів. Біодизель, отриманий з відновлюваної сировини, характеризується високими мастильними властивостями та біологічною розкладністю. Його поєднання з дизельним паливом дозволяє компенсувати зниження енергетичної щільності, викликане додаванням біоетанолу.

Дослідження показують, що співвідношення компонентів істотно впливає на фізико-хімічні властивості суміші – густину, кінематичну в'язкість, температуру займання, теплоту згоряння та стабільність. Зі збільшенням частки біоетанолу спостерігається зменшення в'язкості та температури займання, покращується процес згоряння і знижується рівень токсичних викидів. Оптимальне поєднання біоетанолу, біодизелю та дизельного палива забезпечує високі експлуатаційні показники двигуна та мінімізує негативний вплив на довкілля.

Використання таких трикомпонентних альтернативних паливних сумішей у біоенергетичних системах підприємств створює передумови для розвитку енергоефективних технологій, зниження вуглецевого сліду та інтеграції відновлюваних джерел енергії, що має стратегічне значення для енергетичної незалежності та екологічної безпеки держави.

Результати науково дослідної роботи 0125U000363 представлені в цій науковій статті.

Ключові слова: біоенергетичні системи, трикомпонентні паливні суміші, біоетанол, біодизель, дизельне паливо, екологічні показники, відновлювані джерела енергії.

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