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CONTENTS

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MAIN TRENDS OF BIOFUELS PRODUCTION IN UKRAINE

Summary. The analysis of biological resources for biofuels production in Ukraine has been carried out, and it has been shown that usage of alternative energy sources has great potential for substantially improving energy supply of the state and solving environmental problems. The directions of development and new technologies of obtaining motor fuels from biomass are systematized. It has been established that usage of different types of biofuels and their mixtures for feeding internal combustion engines involves application of modified engines in terms of structure and algorithms and usage of traditional designs of cars without significant structural changes. Moreover, the impact of biofuels on the efficient operation of the engine requires further integrated research.

1. INTRODUCTION

Global reserves reduction of traditional fuels and continued rising of energy prices triggered the rapid development of alternative energy using renewable energy sources. It has become clear that in the 21st century, the subject of gas and oil has gradually moved from an economic category to political one. In order to ensure energy independence, states that do not have a sufficient resource and raw material base should intensively develop alternative energy sources.

Renewable energy allows one to organize self-sufficient and decentralized energy supply and increase the value of local resources without dependence on imports or the need to create expensive energy networks. This is especially true for those regions where there is no access to modern energy systems or for emerging economies with growing energy needs. Using of autonomous decentralized energy supply systems becomes more important [1, 2].

The presence of huge natural reserves of renewable raw materials in the form of plant biomass creates preconditions for the development of technologies for motor fuels alternative to fuels of petroleum origin. World production of biofuels is growing at a rate exceeding 10% a year. Most countries of the world have adopted bioenergy programs. Rapid development of bioenergy has been especially observed in EU member states. The plans of the European Union stating that the share of biomass in the energy balance will be 20% by 2020 will most likely be met. Polish experience shows that this requirement can be met through the use of own, local and renewable sources of energy with efficient consumption of imported energy [3].

About 250 million tons of conventional fuel is used annually in Ukraine while natural extraction from the country is only 80 million tons. Biofuels can become an important potential resource for such a balance of own and imported energy raw materials. The urgency of development of biofuel production in Ukraine has a number of important reasons. The main ones are the availability of plenty of unused land currently, need to reduce energy dependence caused by oil and gas imports, possibility of steady development of agriculture, good geographical location, the possibility of creating new jobs, and need to improve the state of the environment.

Biofuels made from biomass for use in automobile engines, according to the degree of innovation, are divided into the 1st, the 2nd and the 3rd generations [4].

2. BIOFUELS OF THE FIRST GENERATION

The first-generation biofuels are usually called ethanol, produced from crops rich in sugar (sugar beet and sugar cane) and starch (corn, wheat, and manioc) as well as biodiesel from oilseeds (soybeans, sunflower, rape, and palm) or animal fats and pure vegetable oil. In most cases, these types of raw materials can also be used as food and feed [5].

Ethanol from biomass which is used as fuel is called fuel ethanol or bioethanol (Fuels Ethanol). In essence, it is an absolute alcoholic alcohol. Only 7% of its total amount was obtained by chemical synthesis and 93% by yeast fermentation of sugar and grain.

Bioethanol is one of the most important products of modern bioeconomy. Approximately 85% of the world's production of liquid biofuels falls under it. In recent years, bioethanol production in the world has reached a level of about 99 million cubic meters per year [6]. Two largest producers of this product are the USA and Brazil, which provide about 90% of total production, while the rest are mainly China, Canada, the EU (mainly France and Germany) and India.

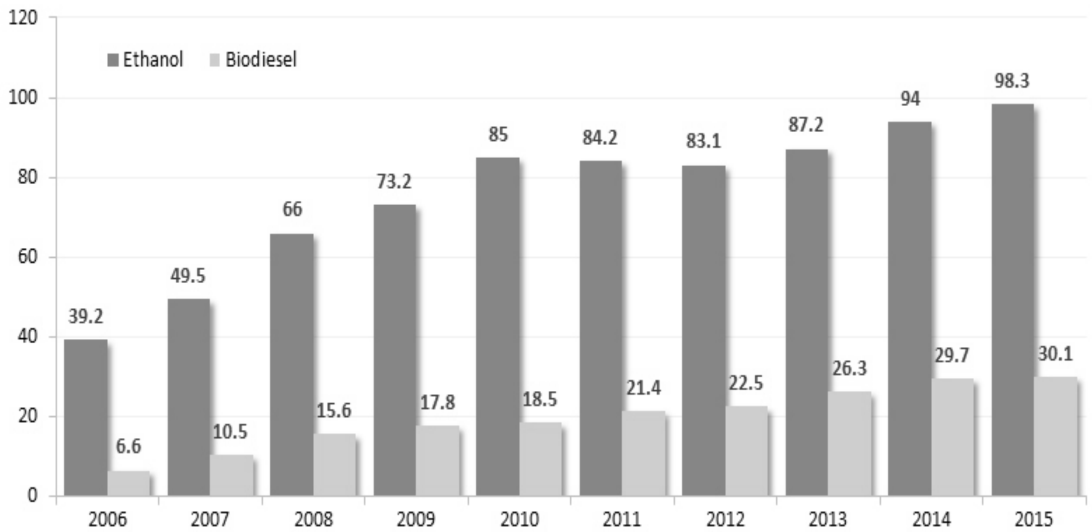

Fig. 1. Dynamics of world production of ethanol and biodiesel

Fuel ethanol is obtained by digesting sugars (glucose, sucrose) in a non-acidic environment with alcoholic yeast Saccharomyces cerevisiae

$$C_2H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

While describing the quality of ethanol as a motor fuel, it should be noted that unlike gasoline it has a higher octane number and a higher vapour pressure. However, due to the presence of oxygen in its molecule, the weight of ethanol contains at least 33% less energy than the same weight of gasoline.

Ethanol increases the anti-knock resistance of gasoline and completes its combustion. However, not the traditional 96% alcohol is added to gasoline, but the dehydrated ethanol, as it does not form an emulsion. Zeolites, azeotropic distillation with cyclohexane and membrane technology are used for draining of alcohol.

Ukraine has significant prospects for development of bioethanol production and the market for its usage. The annual consumption of gasoline in the country is about 5 million tons. Since the beginning of 2014, the legislation provides for the replacement of part (5 % - about 250 thousand tons of gasoline per year) of motor fuel with biofuels.

Concept of bioethanol production in Ukraine includes several areas: the reconstruction of existing distilleries, commissioning of new production lines of low power, and placement of production at existing sugar factories.

It should be noted that the direct processing of sugar beets to bioethanol is the only profitable technology for the production of this type of biofuel in Ukraine under current conditions. Ethanol obtained from sugar syrup is the cheapest, and moreover, its cost is lower than the cost of gas A-95, which it can substitute for [7].

Ethanol can be mixed with gasoline or burned in pure form in some engineered spark-ignition engines. A litre of ethanol contains about 66 percent of the energy provided by a liter of gasoline, but it has higher octane number, and after being mixed with gasoline for usage in vehicles, it leads to improvement in its performance.

In addition, it improves the combustion of fuel in cars and thus reduces emissions of carbon monoxide, unburned hydrocarbons, and carcinogens [8]. It shows promise in the use as additives for commercial gasoline and diesels of fusel oil - wastes in the production of alcohol. Today Brazil is the only country in the world in which 100% bioethanol is used as motor fuel.

However, burning of ethanol also causes a more active reaction with nitrogen in the atmosphere which can lead to a slight increase in gaseous nitrogen oxides. Compared to petrol, ethanol contains only trace amounts of sulfur. Thus, mixing of ethanol with gasoline contributes to reducing the sulfur content of fuel, and thus it reduces emissions of sulfur oxides, acid rains, and carcinogens.

Using of ethyl alcohol (or its compounds) in a motor vehicle in its pure form has a number of difficulties:

- deterioration of engine starting, but at negative environmental temperatures, the practical impossibility of launching due to the greater (in 3,24 times) heat of vaporization of alcohol in comparison with gasoline;
- unstable operation of the engine in virtually all modes of operation in the absence of special heating air-spirit mixture;
- deterioration of environmental performance when operating the engine without heating the mixture; and
- increased aggressive effect of alcohol compounds on some details of the engine power system.

Therefore, the use of ethyl alcohol or alcoholic compounds in place of gasoline requires modification of systems and engine parts.

As an alternative fuel, ethanol is commonly used in mixtures with gasoline in various proportions [9]. Low-grade ethanol mixtures, E5 and especially E10, are currently widely used to power spark-ignition engines in the United States, Canada, Australia, and many European countries where no significant differences in performance or reliability have been identified in the long-term operation compared to traditional gasoline engines [10].

However, in works [11, 12], it is reported that usage of alcohols in larger ratios with fuel mixtures can lead to a negative impact on the durability of the engine and the frictional properties of motor oils. Therefore, this issue requires further integrated research.

To call biodiesel as new fuels is not entirely correct since experiments with it were initiated back in the 19th century. The first engine that worked on pine seed oil (with the prospect of using as a fuel of conventional vegetable oil) was demonstrated at the World Expo in 1900 by Rudolph Diesel but after the triumphant passage of cheap oil fuel, interest in biodiesel went away, recovering only in a crisis of 70-th years of the last century.

Currently, biodiesel has gradually become one of the most important types of fuel. By 2020, in Europe, Brazil, India and China, the share of biodiesel in the total volume of motor fuel can reach 20%. In the case of active state support to the industry through creation of a favorable investment environment and system of production taxation, this figure may even be higher. Today about 90% of the world's consumption of biodiesel fuel is in Europe, but the biodiesel industry is being developed at the highest rates in the USA.

Oil for biodiesel production can be obtained from virtually any oil seeds; the most common sources in the world are rape in Europe and soybeans in Brazil and the United States of America, and in tropical and subtropical countries, biodiesel is mainly derived from palm and coconut oil. For the production of biodiesel, small amounts of animal fats remaining in the food industry as waste are also used.

From a chemical point of view, biodiesel fuel is a mixture of methyl (ethyl) ethers of saturated and unsaturated fatty acids [13]. At present, the largest volume of biodiesel is produced by the method of transesterification of vegetable oils and fats to esters and fatty acids. The process of transesterification takes place by the reaction of an alcohol with triglycerides in the presence of a homogeneous catalyst, usually an acid, alkali, or enzyme, to produce glycerol and fatty acid esters.

Although the industry mainly uses methanol, ethyl, propyl, butyl, and amyl alcohols can also be used as an etherifying agent. The resultant reaction mixture is separated in separators or tanks. As a result, a mixture of methyl esters of fatty acids (biodiesel) and a glycerin phase ("black" glycerin) containing 45-50% glycerol, unreacted methanol, fatty products and other impurities are obtained. Purified glycerin is used to produce detergents, and after deep cleaning, it is used in pharmacy.

$$\begin{array}{ccccccc} CH_2OCOR^1 & & & & CH_2OH & & CH_3OCOR^1 \\ | & & & & | & & | \\ CHOCOR^2 & + & 3\,CH_3OH & = & CHOH & + & CH_3OCOR^2 \\ | & & & & | & & | \\ CH_2OCOR^3 & & & & CH_2OH & & CH_3OCOR^3 \end{array}$$

Fig. 2. Scheme of the reaction of transesterification of triglycerides

Biodiesel can be mixed with conventional diesel fuel or burned in pure form in compression-ignition engines [14]. Its energy content is 88-95 percent of diesel fuel, but it improves lubrication of a conventional diesel engine and increases the methane number, ensuring the overall comparability of both types of fuel at cost.

The higher content of oxygen in biodiesel contributes to better combustion of fuels, reducing emissions of aerosol pollutants, carbon monoxide, and hydrocarbons. As in the case of ethanol, biodiesel contains only a small amount of sulfur, thereby reducing automobile emissions of sulphur oxides.

During transforming of a diesel engine to work on biodiesel fuel, it is necessary to take into account various physical and chemical properties of fuels. This difference in properties is manifested in the change in power and torque in changing the fuel consumption, in changing the qualitative and quantitative characteristics of the harmful substances in the exhaust gases, in changing the thermal mode of the engine, etc.

One of the main problems of engine on biodiesel is based on high viscosity of fuel. It affects the performance of fuel supply system, in particular, the functioning of the fuel pump, fuel filters, and fuel-air mixture formation [15]. Studies have shown that heating of biodiesel fuel improves the characteristics associated with high viscosity, which allows the use of biodiesel fuel during the cold season and provides the same viscosity characteristics despite the temperature variations.

In the future, it is advisable to research each of the options for engine upgrades and determine the quantitative characteristics of the performance indicators for these changes. After that, it will be able to give an objective assessment of the necessary changes in the configuration and design of the engine.

It is worth noting that usage of vegetable oils in pure form for diesels is restrained by increased formation of niche - coke deposition on spray nozzles and other parts forming a combustion chamber. Increasing of formation of carbon deposits is due to the presence of resinous substances in vegetable oils i.e. their increased coke content. To reduce the coking of vegetable fuels, it is necessary to clean the resinous substances as well as using of mixtures of vegetable oils and diesel fuel [16].

Toward the first biofuel generation, a greater number of authors included biogas. Among all renewable energy alternatives, biogas has a special status as it finds diverse applications in the energy sector, and in Ukraine, its production may be the cheapest.

According to various data, development of biogas technologies in Ukraine (Fig. 3) will allow in the long run to receive from 1.5 to 6 billion m3 of natural gas equivalent annually, which will have a significant contribution toward ensuring energy independence of the state, forming an alternative gas and fuel resource, providing an opportunity to cover Peak load in the power grid, solving waste utilization problems, developing local economy, improving the environment, increasing soil fertility, and helping create new jobs.

Fig. 3. Biogas plants

Biogas is a valuable energy source, so, it means that it can be used for different purposes and with high efficiency. Using of biogas as a motor fuel provides significant savings in fuel and energy resources. The experience of using cars with biogas as motor fuel confirms the possibility of using it in traditional car designs. Thanks to a simple, reliable and proven technology, biogas has all the necessary characteristics to become one of the most efficient and economically viable fuels from renewable sources.

Like natural gas, before using in an internal combustion engine, biogas is enriched (up to 95% methane gas content), purified, dried, and compacted. The refined biogas is usually delivered to the filling stations by special tank vehicles or through pipelines.

Recently, in world practice, the number of biogas projects aimed at the production and injection of biomethane into the natural gas network is growing at an increasing rapid pace. The use of biogas in the public network opens new prospects for the production of biogas. This allows the use of gas where it is actually needed. At the same time, it should be noted that in the presence of a sufficient amount of raw materials, biogas plants can replace objects of traditional energy (gas pipelines, boiler houses, electric networks, and transformers) and other infrastructure (waste storage facilities, subways, etc.), and being autonomous, there is no cost of connecting to power networks.

Ukraine is a state with a developed gas supply system. The total length of gas distribution networks is 246 thousand kilometers. More than 70% of Ukraine's population has access to natural gas. Thus, in the greater part of the territory of Ukraine, there is a technical possibility of connecting biomethane producers to medium and low pressure gas distribution networks for local consumption of biomethane.

The existence of a unique system of main gas pipelines makes it possible in principle to export biomethane produced in Ukraine to countries of Western Europe which have developed a system for stimulating the production of biomethane. To develop biomethane exports to the EU, a national registry of biomethane production and consumption is needed to confirm its source in accordance with certain criteria that meet the requirements of similar registries in the EU and ensure interoperability between similar registries of European countries [1].

The main disadvantage of producing the first-generation biofuels is the need to use quality arable land, a variety of heavy agricultural machinery, as well as fertilizers and pesticides.

At the same time, the production of first-generation biofuels in Ukraine can be seen as the first steps toward promoting alternative fuels: creation of a market, attracting public attention, analysis of a set of issues related to the promotion of research, development and implementation of innovative biotechnologies, creation of an appropriate storage infrastructure, transportation and distribution of biofuels, and at the same time reaching an important directive of environmental friendliness through reduction of CO_2 emissions.

3. THE SECOND GENERATION OF BIOFUELS

The second generation of biofuels represents the next stage in the processing of biological raw materials envisaging the possibility of using a wider range of biomass part, of which is lignocellulose. It should be noted that the global production of plant biomass is 200 × 109 tons per year, with 90% of biomass as lignocellulose - a heterobiopolymer consisting of cellulose, various hemicelluloses, and lignin. The percentage of lignocellulosic components may vary depending on the type of raw material, and each of these components can, if appropriately treated, be used in the production of biofuels [17].

Among the most promising new sugar crops in the national botanical garden of the Academy of Sciences of Ukraine, a valuable gene pool of palm millet, sugar sorghum, miscanthus, and millet dumplings has been created that is characterized by speediness, drought tolerance, high yield of seeds or phytomass, high carbohydrate content in grain or in above ground mass, and increased yield of bioethanol. These sugar plants can fully ensure the high productive potential and yield of bioethanol per unit area in Ukraine in comparison with traditional crops such as sugar beet, potatoes, and wheat.

Overall, 16 varieties of high-altitude crops were created by Ukrainian scientists most of which are included in the State Register of Plant Varieties and have valuable productive properties, and they are suitable for the production of biodiesel. In particular, a valuable gene pool of Camelina has been created, which has about 20 forms, hybrids, and variety samples. The most promising forms and hybrids of rice provide 3-4 t / ha of seeds with oil content of 45-50% and yield of 1.0-1.4 t / ha of biodiesel. For this, the yield is 30-40 t / ha biomass, 5-8 t / ha of dry matter, 0.8-1.0 t / ha of feed protein. Unlike rape, as a result of mineralization, the organic mass of rhizia leaves in soil more than 70 kg / ha of nitrogen, 30 - phosphorus, 85 - potassium, and 35 kg / ha - calcium. Biotechnological principles for improving the fatty acid composition and lipid accumulation in the rhizome seed were developed [18].

For the manufacture of second-generation biofuels, biochemical and thermochemical methods are widely used.

Biochemical methods (Fig. 4) are based on hydrolysis of pre-prepared lignocellulosic material using enzymes or acids to xylose $C_5H_{10}O_5$ and glucose C_6 $H_{12}O_6$ followed by their fermentation to bioethanol [19].

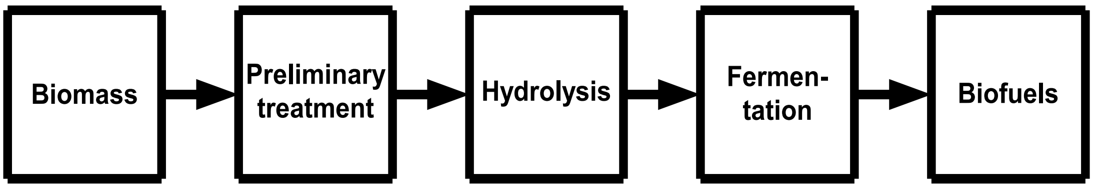

Fig. 4. Scheme of the typical process of biochemical conversion of biomass to liquid fuels

Preliminary treatment is necessary for partial destruction of cellulose microfiber, reduction of its degree of crystallization and polymerization, extraction of hemicellulose, destruction of the complex of lignin and modification of lignin structure, increasing the surface available for action of hydrolyzing enzymes, and also removing of lignin.

Preliminary treatment involves mechanical grinding of plant biomass and treatment by superheated steam or the action of acids or alkalis for delignification. A promising way of delignifying lignocellulose may be the use of fungi capable of degrading this polymer, for example Phanerochaete chrysosporium [20]. As a result of preliminary treatment, not only delignification but also partial hydrolysis of hemicellulose and cellulose is achieved.

Hydrolysis of cellulose and hemicellulose to monosaccharides occurs with involvement of acids or enzymes. Acid hydrolysis is carried out by dilute or concentrated sulfuric or hydrochloric acids. Hydrolysis with dilute acid is the classic and cheapest method, but it has certain disadvantages. In particular, it is the formation of large quantities of toxic by-products that inhibit the growth and fermentation of microorganisms, and detoxification of acid is quite expensive.

The most effective and promising method of hydrolysis of pre-treated lignocellulose is enzymatic, which in general does not produce any toxic by-products. It occurs with the use of cellulases and hemicellulases of prokaryotic and eukaryotic microorganisms mainly fungi.

Introduction of enzymatic hydrolysis in practice is hampered several factors, one of which is the high price. Another negative factor is the strong inhibition of enzymatic hydrolysis of mono and oligosaccharides released during the action of cellulases and hemicellulases, ie, the end product [21].

Characteristic feature of lignocellulosic biomass is the complexity of its cleavage to basic elements - simple sugars. In order to expand the possibilities of using wood to produce bioethanol, various technologies for the destruction of lignocellulose have been intensively developed: mechanical (grinding), physical (gamma irradiation), physical and chemical (steam explosion, or steam cycling), chemical (hydrolysis), biological (enzymatic hydrolysis), and various combinations of these methods.

The most promising technology includes combination of steam-cracking with enzymatic hydrolysis when the raw material is steam treated at high temperature and high pressure. This is followed by an explosion of crystalline structures and the separation of lignin from cellulose, followed by cellulose-rich cellulose-based enzymes hydrolysis.

Thermochemical biofuel production technologies have the advantage of allowing hydrocarbons that are completely compatible with existing fuels, which is very important for the development of infrastructure and the production of fuel mixtures (traditional fuel + alternatives). In addition, thermochemical processes allow the production of synthetic biofuels such as gasoline and diesel [22].

Synthetic fuels have excellent consumer properties so they can be used not only for modern internal combustion engines but also for future promising engine designs. Methanol, dimethyl ether, methane, and hydrogen can also be obtained in this way.

Conversion of biomass to hydrocarbon fuels is a complex process. The most responsible phase of this process is the conversion of biomass to the corresponding quality of synthetic gas and its subsequent transformation by the Fischer-Tropsch process to hydrocarbon fuels.

Scheme of typical process for obtaining synthetic biofuels is shown in figure 5. In this case, three directions of the processes are possible. The first is to carry out the gasification of biomass to biosynthesis. Gasification process can take place in conventional chambers without access to oxygen in either the fluidized bed chambers or the fluidized circulating layer. The product of the wood gasification process is a mixture of combustible gases containing carbon monoxide (CO), hydrogen (H_2), and methane (CH_4).

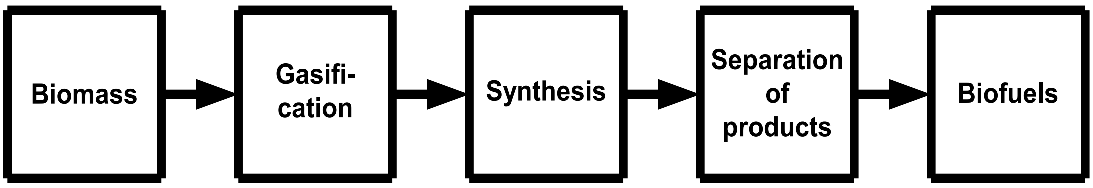

Fig. 5. Scheme of typical process of thermochemical conversion of biomass to liquid fuels

The second direction involves using of pyrolysis, resulting in the formation of pyrolysis gases (methane, carbon dioxide, and water vapor), liquid fraction of biomass, and solid coal and ash. Orumani as a result of pyrolysis of biomass is fed to gasification and subsequently subject to the Fischer-Tropsch synthesis.

The third is the process of direct conversion of biomass to hydrocarbons. In practice, the first two are mostly currently used.

Conversion of synthesis gas to higher hydrocarbons on iron and cobalt catalysts was discovered at the Fertilizer Research Laboratory in Germany by Frans Fischer and Hans Tropps. Synthesis of hydrocarbons from CO and H_2 is a complex catalytic process occurring on heterogeneous catalysts, and includes a set of sequential and parallel transformations. The main reactions are the hydrolysis of CO with the formation of paraffins and olefins:

$$nCO + (2n+1)\, H_2 \rightarrow CnH_2n+2 + nH_2O$$
$$nCO + 2nH_2 \rightarrow CnH_2n + nH_2O$$

On the surface of the catalyst there are two types of reactions: chain growth as a result of attachment of the monomer to an existing intermediate and breakage of the chain to form the product.

Liquid hydrocarbons including synthetic gasoline, diesel fuel, high-quality lubricants, paraffin, and other valuable products can be obtained using Fischer-Tropsch synthesis according to conditions of process and catalyst.

It should be noted that the hydrocarbons obtained with Fischer-Tropsch synthesis have a high content of paraffins and do not contain aromatic substances or sulfur; they burn more purely than petroleum fuels, forming lower emissions of NO_x, SO_x, and particles. This reduces engine noise and wear out of its important components. The fuels generated by Fischer-Tropsch synthesis are fully compatible with the existing infrastructure and engines, which is problematic for other types of alternative fuels. Owing to their high performance, namely, the cytogenic number which is about 70 (while for oil fuels 45 -55), they are often mixed with petroleum diesel to improve the quality of the latter. The benefits of such fuels are recognized by the US Air Force in particular, which tested and certified 50/50 jet fuel mixtures for their aircraft [23].

A promising form of synthetic gaseous fuel is dimethyl ether (DME) which is produced from the synthesis of gas. Despite the fact that DME is inferior to conventional diesel fuel in terms of energy intensity, lubricity, and viscosity, it has a number of undeniable advantages. High oxygen content and the absence of carbon-carbon bonds in the molecular structure of the ether cause its effective combustion in a diesel engine. In comparison with diesel oil (DME), it has a higher methane content (55-60), it has low boiling point (-25 ^{0}C) and ignition (235 ^{0}C), and it does not contain sulfur and its compounds, which contributes significantly to the substantial reduction of soot emissions of oxides of nitrogen and sulfur in exhaust gases, reducing overall noise, and increasing engine life. In addition, such a fuel has excellent starting characteristics at low temperatures.

The disadvantages of this fuel include low kinematic viscosity (leakage propensity) and unsatisfactory lubricating properties. There is also a problem of seals since smoke is an ether is a strong solvent for most rubber products.

There is currently no broad-spectrum dimethyl ether in Ukraine unlike other countries in the world in which it is used not only as automotive fuel but also as energy.

Consequently second-generation biofuels based on lignocellulosic material represents a completely different picture in terms of its importance for agriculture and food security. It allows the use of a wide variety of raw materials other than crops currently used in first-generation technologies and significantly increase the energy output per hectare. The impact of this type of fuel on commodity markets, the changing nature of land use, and the environment is also different, as well as its impact on future production and processing technologies.

4. THE THIRD-GENERATION BIOFUELS

Definition of "the third-generation biofuels" usually refers to biofuels that do not compete with food grain crops or with land. Typically this category includes biofuels produced from algae [24].

Algae are the fastest growing plants in the world. They can double their mass several times a day, contain a record amount of oil (up to 80% Table 1) and have no analogues in the plant world for this indicator. From one technological site for the cultivation of biofuel algae, up to 40 harvests per year can be harvested and about 80% of the organic matter that is created daily on the Earth falls on algae. To this, one should add a lack of lignin and low fiber content, which allows one to easily and quickly transform the bioremediation into fuel. Theoretically from 1 ha of phytoplankton, more than 15,000 liters of lipids per year can be obtained [25, 26].

For industrial processing, simple single-celled and large seaweeds are used. The first ones are used for the production of biodiesel and hydrogen and the second ones in the production of bioethanol, biomethane, and liquid synthetic fuels in the process of Fischer-Tropsch.

Feature of the production of algae is the ability to change the quantitative and qualitative composition of lipids (variability) depending on the culture medium, illumination, and temperature. Due to the large number of lipids in the cell walls, it becomes possible to remove the latter with non-toxic solvents without disturbing the cell's life. Lipid extraction can also be done by centrifugation, which allows, after their selection, to place biomass in the nutrient medium for re-accumulation of hydrocarbons. Of particular importance is the ability of algae to cultivate under all conditions of all climatic zones. To grow algae, carbon dioxide is also used, passing it through a special medium, thereby reducing its content in the atmosphere, which contributes to the slowing of global warming.

Table 1

Content of Lipids in Dry Biomass of Different Types of Algae [25, 26]

Types of algae	The content of lipids in dry matter, %
Botyococcus braunii	25–80
Chlamydomonas reinhardtii	21
Chlorella emersonii	28–32
Chlorella protothecoides	57.9
Chlorella pyrenoidosa	46,7
Dunaliella tertiolecta	35,6
Hormidium sp.	38
Nitzschia sp.	45 -47
Nannochloropsis sp.	31 - 68
Schizochytrium sp.	50 - 77

In addition to raising algae in open ponds, there are technologies for their cultivation in bioreactors, which is the best method for conducting research and introducing new innovative production projects. Although such systems are more expensive in production and operation, they can create a controlled environment for optimizing the growing process: temperature, pH, gas level, uniform mixing, and enough light. In addition, bioreactors can provide for the cultivation of certain gregarious species, without the competitive impact of other species, which is quite problematic in open fields.

In general, biodiesel from microalgae has two main advantages compared with the production of biodiesel fuel from vegetable oils. First, algae contain a large number of polyunsaturated fatty acids, which allow biodiesel not to lose fuel quality at low temperatures, which makes diesel engines in this fuel able to work in winter. Second, the yield of fuel from microalgae is 20-30 times higher than that of plant and vegetable crops when cultivated on an equal area.

Most biofuels of the third generation are to be obtained by converting organic matter into fuel, but there is an alternative approach based on the fact that some algae produce naturally produced ethanol which can be collected without destroying the plant itself. Thus, photosynthetic accumulation of solar energy, deposition of CO_2, and ethanol production occurs during one process [27].

The production of molecular hydrogen by microalgae is today at the stage of experiments and pilot projects. This is absolutely pure fuel, which is characterized by a high calorific value - 143 kJ/g. It has a high energy intensity, which is 3-5 times more than the same indicator of gasoline and oil, with universal energy properties: reducing agent, energy, and fuel. Chemical and electrochemical methods of obtaining H_2 are not economical; therefore, it is more rational to use micro-organisms that are able to emit hydrogen. This property consists in aerobic and anaerobic chemotrophic bacteria, purple and green phototrophic bacteria, cyan bacteria, various algae, and some protozoa [28]. Their use is of particular interest in view of the greater efficiency of their conversion of solar energy compared with higher plants.

Perspective of hydrogen fuel as one of the substitutes for petroleum products is confirmed by innovative programs adopted by the governments of some states, as an ever larger fleet of hydrogen transport and gas stations.

In recent years, attention has been paid to the cultivation of microalgae and technologies for obtaining biodiesel from the United States of America [16]. Working on the Aquatic Species Program, researchers came to the conclusion that industrial production of open sea algae is possible in California, Hawaii, and New Mexico. It has been found that 200,000 ha of ponds can provide fuel that is sufficient for annual consumption of 5% of US cars.

Ukraine has a rich experience in growing algae. It was the first to start the industrial cultivation of blue-green algae chlorella, and in the 70-90's of the last century, in-depth installations were built at 70 livestock farms.

According to the results of the screening of the collection of microalgae cultures of the Institute of Botany. M.G. Holodniy National Academy of Sciences of Ukraine (IBASU-A), a list of 33 strains of algae - promising species that are producers of biomass as a source of raw materials for biofuels - has been formed. For selection of strains, criteria such as ability to accumulate a considerable quantity of lipids, high productivity, resistance to stress factors and biological contamination are used. The current collection will serve as a basis for further research aimed at exploring the potential of microalgae for biodiesel production.

Thus, currently algae are the most dynamic and high-energy plants and can become the basis for large-scale production of motor biofuels, thereby creating the basis for sustainable development of future energy.

5. CONCLUSIONS

1. The production of first-generation biofuels in Ukraine can be seen as the first steps toward the promotion of alternative fuels: market creation, public attention, analysis of a set of issues related to the promotion of research, the development and implementation of innovative biotechnologies, the creation of appropriate infrastructure for storage, transportation and distribution of biofuels, and at the same time, reaching an important goal - reducing CO_2 emissions.
2. Effective transition to second- and third-generation fuels is determined by rapid scientific and technological progress.
3. Algae can now be considered as the most promising raw material for the production of fuel from renewable sources.
4. The use of different types of biofuels and their mixtures for feeding internal combustion engines involves the use of modified engines in terms of structure and algorithms and traditional vehicles without any structural changes. For this, the impact of biofuels on the efficient operation of the engine requires further integrated research.

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