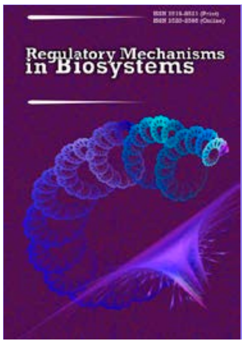

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Prospects of using algae in biofuel production

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The development of industry, agriculture and the transport sector is associated with the use of various energy sources. Renewable energy sources, including biofuels, are highly promising in this respect. As shown by a number of scientific studies, a promising source for biofuel production that would meet modern requirements may be algal biomass. After activation of the third generation biodiesel production it was assumed that the algae would become the most advantageous source, because it is not only able to accumulate significant amounts of lipids, but could reduce the of agricultural land involved in biofuel production and improve air quality by sequestering CO_2. However, a major problem is presented by the cost of algae biomass cultivation and its processing compared to the production of biodiesel from agricultural crops. In this regard, there are several directions of increasing the efficiency of biodiesel production from algae biomass. The first direction is to increase lipid content in algae cells by means of genetic engineering. The second direction is connected with the stimulation of increased accumulation of lipids by stressing algae. The third direction involves the search for new, promising strains of algae that will be characterized by faster biomass accumulation rate, higher content of TAG and the optimal proportions of accumulated saturated and unsaturated fatty acids compared to the already known strains. Recently, a new approach in the search for biotechnologically valuable strains of algae has been formed on the basis of predictions of capacity for sufficient accumulation of lipids by clarifying the evolutionary relationships within the major taxonomic groups of algae. The outcome of these studies is the rapid cost reduction of biofuel production based on algae biomass. All this emphasizes the priority of any research aimed at both improving the process of production of biofuels from algae, and the search for new sources for biofuel production.

Keywords: bioenergy; biodiesel; algae; algal biomass; biofuels from algae

Introduction

The development of industry, agriculture and the transport industry is inevitably connected with the use of various energy sources. Currently, traditional resources are as follows: oil, gas and coal, as well as alternative ones: solar radiation, wind, energy from the sea tides and rivers, the heat of the Earth's interior, nuclear or atomic energy. At the same time, the reduction of mineral resources, primarily fuel and energy, is increasingly stimulating the use of their analogues. Nowadays countries with developed and developing economies are considering renewable energy sources (RES) as the most promising direction. Thus, the share of renewable energy in primary energy consumption in the EU countries reached 12.5% as early as 2010. According to EU Directive 2009/28, the share of renewable energy sources should reach 20% by 2020. This strategy implies an emphasis on overcoming the shortage of energy resources by the development of bioenergy.

One of the important characteristics of all energy sources is their environmental safety. Taking into account the current level of scientific achievements and the requirements of society for sustainable development of the economy in a manner which does not endanger the health of the population, considerable attention is being paid to those energy sources which are characterized by the safest production and use (Dubrovin and Dragnev, 2006; Skoruk et al., 2011; Breuer et al., 2012; Chen et al., 2012; Moheimani et al., 2015; Johnson et al., 2016; Unkefer et al., 2017). One such resource is fuel of biological origin. Obtaining energy from bio resources is one of the directions of environmental biotechnology related to the effective use of photosynthetic energy. It is with the help of bioenergy that it is planned, on the one hand, to step up the transition to environmentally friendly and resource-saving energy, and on the other, to increase the energy efficiency of the world economy (Unkefer et al., 2017).

The use of biomass as fuel is one of the few real mechanisms to reduce the greenhouse effect, since plant waste is neutral with respect to the balance of carbon dioxide in the atmosphere: when it is burned, the same amount of CO_2 is released, which was absorbed during the growth of plants. Compared to fossil fuels, biomass combustion significantly reduces CO_2 and CO_2 emissions, and significantly reduces the amount of ash after combustion (Borowitzka and Moheimani, 2013).

One of the most important tasks of bioenergy is the search for sources suitable to obtain fuel from. A significant number of studies and technologies proposed are based on obtaining fuel from vegetable sources: oilseeds, cereals and sugar crops (biofuel of the first generation) (Dubrovin, 2006; Skoruk et al., 2011). Another source for production could be fat-containing waste of agricultural production, processed by methods of pyrolysis of biomass using BTL technology "Biomass to liquid" (biofuel of the second generation) (Skoruk et al., 2011). As shown by a number of scientific studies, a promising source for biofuel production that would meet modern requirements may be algal biomass (biofuel of the third generation) (Grinyuk, 2009; Ruffing and Trahan, 2014; Piligaev et al. 2015; Newby, et al., 2016; Unkefer et al., 2017).

Despite the fact that the production of bioethanol and biodiesel plays an important role in the transition from a traditional economy based on the use of non-renewable resources to an ecologically safe economy, the active use of biofuels in many countries of the world could lead to a number of problems. The main deterrent effect in the production biofuel of the first generation is the employment of vast areas of fertile land – after all, instead of cultivation of crops on valuable agricultural lands, these lands are used to grow raw materials for biofuel production – rape, soybean, sugar cane, etc. (Bozhydarnyk et al., 2014).

It is the technology of biofuel production from algae that can solve the problems of shortage of sources and reduction in the amount of land used for biofuel production. The efficiency of obtaining oil suitable for biofuel production from corn is 172 liters per hectare per year, palm oil – 5,950 liters per hectare, and from the biomass of algae to 95,000 liters per hectare per year, provided that it is grown in open water (Skoruk et al., 2011; Unkefer et al., 2017). Algae can grow even in very harsh conditions: in salt lakes and deserts, where cultivation of plants is not practiced and even impossible (Round, 1984; Ramanan et al., 2016). In addition, algae play an important role in the accumulation of excess carbon dioxide from the air, produce a number of useful by-products that can be used as feed additives in fish farms and livestock farms or can be considered as promising source of fucoxanthin (Petrushkina et al., 2017), carotenoids (Maltseva et al., 2017). The aim of this article work is discussion of the features and problems of using algae biomass to produce biodiesel.

Advantages of using algae biomass for biofuel production

Any biological source suitable for the production of biodiesel is evaluated by the amount and composition of triglycerides of higher fatty acids and free fatty acids, which are the starting materials for the esterification reaction in the technological process and the sources of methyl esters of fatty acids (components of the finished biodiesel). However, the quality of the fuel produced will directly depend on the qualitative and quantitative composition of the triglycerides. Thus, saturated fatty acids increase the octane number and biodiesel resistance to degradation, while unsaturated fatty acids reduce the pour point and gelling temperature of the fuel at low temperatures (Talebi et al., 2013). At the same time, the accompanying components of vegetable oil, such as insoluble impurities, fat soluble substances and water, impair the quality and even can adversely affect the production and yield of biodiesel. Therefore, one of the primary tasks in the production of biodiesel of the third generation is the search for such strains of algae in which the composition of produced lipids would ensure maximum economic profitability.

Compared to crops and sources from animal origin, the prospects of using algae as a source of lipids for the production of biofuels, human and animal nutrition are largely determined by their high productivity and broad environmental sustainability (Chisti, 2007; Bona et al., 2014; Fields et al., 2014). The productivity of obtaining oil from the biomass of algae per unit of the area involved is many times more efficient than the most popular sources for biofuel of the first generation – soybean (201 times) and palm oil (33.5 times) (Skoruk et al., 2011). At the same time, different groups of algae can solve various biotechnological problems. So green algae can be successfully used for biodiesel production because of rapid growth in photoautotrophic conditions, high content of saturated and monounsaturated fatty acids, ability to produce a large amount of triglycerides (TAG) (Goncalves et al., 2016). Diatom algae can serve as an industrial source of lipids due to their good growth under culture conditions, as well as the highly productive accumulation of chrysolaminarin, lipids (including TAG) in conditions of nutrient deficiency (Chen et al., 2012; Hildebrand et al., 2012; Scholz and Liebezeit, 2013). Yellow-green and eustigmatophytes algae, for which the possibility of accumulating lipids is more than 50% of the dry weight, have also been identified as potential biotechnological objects (Eltgroth et al., 2005; Chen et al., 2009).

The use of various biological approaches to detect promising strains of algae for biotech or increase their productivity continues to grow. However, the unambiguous understanding of the differences between algal taxa is one of the most significant steps in the selection of commercially valuable strains, since it is the interspecific differences that will determine the needs for the composition of the culture medium, the growth rate, the quantitative and qualitative composition of the lipids and other cellular inclusions (Chisti, 2007). So, Fields and Kociolek (2015), using the example of literary and their own data on diatom algae, showed that under conditions of nutrient deficiency in the medium, the lipid composition is a partially inherited evolutionary feature and, consequently, the evolutionary-phylogenetic approach can be used to facilitate selection of species by identifying differences in the content of lipids inside and between phylogenetic clades. Therefore, simultaneous use of morphological, phylogenetic, comparative genetic, genetic engineering and biochemical methods will ensure the greatest effectiveness of search and testing of biotechnologically promising strains of algae for the production of biodiesel.

Despite convincing indicators in the productivity of lipid accumulation by algae, work is also underway to enhance their ability to accumulate valuable compounds, primarily by changing the intensity of illumination or the composition of nutrient media during cultivation. It has been shown that representatives of different taxonomic groups of algae react differently to depletion of nutrients. For example, for the green alga *Scenedesmus obliquus* (Turpin) Kützing, nitrogen starvation leads to an increase in the content of monounsaturated oleic acid (18:1ω9), in diatom *Phaeodactylum tricornutum* Bohlin it increases the content of monounsaturated palmitoleic acid (16:1ω7) (Breuer et al., 2012). In the cells of *Neochloris oleabundans* S. Chantanachat & Bold, nitrogen starvation increased the percentage of oleic and palmitic (16:0) fatty acids and reduced the percentage of stearic acid (18:0) (Sun et al., 2014). Khozin-Goldberg and Cohen (2006) showed that the percentage of saturated fatty acids (mainly stearic acid) in the cells of the yellow-green alga *Monodus subterranea* J. B. Petersen during phosphorus starvation increased from 24.4% to 32.8%, while the percentage of polyunsaturated eicosapentaenoic acid (20:5) decreases.

The main advantages of using algal biomass for biofuel production are given below (Berchmans and Hirata, 2008; Abou-Shanab et al., 2011; Skoruk et al., 2011):

1) the use of algal biomass for the production of fuels does not pose a threat to food security;

2) algae grow 20–30 times faster than terrestrial plants (some species can double biomass several times a day);

3) 15–100 times more oil per hectare is produced than in alternative canola, soybean, maize, jatropha or palm oil;

4) the absence of a solid cell wall and the almost complete absence of lignin in a number of algae species makes their processing into liquid fuels more simple and effective than the processing of biomass from any sources of higher plants;

5) the production and use of biodiesel of the third generation does not require a change in legislation, as is the case with ethanol;

6) algae grow in fresh, salt water or industrial wastewater, where they can also be used for cleaning them;

7) algae can be grown industrially in bioreactors or photobioreactors illuminated by an artificial light source, or in open reservoirs and lakes on lands unfit for agriculture, including deserts;

8) photobioreactors are integrated into the technological lines of existing industrial enterprises (thermal electric power station, petrochemical plants, cement plants);

9) algae reduce the emission of carbon dioxide – absorb up to 90% of CO_2 with the release of oxygen;

10) compared with oils obtained from soy and rapeseed, the oil produced by algae has a higher content of saturated fatty acids (palmitic, stearic, etc.), which increase the octane number of biodiesel.

Obtaining algae biomass for biodiesel production

At the present moment, various approaches have been developed for the cultivation and production of algae biomass, which can be used for biodiesel production. First of all, it should be taken into account that algae biomass can be obtained with their mass growth in open water during their blooming. Collecting such algae biomass helps to clear water bodies. However, the species composition of algae biomass cannot always guarantee its high value for biodiesel production. At the same time, it allows one to solve the problem of removing algae sprouts during the blooming of water bodies and to use biomass, for example, for the production of biogas. The biomass of cyanobacteria, which grows intensively in the reservoirs of the Dnieper, can be used in plants for the production of biogas by methods developed by the scientists of Kremenchuk Mikhailo Ostrogradskyi National University (Yelizarov and Yelizarov, 2011). The heat-generating capacity of the gas obtained from algae biomass is compatible with household gas.

An enormous amount of seaweed biomass, which is formed on the coast of Japan, is also used to produce methane in special plants (Titlova, 2015).

However, for the production of algae biomass with a high content of oil and suitable for biofuel production, it is necessary to cultivate the algae of certain types or strains characterized by the highest efficiency. In this case, open water bodies or special biotechnological constructions – bioreactors (photobioreactors) are used. Cultivation of algae in open water is the least costly and most acceptable in countries where climatic conditions allow algae to grow throughout the year (Titlova, 2015). An essential disadvantage of this method of obtaining biomass is other microorganisms (microalgae, fungi, bacteria) getting into the captive reservoir, which can change the qualitative and quantitative indices of the biomass and interfere with the yield of oil to produce biodiesel. Photobioreactors, which are closed systems, allow the possibility of growing biomass of algae irrespective of climatic conditions, have a high degree of protection against the occurrence of unwanted organisms and allow the use of various methods for increasing the rate of growth and productivity of algae. Such plants are usually costly, therefore, their modern development is aimed at both reducing the cost of biomass and expanding their functionality. For example, on the one hand, they clear the emissions of various productions when used in photobioreactors and, on the other hand, they produce an additional effect on the saturation of these emissions with carbon dioxide, their temperature indices, and so on. This makes it expedient to place such photobioreactors near various productions, where large amounts of carbon dioxide are formed from combustion or, for example, fermentation carried out by yeast.

The details of design decisions for photobioreactors are presented in the works by Zolotaryova et al. (2008), Borowitzka and Moheimani (2013). Various variants of flat, tubular photobioreactors have been developed. To improve productivity, a spectral luminous stream is achieved by fiber optic systems, GSC technologies that allow the use of sunlight without loss, PBRs – providing a deep penetration of light flux into a culture, growing algae on membranes with subsequent flushing to yield crops, but at the same time minimizing water costs and harvesting costs, etc. The system developers present promising strategies for obtaining algae biomass which are based on a combination of open water growing algae and photobioreactors (Borowitzka and Moheimani, 2013). Protection against possible contamination of algae biomass in ponds is ensure by the high rate of algae formation (several days). In the pilot project , the average annual productivity of such combined systems reached 38 tons per hectare.

Nevertheless, the predominant global practice at the present time in the growing of algae for commercial purposes is cultivation in open water – about 20,000 tons per year, compared with only a few hundred tons in closed photobioreactors. The creation of the most productive plants for the cultivation of microalgae continues in different countries, including Ukraine (Chernov and Ivko, 2010; Fedotkina-Ginczgejmer and Fedotkin, 2011).

Equipment for the production of algae biomass for the purpose of obtaining biofuel is offered on the Ukrainian market, for example, by the company Biodiesel Dnipro (c. Dnipro). The introduction of technologies of renewable biotechnoenergetics in the domestic market is undertaken by a number of companies and enterprises, detailed information on which can be found in the review work of Gamkalo and Maksishko (2017). According to the data of Skoruk et al. (2011) considerable success in the development of design documentation for the production of biofuels from algae was achieved by the staff of the Scientific and Production Corporation "Kiev Institute of Automation". Thus, Ukraine has sufficient potential for the development of this direction of production and for market saturation by biodiesel obtained as a result of processing of algae biomass, considering that according to forecasts, biofuel will account for 20% of the total amount of fuel consumption in Ukraine by 2020 (Bozhydarnyk et al., 2014). The importance of research in this field was emphasized by the approval of the Targeted Complex Programs of Scientific Research of the National Academy of Sciences of Ukraine: "Biomass as Fuel Raw Materials" ("Biofuels") for 2007–2012, "Biological Resources and Latest Technologies of Bioenergy Cavitation" for 2013–2017 (Decision, 2010; Tselevaya, 2012). As part of the program, a collection of microalgae strains (16 species, 32 promising lipid-producing strains) was created, their molecular genetic analysis was performed and the conditions of cultivation were chosen (Decision, 2010; Blume et al., 2014, Buntov, 2017).

The main directions of increasing the efficiency of biodiesel production from algal biomass

After activation of the third generation biodiesel production it was assumed that the algae would become a most advantageous energy source, because they are not only able to accumulate significant amounts of lipids, but also have the potential to reduce the area of agricultural land used for biofuel production, and could also improve air quality by sequestering CO_2. However, a major problem is presented by be the cost of algae biomass cultivation and its processing compared to the production of biodiesel from agricultural crops. In this regard, there are several directions of increasing efficiency of biodiesel production from algae biomass.

The first direction is to increase lipid content in algae cells by means of genetic engineering and is concerned with the modification of genes DGAT2b, DGAT2c, CeDGAT1, Wrinkled1 (wri1) encoding enzymes responsible for synthesis of triglycerides (TAG), and is directed to stimulation of extra-expression of these genes (Xu et al., 2008; Taylor et al., 2009; Li et al., 2012; Yoon et al., 2012). It is shown that manipulation of the gene of DGAT can increase the lipid content in the cell by 11–28% (Jako et al., 2001). Work is also being carried out on the transplantation of the same plant genes into other model objects (bacteria, yeast) with the aim of obtaining greater concentration of TAG than in the source organism (Guo et al., 2017). Transplantation of the analogue gene DGAT from green algae (CeDGAT1) of *Chlorella ellipsoidea* Gerneck into the yeast genome caused a 142% increase of lipid content (Guo et al., 2017).

The second direction is connected with the stimulation of increased accumulation of lipids by stressing algae. The most common factors used to enhance the production of lipids, are change of intensity and duration of lighting, limitation of nutrient content (primarily nitrogen and phosphorus). It was found that the yellow-green alga *Monodus subterraneus* J. B. Petersen accumulates 0.1 pg/cell TAG in the conditions of normal nutrient content, and phosphate starvation increases the content TAG to 1.7 pg/cell, which amounts 39.3% of total lipids content (Khozin-Goldberg and Cohen, 2006). Besides, in phosphate-deficient conditions the total lipid content of *Monodus subterraneus* increased from 1.66 pg/cell to 4.3 pg/cell (Khozin-Goldberg and Cohen, 2006). On the other hand, the green alga *Rhopalosolen saccatus* (Filarsky) Fott had the highest biomass and lipid content when grown in standard nutrient conditions, and the restriction of phosphorus resources did not lead to a significant increase of either biomass or lipid content (Challagulla et al., 2015). Phosphate starvation of the green alga *Scenedesmus* sp. caused an increase of lipid content from 20% to 50% of dry weight, in contrast to nitrogen starvation, which increased the lipid content from 25% only to 30% of dry weight (Xin et al., 2010). It was also found that nitrogen starvation can induce in the green alga *Dunaliella parva* W. Lerche expression of a gene Wrinkled1 (wri1), which is an important transcription factor of many genes involved in the regulation of fatty acid biosynthesis (Shang et al., 2016).

The main drawback of the first two directions is that all studies are based on a narrow set of well-known strains of algae: *Nannochloropsis oceanica* Suda & Miyashita (Jia et al., 2015), *Chlorella ellipsoidea* (Yang et al., 2011; Guo et al., 2017), *Chlamydomonas reinhardtii* P. A. But (Scranton et al., 2015), *Dunaliella parva* (Shang et al., 2016), and only few works are devoted to testing new, previously non-studied strains (Fujii et al., 2014).

The third direction involves the search for new, prospective strains of algae that will be characterized by faster biomass accumulation rate, higher content of TAG and the optimal proportions of accumulated saturated and unsaturated fatty acids compared to the already known strains. Lately the perspective of use of a number of strains belonging to the genera of green algae *Desmodesmus* (Chodat) S. S. An, T. Friedl & E. Hegewald, *Coelastrum* Nägeli and *Scenedesmus* Meyen (Valdez-Ojeda et al., 2015), Cyanoprokaryota *Anabaena* Bory ex Bornet & Flahault (Johnson et al., 2016), diatom *Halamphora* (Cleve) Levkov (Stepanek et al., 2016), Eustigmatophyta *Vischeria* Pascher (Gao et al., 2015) and *Eustigmatos* D. J. Hibberd (Zhang et al., 2015) has been shown to be highly promising. The testing of new strains showed that at different stages of growth, the algae biomass significantly differs in content of fatty acids, e.g., in the exponential phase, the content of linoleic acid (18:2) in *Chlorella vulgaris* Beyerinck [Beijerinck] is 9.5% of dry weight, *Scenedesmus obliquus* is 3.9% and in *Botryococcus* sp. is 13.1%; and in stationary phase, these figures increased almost two times, up to 21.5%, 6.9% and 20.2%, respectively (Piligaev et al., 2015).

Recently a new approach in the search for biotechnologically valuable strains of algae has been formed on the basis of predicting their capacity for sufficient accumulation of lipids with the help of clarifying the evolutionary relationships within the major taxonomic groups of algae (Fields and Kociolek, 2015). The prospects of testing the possibility of using the strains of diatoms from the orders Thalassiosirales, Chaetocerotales and Bacillariales (Fields and Kociolek, 2015) for biodiesel production have been shown. The value of this approach is projected to increase due to the constant enlargement of of nucleotide sequences of not only diatom, but also other groups of algae available for analysis and the possibility of filtering out less promising strains while avoiding expensive biochemical experiments.

In international scientific practice, research on finding new strains for biodiesel production is very widespread, as evidenced by the abundance of publications in such specialized scientific journals as Algal Research, Photosynthesis Research, International Journal of Hydrogen Energy, Journal of Applied Phycology, etc. Meanwhile, many publications reflect only a few results, ase there are not so many experienced research groups.

The group of C. Wu Zhang and S. Xia and colleagues (Jinan University, China) are exploring the peculiarities of fatty acid composition in different representatives of eustigmatophyceae algae: *Vischeria stellata* (Chodat) Pascher (Gao et al., 2015), *Eustigmatos* cf. *polyphem* (Pitschmann) D. J. Hibberd (Zhang et al., 2013), and its changes under the stressing conditions of cultivation.

The group of T. J. Johnson, S. Halfmann, R. Zhou, and W. R. Gibbons (South Dakota State University, USA) are developing the mechanisms for obtaining the sufficient amount of Cyanoprokaryota biomass for the third generation biofuels production (Johnson et al., 2016).

K. Fujii (Yamaguchi University, Japan) is studying the diversity of algae of Yamaguchi Prefecture with the testing of green algae individual strains of the genera *Chlorella* Beyerinck [Beijerinck], *Scenedesmus*, *Coccomyxa* Schmidle, *Macrochloris* Korshikov and *Oogamochlamys* Pröschold, B. Marin, U. W. Schlösser & Melkonian as raw materials for biofuel production and cultivation in aquaculture conditions (Fujii et al., 2014).

D. V. Subba Rao (Raymond G. Murphy VA Medical Center, USA) is working on the search for biotechnologically promising strains of algae in natural and anthropogenic ecosystems by combining biochemical studies with molecular-phylogenetic ones (Subba Rao et al., 2005; Durvasula et al., 2015). The studies are conducted with the representatives of different genera of algae: *Chlamydomonas* Ehrenberg, *Dunaliella* Teodoresco, *Scenedesmus* (green) and *Nitzschia* Hassall (diatom).

J. E. W. Polle and P. Neofotis (The Graduate Center of the City University of New York, USA) are working on the search for highly productive microalgae for the production of biofuels and bioproducts among the representatives of the green algae genera *Ankistrodesmus* Corda, *Acutodesmus* (Hegewald) Tsarenko, *Chlorella*, *Desmodesmus*, *Dunaliella* (Moheimani et al., 2015; Slocombe et al., 2016).

In Ukraine, scientists are studying the problems of increasing the efficiency of lipid accumulation by means of genetic engineering methods, searching for highly effective algae strains and selecting cultivation conditions (Zolotaryova et al., 2008; Blume et al., 2014; Korkhovoy and Blume, 2014).

At the present stage on the commercial level, the following directions are being implemented: the Israeli company "Seambiotic" is developinge technologies that allow the industrial cultivation of algae by using carbon dioxide, which is released in emissions of power plants. The corporation "GreenFuel Technologies" (USA) suggested the technology Emissions-to-Biofuels that allows growth of algae by using emissions of thermal power plants. The Japanese company "Tokyo Gas" and "NEDO" are creating a system of algae biomass fermentation by using bacteria for producing methane, which can be used in gas engines. They have already developed mechanisms which can process up to 1 ton of algae per day with the formation of 20 thousand cubic meters of methane (Skoruk et al., 2011).

The outcome of the studies is the rapid cost reduction of biofuel production based on algae biomass. If in the middle of the first decade of the 21st century the cost of obtaining 1 ton of algae biomass was about $4,300, by 2011 it had dropped to $1,279, and in 2016 mechanisms to reduce the cost to $430/t were already being proposed (Skoruk et al., 2011; Dutta et al., 2016). There is a significant reduction in the cost of fuels – in 2011 the minimum price was about $2.32/l, then by 2016, it had decreased to $0.96/l (Dutta et al., 2016). All this emphasizes the priority of any research aimed at both improving the process of production of biofuels from algae, and the search for new sources for biofuel production.

Conclusion

Undoubtedly, research on the possibility of using algae as sources for the production of biodiesel fuel and improvement of specific technological features has changed significantly over the last 30 years. If the first analysis and recommendations were based on the analysis of morphology, physiology and biochemistry of individual strains, modern approaches are increasingly shifting towards deep screening, comparative genetics and genetic engineering. Taking into account the fact that none of the existing terrestrial plants is able to compete with algae both on the effectiveness of photosynthesis underlying the yield, and on the oil content and the energy stored in it, then, of course, the screening of biotechnologically promising algal strains for biodiesel production remains urgent more than ever.

The development of algae in culture neutralizes the influence of climatic and seasonal growth factors, and understanding of species specificity and productivity makes it possible to obtain biomass all year round. Leaders in this area are the Netherlands, Germany, South Africa, as well as the USA and Australia. An active search is also being conducted by specialists from China and Japan. Scientists are working on optimizing the parameters of biocultivators and bioreactors for actively growing the biomass of algae and processing sources, searching for productive species and strains of algae. Ukraine has all the necessary scientific and production potential for the development of algotechnoenergetics. This is proved by the development of technological solutions to improve the efficiency of production and the processing of microalgae biomass, as well as the creation of collections of microalgae and their strains.

Obviously, further searches for new strains of algae that can be used for the production of biodiesel must differ from the research on individual single strains, but should rather concentrate on the creation and implementation of a screening system that would consist of scientifically sound and economically viable stages and would allow the stage-by-stage testing of a large sample of strains of algae, excluding at each stage the less promising strains.

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